Laboratory work 1
GENERAL LAYOUT OF CARS,
THEIR CLASSIFICATION AND TECHNICAL DATA

*The purpose of the work is –*studying layout diagrams and technical characteristics of cars, trucks and buses.

Visual aids:

• albums, instructions and posters on car construction and buses;

• electronic information material on the construction of modern cars and buses;

• main components of the car, transmission

layout. **Tasks for work:**

• study the composition, location and purpose of the main parts car;

• get acquainted with the layout diagrams of cars, trucks cars and buses;

• get acquainted with electronic information materials regarding layout, characteristics of trucks, cars and buses;

• make a sketch of the layout diagram of the car in accordance with tasks and submit the composition, purpose of the main parts in the report;

• get acquainted with the technical characteristics of freight, passenger cars and buses, submit a specification option according to the task;

• determine the vehicle according to the European classification for the task teacher.

Cars. Main parts of a car

*Engine*converts the chemical energy of the fuel that burns into its cylinders, into thermal energy, and then, using a crank mechanism, into mechanical energy, which drives the driving wheels of the car. The most common are gasoline engines and diesel engines.

*Transmission*serves to transmit torque from the crankshaft engine shaft to the driving wheels of the car and changes in its size and direction. The transmission includes a clutch, gearbox, cardan shaft and drive axle.

*Chassis*converts the rotational movement of the drive wheels into The forward motion of a car. It consists of a frame on which the body and all the mechanisms of the car, suspension, front and rear axles and wheels are mounted.

*Body*serves to accommodate the driver, passengers and cargo. In A truck consists of a cargo platform and a cabin.

*Control mechanisms*assigned according to management These include the steering system, which changes the direction of the car, and the braking system, which allows you to reduce speed or stop the car.

The transmission, chassis, and steering mechanisms as a whole are called*chassis*.

*Auxiliary equipment*car is a winch, a towbar device and other additional equipment.

Cargo layout diagram car is determined the mutual arrangement of the front axle, engine and cab. To date, four layout schemes of trucks have been developed (Fig. 1.1):

and– engine above the front wheel axle, cabin behind the engine;
b– engine above the front wheel axle, cabin pushed onto the engine; *in*– engine above the front wheel axle, cabin above the engine; *g*– engine behind the front wheels, cabin in front of the engine.

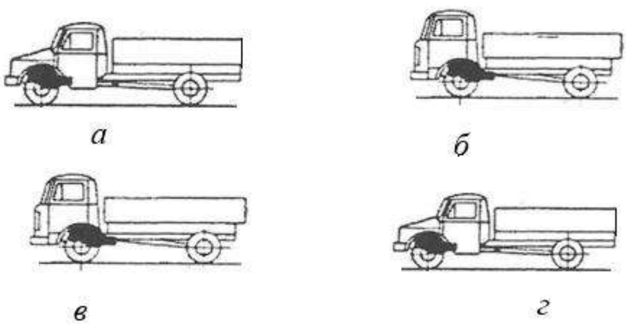

Figure 1.1 – Layout diagrams of trucks

Bus layout diagrams Layout diagram of the bus with the location of the engine and drive wheels is determined mutual (Fig. 1.2 – 1.9).

With a front-wheel drive layout, it can be installed engine maybe along the longitudinal axis of the bus and across.

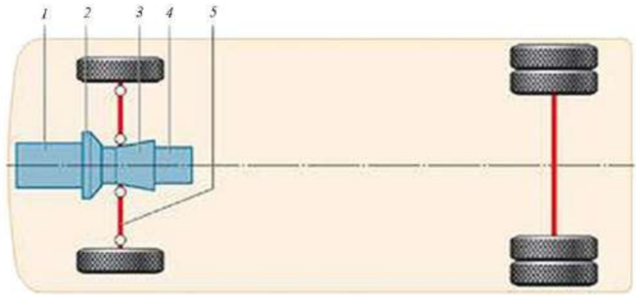

Figure 1.2 – Front-wheel drive layout with longitudinal engine location:
1– engine; *2*– clutch; *3*– main gear; *4*– gearbox; *5*– drive shafts of the driving wheels

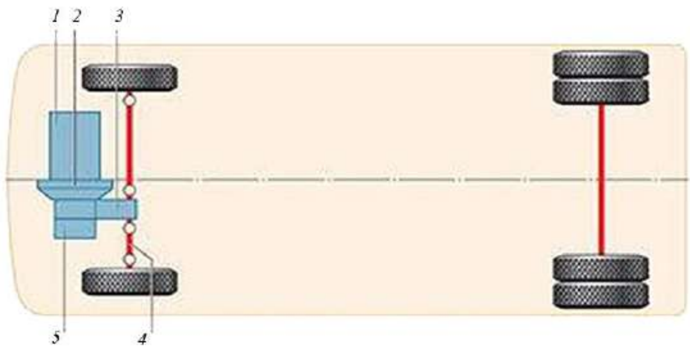

Figure 1.3 – Front-wheel drive layout with transverse engine location:
1– engine; *2*– clutch; *3*– main gear; *4*– drive shafts driving wheels; *5*– gearbox

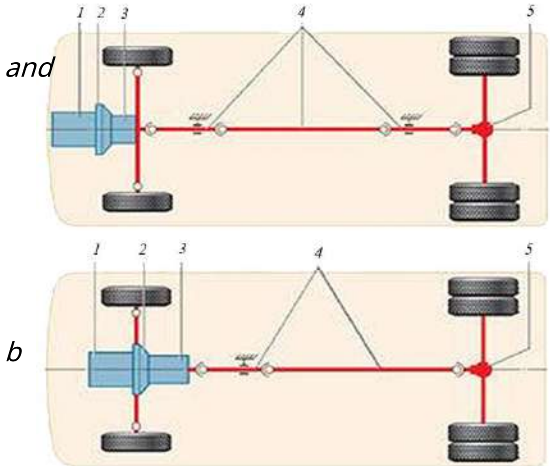

Figure 1.4 – Front-engine rear-wheel drive layout with the engine located in the longitudinal plane of symmetry of the bus: *and*– with a gearbox located in front of the front axle; *b*– inside the bus base; *1*– engine;*2*– clutch;*3*– box gears;*4*– cardan transmission;*5*– main gear

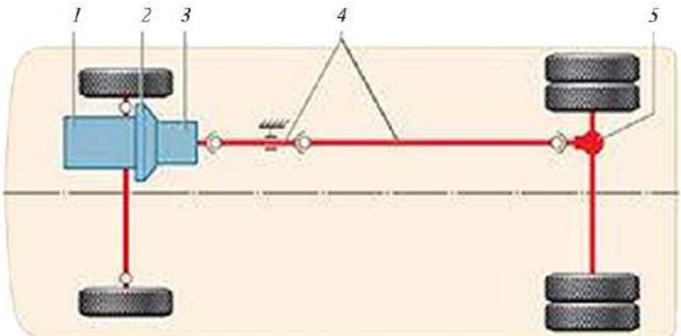

Figure 1.5 – Front-engine, rear-wheel drive layout with offset engine location: *1*– engine;*2*– clutch; *3*– gearbox;*4*– cardan transmission;*5*– main gear

In a rear-wheel drive scheme, the engine is located in the longitudinal plane of symmetry of the bus or offset relative to the axis of symmetry.

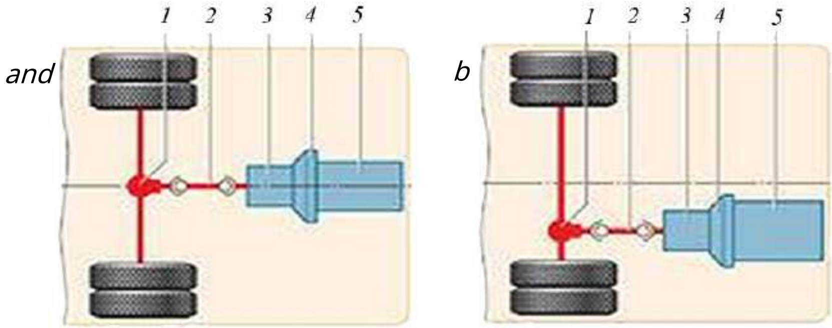

Figure 1.6 – Rear-wheel drive rear-engine layout with longitudinal central (*and*) and shifted (*b*) engine location:
1– main gear;*2*– cardan transmission;*3*– gearbox;
4– clutch;*5*– engine

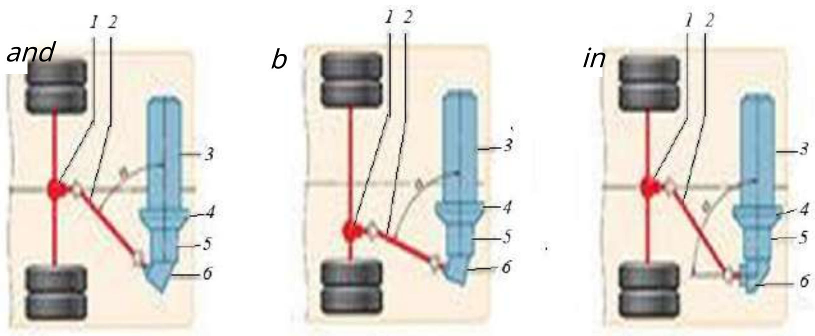

Figure 1.7 – Rear-wheel drive rear-engine layout with transverse engine location and angle α equal to 60 or 65 ° (*and*), 80 ° (*b*) and 90° (*in*):
1– main gear;*2*– cardan transmission;*3*– engine; *4*– clutch;*5*– gearbox;*6*– angle reducer

With the rear engine location, there are two possible installation options – along and across the longitudinal axis of the bus.

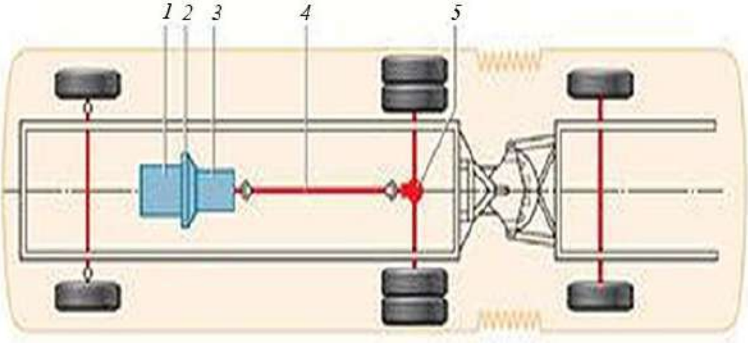

Figure 1.8 – Articulated bus with a towing front section and engine located inside the base:
1– engine; *2*– clutch; *3*– gearbox; *4*– cardan transmission;
5– main gear

Articulated buses are mostly city buses and are usually low-floor. The engine in articulated buses is mounted inside the base.

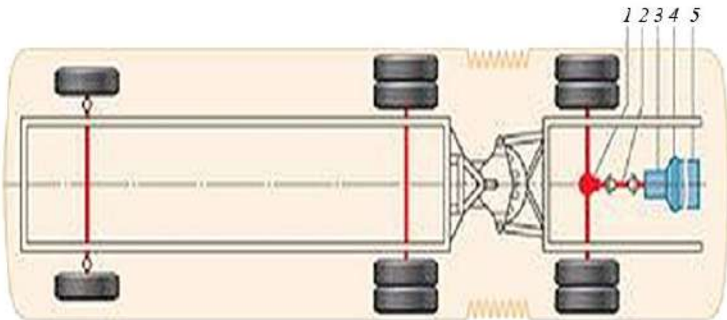

Figure 1.9 – Articulated bus with push-pull rear section and longitudinal arrangement of the engine in the rear trailer section: *1*– main gear; *2*– cardan transmission; *3*– gearbox;
4– clutch; *5*– engine

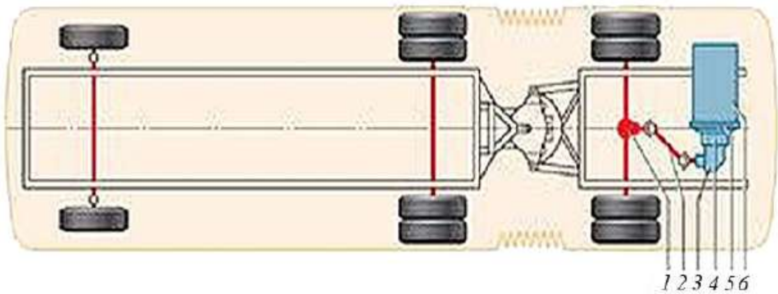

Figure 1.10 – Articulated bus with push-pull rear section with transverse engine location in the rear trailer section: *1*– main gear;*2*– cardan transmission;*3*– angular gearbox; *4*– gearbox;*5*– clutch;*6*– engine

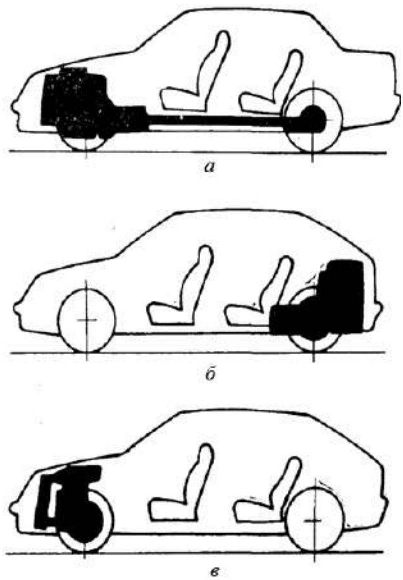

Figure 1.11 – Connection diagrams cars

Layout diagrams passenger cars

Layout scheme passenger car car is determined relative location engine and driving wheels. The main layout schemes of passenger cars (Fig. 1.11) are as follows:

and)*classical*(Fig. 1.11,*and*), when the engine is located in the front and the drive wheels are rear;

b) *rear-wheel drive* (Fig. 1.11,*b*), when the engine is located at the rear, the drive wheels are rear;

in) *front-wheel drive* (Fig. 1.11,*in*) when the engine is located ahead, The driving wheels are the front wheels.

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Classic layout

In this case, the engine and gearbox are located in the front of the car (Fig. 1.12), and the torque is transmitted to the rear wheels. In a car with a classic layout, the weight distribution (weight distribution along the axles) is usually close to the optimal 50/50. As a result, the car “obeys” the steering wheel well, and its tires wear out more evenly. In addition, such models are often distinguished by a fairly large trunk, since its volume is limited only by the suspension and wheel drive elements.

Figure 1.12 – Example of a classic passenger car layout car*BMW*

However, the classic arrangement of units has significant drawbacks. First of all, such cars are characterized by unsatisfactory stability. Conduct a simple experiment - try to quickly push a pencil lying on the table with your finger. It will always strive to turn somewhere. The same thing happens with a car. Moreover, the skidding occurs in this case progressively - the force of inertia tends to turn the car even more. Therefore, automakers are forced to pay great attention to the adjustment of electronic safety systems of models with a classic layout, thereby increasing their price.

In addition, the large central tunnel required to accommodate the driveshaft takes up a lot of space in the cabin. Often, this does not even allow for the middle passenger to be accommodated in the back row of seats.

The longitudinally located engine also forces the body to be stretched in length so as not to reduce the interior space. And in general, the classic scheme is quite bulky, and therefore does not have the best effect on the weight of the car.

Therefore, today only a few automakers have remained faithful to tradition. And the classic layout can now be found mainly only on some models of premium brands -*BMW*,*Mercedes-Benz*, *Lexus*,*Jaguar*.

Front-wheel drive layout

This layout is characterized by the fact that the power unit and the drive wheels in this case are located in the front of the car (Fig. 1.13). Today, the front-wheel drive layout is the most popular among modern cars.

Figure 1.13 – Example of a front-wheel drive vehicle layout

This arrangement of units has a number of advantages: compactness, low weight, low noise and vibration (due to the absence of a cardan shaft). In addition, a front-wheel drive car is usually distinguished by a spacious interior and a large trunk. Finally, a front-wheel drive car is more stable than a rear-wheel drive one. Repeat the experiment with a pencil, only take it by the tip and pull. It will obediently follow your hand. If a skid occurs, the force of inertia prevents the car from turning.

The front-wheel drive scheme also has its drawbacks. For example, during intensive acceleration, the drive wheels are heavily unloaded and cannot realize a large torque, which is especially noticeable on models with sporty by inclination. Except that, front axis it turns out overloaded, causing the tires to wear out faster. The car's maneuverability often suffers, as the steering angle is limited by the tight layout of the engine compartment and the design of the CV joints - the equal angular velocity joints necessary to transfer traction to the wheels.

Rear-engine layout

This layout involves rear-mounted engine and drive wheels. As a result, the rear of the car is overloaded, which gives it very interesting features. For example, a similar scheme can be found on sports models (such as *Porsche 911,* rice.
1.14), since in this case, during acceleration, the driving wheels are loaded more heavily and allow the engine's potential to be fully realized. At the same time, due to the good loading of the driving axle, such cars often have very good cross-country ability (remember our domestic "Zaporozhets"). We should not forget that the rear-engine layout, like the front-wheel drive, is compact and has a small mass.

Figure 1.14 – Car with rear-engine powertrain layout unit

The disadvantages of this scheme follow from its advantages. When the mass of the car is shifted back, its steered wheels are unloaded. Therefore, such a car is sometimes unstable on the road, and the higher the speed, the more the driver has to steer. Only modern electronic safety systems help to partially solve this problem.

And rear-engine models are usually very impractical. After all, the entire rear part of the body is occupied by the power unit, and the trunk has to be placed in front. But in this case, its volume is limited by the suspension elements, steering, and even the feet of the driver and front passenger. So, you can't count on a spacious cargo compartment.

Mid-engine layout

This layout is a characteristic feature of supercars (Fig. 1.15). The power unit on such cars is located within the wheelbase, directly behind the driver. There is a reason for this: such a scheme allows you to concentrate the heaviest elements of the car near its vertical axis, thereby reducing the moment of inertia and distributing the mass along the axles in an optimal ratio. As a result, excellent handling.

Figure 1.15 – Mid-engine all-wheel drive vehicle layout

But for ordinary civilians models medium-engine The layout is unacceptable: the interior is cramped, the trunk is small, and maintenance is expensive, since it is very difficult to get to the engine and gearbox in this case.

However, in the future, engineers may place the power unit under the floor of the body, and then mid-engine cars may prove themselves in a new, practical role.

A separate type of mid-engine layout can be called the so-called scheme*transaxle*, whose supporter remains, for example,*Maserati*In this case, the motor is mounted in front, but it is shifted as far back as possible, within the limits of the wheelbase, and the thrust is transmitted to the rear wheels via a propeller shaft and a gearbox interlocked with the rear axle.

All-wheel drive layout

Recently, this layout is gaining more and more popularity. With this layout, the engine is usually placed in front, and the traction is distributed to all wheels by a system of shafts and gearboxes. The design is complex, heavy and quite expensive, but its disadvantages are compensated by a number of undeniable advantages, such as excellent stability on slippery surfaces, the most complete realization of the engine's potential, increased cross-country ability.

The perfection of the layout scheme is assessed according to the following indicators: material consumption, cross-country ability, ease of control, comfort, visibility, braking properties, handling, stability, maneuverability, compactness, passive safety, reliability, maintainability, simplicity of design, and manufacturing cost.

Review questions

1. List the main parts of a car and a bus.
2. Purpose of the car engine.
3. Purpose and composition of the transmission.
4. Purpose and composition of the running system.
5. What is the purpose of a car body?
6. Management mechanisms and their purpose.
7. What is the chassis of a car called?
8. List the layout diagrams of a truck.
9. Layout diagrams of a passenger car and a bus.
10. What does the technical specification of a car contain?
11. What are the advantages of front-wheel drive cars compared to rear-wheel drive?
12. Why are four-wheel drive cars popular?
13. By what indicators is excellence assessed?
layout diagram?

Laboratory work 2
INTERNAL COMBUSTION ENGINES OF AUTOMOTIVES

Purpose of work– study the types of engines used on cars; general structure, purpose and operation of the main mechanisms and systems.

Visual aids:

• albums, instructions and posters on the design of car engines;

• electronic information material on the construction of modern engines;

• engines in section;

• cars.

Tasks for work:

• identify the types of engines currently used on modern cars;

• study the components of an internal combustion engine (ICE), Identify the component mechanisms and systems. Indicate their purpose;

• study and present in the report the basic concepts and definitions of ICE;

• study the working cycles of internal combustion engines;

• characterize the internal combustion engine according to the task and provide its data and characteristics.

Basic concepts and terms

Engine– a machine that converts any type of energy into mechanical energy work. Many cars are equipped with thermal piston internal combustion engines. The heat released during the combustion of fuel in their cylinders is converted into mechanical energy, which is used to move the car and tractor.

*Engine classification*ICEs are classified according to the following criteria:

– purpose – transport and stationary;

– by the method of implementing the working cycle – four-stroke and two-stroke;

– by the method of mixing – with external mixing (gasoline and gas) and internal mixture formation (gasoline and diesel engines);

– by the method of ignition of the working mixture – with forced ignition from an electric spark (gasoline, gas, etc.) and by compression ignition, i.e. self-ignition (diesel);

– fuel used – they run on gasoline, heavy diesel fuel (diesel), compressed or liquefied gas, other types of fuel;

– by the number of cylinders – single and multi-cylinder (2-, 3-, 4-, 6-, 8-cylindrical, etc.);

– cylinder arrangement – single-row with vertical arrangement of cylinders or with an inclination of the cylinder axis to the vertical by 20...40°; V-shaped two-row with an arrangement of cylinders at an angle and opposed with an opposite horizontal arrangement of cylinders at an angle of 180°;

– by the method of filling the cylinders with a fresh charge – without supercharging and with supercharging;

– cooling method – liquid and air cooling ***Engine components***

The piston internal combustion engine includes:

– crank mechanism (CKM), which perceives gas pressure and converts the rectilinear reciprocating motion of the piston into the rotational motion of the crankshaft;

– gas distribution mechanism (GDM), designed for timely opening and closing of valves, which is necessary for the intake of a combustible mixture (gasoline and gas engines) or air (diesel engines) into the cylinder and the release of exhaust gases;

– a supply system that serves to supply fuel and air separately into the cylinders of a diesel engine or preparing a combustible mixture of finely atomized fuel and air and feeding the mixture into the cylinders of a gasoline or gas engine;

– a cooling system that ensures normal thermal conditions engine;

– a lubrication system that serves to supply lubricant to friction surfaces in order to reduce friction, reduce wear and remove heat from contacting surfaces;

– an ignition system that ensures ignition of the working mixture in gasoline and gas engines;

– a starting system that serves to rotate the crankshaft engine when starting it.

Basic concepts and terms

Main engine parameters: cylinder diameter, piston stroke and number of cylinders.

During one revolution of the engine crankshaft (Fig. 2.1), the piston makes one downward stroke and one upward stroke. The change in the direction of movement of the piston in the cylinder occurs at two extreme points, which are called dead. The uppermost position of the piston is considered the top dead center (TDC), and its lowermost position is considered the bottom dead center (BDC).

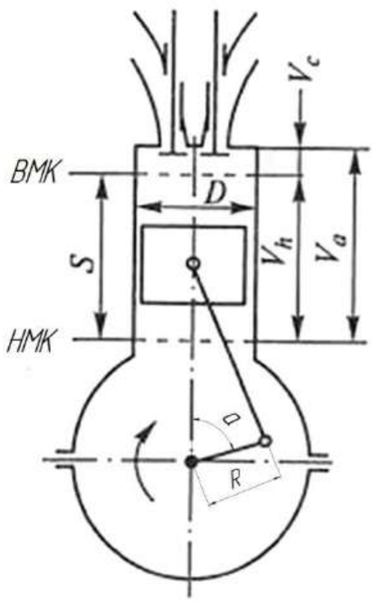


Figure 2.1 – Scheme for determining the main engine parameters

The distance the piston travels from TDC to NDC is called the piston stroke.S, which is equal to twice the radius$R$crank:S=2RWhen the piston moves from one dead center to another, the crankshaft rotates through an angle of 180°, i.e., it makes half a revolution.

The space above the bottom of the piston when it is at TDC is the combustion chamber. Its volume is denoted byV_{with}.The space between the cylinder The two dead centers (TDC and BDC) are called the working volume and denoteV_h. Sum of combustion chamber volume$V_{with}$and working volume is the total volume of the cylinder, denoted byV_{and}.

Cylinder displacement, cm^3or l:

$$V_h = \pi D^2 S / 4,$$

where$D$– cylinder diameter, cm or dm.

The sum of all the working volumes of the cylinders of a multi-cylinder engine is called the working volume of the engine or displacement:

$$V_l = and V_h,$$

where*and*– number of cylinders.

Total cylinder volume ratio$V_{and}$to the volume of the combustion chamber $V_{with}$is the compression ratio:

$$\varepsilon = (V_c + V_h) / V_c.$$

*Compression ratio*is a dimensionless quantity that shows, in how many times the volume of the working mixture or air in the cylinder decreases when the piston moves from N.T.C. to T.D.C. The higher the compression ratio, the greater the temperature and pressure of the working mixture at the end of compression.

As the compression ratio increases, the engine's power and fuel efficiency increase.

Different types of liquid and gaseous fuels have different auto-ignition temperatures, so the type of fuel the engine runs on determines the limits

its compression ratio. Automobile engines running on gasoline (petrol engines) have a compression ratio of 6...10, gas engines - 7...9, and diesel engines - 15...20.

Combustion chamber design options. Different shapes of combustion chambers of gasoline and diesel engines are shown in Fig. 2.2 – 2.4. Two types of combustion chambers are used: undivided (Fig. 2.2 I, II, III, IV, V, VII) and divided (Fig. 2.2 VI, VIII). The nature of the combustion process depends on the shape of the combustion chamber. The main requirements for the design of combustion chambers are to ensure high-quality filling of the cylinder and the efficiency of the combustion process.

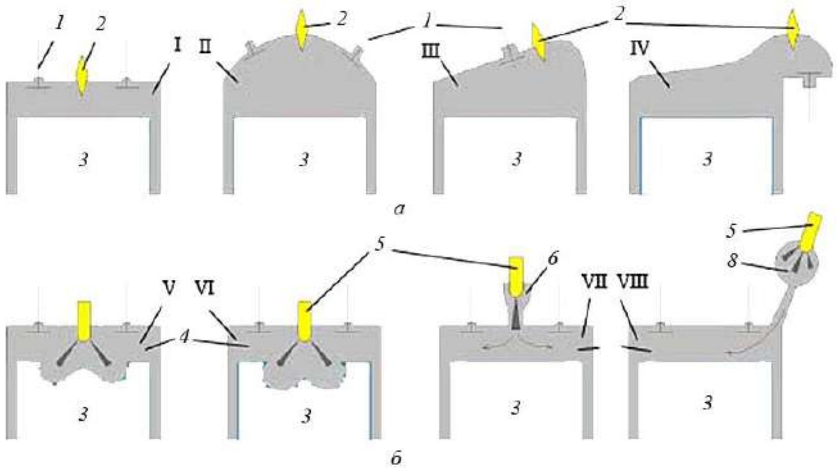


Figure 2.2 – Combustion chamber shapes:
and– gasoline engines;*b*– diesel engines;I – cylindrical; II – hemispherical; III – wedge-shaped; IV – displaced (L-shaped); V and VI – undivided; VII and VIII – divided;*1*– valve;*2*– spark plug;*3*– piston; *4*– combustion chamber;*5*– nozzle;*6*– antechamber;*7*– main camera; *8*– vortex chamber

Combustion chambers are evaluated according to the following indicators:

– the possibility of high-quality gas exchange, which depends on the location and valve passage cross-sections;

– the ratio of the combustion chamber surface to its volume, which is related to with heat losses;

– the nature of the movement of the mixture flows in the combustion chamber;

– the possibility of increasing the degree of compression and reducing detonation.

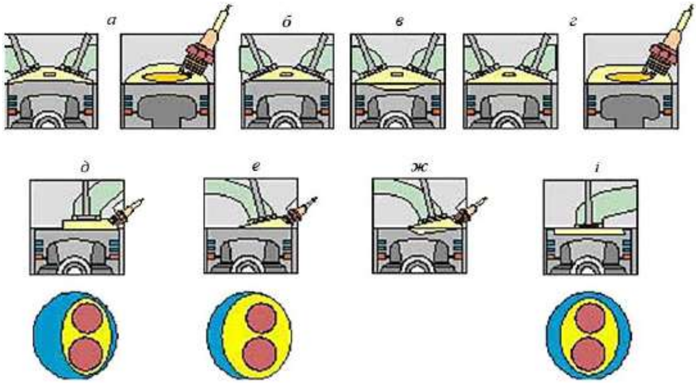


Figure 2.3 – The most common combustion chamber designs gasoline engines:

and– hemispherical;*b*– hemispherical with an ejector;*in*– spherical;*g*– tent; *d*– flat-oval;*there are*– wedge-shaped;*w*– half-wedge with part chambers in the piston;*and*– cylindrical combustion chamber in the piston

Internal combustion engine operating cycles

*Engine duty cycle*is a complex of sequential processes within cylinder, as a result of which the fuel energy is converted into mechanical work.

Tact– this is the part of the work cycle during which movement occurs piston from one dead center to another, that is, in one piston stroke.

Four-stroke engines are those in which the working cycle is completed in two revolutions of the crankshaft, or in four piston strokes. Two-stroke engines are those in which the working cycle is completed in one revolution of the crankshaft, or in two piston strokes.

*Gasoline duty cycle*A four-stroke engine consists of successive intake, compression, expansion and exhaust strokes.

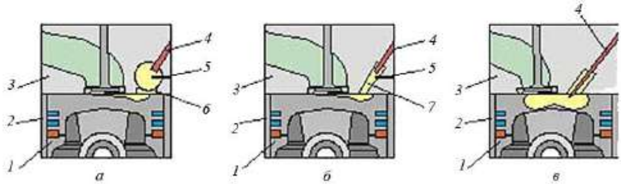


Figure 2.4 – Diesel combustion chambers:

and– vortex chamber;*b*– antechamber;*in*– with direct fuel injection;

1– piston;*2*– cylinder block (liner);*3*– head;*4*– nozzle; *5*– glow plug;*6*– prechamber cover;*7*– antechamber

Intake stroke(rice.2.5,*and*). Piston*6*moves from the upper limit to the lower limit, creating a vacuum in the cylinder cavity*3*above the piston. Intake valve*7* open, and the cylinder through the inlet pipe and carburetor communicates with the atmosphere. Under the influence of the pressure difference between the atmosphere and the cylinder, the air, passing through the carburetor, atomizes the fuel and, mixing with it, forms a combustible mixture. Cylinder*3*is being filled combustible mixture after the piston reaches NDC. By this time, the intake valve is closed.

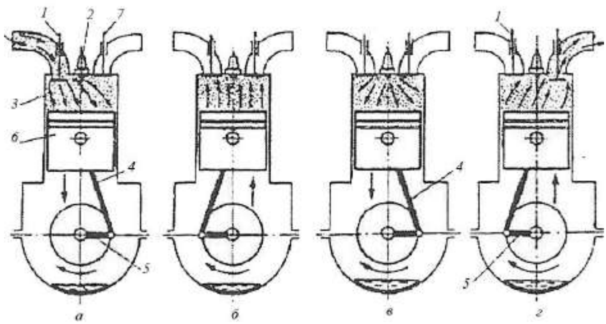


Figure 2.5 – The working cycle of a single-cylinder four-stroke gasoline engine:

and– intake stroke;*b*– compression stroke;*in*– expansion stroke;*g*– tact release; *1*– inlet valve;*2*– spark plug; *3*– cylinder;*4*– connecting rod;*5*– crankshaft;*6*– piston;*7*– graduation valve

At the beginning of the intake stroke, when the piston was at TDC, there were residual combustion products from the previous cycle above the piston in the volume of the compression chamber. The combustible mixture, filling the cylinder, mixes with the residual gases and forms a working mixture. The pressure at the end of the intake stroke is 0.07...0.09 MPa, the temperature of the working mixture is 330...390 K.

Compression stroke(rice.2.5,*b*). With further rotation of the crankshaft*5*the piston moves from N.T.C. to T.D.C. At the same time, the intake and exhaust valves are closed. The piston in the process of movement compresses the working mixture in the cylinder. In the compression stroke, the components of the working mixture are well mixed and heated. The pressure at the end of the stroke increases to 0.9...1.2 MPa, and the temperature - to 500...700 K. At the end of the compression stroke on the spark plug electrodes*2*an electric spark is created, from which the working mixture ignites. During the combustion of fuel, a large amount of heat is released, as a result of which the temperature of the gases increases to 2700 K, and the pressure - to 3.0 ... 4.5 MPa.

Expansion stroke(working stroke; Fig.2.5,*in*). Both valves are closed. Under the pressure of the expanding gases, the piston moves from TDC to NDC and through the connecting rod*4*drives the crankshaft*5*, performing useful work. By the end of the working stroke, the pressure decreases to 0.3...0.4 MPa, and the temperature to 1200...1500 K.

Release cycle(rice.2.5,*g*). When the piston*6*suitable for n.m.t., the exhaust valve opens*7*and exhaust gases under the influence of excess pressure begin to escape from the cylinder into the atmosphere through the exhaust pipe. Then the piston moves from NDC to TDC and pushes the exhaust gases out of the cylinder. By the end of the exhaust stroke, the pressure in the cylinder is 0.11...0.12 MPa, and the temperature is 700...1100 K.

Then the work cycle repeats.

The working cycle of a four-stroke diesel engine. Unlike a gasoline engine, air and fuel are introduced separately into the cylinder of a diesel engine.

Intake stroke(rice.2.6,*and*). Piston*5*moves from the upper limit to the lower limit, intake valve*1*open. In the cylinder*4*under the influence of pressure drop in air enters the atmosphere and the cylinder, mixing with the residual gases. Pressure at the end of the stroke 0.08...0.09 MPa, air temperature 320... 340 K.

Compression stroke(rice.2.6,*b*). Both valves are closed. Piston*5* moves from NDC to TDC, compressing the air. Due to the high compression ratio (14 ... 18), the pressure at the end of this stroke reaches 3.5 ... 4 MPa, and the temperature is 750 ... 950 K (exceeds the autoignition temperature of the fuel).

Into the cylinder through the injector*2*liquid fuel is injected, which fed by a pump*6*high pressure. The nozzle provides a fine atomization of fuel in compressed air. The fuel injected into the cylinder mixes with heated air and residual gases, forming a working mixture. Most of the fuel ignites and burns. The temperature of the gases reaches 1900...2400 K, and the pressure is 5.5...9 MPa.

Expansion stroke(working stroke; Fig. 2.6,*in*). Both valves are closed. Piston*5* under the pressure of expanding gases moves from the top dead center to n.m.t. and through the connecting rod rotates the crankshaft, performing useful work. At the beginning of the stroke, the rest of the fuel burns. By the end of the working stroke, the gas pressure decreases to 0.2...0.3 MPa, the temperature - to 900... 1200 K.

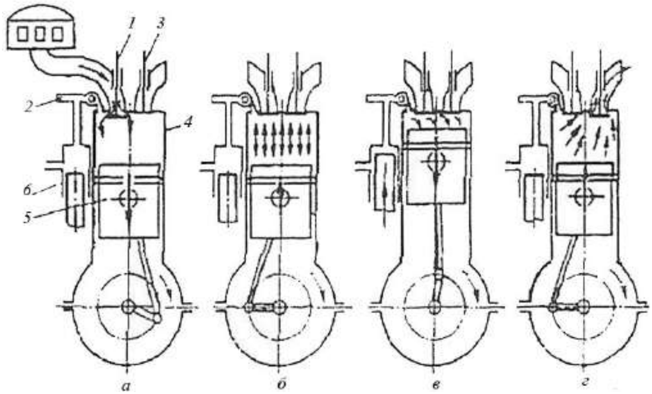


Figure 2.6 – The working cycle of a single-cylinder four-stroke diesel engine:
and– intake stroke;*b*– compression stroke;*in*– expansion stroke;
g– tact release;*1*– inlet valve;*2*– nozzle;*3*– exhaust valve;
4– cylinder;*5*– piston;*6*– high pressure fuel pump

Release cycle(rice.2.3,*g*). Exhaust valve*3*opens. Piston*5*moves from N.T.C. to T.C. and through the open valve pushes the exhaust gases out of the cylinder into the atmosphere. By the end of the stroke, the gas pressure is 0.11...0.12 MPa, the temperature is 650...900 K.

Then the work cycle repeats.

During the power stroke, the piston moves under the pressure of gases and, using a connecting rod, drives the crankshaft into rotational motion. During the exhaust, intake, and compression strokes, the piston must be moved by rotating the crankshaft. This process is also carried out due to the kinetic energy accumulated by the massive flywheel during the power stroke.

Comparison of diesel and gasoline engine performance

Compared to a gasoline engine, a diesel engine has advantages: it consumes an average of 25...30% (by mass) less fuel to perform a unit of work; the fuel used is less flammable.

The high pressure of gases in the diesel engine cylinder requires parts of increased strength, which increases the size and weight of the diesel engine. Starting in winter is difficult.

Two-stroke engines are less economical than four-stroke engines.

Review questions

1. What engines and their combinations are used in cars?
2. How many mechanisms and systems are there in the design of an internal combustion engine?
3. Purpose of internal combustion engine mechanisms. Purpose of internal combustion engine systems.
4. What are the main parameters of an internal combustion engine?
5. What is the duty cycle, stroke of an internal combustion engine?
6. The operating cycle of a gasoline internal combustion engine.
7. The operating cycle of a diesel internal combustion engine.
8. What are the differences between 4- and 2-stroke internal combustion engines?
9. How do the pressure and temperature change during the cycle?
10. How to determine the compression ratio of an internal combustion engine?
11. What is the compression ratio of the internal combustion engine used in cars?
12. Does the compression ratio change during the operation of an internal combustion engine?
13. Advantages and disadvantages of two-stroke engines.
14. Which internal combustion engine has the highest efficiency? What are the consequences of this in operation? cars?

Laboratory work 3
ELECTRIC MOTORS OF ELECTRIC VEHICLES AND HYBRID CARS

Purpose of work– study the structure and operation of modern electric motors and hybrid cars.

Visual aids:

• albums, instructions and posters on electric motors;

• electronic information material on structures electric motors;

• electric motors in section;

• car.

Tasks for work:

• study the structure and design features of electric motors;

• study the purpose and interaction of the main elements of the node;

• study the features of electric motors of electric vehicles and hybrids cars;

• provide data, characteristics of electric motors of electric vehicles and hybrid cars according to the teacher's instructions, the structure of the voltage conversion system for powering the electric motor.

Main provisions

At present, traditional synchronous, synchronous reactive and asynchronous brushless three-phase alternating current electric motors are used as electric motors for electric vehicles. In a brushless electric motor, electrical energy is converted into mechanical energy by changing the polarity. In such electric motors, it is necessary to apply a constant voltage to the stator windings at certain time intervals, simulating the operation of the collector. For this purpose, control units (switches) are provided or this function is performed by an inverter. Transistors, according to processor signals, based on signals received from Hall sensors or a transformer, depending on the rotation frequency and position of the rotor shaft, switch the stator windings, creating a rotating magnetic field that interacts with the field of the rotor magnets. As a rule, three pairs of windings are used in the design of the stator of a brushless electric motor, and voltage is applied to them alternately. When voltage is applied to the first pair of windings, the armature with permanent magnets rotates, aligning its position in accordance with the direction of the magnetic field lines, which arose. At this moment, the voltage from the first pair of windings is removed and applied to the second pair. Since the armature of the electric motor has a certain moment of inertia, it does not stop instantly, but continues its rotation, and its magnets begin to interact with the next magnetic field. This continues until voltage is applied to the stator windings in turn.

A synchronous electric motor is an electric motor that operates on alternating current. The main feature of such a motor is that its rotor uses a permanent magnet, or an electromagnet (a winding with power supply), which constantly interacts with the rotating magnetic field of the rotor, which creates a rotation of the rotor equal to the frequency of rotation of the magnetic field. Synchronous electric motors are usually used if the required power must exceed 100 kW. Consider synchronous electric motors of a passenger car *JAGUAR I-PACE*An electric vehicle can have one or two traction electric motors. For example, in*JAGUAR I-PACE*two installed The traction electric motors are located on the front and rear axles (Fig. 3.1). This allows acceleration to 100 km/h in 4.5 seconds.

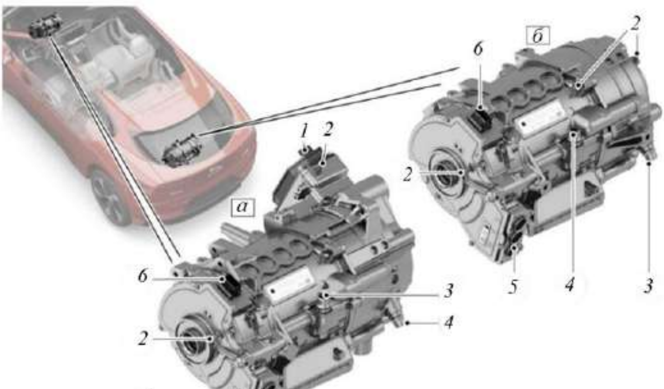


Figure 3.1 – Location of electric motors in*JAGUAR I-PACE: A*– front electric drive unit;*IN*– rear electric drive unit; *1*– parking drive wiring harness connector;*2*– breather connection locking;*3*,*4*– coolant connection;*5*– three-phase connector cable to the corresponding inverter;*6*– wiring harness connector12 V

IN movement electric car lead two synchronous blocks electric drive (*EDU*) with permanent magnets, built into the front and rear axles. Each unit is equipped with a single-stage gearbox with a planetary gear and an open differential connected directly to the electric motor. Each wheel is connected to the gearbox via a half-axle, providing the possibility of all-wheel drive.*EDU* provides 147 kW of power and 348 N m of torque from each motor. Each motor is connected to an inverter. The inverter controls the motor operation in response to input signals from the accelerator and brake pedals. Permanent magnet synchronous motors (Fig. 3.2) use a rotor with permanent magnets that are synchronized with the electromagnetic field created by the stator windings. If three-phase alternating current is applied to the stator windings in a sequence that gradually changes the polarity of each winding, a rotating electromagnetic field is created around the stator. The position of the rotor coincides with this rotating electromagnetic field, which attracts the rotor's magnetic field, causing the rotor to rotate. When the rotor and the rotating stator magnetic fields are fully synchronized, the rotor's rotational speed is directly proportional to the frequency of the alternating current applied to it. In this state, the motor produces maximum power.

Figure 3.2 – Synchronous electric motor of an electric vehicle with permanent magnets: *1*– gearbox drive gear; *2*– permanent magnet gears; *3*– rotor; *4*- stator windings

Fig. 3.3 shows the rotation process of a simple synchronous electric motor with a permanent magnet rotating clockwise.

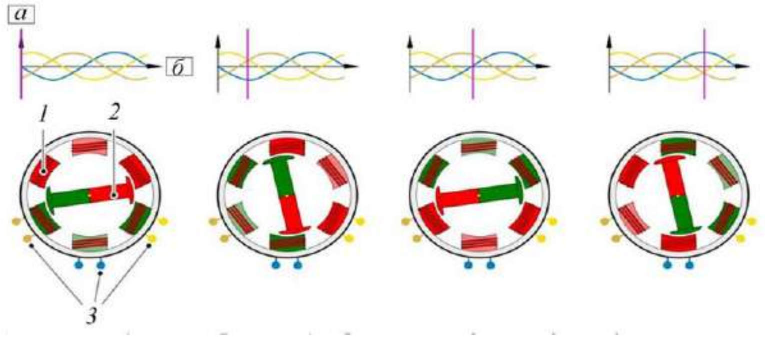


Figure 3.3 – Principle of operation of a synchronous electric motor:
AND– voltage/amplitude;*B*– time;
1– stator windings;*2*– rotor;*3*– three-phase connection

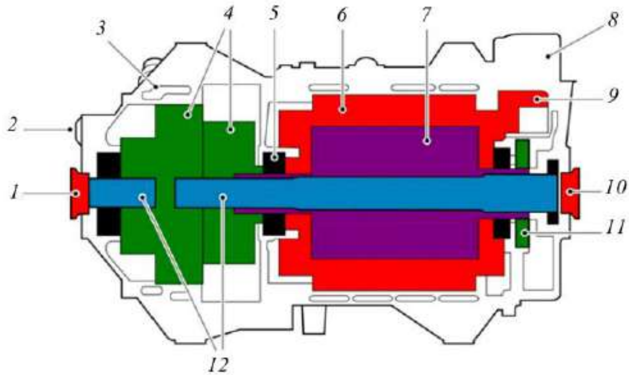


Figure 3.4 – Schematic of a synchronous electric drive unit:
1– axle shaft seal;*2*– oil filler plug*EDU*;*3*– shirt coolant;*4*– gearbox and differential;
5– bearing;*6*– stator;*7*– rotor;*8*– body;*9*– three-phase connection;
10– axle shaft seal;*11*– resolver ring position sensor;
12– half-axle drive

The three-phase alternating current supplied to the stator windings is regulated to switch from one set of windings to the next, and the rotor rotates at the same speed. The magnitude and phase of the current supplied to the stator windings are proportional to the motor output, so precise control is required to ensure the efficiency of the electric motor. Resolver Ring Position Sensor *11*(see fig.3.4) is used to accurately determine the speed and position of the rotor relative to the rotating electromagnetic field to provide complete control of the output of the electric motor.

Resolver– is a rotating transformer, the principle of operation of which is conversion of the angle of rotation into an electric voltage. The amplitude of the voltage, which is proportional to the angle, or is a function of the sine (cosine) of the angle, is used as a measurement. Their operating principle determines the current position of the rotor of the electric motor, with the help of which, for example, the speed of rotation of the motor shaft can be determined. During the operation of the resolver, EMFs are induced between its windings, the amplitude and phase of which depend on the position of the resolver rotor, on which one (or several) of the windings of the AC electric motor are located. During the operation of the resolver, within one complete revolution of the rotor, the shape of the EMF amplitudes of the secondary windings of the resolver characterizes the angle of rotation of the rotor. The output signal of the resolver is fed directly to the inverter. The inverter then feeds the appropriate frequency and voltage to the stator coils. In addition, the inverter uses position information to ensure that the rotor always remains synchronized with the rotating magnetic field. Torque is created when the rotor magnetic field lags behind the rotating stator magnetic field. Since the permanent magnets always try to catch up with the rotating stator magnetic field, rotating the rotor shaft, and thus driving the electric vehicle. The timing of the AC input signal is ahead of the rotor position, the more the input signal is ahead, the more torque is created. However, if the AC input signal is too far ahead, the magnetic fields will go out of sync and the motor will stop. The timing of the AC input signal is

The AC signal may lag behind the rotor position. The rotating magnetic field acting on the rotor tries to rotate the rotor in the opposite direction, creating a controlled braking torque. It is in this state that the kinetic energy of the braking is converted into electrical energy, the electric motor becomes a generator. As the rotor moves around the stator, the rotor's magnetic field passes through the stator winding, inducing a three-phase alternating current. The rotor rotation frequency and the field strength of the stator windings are proportional to the generator power.

Everyone's work*EDU*controls the connected inverter depending on torque request issued by the powertrain control unit. The inverter switches*EDU*between the modes of the electric motor and generator on demand. When*EDU*operates in electric motor mode, The inverter receives direct current from the high-voltage battery and converts it into three-phase alternating current. The high-voltage alternating current is supplied to the three-phase stator windings of the electric motor. The data from the resolver position sensor is used to control the phase of the three-phase alternating current. The inverter divides the three-phase high-voltage alternating current into*EDU*depending on torque requirements. Inverter and*PCM*exchange data over a bus network*FlexRay*When operating in regenerative braking mode,*EDU* generates three-phase alternating current for the inverter. The inverter rectifies the alternating current into direct current and regulates the voltage for charging the high-voltage battery. The inverter manages the electrical energy recovered during regenerative braking and regulates the braking effect on the front and rear wheels. Data for the amount of braking required by each*EDU*, are sent to the inverter from *PCM*via network bus*FlexRay*.

Synchronous reluctance electric motors with internal permanent magnet (SynRM).For an electric vehicle, the most important thing is its starting torque, which determines the starting time of an electric vehicle. In existing asynchronous electric motors used for electric vehicles, the starting torque is not effective. In addition, a disadvantage of a synchronous electric motor is that during long trips at high speed, 3–4% of the power is lost to generate current in rotor rods. To eliminate these shortcomings, the company is now *Tesla* started production of their cars synchronous electric motors, which use both electromagnetic and reactive influences on the rotor of the electric motor. Such motors are called "synchronous reactive motors". In such motors, the interaction of the magnetic fields of the rotor and stator causes the rotor to rotate. If the magnetic field of the stator is rotated by 45° relative to the rotor, the rotor receives maximum torque. This is due to the fact that the forces of attraction and repulsion (the pushing force of the stator magnetic field and the force of the magnetic field of the traction rotor) pass almost tangentially to the rotor and create torques in almost the same direction. This can be seen from the example of pushing a ball along a horizontal plane (Fig. 3.5, *and*, *in*). With the same direction of the pushing and pulling forces, the total force moving the ball will be greater than the total force when the pulling force is at an angle. Another disadvantage of an electric motor with permanent magnets is that when an electric vehicle moves along a flat surface at a constant high speed, the lines of force created by the permanent magnets intersect the turns of the stator winding, creating a reverse electromagnetic force there. The higher the rotor speed, the stronger the reverse electromagnetic force becomes, which reduces the efficiency of the electric motor and increases its heating. Synchronous electric jet motors are devoid of these disadvantages.

The principle of operation of a reactive synchronous motor is as follows. It is known that iron, compared to air, holds magnetic lines of force of a magnetic field well. In this regard, if slots are made in the iron rotor, then the resistance to magnetic lines of force will change depending on the position of the rotor, increasing or decreasing, depending on whether they pass through iron or air (Fig. 3.6). In the position of the rotor (Fig. 3.6, *and*) the resistance to magnetic lines of force will be high because they pass through iron, and in the position (Fig. 3.6, *b*), at which the rotor is rotated 45° – low. The rotor always tends to move to a position where the resistance of the magnetic field is low, rotating with it. Thus, the rotor can always be in a position where the magnetic field has low resistance, while the rotor rotation speed will coincide with the speed of rotation of the stator magnetic field. The torque in this mode of the electric motor is called reactive torque, and electric motors that use this principle of operation are called synchronous reactive electric motors, adapted for high speeds of electric vehicles.

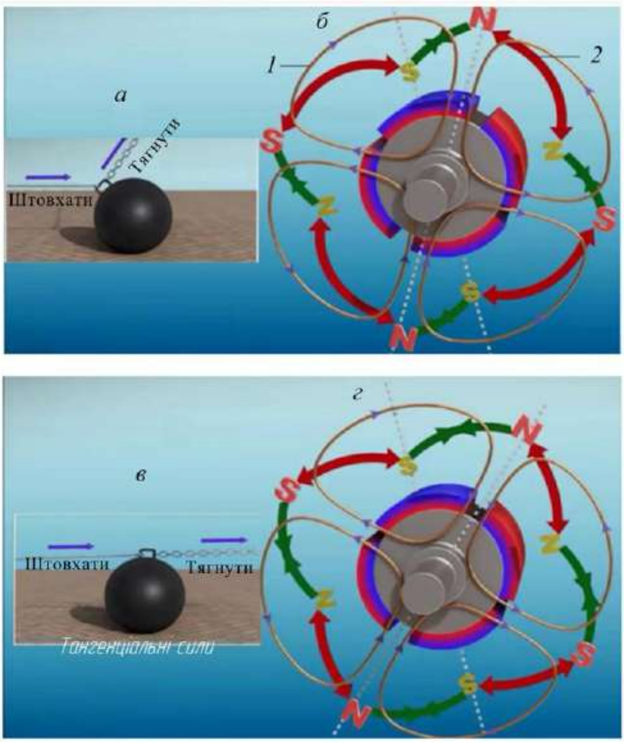


Figure 3.5 – Scheme of the action of magnetic forces:

and– pulling and pushing forces at different angles;*b*– magnetic field the stator coincides with the rotor magnetic field;*in*– pulling and pushing forces at the same angle;*g*– the stator magnetic field, located at an angle of 45° relative to the rotor magnetic field;*1*– stator magnetic field;*2*– magnetic rotor field

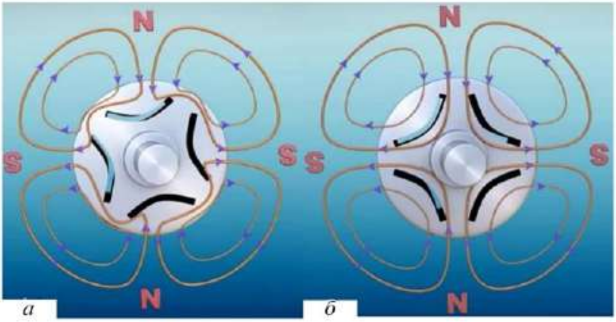


Figure 3.6 – State of magnetic field lines depending on position rotor:
a, b– high and low resistance to magnetic field lines, respectively

In order to combine the positive features of the operation of synchronous electric motors, which use the possibility of obtaining maximum torque, as well as synchronous reactive electric motors, which use the possibility of obtaining low magnetic field resistance and, therefore, reducing the reverse electromagnetic force when driving an electric vehicle at high speeds, designers*Tesla*created a new electric motor. Such an electric motor installed on electric vehicle models*Tesla M3*(rice.3.7).

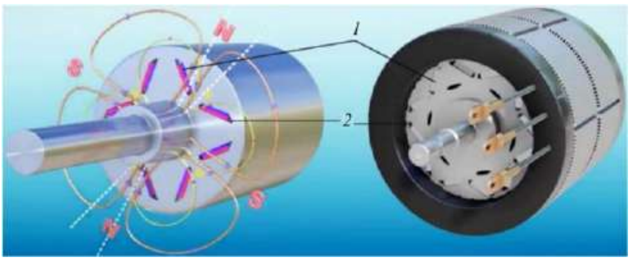


Figure 3.7 – Electric motor*Tesla M3*

The change in torque is shown in Fig. 3.8. At the initial moment (point*1*, curve *and*) the rotor does not rotate and the torque is zero. If the stator magnetic field is rotated by an angle of 45° (point 2, curve*and*), torque acts on the permanent magnets clockwise due to the influence of the stator magnetic field. At this angle, the maximum torque from the permanent magnets is achieved. Rotating the magnetic field another 45° (point*3*, curve*and*) causes the torque that rotates the rotor to approach zero.

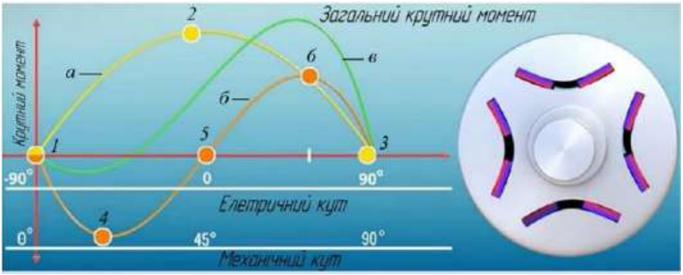


Figure 3.8 – Torque change graph:

a, b– the influence of the magnetic field of the stator and rotor on the change in torque moment, respectively;*in*– total torque

The iron part of the rotor has the opposite effect on the change in torque (curve*b*). At the initial angle, the torque is zero, because this is an unbalanced and symmetrical behavior of the stator magnetic field. By shifting the stator magnetic field clockwise, the rotor will experience a maximum and negative torque (point*4*, curve*b*). When the stator magnetic field is rotated by an angle of 45°, the torque becomes zero again (point*5*, curve*b*), since this is again a symmetrical case. With further rotation of the stator magnetic field, the generated rotor reactive torque becomes positive (point*6*, curve*b*). From the curve of the total torque graph, it can be seen that at an angle of the stator magnetic field of about 50°, the maximum torque of the electric motor is obtained, therefore, when the electric vehicle starts from a standstill, the angle of the stator magnetic field relative to the rotor magnetic field is about 45...50°. As the speed of the electric vehicle increases, a reverse magnetic field is induced on the stator coils. To eliminate this problem in the electric motor*Tesla M3* At high speeds of the electric vehicle, the magnetic field of the stator is equalized. In this case, the magnetic field of the permanent magnet (stator) weakens to a minimum, practically not creating a reactive moment, and the occurrence of torque will occur due to the resistance effect.

The synchronous electric motors with internal permanent magnets (SynPM) discussed above have an efficiency of up to 96%, while asynchronous motors have an efficiency of up to 94%. In asynchronous motors, a rotor cooling system is required, in a SynPM electric motor the rotor does not heat up and there is no need for a cooling system. Similar types of electric motors are used in a hybrid car *Toyota Prius*The difference is in the magnets. In*Toyota Prius*are used integral magnets, in*Tesla M3*– compound. Those that consist of four parts, allow to reduce eddy currents, and hence their heating, which also protects such magnets from demagnetization.

Asynchronous motors– alternating current electric motor, frequency the rotation of the rotor of which is equal to (in the driving mode less than) the frequency of rotation of the magnetic field created by the current of the stator winding. Sometimes asynchronous motors are called induction motors, because in the rotor, according to Lenz's law, an electromagnetic force is induced in them. The rotor rotates not synchronously with the rotating field of the stator. The general structure of an asynchronous motor is shown in Fig. 3.9.

Figure 3.9 – General structure of an asynchronous electric motor:
1– rotor;*2*– stator;*3*– body;*4*– groove;*5*– winding;
6– shaft;*7*– rod;*8*– ring

An induction motor consists of two main parts: a squirrel-cage rotor*1*and stator*2*, which are installed in the housing*3*The basis of the stator is the core, which is assembled from sheets of special electrical steel. The sheets are insulated from each other and have grooves *4* with The insulation is installed in the grooves of the core and the winding is placed *5* made of copper insulated with special varnish wire.

The rotor is arranged similarly, the core of which is a "squirrel wheel" (Fig. 3.10), fixed on a shaft and consisting of a set of metal copper rods. *2*, soldered or cast into the core *1,* closed between each other with rings *3* To reduce higher harmonics of the EMF and field pulsation, the rods are placed not along the shaft, but at a certain angle to the axis of rotation.

There is no electric current in the rotor of an asynchronous motor during start-up. However, after the magnetic force field of the stator begins to rotate, it affects the metal rods (windings) of the "squirrel wheel", exciting an EMF in it. After that, a magnetic field appears in the rotor, which interacts with the magnetic field of the stator and the electric motor begins to operate in normal mode.

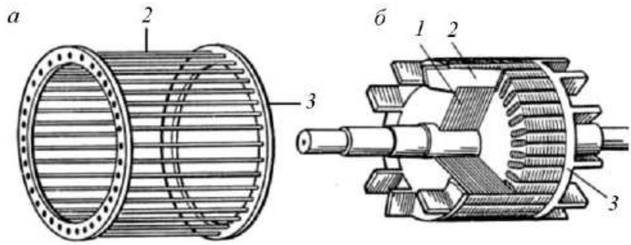


Figure 3.10 – “Squirrel Wheel” (*and*) and squirrel-cage rotor (*b*):
1 – core; *2* – a set of metal rods; *3* – ring

Due to the loss of time of emergence of the working magnetic field of the rotor, its magnetic field lags behind the magnetic field of the stator, therefore such a motor is called asynchronous. The principle of operation of an asynchronous motor is based on the force action of the magnetic field. The rotating magnetic field created by the currents of the stator winding induces an EMF in the rotor winding. Since the rotor winding is always closed, then under the action of this EMF currents will flow. The magnetic field interacting with these rotor currents creates a rotating electromagnetic torque on its shaft, which is always directed in the direction of rotation of the magnetic field. Under the influence of this, the rotor begins to rotate at a speedn_2. According to the law of electromagnetic induction, an EMF will be induced in the rotor winding only if the plane of the winding turns does not coincide with the direction of the magnetic field, i.e. the rotor rotates either slower or faster than the field. According to the principle of operation of an asynchronous machine, the speed of rotation of the magnetic field and the speed of rotation of the rotor must always be different:n_2-n_1If the rotor speed coincided with the speed of the stator magnetic field, then the motor force would not be created in the rotor rods, and therefore, the current. From the principle of operation it follows that the asynchronous motorn_2-n_1(the rotor lags behind the magnetic field), and in an asynchronous generator –n_2-n_1 (the rotor is ahead of the magnetic field). The magnitude of the induced EMF depends on the frequency of intersection of the conductors by the rotating magnetic field. That is, the higher the difference betweenn_1 andn_2, the greater the magnitude of the EMF. The rotor will rotate at a frequency of n_2, which will always lag behind the synchronous frequency of the stator fieldn_1This difference between both frequencies will be the slip frequency $\Delta n=n_1-n_2$. This inequality is a necessary condition for the appearance of an electromagnetic torque rotating in an asynchronous motor. Therefore, the electric motor is called so, since the rotation of the rotor occurs asynchronously with the stator field. The concept of slip is the ratio of the rotation frequency to the field frequency. This quantity$S$is taken as a percentage of frequency of rotation of the magnetic field. Accordingly, the rotor frequency, determined by slip, will be:$n_2=n_1(1 – S)$. The rotor of an asynchronous motor rotates in the same direction as its magnetic field. In turn, the direction of rotation of the field depends on the phase sequence of the three-phase network. It is possible to change the direction of rotation of the rotor by changing the direction of current flow. Since the current is alternating, in order to reduce losses due to stray currents, the stator core is made of thin steel plates insulated from each other.

scale and bonded with varnish. The stator windings are supplied with a supply voltage, the current flowing in them is called the stator current.

A typical asynchronous three-phase motor is equipped, for example, with well-known cars*Tesla Model S*and*Tesla X*, it consists of a stator and a rotor (Fig. 3.11). The rotor is a set of electrically conductive rods*3,* closed at the ends by disks*2*. Three-phase alternating current is supplied to the stator. Passing through the windings, the current creates a rotating four-pole magnetic field*4*, which induces a current in the rotor rods.

In an asynchronous electric motor*Tesla*rotor speed depends on the frequency of the alternating current. By changing the frequency of the alternating current in the (power source) inverter, you can change the speed of rotation of the rotor, and therefore the driving wheels of the car.

The electric motor is powered by a frequency-controlled

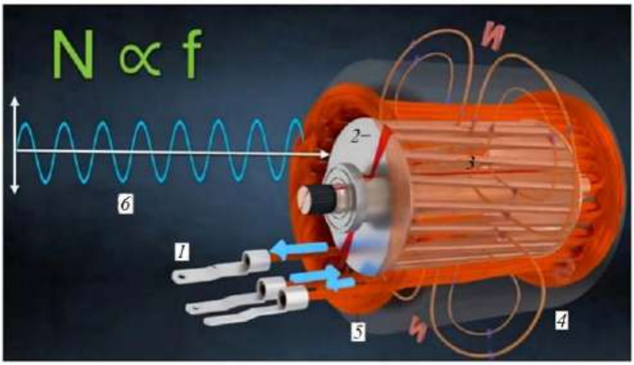


Figure 3.11 – Circuit diagram of an induction asynchronous electric motor: *1*– contact terminals;*2*– disk;*3*– rod;*4*– pole magnetic field; *5*– stator winding;*6*– current pulses;*N*– shaft rotation frequency rotor;*f*– alternating current frequency

a drive that controls the rotor (armature) speed from 0 to 18,000 rpm^{-1}.

The electric motor is powered by a battery that produces a voltage of about 288 - 440 V, the current from which is transmitted to the inverter.*3*(rice.3.12).

To control the electric motor, an inverter is used, which converts the battery's direct current into three-phase alternating current, and also increases and decreases the strength and frequency of the alternating current, which allows you to control the speed of rotation of the stator's magnetic field, and therefore the speed of rotation of the rotor and, in proportion to the speed of rotation of the wheels of the electric vehicle.

By changing the current frequency, the rotor shaft rotation frequency is changed, and therefore the speed of the electric vehicle: by changing the amplitude, the torque is changed. To change the direction of rotation of the rotor, for example, to obtain reverse gear, the phases are changed.

The inverter also changes the phases of the rotor rotation voltage change if reverse motion is necessary.

The electric car has an energy recovery system. During braking, the rotor rotates faster than the magnetic field, and the electric motor starts to operate in generator mode (Fig. 3.13). In this case, the magnetic field of the recuperation system begins to counteract the rotation of the car's electric motor shaft, energy is recovered and charges the battery.

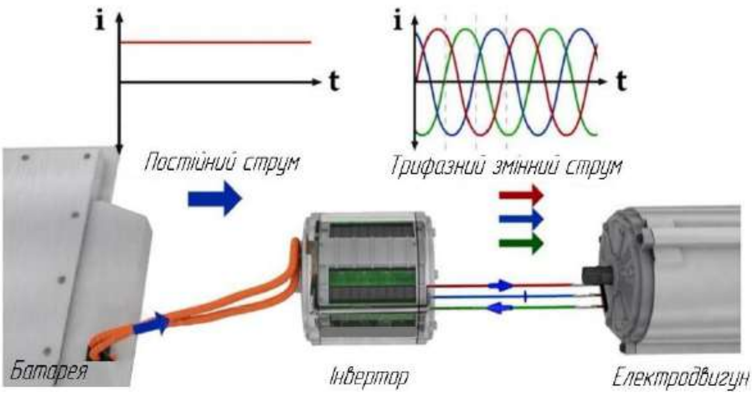


Figure 3.12 – Inverter connection diagram to the control system electric motor:

and– current strength; *t*– time

The inverter generates electricity in the stator coils, creating more energy than is needed to operate the electric vehicle. The excess electricity generated, after being converted to direct current, is used to charge the battery. During charging, a counter-electromotive force acts on the rotor, which slows down the vehicle's drive wheels.

Review questions

1. Purpose of the electric motor when used in electric vehicles and hybrid car;
2. Which electric motor is not provided in the work materials and why?
3. Give a classification of electric motors used in electric vehicles for driving the drive wheels;
4. Provide a diagram of how the inverter is connected to the control system. electric motor.
5. The principle of operation of an electric motor in generator mode.
6. Purpose of the inverter in different modes of machine movement.
7. What does synchronous electric motor mean?
8. What does asynchronous electric motor mean?
9. Why are permanent magnets introduced into the design of an electric motor?
10. What is the efficiency of electric motors?
11. The principle of operation of a reactive synchronous electric motor.
12. By changing the frequency of the alternating current in an electric motor electric car?

Laboratory work 4
CRANK-CONNECTING ROD MECHANISM OF ICE

Purpose of work– study of modern structures, basic parameters of the crank mechanism (CKM) parts of an internal combustion engine.

Visual aids:

• albums, instructions and posters on the design of car engines;

• electronic information material on the design of modern KSHM

Internal combustion engine;

• engines in section;

• presentations;

• animations;

• car.

Tasks for work:

• study the components of the CSHM;

• determine their purpose;

• identify and classify mechanisms and devices of the KShM according to option.

General information

The KSHM consists of two groups of parts:*movable and immovable*

. *To the immovables*KSHM parts include: cylinder block, insert liners (if any), insert liner installation parts, block head (or cylinder head), crankshaft installation and sealing parts, sump, covers, gaskets, mounting parts.

*To the moving ones*KSHM parts include: piston group, crankshaft shaft assembly and flywheel.

*Piston group*consists of the following: piston, piston rings (compression and oil scraper), piston pin, floating piston pin retaining rings, connecting rod with liners.

An example of the mutual arrangement of most of the fixed parts of the V-shaped ICE is shown in Fig. 4.1.

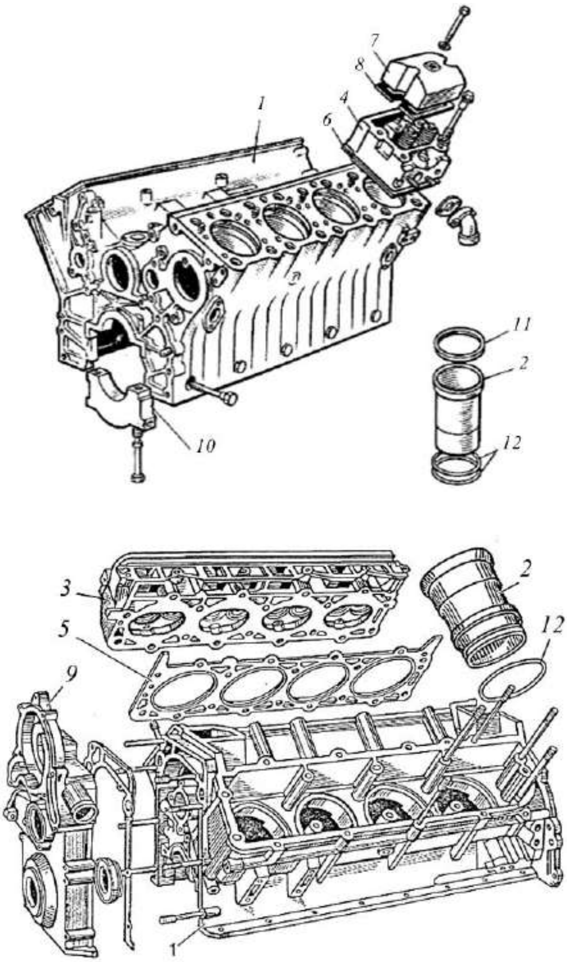


Figure 4.1 – Mutual arrangement of the main fixed parts of the KShM:
1– cylinder block; *2*– cylinder liner; *3*- block head; *4*– head cylinder; *5*, *6*– head and cylinder head gaskets; *7*– head cover cylinder; *8*– cover gasket; *9*– gear cover; *10*– lid crankshaft main bearing; *11*– upper sleeve seal cylinder; *12*– lower cylinder liner seal

The main basic part of the internal combustion engine and the cylinder block is the cylinder block (Fig. 4.2). Depending on the design of the internal combustion engine, the block contains cylinders made in the form of removable or non-removable liners.

Figure 4.2 – Cylinder block of an inline four-cylinder engine

The V-shaped layout of the cylinder block has become widespread (Fig. 4.3).

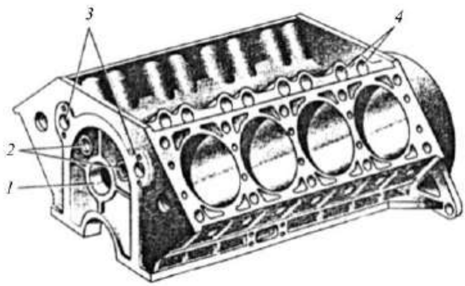


Figure 4.3 – Traditional V-shaped ICE cylinder block: *1*– camshaft bearing;*2*– longitudinal oil plug caps channels;*3*– cooling system openings;*4*– holes for parts gas distribution mechanism

Variants of insert sleeves in cylinder blocks are shown in Fig. 4.4.

To increase the wear resistance of the upper part of the cylinders, inserts are used (Fig. 4.4,*and*) made of wear-resistant cast iron. Sleeve are made of high-strength cast iron or subjected to volume hardening. Liners made of an aluminum-silicon alloy are successfully used for passenger car engines. The inner surface of cylinder liners in aluminum alloy blocks is made in the same way, using silicon carbide and nickel.

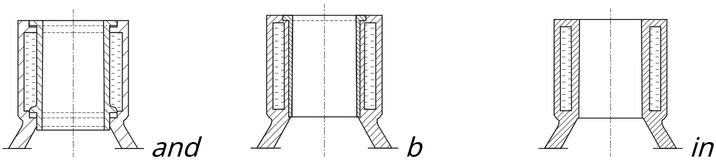


Figure 4.4 – Sleeve location diagrams:
and– insertable “wet” cylinder liner;*b*– insertable “dry” cylinder liner;
in– monolithic

Insert sleeves, depending on the design and installation in the block, are called “wet” (see Fig. 4.4,*and*) or “dry” (see Fig. 4.4,*b*).

Types of air-cooled ICE liners are shown in Fig. 4.5. Ribs can be made directly on the sleeve (Fig. 4.5,*and*) or be removable (Fig. 4.5,*b*).

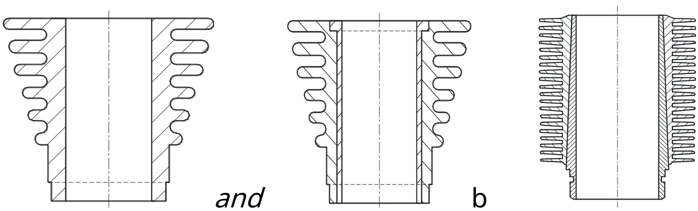


Figure 4.5 – Cylinder liners of air-cooled internal combustion engines:
and– solid;*b*– made of folded sleeves

The most commonly used block head. The appearance of the inner and outer surfaces of a typical block head is shown in Fig. 4.6. The block head is a complex part of the engine block, it usually houses the combustion chamber, intake and exhaust ducts, and parts gas distribution mechanism, power supply systems, ignition, channels of lubrication and cooling systems. Thus, the cylinder head is a multifunctional part of the internal combustion engine.

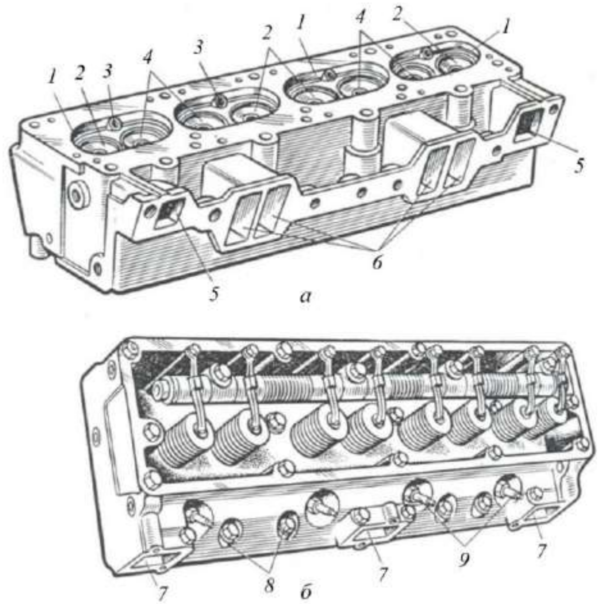


Figure 4.6 – Cylinder head:
and– bottom view; *b*– top view;
1– combustion chamber; *2*– exhaust valve; *3*– threaded hole for a candle ignition; *4*– intake valves; *5*– gas outlet; *6*– intake holes; *7*– cooling system openings; *8*– head mounting bolts;
9– spark plugs

For diesel engines, cylinder heads are typically cast from alloyed gray cast iron. For spark-ignition engines, cylinder heads are made from aluminum alloys.

The general view of the location of the moving parts of the V-shaped ICE is shown in Fig. 4.7.

The crankshaft is the most important and expensive moving part of the crankshaft. The main requirements for crankshafts of modern internal combustion engines are:

- high surface accuracy;
- high wear resistance;
- small mass;
- high stiffness and fatigue strength;
- balance.

Crankshafts (Fig. 4.8,*and)*Most internal combustion engines are cast from high-strength cast iron with spheroidal graphite. Forged shafts from high-strength alloy or medium-carbon alloy steels are used in highly accelerated internal combustion engines of passenger cars and trucks.

In some crankshafts, in addition to the main ones, removable counterweights are used (see Fig. 4.8,*b*,*in)*In case of limited dimensions, the missing counterweight mass is placed on the flywheel and on the vibration dampers in the front of the crankshaft.

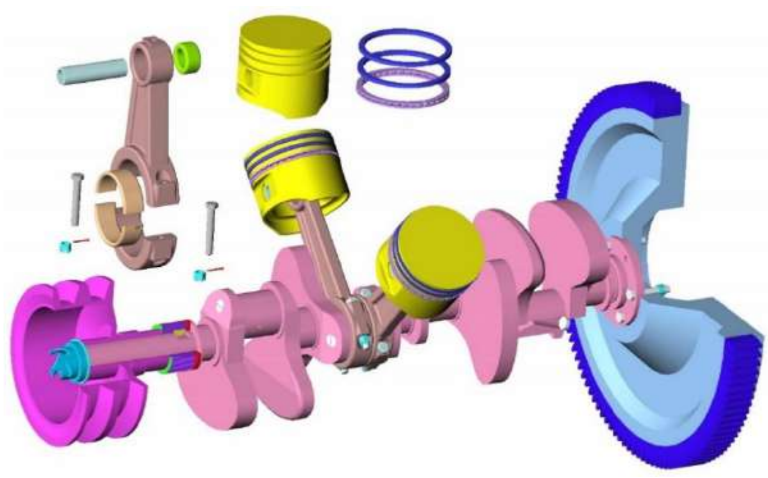


Figure 4.7 – Moving parts of the KShM

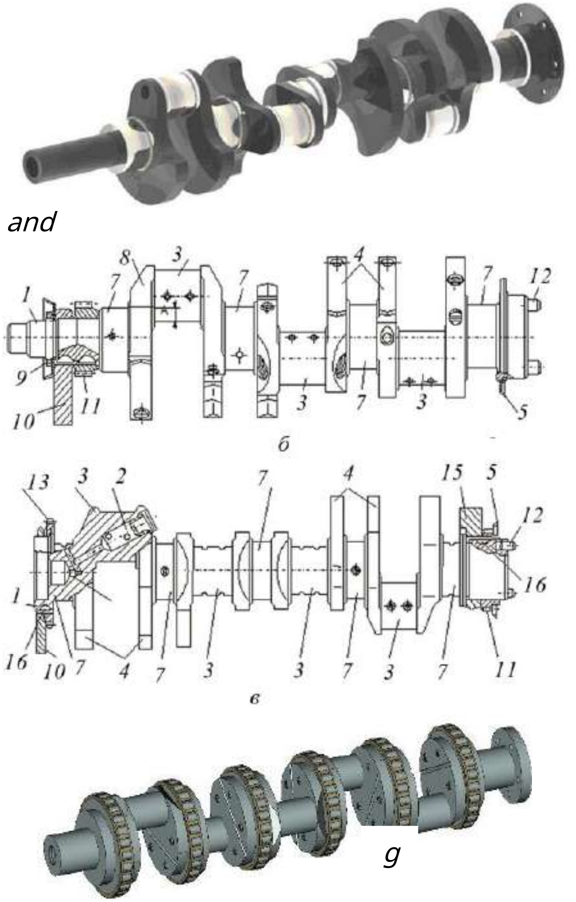


Figure 4.8 – Crankshafts: *a* – ZIL car engine130; *b* – YaMZ-236 diesel engine; *in* – KamAZ-740 diesel engine; *g* – design of a collapsible crank shaft (TATRA-815 car engine); *1* – front end of the shaft; *2* – dirt-catching cavity; *3* – connecting rod neck; *4* – counterweights; *5* – oil deflector; *6* – flange for fastening the flywheel; *7* – root collar; *8* – cheek; *9* – nut; *10* and *15* – removable counterweights; *11* – timing gear wheel; *12* – installation pin; *13* – drive gear wheel oil pump; *14* – screw; *16* – key;

A – the amount of neck overlap

Shafts can be with single and double counterweights Fig. 4.9 and 4.10.

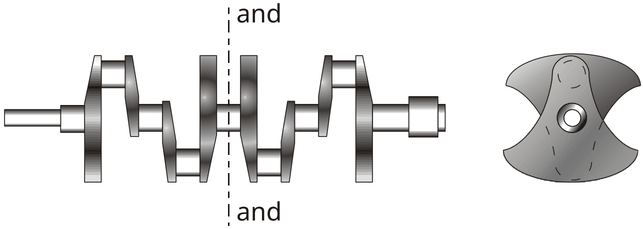


Figure 4.9 – Crankshaft of an inline four-cylinder engine with single counterweights: a-a – plane of symmetry

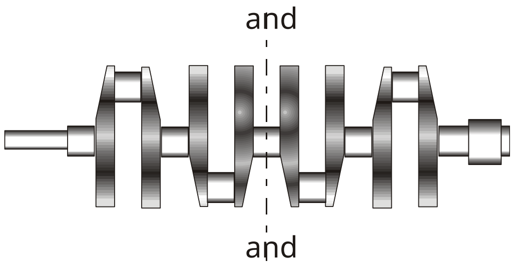


Figure 4.10 – Crankshaft with double counterweights: a-a – plane of symmetry

The crankshafts in most internal combustion engines are cast from high-strength cast iron with spheroidal graphite. Forged shafts from high-strength alloy or medium-carbon alloy steels are used in highly accelerated internal combustion engines of passenger cars and trucks.

To completely balance inline four-cylinder engines, two balancer shafts (Fig. 4.11) are sometimes used, rotating in opposite directions at twice the frequency of the crankshaft.

For lubrication, the most common layouts of the lubrication channels are shown in Fig. 4.12 and 4.13. In the crankshafts of truck engines, the connecting rod journals may have special dirt-catching cavities (Fig. 4.12).

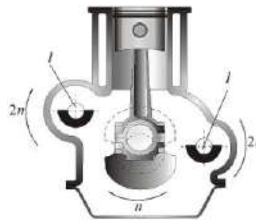
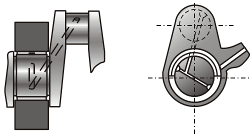
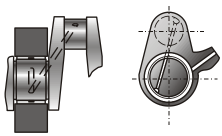


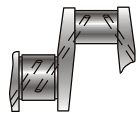
Figure 4.11 – Installation of inline balancer shafts
four-cylinder engine:
1– balance shafts



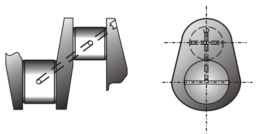
and



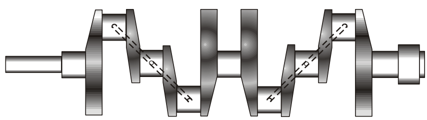
b



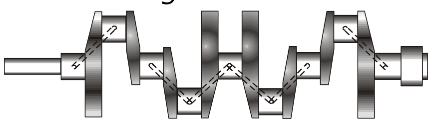
in



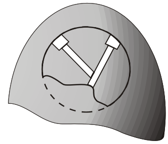
g



d



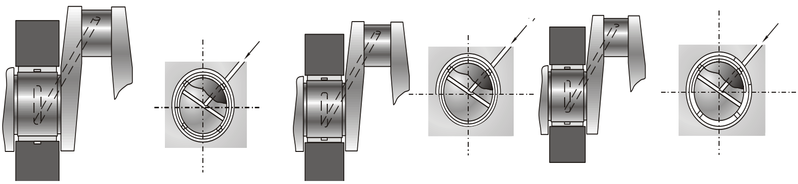
there are



w

Figure 4.12 – Diagrams of lubrication channels for connecting rod bearings
crankshaft:

and– hole from the connecting rod journal to the through hole in the main bearing; *b*– hole from the main journal to the connecting rod; *in*– diagram of the lubrication channels of the shafts of V-shaped engines; *g*– a hole connecting the through holes through the connecting rod and root neck; *d*– lubrication of two connecting rod journals through one main journal; *there are*– lubrication of main journals through connecting rods; *w*– additional lubrication hole on the connecting rod journal



and *b* *in*

Figure 4.13 – Schemes of lubrication channels of main bearings: *and*– circular groove in the bed opening and on the tabs;*b*– groove on half holes in the bed and on the tabs;*in*– circular groove in the bed opening and on upper liner

When the engine is running, axial forces act on the crankshaft. The movement of the crankshaft in the axial direction is limited by thrust bearings (Fig. 4.14). These bearings are usually located in the front or middle support of the shaft, and in some cases - on the rear main support.

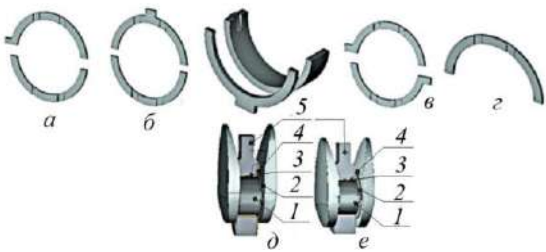


Figure 4.14 – Diagram of a thrust bearing with half rings: *and*,*b*,*in*– pairs of half rings, one of which has a locking protrusion;*g*– simple semicircle;*d*– installation of two pairs of half rings;*there are*– installation of two simple half-ring;*1*– shaft neck;*2*– cheek; *3*– semicircle;*4*– insert;*5*– block support

The two most common types of thrust bearings are: single half rings Fig. 4.14; or flanged bearings. Half ring thrust bearings typically use two pairs of half rings, one from each pairs has protrusions for fixing from turning. To place the half rings in the block and cover of the shaft support, grooves are made for fixing and turning, which hold the half rings. Less often, two simple half rings are used, which are installed in the support, one on each side, Fig. 4.14 *d, f*The half rings usually have a thickness close to the thickness of the root liners.

Grooves are made on the working side of the half rings in the direction of the shaft.
for lubrication.

The responsible parts of the engine crankshaft are the front end of the shaft and the rear part (flange).

A keyway (Fig. 4.15) or a hole for a cylindrical pin is made at the front end of the crankshaft for the purpose of installing

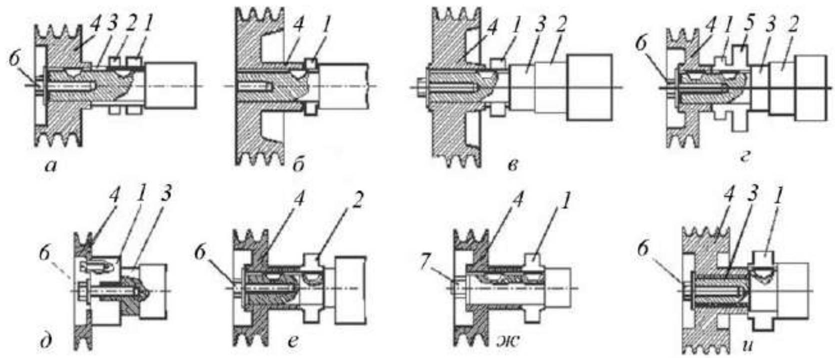


Figure 4.15 – Typical designs of the front ends of crankshafts: *and*,*in*,*g*,*there are*– installation and fixation with a bolt and keys;*b*– fixation by friction force (press fit); *d*– installation of the protrusion on the part into the groove at the end of the shaft; *w*– fixing with a nut;*and*– installation of parts on slots;*1*– asterisk (pulley);*2*– oil pump drive sprocket (splines);*3*– sleeve or surface anterior omentum;*4*– pulley (vibration damper);*5*– sprocket (pulley) drive additional shafts;*6*– bolt;*7*– nut

drive parts of internal and external engine mechanisms. The drive elements are: gears, sprockets, pulleys.

The drive of an oil pump with internal gearing is usually carried out by a section of the front end of the shaft that has two flats (Fig. 4.15 *in*) or splined connection, as well as a special bushing with a tongue (Fig. 4.15*there are*).

At the front end of the crankshaft there is a section for placing the oil seal.

The rear section (flange) (Fig. 4.16) of the crankshaft in most engines is made with a sealing surface (oil seal) and a mounting surface for the flywheel and gearbox input shaft bearing.

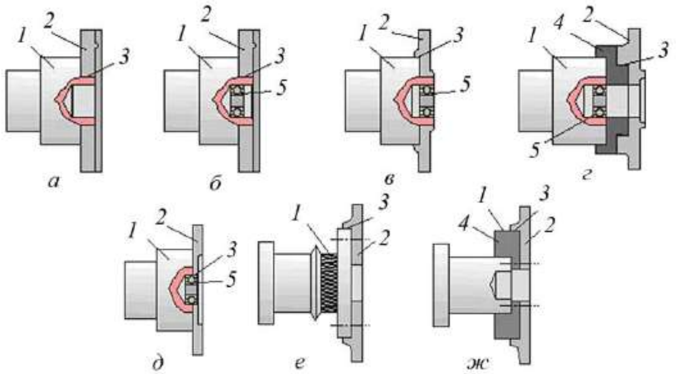


Figure 4.16 – Designs of crankshaft rear flanges and methods of centering the flywheel:*and*– in the center of the belt (for automatic transmissions) transmission);*b*– the same for manual transmissions;*in*– along the belt of the posterior omentum;*g*– using an adapter sleeve;*d*– using a bearing; *there are*– design with gland packing;*w*– using a sleeve that forms the surface of the posterior omentum;*1*– sealing belt of the stuffing box; *2*– flywheel;*3*– centering belt;*4*– bushing;*5*– bearing;*6*– adapter

The front end of the crankshaft (Fig. 4.17,*and*) sealed by a rubber self-pressurizing seal located in the cover*7*. The seal contains an oil deflector*18*, which protects with curved edges oil seal against intensive oil ingress. A dust deflector is pressed onto the pulley hub*2*, which protects the oil seal from dust and sand.

Crankshaft rear end seal (Fig. 4.17*b*) consists of an epiploon*24*, oil drain groove*21*and oil-reflecting crest*19*.

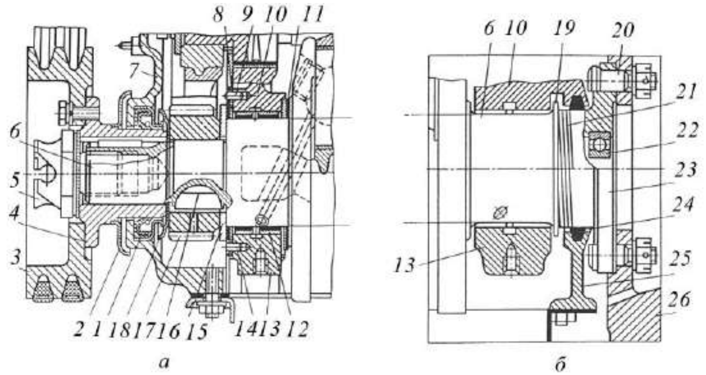
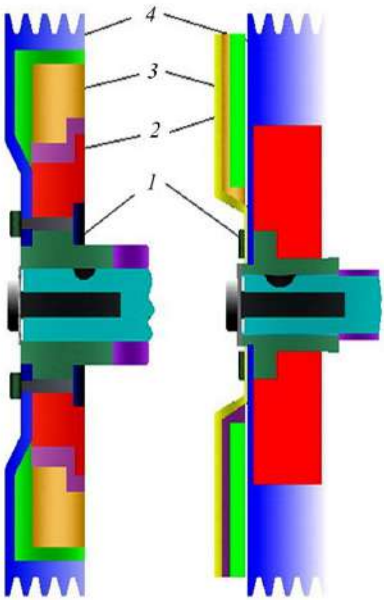


Figure 4.17 – Crankshaft seal:

and– front end shaft seal,*b*– rear end of the shaft: *1*– self-tightening gland;*2*– dust collector;*3*– drive pulley water pump, fan and generator;*4*– hub;*5*– ratchet;
6– crankshaft;*7*– cover of the distribution gear unit; *8*– front fixed washer;*9*and*14*– pins;*10*– cylinder block; *11*– rear fixed washer;*12*– insert;*13*– root cap bearing;*15*– persistently rotating washer;*16*– key;
17– distribution gear;*18*– oil separator; *19*– oil-discharging comb;*20*– flywheel mounting bolt;
21– oil-cutting thread;*22*– clutch shaft ball bearing; *23*– flange;*24* –stuffing box;*25*– oil seal holder;*26*– flywheel

The moving parts of the crankshaft include a torsional vibration damper directly connected to the crankshaft, often located at the front end of the crankshaft, and a flywheel, which may also have a torsional vibration damper built into it. The damper is usually used on multi-cylinder engines. During engine operation, torsional vibrations are damped by a damper as a result of internal friction in elastic rubber gaskets (Fig. 4.18) and (Fig. 4.19*and*,*b*,*in*), as well as through additional friction elements (Fig. 4.19*g*,*d*and*there are*). A flywheel is installed at the rear end of the crankshaft (at the output of the internal combustion engine) (Fig. 4.20).



and *b*

Figure 4.18 – Torsional vibration dampers:

and– inside the pulley;*b*– outside;

1– hub;*2*– inertial mass;*3*– rubber gasket;*4*– pulley

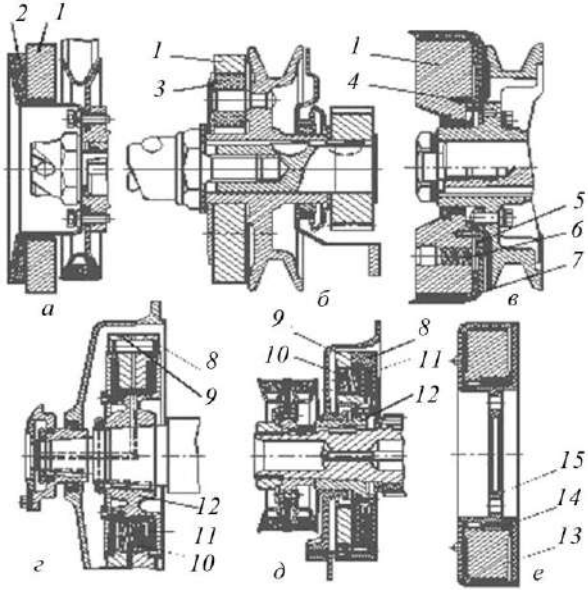


Figure 4.19 – Torsional vibration dampers:
and,*b*and*in*– molecular friction;*g*and*d*– frictional;*there are*– fluid friction; *1*and*13*– inertial masses;*2*– gasket;*3*– rubber ring;*4*– pin; *5*– friction disc;*6*and*10*– springs;*7*and*15*– buildings;*8*and*9*– disks;
11– friction ring;*12*– hub disc;*14*– bushing

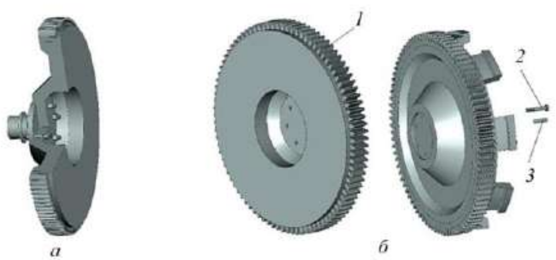


Figure 4.20 – Placement*and*and general view of the flywheel*b*:
1– steel gear ring;*2* –mounting bolt;
3– installation pin

Flywheel, accumulating energy workers moves, reduces uneven crankshaft rotation. To start the engine with a starter, a steel gear ring is pressed onto the flywheel rim.

The flywheel is cast from cast iron, having the bulk of the metal closer to the outer diameter to increase the moment of inertia. As a rule, the flywheel is attached to the crankshaft flange with special bolts with reliable fixation (Fig. 4.21). The flywheel assembly with the crankshaft is subjected to dynamic balancing.

On the end face or rim of the flywheel of many engines, marks are applied that determine the position of the piston of the first cylinder at top dead center to calculate the engine operating order, set the ignition timing, the injection timing of diesel engines, and adjust the gas distribution mechanism.

The damper in the driven clutch disc is ineffective at low crankshaft speeds. The designs of two-disk flywheels with built-in torsional vibration dampers are presented in Fig. 4.22 and 4.23.

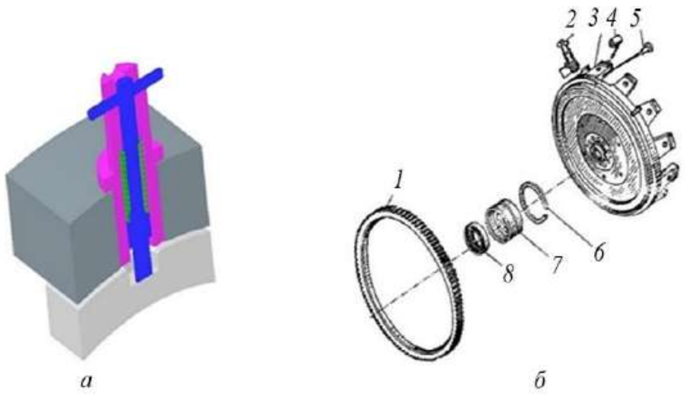


Figure 4.21 – Flywheel with lock:
and– flywheel in a fixed position;*b*– flywheel design: *1*– toothed crown;*2*– retainer;*3*– flywheel;*4*,*7*– installers bushings;*5*– clutch release lever crumb;*6*- persistent spring ring;*8*– gearbox shaft sleeve

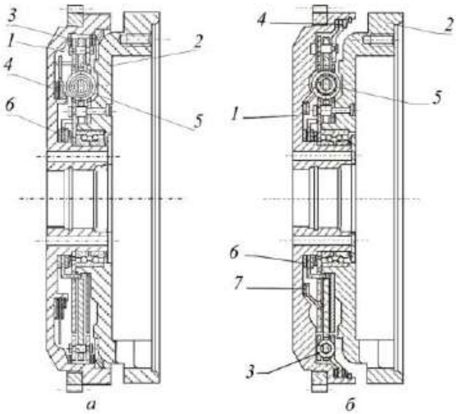


Figure 4.22 – Damping element, built into the flywheel

Figure 4.23 – Double-disk flywheels

Double-disk flywheel (Fig. 4.23,*and*) consists of the first*1*and second*2*discs and two torsional vibration dampers (external and internal), connected in series. The second disc is mounted on the first stage using a double-row ball bearing with a split inner ring and is connected to it through dampers. The external damper consists of two friction pairs - the main*3*with a big moment friction and additional*4*, which is activated after passing a certain gap. The internal elastic-friction damper of torsional vibrations includes a set of springs*5*and a couple of frictions*6*, which starts working after passing the appropriate gap.

This design has a dense layout and, due to the serial connection of dampers and the transmission of torque through friction pairs, provides a substantially nonlinear elastic-frictional characteristic, which is necessary for operation in resonant modes during engine start-up. The second version of the two-disk flywheel (see Fig. 4.23,*b*) also consists of two disks*1*and*2*and two elastic-friction dampers connected in series. But the design of the dampers differs from the previous ones. In this case, the damper consists of a set of springs *3* and friction pairs *4* with a large friction moment. The internal damper has a set of coil springs *5* and two friction pairs *6* and *7*, which are included in the work after passing the corresponding gaps. This design has the ability to create a large (up to 30 ° and above) angle of closure of the damper before its slippage due to the serial connection of two sets of coil springs, but has a complex design. In the two-disk flywheel (Fig. 4.24) also use two dampers - the main and additional. But unlike the previous ones, the main one here is the external elastic-friction damper. It has a set of springs *1* and a couple of frictions *2*. The internal damper consists of two friction pairs *3* and *4*. Disks *5* and *6* external damper, between which the disc springs are inserted, are also the driving ones for the inner. Friction rings *7* and *8* located between the disks damper and a second flywheel disk, consisting of two parts, which, when connected by bolts, clamp the friction pairs.

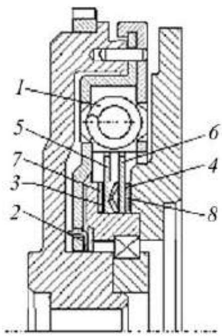


Figure 4.24 – Double-disk flywheel with external elastic-friction damper

The transitional - moving and fixed parts of the crankshaft include crankshaft bearings. In the vast majority of engines, sliding bearings are used - main and connecting rod bushings. Of great importance for the mutual operation of the shaft and the bearing are dimensions of the shaft journals. The diameters of the shaft and shank journals are usually maintained with an accuracy of 0.015 mm, and the mutual runout of the main journals does not exceed 0.005...0.008 mm. The misalignment of the axes of the connecting rod and main journals should not exceed 0.03...0.05 mm along the length of the shaft. General requirements for all journals - ovality and taper should be no more than 0.005 mm. When the engine is operating, oil is supplied under pressure into the gap between the inner surface of the bearing and the shaft journal. Due to the displacement of the shaft to the bearing in the direction of the load, an eccentricity (oil wedge) occurs, which holds the shaft, which rotates from contact with the surface of the liner. The greater the width of the bearing, viscosity and oil supply pressure, the greater the load the bearing is able to hold.

At present, passenger car engines use plain bearings in the form of thin-walled liners with a thickness of 1.0...2.5 mm. The main bearings of the crankshafts have an increased thickness, which is due to the need to arrange recesses for supplying oil to the crankshaft channels and to the connecting rod bearings. Typically, the grooves have a depth of 1.0...1.2 mm with a width of 3.0...4.5 mm. The materials and design of the liners depend on the type and operating parameters of the engine.

All liners are made of multilayer materials, with the base being a steel strip, onto which materials are applied layer by layer in various ways, providing:

– fatigue strength and corrosion resistance;

– good heat dissipation from the bearing;

– low friction coefficient;

– small guaranteed gap in combination with soft material bearing;

– absence of solid fractions in the soft bearing material. The main characteristics of the liner material are the maximum specific load and the maximum permissible sliding speed.

The general trend in engine building is to reduce the thickness of liners, which is usually 1.8–2.0 mm for original and 1.4–1.5 mm for connecting rod bearings. The thinner the liners, the better they fit the bed, the better the heat dissipation, the more accurate the geometry of the bearing surface, the smaller the permissible clearance in the bearing and the longer its service life.

In the free state, the liner has a non-cylindrical shape of the outer surface to ensure tension along the bed diameter and higher accuracy of fit to it. These conditions are satisfied by a liner, the outer surface of which has a variable radius of the outer surface, which coincides with the bed radius only at the edges, and in the middle the radius is made larger, but so that the outer size of the liner in the free state is greater than the bed diameter by 0.5–1.0 mm. In addition, the liner must have tension not only along the diameter, but also along the bed length, that is, have a protrusion beyond the bed. The protrusion required to ensure guaranteed fit of the liner to the bed depends on the length of the liner (bed diameter), its width and thickness. The protrusion is on average from 0.03–0.05 mm for shafts with a diameter of 70 mm.

The base of the liner is made of steel strip by stamping.

Antifriction materials are applied to the base:

1) aluminum alloys with a lead content of about 5%, as well as tin and silicon, for example Al Pb5 Si4 S1 (the numbers after the metal designation indicate its percentage content) is applied to a steel base without additional coating;

2) aluminum alloys with a tin content of about 20%, for example Al Sn20 Cu1, also used without coatings;

3) aluminum alloys with reduced tin content to 6% Al Sn6 Cu1 used only with tin-lead coating Pb Sn10 Cu2;

4) aluminum alloys with cadmium and nickel Al Cd3 Ni1 Si1 used only with Pb Sn10 Cu2 coating;

5) aluminum alloys with zinc and lead Al Zn5 Si2 Pb1 Cu1 take only with Pb Sn10 Cu2 coating;

6) lead-tin bronzes Cu Pb22 Sn1 are used with coated with tin-lead alloy Pb Sn10 Cu2;

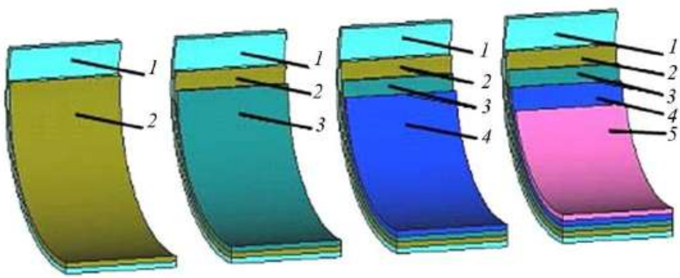
7) bronzes with different lead and tin contents Cu Pb24 Sn3 used with Pb Sn10 Cu2 coating;

8) bronzes with a content of Cu Pb14 Sn3 are used with a Pb coating Sn10 Cu2.

Depending on the material, the liners can be two-, three-, four- or five-layer (including the steel base) (Fig. 4.25). The large number of layers is due to the need to apply a nickel underlayer before the Pb Sn10 Cu2 coating, as well as the fact that in the final form, a thin layer of tin is applied to the liner to improve running-in. As a rule, the thickness of the layers is:

– steel base 0.9 mm or more;
– base layer 0.25–0.5 mm;
– nickel sublayer 0.001 mm;
– tin-lead alloy 0.02 mm;
– tin 0.003–0.005 mm.

Comparative characteristics of the listed materials in terms of specific loads are shown in Fig. 4.26.



and *b* *in* *g*

Figure 4.26 – Typical designs of plain bearings:
and–2-layer; *b*– 3-layer; *in*– 4-layer; *g*– 5-layer; *1*– steel base; *2*– basic material; *3*– sublayer; *4*– basic coverage; *5* –additional coating (tin)

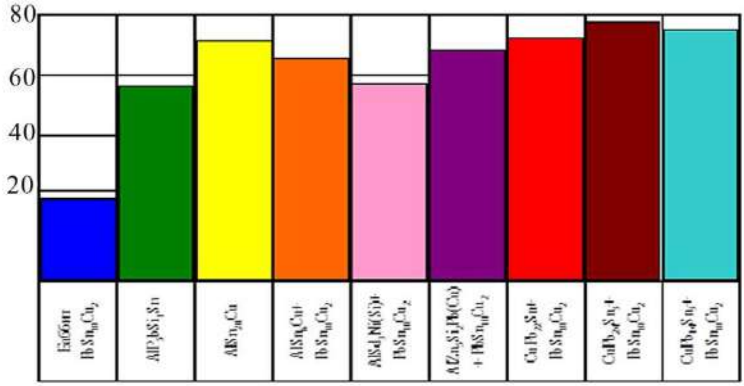


Figure 4.26 – Comparison of liner materials by permissible load

Diesel engines often have liner materials that are different from those used in gasoline engines, this is due to the significantly higher loads in the crankshaft bearings of diesel engines.

To prevent the liners from turning, locks are made on them (Fig. 4.27). The lock is a protrusion 2.5–4.5 mm wide, bent 0.8–1.2 mm from the plane of the liner base when stamping the liner. The lock is made without tearing the liner base.

The locks are usually oriented with the shaft rotation in mind. For example, the connecting rod bearings in most engines have the upper lock oriented in the direction of rotation, and the lower one - against it. The main bearings have a similar orientation.

Figure 4.27 – Insert locks:
and– traditional design liner lock, obtained by extrusion in the radial direction;*b*– liner lock, extruded tangentially;*in* – insert with two locks extruded tangentially

The moving parts of the crankshaft are the parts of the connecting rod-piston group. The mutual arrangement of the parts of this group of different engines is shown in Fig. 4.28. The moving parts of the crankshaft of a diesel engine are shown in Fig. 4.28,*and*, and the internal combustion engine with spark ignition – in Fig. 4.28,*b*,*in*.

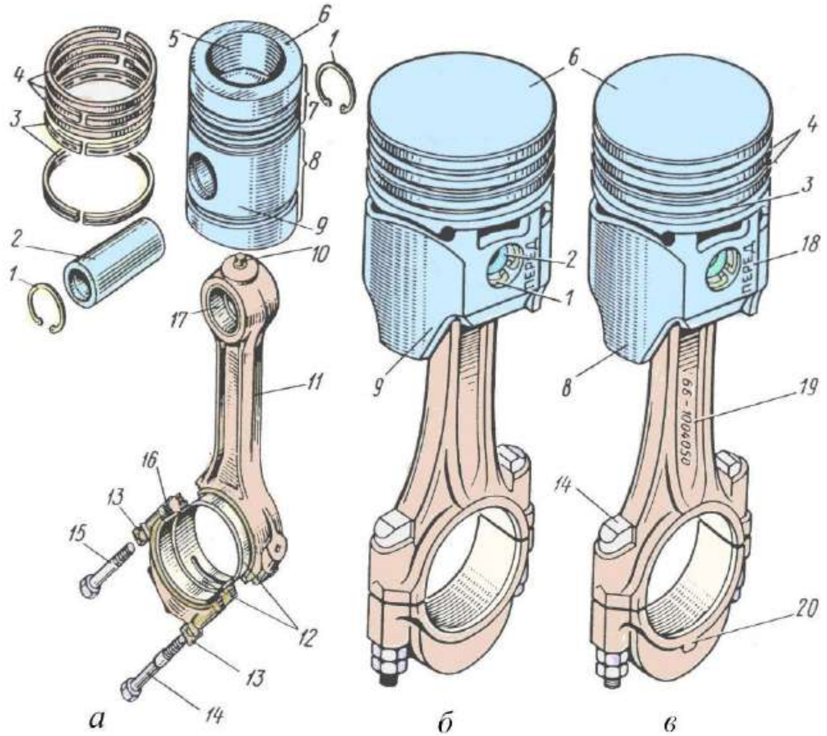


Figure 4.28 – Connecting rod and piston groups of parts of the crankshaft of various internal combustion engines:

1– piston pin retaining ring;*2*– piston pin; *3*– oil scraper ring;*4*– compression rings;*5*– combustion chamber;

6– piston bottom;*7*– piston head;*8*,*9*– piston skirt; *10*– upper connecting rod head;*11*– connecting rod;*12*– connecting rod bushings;*13*,*14*, *15*– connecting rod bolts;*16*– connecting rod lower head cover;*17*– bushing upper connecting rod head;*18*,*19*,*20*– marks and designations on the piston and

connecting rods

The piston group includes: piston, piston rings and piston pin. The piston takes the first place in the piston group in terms of importance. The piston (Fig. 4.29) is a rather complex structure both in shape and in terms of execution technology. General trends in the development of piston designs:

– reducing the distance from the bottom to the axis of the finger, in order to reduce engine height and weight;

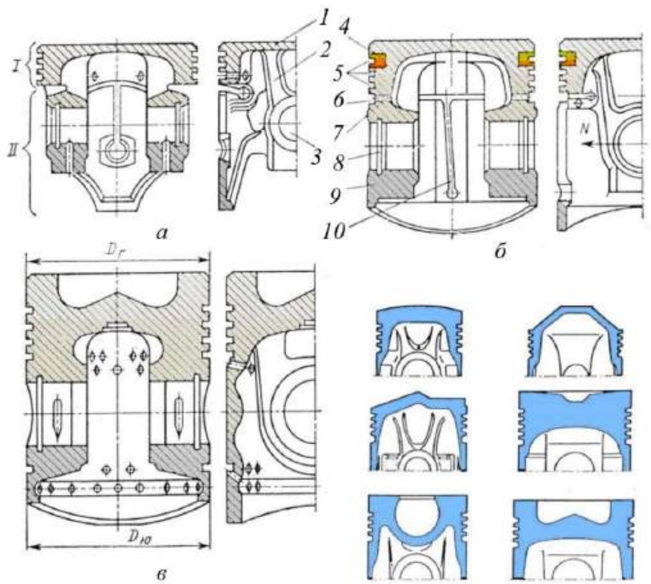


Figure 4.29 – Piston design options for different engines: *and*– gasoline engines of passenger cars;*b*– gasoline engines trucks;*in*– diesel engines of trucks;

I– piston head;*II*– piston skirt;

1– bottom;*2*– stiffening rib;*3*– hole for the piston pin; *4*– cast iron ring insert;*5*– grooves for compression rings; *6*– groove for oil scraper ring;*7*– drainage hole;*8*– groove for the retaining ring;*9*– boss;*10*– cut

– reduction of finger diameters, including the outer and internal;

– reduction of the finger length with fixing the connecting rod from the axial movement in the piston bosses;

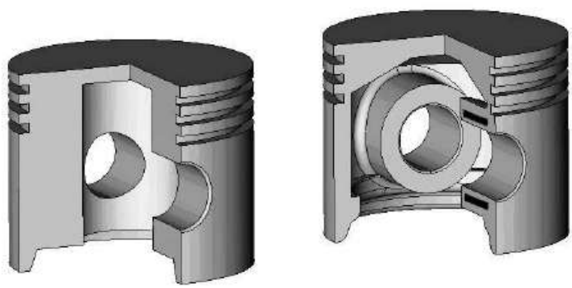
– reducing the height of the piston head and skirt;

– special profiles of the bottom, side and inner surfaces of the piston;

– special treatment and coating of the piston surface.

Some of the most common piston design options are shown in Fig. 4.29.

Eutectic alloys of aluminum with silicon up to 12–13% were widely used as piston materials. Silicon reduces piston wear and reduces the coefficient of linear expansion. However, increasing the amount of silicon in the melt requires alloying the alloy with nickel, magnesium, copper and special cooling modes for castings. Aluminum alloys with a silicon content of more than 13% to 18% are called hypereutectic and allow the introduction of new technologies, including stamped piston blanks. The difference in the shapes of cast and stamped pistons is shown in Fig. 4.30.



and *b*

Figure 4.30 – Internal configuration of pistons:
and– stamped (forged);*b*– cast

During the working stroke, the piston bottom is loaded with a heat flow of gases with a temperature of over 1800–2000 °C. Part of the heat from the piston head is transferred to the skirt and bosses. Considering the uneven heating-cooling of different surfaces of the piston, it must have a complex shape: stepped in height, but round towards the top; an oval skirt that widens downwards, as shown in Fig. 4.31.

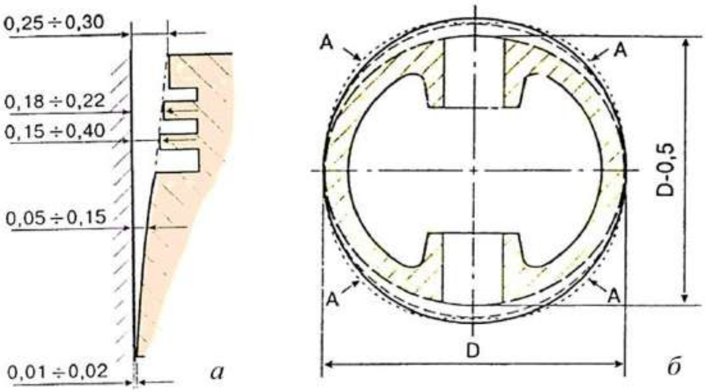


Figure 4.31 – Piston shape, compensating for thermal expansion:

and– change in height of the gaps between the piston and the cylinder;

b– change in the cross-sectional profile of the skirt;

A – places where the skirt may jam in the cylinder during overheating;

———— – circumference of the cylinder; — — — — — – cold profile piston; -·-·-·-·- – operating mode; - - - - - - - – overheating

Sometimes, to compensate for the expansion of the skirt, a vertical (italic) is used, Fig. 4.31,*and*or combined T-section Fig. 4.32,*b*There is a cut on the side of the skirt opposite the action of the lateral force during the working stroke (Fig. 4.32).

One way to compensate for thermal expansion using cuts is with X-shaped pistons (Fig. 4.33). These cuts lack the middle part of the skirt. The heating of the lower part and the mass of the piston are reduced.

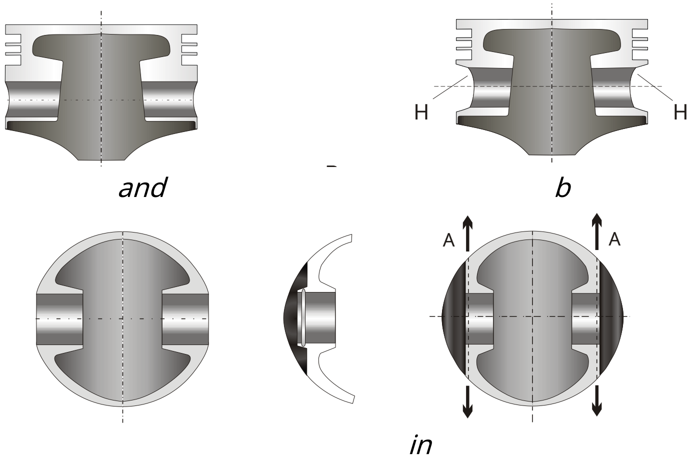


Figure 4.32 – Effect of coolers on piston skirt expansion:
and– piston without coolers;*b*– piston with deep grooves refrigerators (H);*in*– floating finger option

Arrow A in Fig. 4.32 indicates the directions of heat flow propagation and additional thermal deformation of the piston.

Figure 4.33 – X-shaped piston design

The piston head has grooves for compression and oil scraper rings (Fig. 4.34). The number of rings depends on the type and operating parameters of the engine. Axial drainage holes are made in the groove of the oil scraper rings to drain oil removed from the cylinder walls into the piston. Sometimes the drainage holes are located in the chamfers of the groove.

The responsible part of the piston is its bottom. As a rule, it has a greater thickness than other parts of the piston. The thicker the bottom, the

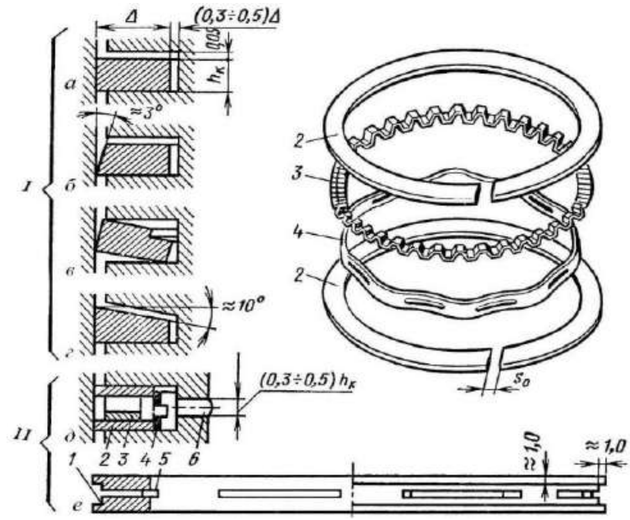


Figure 4.34 – Piston rings: I – compression rings (position in the piston groove in working condition); II – oil scraper rings; *a* –rectangular cross-section;
b– trapezoidal cross-section (with a conical outer surface);
in– with a step on the inner surface;
g– wedge-shaped cross-section; *d*– folded; *there are*– solid; *1*– oil collecting groove; *2*– flat ring; *3*– axial expander;
4– radial expander; *5*– drainage slot;
6– drainage hole in the piston; $h_к$– ring height

its temperature is lower, but the piston mass is greater. On average, for passenger car engine pistons, the thickness is 8–9 mm, and sometimes 7 mm.

Rarely, the thickness is 5.5–6 mm. For diesel engines, the thickness of the bottom varies between 10–16 mm. The configuration of the bottom of the pistons in gasoline and diesel engines is different.

The piston bottoms of diesel engines have shaped recesses to accommodate part of the combustion chamber and improve the mixture formation process (see Fig. 4.28 and Fig. 4.29).

It should also be noted the trend of applying wear-resistant coatings to the piston crown. Most often, the coating is performed by anodizing, i.e. by converting a thin surface layer of aluminum into Al ceramics$_2$About$_3$ with a thickness within 0.008–0.012 mm.

Piston rings, which are part of the piston group,
Designed to seal the piston against the cylinder; dissipate heat from the piston to the cylinder; and provide the necessary oil to the rings, piston, and cylinder.

Depending on their purpose, piston rings are divided into compression and oil scraper rings.

Depending on the type of engine, the compression ring set includes two or three rings. There is usually only one oil scraper ring, and very rarely two oil scraper rings are used (powerful diesel engines, see Fig. 4.34,*and*). A general view of the placement of both types of rings relative to the piston and cylinder is shown in Fig. 4.34.

The upper compression ring is the most loaded thermally and mechanically. In this regard, most passenger car engines have upper compression rings made of spheroidal graphite cast iron alloyed with nickel, chromium, molybdenum and other metals.

Diesel engines sometimes use upper rings made of high-carbon chromium steel. Steel rings are sometimes used on gasoline engines. To reduce wear, the upper rings are coated with porous chromium 0.1–0.15 mm thick, and more often hard chromium plating is used. Often, instead of chromium, molybdenum coating is used.

Lower compression piston rings operate in much more favorable conditions. They are most often made of gray alloyed cast iron with lamellar graphite and, as a rule, without special coatings.

The lower rings of passenger car engines have a reduced profile height of 1.5–1.75 mm (previously 2–2.5 mm). For diesel engines, the height of the upper and lower rings is within 2–2.5 mm.

In the free state, the piston ring has a non-circular shape, and the radius of its outer surface at the lock is equal to the radius of the cylinder (Fig.

4.35). As the distance from the lock increases, the radius of the ring increases, and on the side opposite the lock, it is largest.

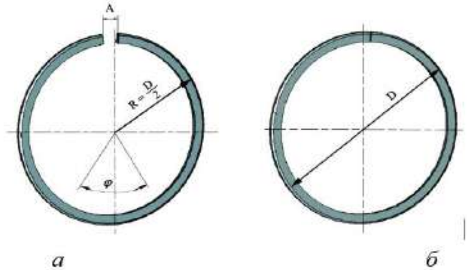


Figure 4.35 – Piston compression ring:
and– in a free state;*b*– in a compressed state;*AND*– gap in the lock in the free condition;*D*– cylinder diameter;*R*– radius of the outer surface of the ring;
φ– a section with equal diameters of the ring and cylinder

The lower rings, as a rule, have an increased radial width and high elasticity while maintaining increased pressure on the cylinder in the lock. The lock section can have a different shape and be stepped (Fig. 4.36,*and)*, inclined (Fig. 4.36,*d)*, straight (Fig. 4.36,*b)*or have a complex shape (Fig. 4.36,*in)*As the easiest to manufacture and most reliable in operation, straight locks have become the most widespread.

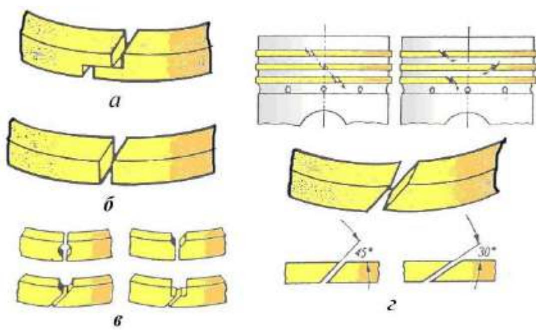


Figure 4.36 – Piston compression ring locks: *and*– stepped;*b*– straight;*in*– combined;*g*– inclined (oblique)

Oil scraper rings are designed to remove oil from the cylinder surface. Oil scraper rings are installed below the compression rings. Due to the specifics of the work, this ring must have high adaptability to the cylinder surface and have high pressure on its walls.

Two main types of oil scraper rings are used on modern engines: solid - box-shaped or drainage (Fig. 4.34,*there are*); folded (Fig. 4.34,*d*). Solid oil scraper rings, usually made of gray alloyed cast iron, unlike compression rings, have a large height, sometimes reaching 5 mm. In addition, there are annular grooves and through slots or radial holes on the outer surface.

Almost complete oil separation or removal is ensured by composite rings (Fig. 4.34,*d*). Such a ring consists of two thin disk rings *1*and expander*2*(rice.4.37). Two expanders are also used – in the radial and axial directions.

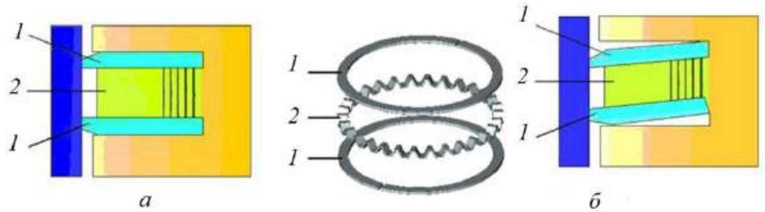


Figure 4.37 – Folded oil scraper ring with dual-function expander:

and– position of the chamfered discs;*b*– position of discs without chamfer;

1– disks;*2*– expander

The piston pin serves to pivotally connect the piston with the connecting rod. During operation, the piston pin is subjected to friction and a large cyclic alternating load. In addition to the hardness of the outer surface, the piston pin must have high rigidity and be light. These requirements are met by a hollow cylindrical design, the variants of which are shown in Fig. 4.38.

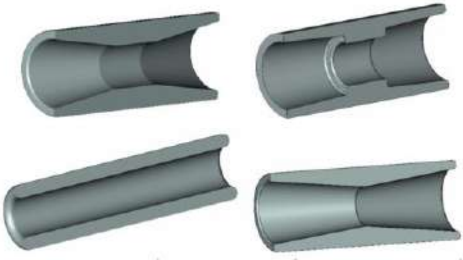


Figure 4.38 – Piston pin design options

The outer surface of the finger is processed with high precision: ovality and taper of no more than 2–3 microns and roughness of no more than 0.2 microns.

Typically, spark-ignition engines have piston pins with a diameter of 20–23 mm or more, and small-displacement engines have 17–19 mm. Piston pins in passenger car diesel engines have diameters in the range of 24–30 mm. Increasing the diameter of the pin allows you to maintain low specific loads on the working surfaces.

The most common use is for the possibility of rotating the finger in both the bosses and the upper head of the connecting rod. This type of finger is called floating. To fix it in the axial direction, locking rings are most often used (Fig. 4.39).

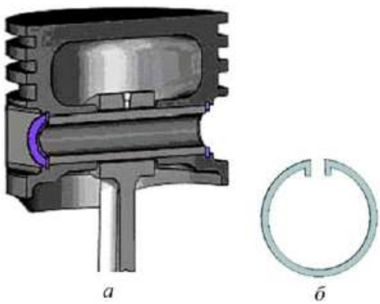


Figure 4.39 – Fixing the floating piston pin: *and*– installation diagram; *b*– the main type of retaining rings

The connecting rod transmits forces from the piston pin to the connecting rod journal of the crankshaft. The upper head moves back and forth, turning at a certain angle relative to the axis of the piston pin. The lower head rotates together with the connecting rod journal of the crankshaft, and the connecting rod rod performs oscillatory movements relative to the axis of the piston pin. The connecting rod is subjected to alternating asymmetrical cyclic loads, and therefore its main characteristic is fatigue strength. In addition, the connecting rod must have high rigidity and be light in weight. The general view of the assembled connecting rod is shown in Fig. 4.40.

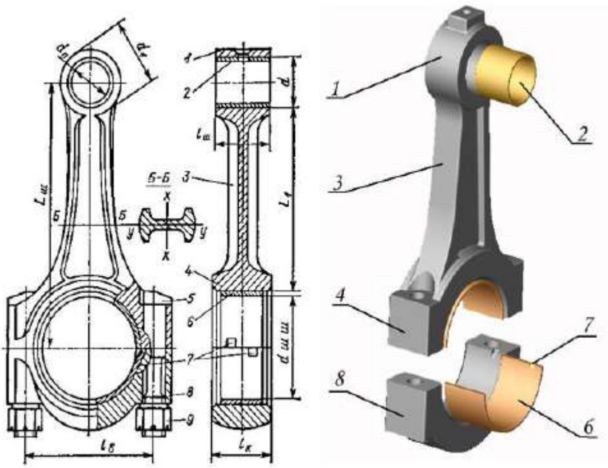


Figure 4.40 – General view of the connecting rod:

1– upper connecting rod head;*2*– connecting rod upper head bushing; *3*– connecting rod rod;*4*– lower connecting rod head;*5*– connecting rod bolt;
6– connecting rod bushings;*7*– connecting rod liner locks;*8*– lid lower connecting rod head;*9*– connecting rod bolt nut

The connecting rod consists of a rod, upper and lower heads. The lower head of the connecting rod is detachable. In most connecting rods, the connector of the lower head of the connecting rod is made flat, straight and perpendicular to the axis of the connecting rod. Sometimes, in order to ensure installation, the connector of the lower head is made at an angle to the axis of the connecting rod. The connecting rod has an I-section to increase rigidity (Fig. 4.41).

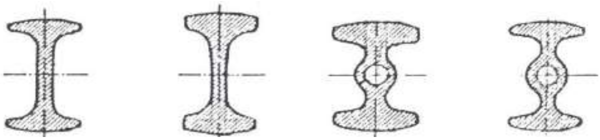
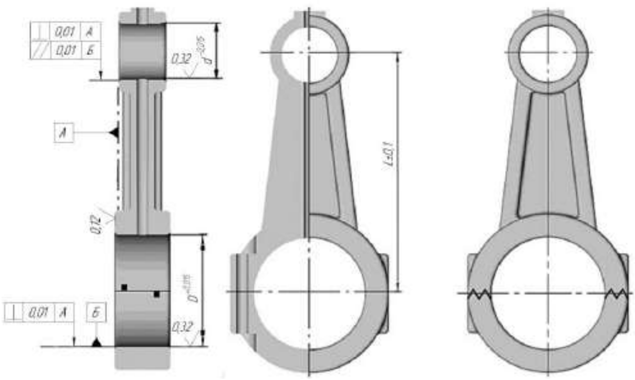


Figure 4.41 – Connecting rod cross-section options

The materials for connecting rods are manganese, chromium, chromium-nickel, or chromium-molybdenum steels with a carbon content of 0.3–0.45%. Connecting rod blanks are obtained by stamping with intermediate heat treatment for strengthening while maintaining low hardness, but high toughness and plasticity.

If the overall width of the lower connecting rod head is less than the cylinder diameter, then the head connector has a straight flat joint (Fig. 4.42 a) on the ground surfaces. On some connecting rods, a brittle fracture of the connector line of the lower connecting rod head is used, which gives almost perfect centering of the lower connecting rod head cover. Sometimes the cover is centered on triangular slots (Fig. 4.42,*b*).



and *b*

Figure 4.42 – Connecting rods with a straight lower head connector: *and*– requirements for dimensions and surfaces;*b*– centering the cover on triangular slots

Connecting rod bolts operate under asymmetric cyclic loading and require a fairly large pre-tightening force with a relatively small diameter. Steels with a carbon content of at least 0.3% are used for connecting rod bolts. The thread is fine and, as a rule, rolled.

The nuts of the connecting rod bolts are made high, sometimes with an enlarged bearing surface. The nuts are held either by a lock nut or a special nut, or only by friction forces in the thread and on the bearing surface.

When the crankshaft rotates, the connecting rod contacts the side (end) surfaces of the connecting rod journal. When the connecting rod is axially fixed in the piston bosses, the pin rotates much less, and therefore the piston pressure is lower. The piston pin in this version is shorter, stiffer and lighter. For floating pins, a sleeve - a sliding bearing is installed in the upper head of the connecting rod.

Review questions

1. Purpose, features of crank-rod designs mechanisms, internal combustion engine parts and their purpose.
2. The main elements of the piston, parameters of the piston head and skirt.
3. Design features of compression and oil scraper rings.
4. Types of cylinder liners, their installation in the cylinder block.
5. Describe the purpose and structure of crankshafts. What metals and How are they made? What are the advantages and disadvantages of the materials used?
6. What is the purpose and structure of connecting rods and their bearings?
7. Describe the purpose and structure of pistons.
8. What is the purpose, structure and operating conditions of piston rings?
9. What is the purpose, structure and operating conditions of piston pins?
10. Describe the purpose of a flywheel. How is the correct connection of the flywheel to the crankshaft?
11. How do crankshafts of different engine models prevent axial displacement?
12. What is the purpose and structure of the main bearings of a crankshaft? shaft?

Laboratory work 5

MECHANISMS AND DEVICES FOR CHANGING THE GAS DISTRIBUTION PHASE OF ICE

Purpose of work– study of modern basic structures parameters of the gas distribution mechanism of an internal combustion engine.

Visual aids:

- albums, instructions and posters on the design of car engines;
- electronic information material on the design of modern timing belts Internal combustion engine;
- engines in section;
- car.

Tasks for work:

- study the components of variable valve timing devices;
- determine their purpose;
- identify and classify the mechanisms and structure of the timing belt according to option;
- present in the report the structure of each variable valve timing system Timing according to the task.

General provisions

The phases of gas distribution in piston internal combustion engines are the moments of opening and closing of the intake and exhaust valves (windows). The phases of gas distribution (Fig. 5.1) are usually expressed in degrees of rotation of the crankshaft and are noted in relation to the initial or final moments of the corresponding strokes (Fig. 5.1).

For example, narrow valve timing with late opening and early closing of the valves without overlapping phases (the time when the intake and exhaust valves are open simultaneously) is appropriate for idling, because this prevents exhaust gases from being blown into the intake manifold.

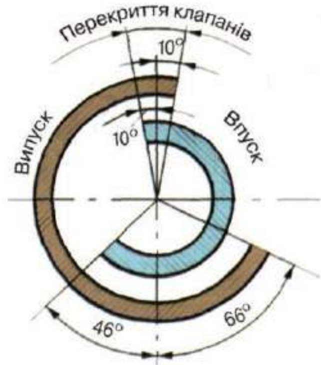


Figure 5.1 – Engine timing phases

The efficiency of an engine – its efficiency, power, torque and economy – depends on many factors, including the timing of the gas distribution, i.e. the timing of the opening and closing of the intake and exhaust valves. In a conventional four-stroke internal combustion engine, the valves are actuated by camshaft cams.

The profile of these cams determines the moment and duration of opening (i.e., the width of the phases), as well as the amount of valve travel. In most modern engines, the phases cannot change. And the operation of such engines is not characterized by high efficiency. The fact is that the nature of the behavior of gases (combustible mixture and exhaust gases) in the cylinder, as well as in the intake and exhaust tract, changes depending on the engine operating modes. The current speed also changes constantly, various kinds of oscillations of the elastic gas medium arise, which lead to useful resonances or, conversely, parasitic stagnation phenomena. Because of this, the speed and efficiency of filling the cylinders at different engine operating modes are not the same.

When operating at maximum power, the situation changes significantly. With increasing crankshaft speed, the valve opening time naturally decreases, but to ensure high torque and power, a much larger volume of gases must be driven through the cylinders than at idle. To solve this problem, It is necessary to open the valves a little earlier and increase the duration of their opening, in other words, to make the phases as wide as possible. At the same time, for better cylinder purge, the overlap phase is usually made wider the higher the rpm.

So, when developing and perfecting engines, designers have to combine a number of mutually exclusive requirements and make difficult compromises. With the same fixed phases, the engine must have good traction at low and medium crankshaft speeds, acceptable power at high ones. And in addition, it must work stably at idle, be as economical and environmentally friendly as possible.

"Phase shifters" are special clutches that, under the influence of control electronics and hydraulics, can rotate the camshaft by a certain angle relative to its initial position. Most often, such a system is installed on the intake. As the crankshaft speed increases, the clutch rotates the camshaft in the direction of rotation, which leads to earlier opening of the intake valves and, as a result, better filling of the cylinders at high speeds.

The world's leading engineers did not stop there and developed a number of systems that can not only move the phases, but also expand or narrow them. Depending on the design, this can be achieved in several ways. For example, in the Toyota system *VVTL-i* after reaching certain revolutions (6000 min^{-1}) instead of the usual cam, an additional cam with a modified profile begins to operate. The profile of this cam sets a different law of valve movement, wider phases and, by the way, provides its longer stroke.

When the crankshaft is spun up to maximum speed (about 8500 rpm)$^{-1}$) at a speed of 6000–6500 min^{-1}The engine seems to have a second wind, capable of giving the car a sharp and powerful pick-up during acceleration.

Changing the moment and duration of opening is great. What if you try to change the lift height? After all, this approach allows you to get rid of the throttle valve and transfer the process of controlling the engine operating modes to the gas distribution mechanism (GDM). The damper is a harmful damper in that it worsens the filling of the cylinders at low and medium crankshaft speeds. After all, in the intake tract

Under the closed throttle, a strong vacuum is created when the engine is running. It leads to a high inertia of the rarefied gas medium (fuel-air mixture), a deterioration in the quality of filling the cylinder with a fresh charge, a decrease in recoil and a decrease in the speed of response to pressing the gas pedal.

Therefore, the ideal option would be to open the intake valve only for the time required to achieve the desired filling of the cylinder with a combustible mixture. The engineers' answer is a mechanical system for controlling the lift of the intake valves. In such systems, the lift height and, accordingly, the duration of the intake phase change depending on the pressure on the gas pedal. According to various sources, savings from the use of a throttleless control system can be from 8 to 15%, and the increase in power and torque is within 5–15%. But this is not the last frontier. Despite the fact that the number and size of valves have approached the maximum possible, the efficiency of filling and cleaning the cylinders can be made even higher. This can be done at the expense of the speed of opening the valves.

In truth, the mechanical drive is inferior to the electromagnetic drive here. The advantage of the electromagnetic drive is also that the law (acceleration at each moment of time) of the valve lift can be brought to the ideal, and the duration of the valve opening can be changed within very wide limits. The electronics, according to the prescribed program, from time to time may not open unnecessary valves, and the cylinders may be turned off altogether.

This is done to save energy, for example when idling, when driving in a constant mode or when braking with the engine. So, right during operation, the electromagnetic timing is able to convert a conventional four-stroke engine into a six-stroke.

It seems that further increase in engine efficiency due to timing is no longer possible. It will be possible to squeeze even more power and torque from the same volume at lower consumption only by using other means. For example, combined supercharging or designs that change the compression ratio, other types of fuel.

Valvetronic system(*VT*) (Fig. 5.2) – provides air supply to the engine cylinder without a throttle valve (electromechanical drive with electronic control).

Structure: electric motor, worm gear, intermediate lever drive shaft, intermediate lever springs ensure constant contact of the lever roller with the surface of the camshaft cam. The intermediate lever rests with its heel (end) on the valve mechanism drive lever roller (the heel of this lever contacts the valve stem). The electric motor, controlled by the on-board computer, rotates the eccentric shaft through a worm gear in order to change the state of the intermediate lever and the transmitted force to the valve drive lever. Changing the position of the intermediate lever affects the amount of valve opening. (Fig. 5.2).

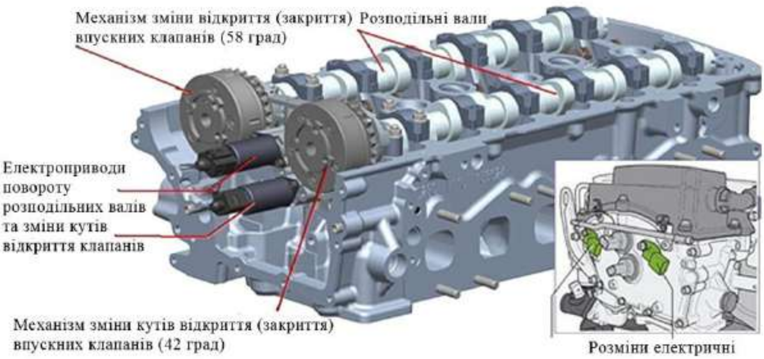


Figure 5.2 – Mechanism for changing valve opening angles

System*Valvetronic*allowed to abandon the throttle, The system changes both the degree of valve opening and the phase. It is used on engines*BMW*with2001. The valve stroke is changed using an electric motor and a complex kinematic scheme within the range of 0.2–12 mm in multi-stage steps.

System*Variable Valve Event and Lift System*(*VEL*), developed by Nissan. A special eccentric, which is driven from electric motor, shifts the rocker arm fulcrum, and thereby changes the valve stroke. The lift height varies within 0.5–12 mm.

System *Variocam Plus* (*VP*) Veriochem Plus (Fig. 5.3) - coordinates the valve timing and valve lift height (electromechanical drive with electronic control) gradually.

Figure 5.3 – System *Variocam Plus*

Between the intake camshaft and the chain drive gear is a device called a “phase shifter”, which shifts them relative to each other, changing the moment of opening the valves. The lift height is determined by a pusher of two cylinders - one inside the other. When the inner one works, the valve opens by 3.6 mm, the outer one starts to work - the stroke increases to 9.35 mm.

The inner cylinder in the form of a rod is driven by a cam, which has a small protrusion. The sequence of force transmission to the valve is as follows: the shaft cam, the rod, that is, the small cylinder, and then the valve. At the same time, the other two shaft cams have large protrusions that move the large cylinder, inside which there is a spring. The spring is compressed and at the same time creates a force insufficient to move the timing valve. When the load on the engine changes in the direction of increase, the microprocessor gives command to the hydraulic system to block the cylinders. In this case, the movable pins (by a pusher placed in the radial channels of the large cylinder) under oil pressure enter the holes of the rods (of the small cylinder) and block the relative movement of the large and small cylinders. The cams of the shaft, which have large protrusions, advance the cylinders, which constitute a "single whole", moving the timing valve a long distance, ensuring an increased supply of fresh weight charge (air or combustible mixture, depending on which engine this system is installed on).

System *Valve Timing and Lift Electronic Control* (*VTEC*) (Fig. 5.4) – Timing with electrical control of valve time and lift height provides two options for step control of intake valves (electromechanical drive with electronic control).

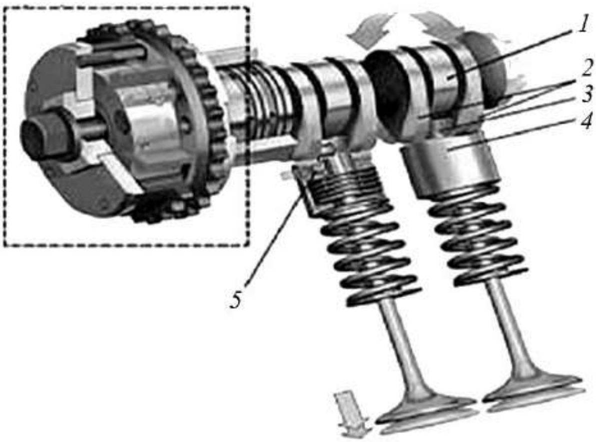


Figure 5.4 – System *Valve Timing and Lift Electronic Control:*
1, 2 – high and low speed cams, respectively; *3* – cam rocker *1*;
4 – cam rocker *2*; *5* – valve

These systems are valve mechanisms with groups of cams of different profiles, providing different valve timing and lift heights.

valve. Each such group is designed for a valve (valves of the same name), separately for each cylinder. One cam *1* works at at reduced crankshaft speeds, another (or others – *2*) replace it when the engine speed increases. Structure: the camshaft in the combustion chamber area has two cams *1* and *2* for driving the intake valves. These valves are actuated by two rocker arms. The degree of opening of the valves differs from each other and is ensured by the corresponding cam profiles. At minimum load on the engine, one valve opens to a greater extent (up to 100%). WithandBy increasing the load on the engine, the electronic control system moves the pin that connects both rockers into a "single whole". In this case, the valve drive lever system ensures simultaneous opening of the valves up to 100% by the operation of the second cam of the shaft. The latter has a large protrusion compared to the first cam and works until the rockers are blocked by moving the pin under oil pressure controlled by the system's microprocessor.

The system appeared simultaneously with *SOHC VTEC* (rice.5.5), and is similar to it in some features. This system, however, is used for other purposes, namely: to increase economic performance

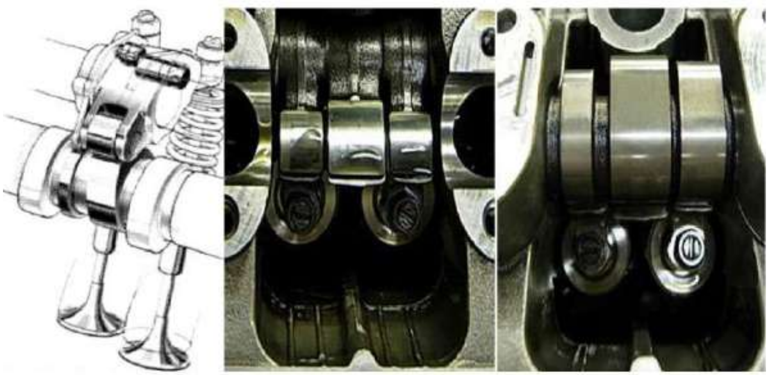


Figure 5.5 – System *VTEC* (*Valve Timing and Lift Electronic Control*)

engine. Its design features are:

– one camshaft, four valves per cylinder;

– roller rockers are used;

– system*SOHC VTEC*used only for intake valves;

– there are two cams for every two intake valves, profile one of which is almost intact.

SOHC VTEC-E(rice.5.6.) also has two operating modes. At low engine speeds, both intake valves control their cams, but since one of these cams is practically round, only slightly opening the valve to prevent the accumulation of the combustible mixture, only the second valve actually works. Due to the asymmetry of the incoming air flow (one valve is closed and the second is open), turbulence occurs, which allows operation on a fairly lean mixture. When the crankshaft speed increases, the system is triggered*VTEC,*and both valves begin to be controlled by one normal cam.

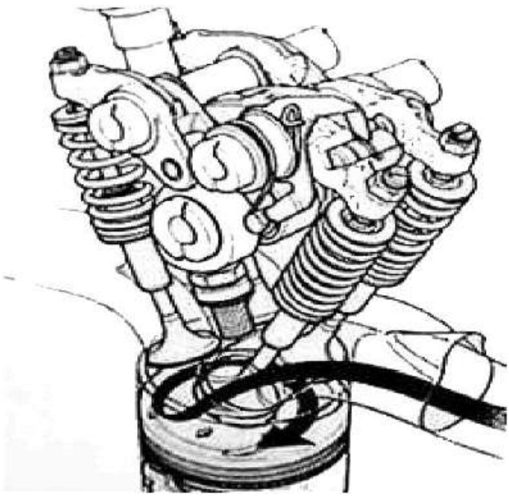


Figure 5.6 – System*SOHC VTEC-E*

System *VLT* (rice.5.7) with a locking shaft with an eccentric (Fig. 5.7). The operation of this system provides for a change in the size of the rocker arm, which affects the timing valve. The size of the rocker arm is changed by shifting its roller by the eccentric of the locking shaft. The position of the shaft and, consequently, the eccentric is provided by the operation of an electric motor connected by a worm gear to the shaft and controlled by a computer. The system provides multi-stage opening of the intake valve, thereby turning off the air damper in the intake tract.

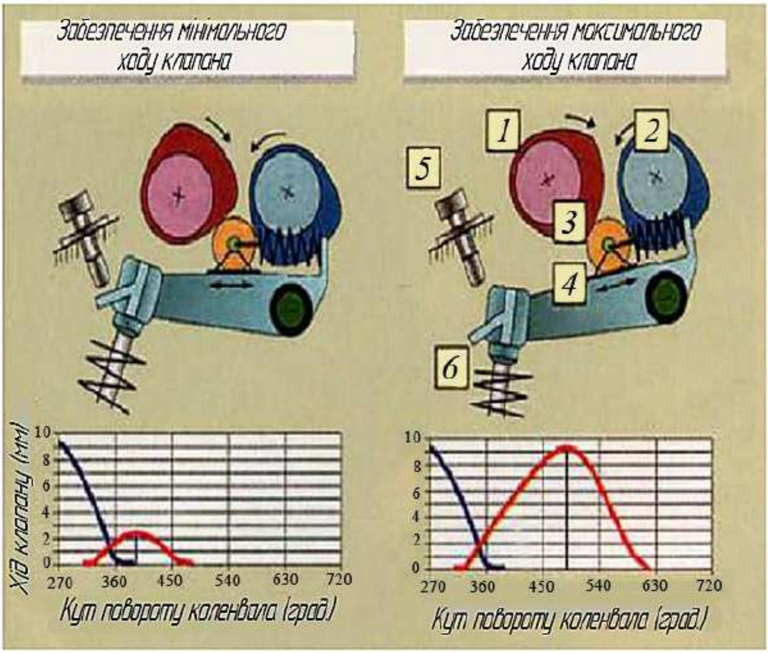


Figure 5.7 – System *VLT*: *1*,*3* – eccentrics; *2* – video; *4* – rocker arm; *5* – emphasis; *6* – valve

System *Active Valve Train* (*AVT*) (Fig. 5.8) – timing system without a camshaft (valves are opened by an electromagnetic or hydraulic drive controlled by electronics).

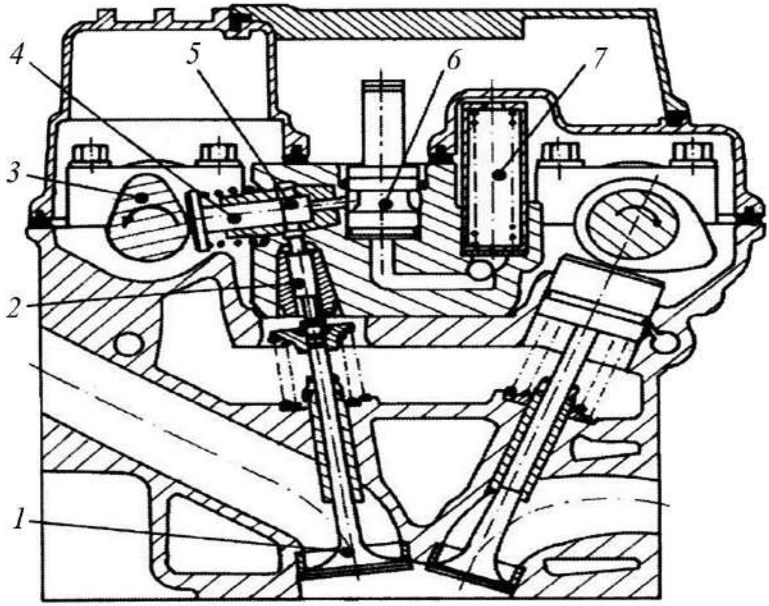


Figure 5.8 – System *Active Valve Train* (*AVT*):
1 – inlet valve; *2* – piston; *3* – camshaft; *4* – plunger pusher; *5* – oil chamber of the plunger pusher cylinder; *6* – solenoid valve; *7* – oil tank

Electromagnets

Camless timing with electromagnetic valve drive (*Valeo*) (Fig. 5.9). The valve stem is affected by a powerful electromagnet with a force of up to 800...1000 N. With less force, the valve timing will not hold.

The electromagnets are controlled by a microprocessor system, ensuring timely operation of the valve mechanisms and the corresponding the height of their lift. This corresponds to the degree of valve opening. In such a system there are no camshafts, as well as valve mechanism drive parts. This design solution eliminates the inertia of the valve mechanism drive.

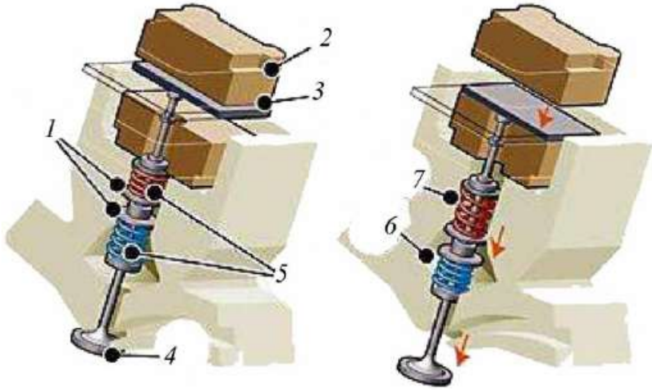


Figure 5.9 – Electromagnetic valve mechanism *Valeo*: *1* – washers; *2* – electromagnet; *3* – plate; *4* – valve; *5* – spring; *6* – spring compression; *7* – spring tension

Advantages of using an electromagnetic valve actuator

Timing:

– eliminates the influence of torsional vibrations of the crankshaft on the phases gas distribution;

– the valve opens and closes within fractions of a degree crankshaft rotation, which allows for flexible adjustment of the valve timing;

– high speed allows to significantly reduce the head contact time valves with high-temperature working medium;

– additional cooling of the exhaust valve, which occurs due to due to the overlapping effect, it allows to reduce the thermal stress of the valve;

– gas distribution mechanism with electromagnetic valve drive can be installed on the engine, regardless of what type of fuel (gasoline, methanol, ethanol, hydrogen, etc.) it runs on;

– ensures optimal flow of the work cycle and processes fuel and air supply, gas exchange, reduction of exhaust gas toxicity.

System *DOD* (*Disproportion On Demand*) – (displacement on demand) – cylinder shut-off system: electromagnets “close” the valve tappets of half of the cylinders (Fig. 5.10).

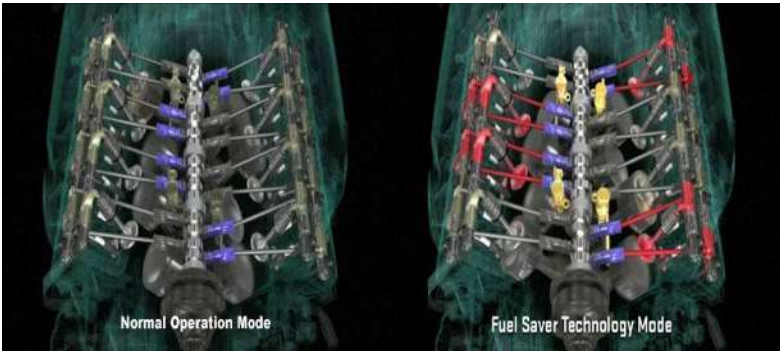


Figure 5.10 – System *DOD* (*Disproportion On Demand*)

Phase inverters

Mechanism *Double VANOS* – the hydraulic mechanism can change configuration of the chain drive connecting both camshafts, and thus change the gas distribution phases (Fig. 5.11). For this purpose, a hydraulic cylinder with a piston and a rod is installed in the camshaft drive mechanism. At the end of the rod, a guide for the camshaft drive chain is fixed, which is placed in the guides of the hydraulic cylinder cover. When oil is supplied under pressure to the hydraulic cylinder of the mechanism, the position of the camshaft drive chain changes, that is, lifting the chain on its guides, it bends, and at the same time the camshaft sprockets turn towards each other, changing the position of the shafts, and therefore the cams. In this case, the cams of the shafts act on the valve mechanisms in advance, changing the gas distribution phases. When the pressure in the hydraulic cylinder is released, the camshaft drive chain is lowered and helps to rotate the cams shafts in the opposite direction. In this case, the cams of the shafts act on the valve mechanisms with a delay.

Oil is supplied to the hydraulic cylinder through an oil channel, which is closed by a valve device with a solenoid controlled by the vehicle's computer.

Double VANOS(*Doppel Variable Nockenwellen Steuerung*) from*BMW* is able to move the phases smoothly from the initial to the final value. Using hydraulics, the system controls both the intake and exhaust processes (Fig. 5.11).

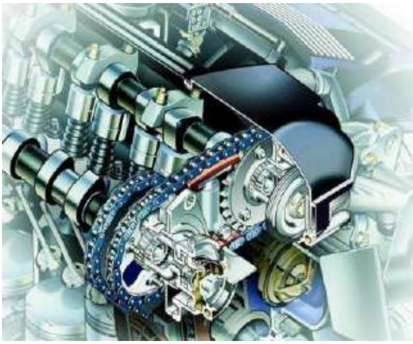


Figure 5.11 –*Double VANOS*

System*VIVT*(*Variable Inlet Valve Timing*) – an electronically controlled hydraulic system is installed in the intake valve camshaft drive, and the effect of oil pressure is transmitted to a sleeve with spiral teeth, which acts as a piston. The piston – sleeve, moving under oil pressure relative to the drive sprocket, rotates the camshaft, changing the moment when the intake valves begin to open.

System*VVT-i*(see fig.5.12 and 5.13) (*Variable Valve Timing intelligent)*– changing the gas distribution phases ("phase inverter") allows for smooth change the valve timing according to the engine operating conditions. This is achieved by rotating the intake camshaft relative to the exhaust camshaft in the range of 40–60 ° (according to the crankshaft rotation angle). As a result, the moment of the start of opening of the intake valves changes valves and the value of the "Overlap" time (i.e. the time when the exhaust valve is not yet closed and the intake valve is already open).

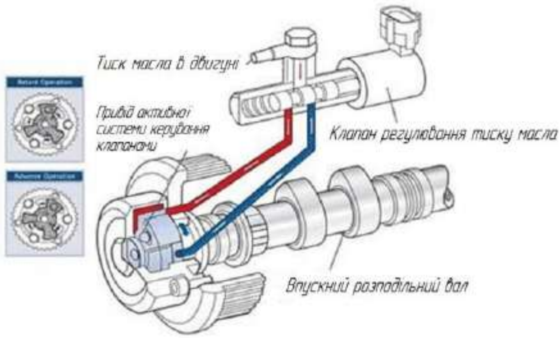


Figure 5.12 – System *VVT-i*

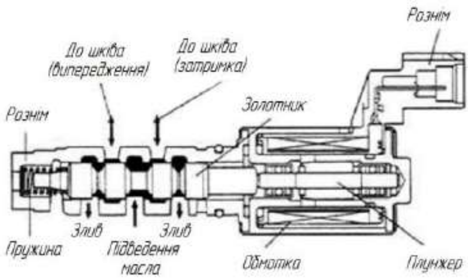


Figure 5.13 – System spool *VVT*

Executive mechanism *VVT-i* located in the camshaft pulley – the drive housing is connected to a sprocket or toothed pulley (Fig. 5.12), the rotor – to the camshaft. Oil is supplied from one or the other side of each of the rotor blades, forcing it and the shaft itself to rotate. If the engine is shut off, then the maximum delay angle is set (i.e. the angle corresponding to the latest opening and closing of the intake valves). So that immediately after starting, when the pressure in the oil line is not yet sufficient for effective control *VVT-i*, there were no shocks in the mechanism, the rotor is connected to the housing with a locking pin (then the pin is pressed out by oil pressure).

Management *VVT-i* carried out using an oil valve *VVT* (*OCV – Oil Control Valve*) (Fig. 5.14 – 5.16). At the signal of the control unit, the electromagnet moves the main spool through the plunger (see Fig. 5.13), passing oil in one direction or another. When the engine is turned off, the spool is moved by a spring in such a way that the maximum delay angle is set. To rotate the camshaft, oil under pressure is directed to one of the sides of the rotor lobes by means of a spool (Fig. 5.14 or 5.15), at the same time the cavity on the other side of the lobe is opened for drainage.

After the control unit determines that the camshaft has taken the required position, both oil channels to the pulley are closed, and it is held in a fixed position (Fig. 5.16).

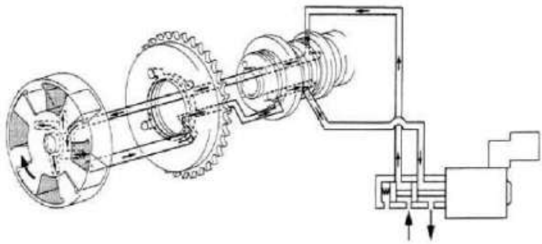


Figure 5.14 – System Operation *VVT-i* when turning camshaft towards earlier valve opening

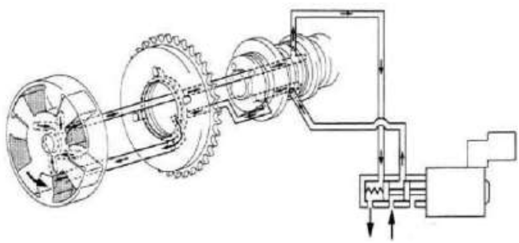


Figure 5.15 – System Operation *VVT-i* when turning camshaft towards later valve opening

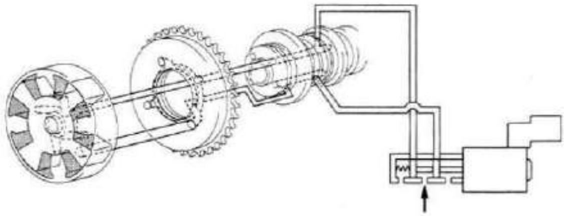


Figure 5.16 – System Operation *VVT-i* in mode maintenance

When using modern timing mechanisms, it is possible to obtain an increase in internal combustion engine performance within the range of 8...15% in both power and torque.

Test questions

1. Why change the valve timing?
2. Principle of operation of the system *Valvetronic* (*VT*).
3. Working principle systems *Variable Valve Event and Lift System* (*VEL*).
4. System *Variocam Plus* (*VP*).
5. System *Valve Timing and Lift Electronic Control* (*VTEC*).
6. Where is the system used? *SOHC VTEC?*
7. Principle of operation of the system *VLT.*
8. Principle of operation of the system *Active Valve Train* (*AVT*).
9. The principle of operation of a camless timing system with an electromagnetic valve actuator (*Valeo*).
10. Principle of operation of the system *DOD* (*Disproportion On Demand*).
11. Phase inverters. Mechanism *Double VANOS*.
12. Principle of operation of the mechanism *Double VANOS* (*Double Variable Camshaft control*).
13. The principle of operation with systems *VIVT* (*Variable Inlet Valve Timing*).
14. The principle of operation of the system *VVT-i* (*Variable Valve Timing intelligent).*
15. Purpose of the oil valve *VVT-i* (*OCV - Oil Control Valve*).
16. Principle of operation of the system *VVT-i* when turning camshaft towards earlier valve opening.
17. System operation *VVT-i* in hold mode.

Laboratory work 6
INTERNAL COMBUSTION ENGINE SYSTEMS

Purpose of work– study the purpose, design and operation of systems, used in various internal combustion engines of automobiles.

Visual aids:

• albums, instructions and posters on the design of car engines;

• electronic information material on the construction of modern engines;

• engines in section;

• car.

Tasks for work:

• identify and classify gasoline and diesel fuel systems engines;

• study the components of internal combustion engine systems (internal combustion engine), identify the component mechanisms and devices. Determine their purpose;

• display the structure of each internal combustion engine system in the report.

Power system

Purpose of the power supply system:

– air and fuel purification;

– preparation of a combustible mixture of a certain composition from them;

– supplying it (or separately air and fuel) to the combustion chamber;

– exhaust gas removal from the cylinders.

Accordingly, the following components can be distinguished in the power system: air preparation system, fuel system, exhaust gas suppression system.

Based on the purpose, the power system must provide:

– fuel dosing (supplying the required amount);

– high-quality preparation of the mixture;

– timely supply of fuel or mixture.

*Classification of power systems*In diesel engines, power systems are divided according to the following characteristics:

– by the way fuel moves –dead ends and**with**fuel circulation;

– **type of feed mechanism –**with combined pump and nozzle **(pump-nozzle)**and separated by a pump and nozzles.

In spark-ignition engines, the power supply systems are carburetor and gasoline injection.

The air supplied to the cylinders must be prepared - cleaned of dust. Three methods are used to clean the air:

– **filtration**– polluted air passes through the filter element (most often made of special paper);

– **inertial**– moving at high speed, the air changes dramatically direction. Under the action of the centrifugal forces arising from this, heavy mechanical impurities are thrown out of the air flow towards the walls of the housing;

– **contact**– during the movement of air, it comes into contact with the sticky substance (oil) to which mechanical particles adhere.

Requirements for air purifiers: high degree of air purification; low resistance to air flow; simplicity of design and maintenance.

Dry air purifiers are used in almost all cars. Their main element is a disposable filter cartridge.

Engine power depends primarily on the amount of fuel that can be burned in the cylinder during one cycle. It, in turn, depends on the amount of air supplied to the cylinder during “start-up”. If air is pumped into the cylinder under pressure, its mass will be greater, therefore, more fuel can be burned. This method of supplying air is called supercharging. It can be forced, when the air is pumped by a mechanical pump driven by the crankshaft, and gas turbine (turbocharging), when the air pump is driven by a gas turbine that rotates the exhaust gases at the outlet from the cylinder.

Gas turbine supercharging is the most common. A turbocharger, consisting of a pump and turbine wheels, is installed on engine. The exhaust gases from the cylinder through the exhaust manifold enter the turbine and rotate its shaft at a frequency of 15...100 thousand rpm.$^{-1}$. A pump wheel (axial compressor) is installed on the same shaft as the turbine, which forces air into the intake manifold. Depending on the injection pressure, the boost can be low (pressure up to 0.15 MPa), medium (up to 0.22 MPa) and high (over 0.22 MPa).

Gasoline injection fuel systems are classified according to the following criteria:

– *fuel supply point*– central (single-point) injection, distributed (injectors at each intake valve), direct (injectors in the cylinder head);

– *fuel supply method*– with continuous injection (in in the "Jetronic" systems of types D and K) and intermittent injection (in the "L Jetronic" system), which can be phased (gasoline supply only at the intake) and unphased (supply at each revolution of the crankshaft);

– *by way of regulating the amount of fuel*– pneumatic, mechanical, electronic;

– *method of determining air flow*– by rarefaction in intake manifold, the angle of rotation of the throttle or special (sail type) damper, the readings of the thermoanemometric sensor.

Consider a fuel injection system with gasoline injection (Fig. 6.1). Gasoline from the tank is supplied under pressure through a hydraulic accumulator and a fuel filter to the metering device, and from it to the ramp - through a special pipeline in which constant pressure is maintained. The ramp is equipped with nozzles that inject gasoline into the intake manifold. Since constant pressure is maintained in the ramp, the amount of fuel injected by the fuel injector will depend only on the time of its opening. Knowing the air flow rate required at this moment, it is possible to supply an exact dose of fuel. The amount of air is measured by a flow meter. It also affects the fuel pressure regulator, which in turn affects the metering device, providing a set pressure and cyclic supply. The pump is designed to supply fuel 5...10 times greater than is required for engine operation at full load, so most of the fuel from the pressure regulator goes to the drain, which ensures that the fuel is pumped through the filter several times an hour.

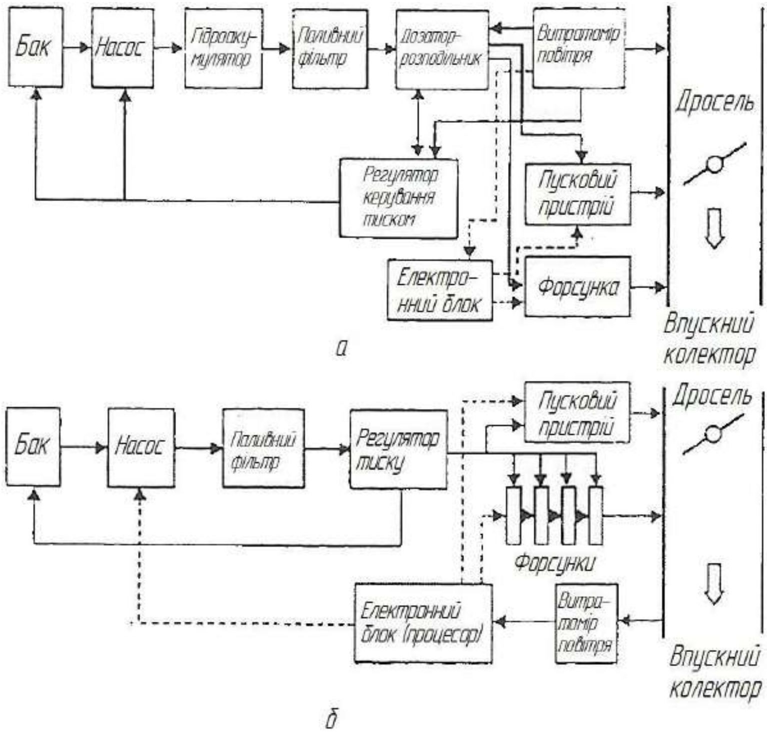


Figure 6.1 – Block diagrams of “Jetronic” power supply systems of types K (*and*) and L (*b*) (dashed lines for KE and LE type systems)

When the engine starts, the starting injector is activated, and air enters the cylinders through a special additional channel in the intake manifold.

For precise control of the system operation, the latest models (such as KE) are equipped with an electronic control unit that controls the operation of the pump and nozzles together with the dispenser-distributor (shown in Fig. 6.1 by dashed lines).

Exhaust system

Designed to remove exhaust gases and reduce noise during engine operation.

A system with a noise silencer for exhaust gases is shown in Fig. 6.2.

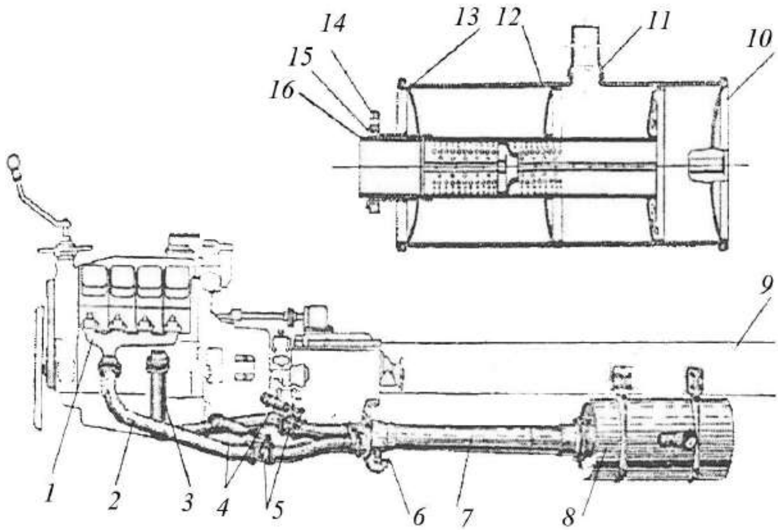


Figure 6.2 – Exhaust system silencer: *1*– engine; *2*– left receiving pipe; *3*– right intake pipe; *4*– pneumatic cylinders engine brake; *5*– engine brakes; *6*– tee; *7*– sleeve receiving pipes; *8* – muffler; *9*– frame; *10*– rear bottom of the case muffler; *11*– muffler outlet pipe; *12*– muffler body; *13* – front bottom of the muffler housing; *14*– tension flange of the receiving branch pipe; *15*– thrust flange of the muffler intake pipe; *16*– perforated tube

Lubrication system

This system (Fig. 6.3) serves to supply oil to the surfaces of friction parts.

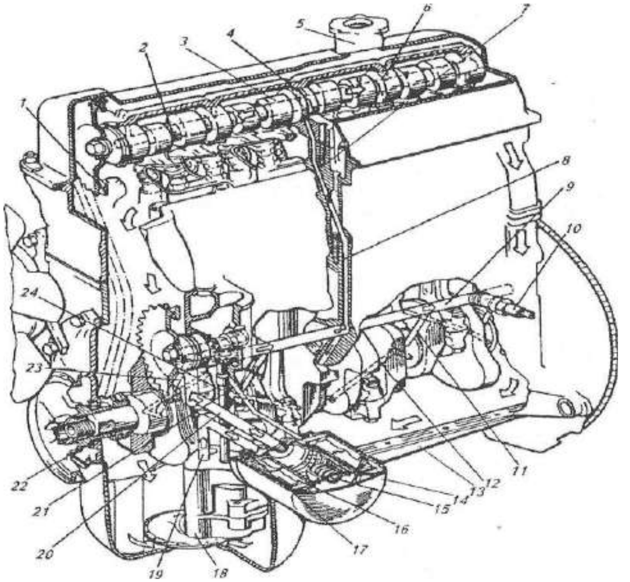


Figure 6.3 – Car engine lubrication system:
1– hole in the sprocket for chain lubrication;*2*– main canal in camshaft;*3*– channel in the camshaft cam;*4*– ring a groove on the middle camshaft journal;
5– oil filler neck;*6*– channel in the support neck of the distribution shaft;*7*– inclined channel in the cylinder head;*8*– oil supply channel to the gas distribution mechanism;*9*– main oil line in the block cylinders;*10*– low oil pressure warning lamp sensor; *11*– oil supply channel to the main bearing;*12*– feed channel connecting rod bearing oils;*13*– oil pan;*14*– oily filter;*15*– bypass valve;*16*– cardboard filter element;
17– anti-drainage valve;*18*– oil pump;*19*– feed channel oil from the pump to the filter;*20*– oil supply channel from the filter to the main oil line;*21*– oil supply channel to the drive gear bushing oil pump;*22*– front crankshaft sleeve;*23*– channel oil supply to the main bearing and oil drive roller pump;*24*– oil pump and distributor drive roller ignition

*Classification*Depending on the operating conditions of engine parts and mechanisms, lubricant can be supplied to them in several ways:*under pressure, drip (sprayed with oil) and oil mist*.IN Modern engines use a combination of different methods to supply oil to the surfaces of the mating friction parts. This lubrication system is called *combined*.

Under pressure, oil from the oil pump is supplied:

– to the main and connecting rod bearings of the crankshaft;

– to the camshaft journal bearings;

– to the rocker arms;

– to the upper tips of the rods.

In some designs, the connecting rod upper head bushings and piston pins are pressure lubricated.

The camshaft cams, lower rod tips, valve guide bushings, exhaust valve rotation mechanisms, timing gear wheels and other parts, as well as the most loaded part of the cylinder mirror (through the hole in the lower head), are lubricated by spraying and oil mist.

Cooling system

Purpose and classification, the influence of the engine's thermal regime on its operation

The cooling system serves to forcibly remove heat from hot engine parts and transfer this heat to the environment. The cooling system (Fig. 6.4) is designed to maintain a given thermal regime of the engine by forcibly removing heat from engine parts to the ambient air. As a result, a certain temperature regime is created at which the engine does not overheat or overcool, i.e. the operating cycle proceeds normally.

When the engine overheats, friction forces and the intensity of wear of parts increase, thermal gaps decrease, oil coking occurs with carbon deposits, and the filling of the cylinders with a fresh charge deteriorates.

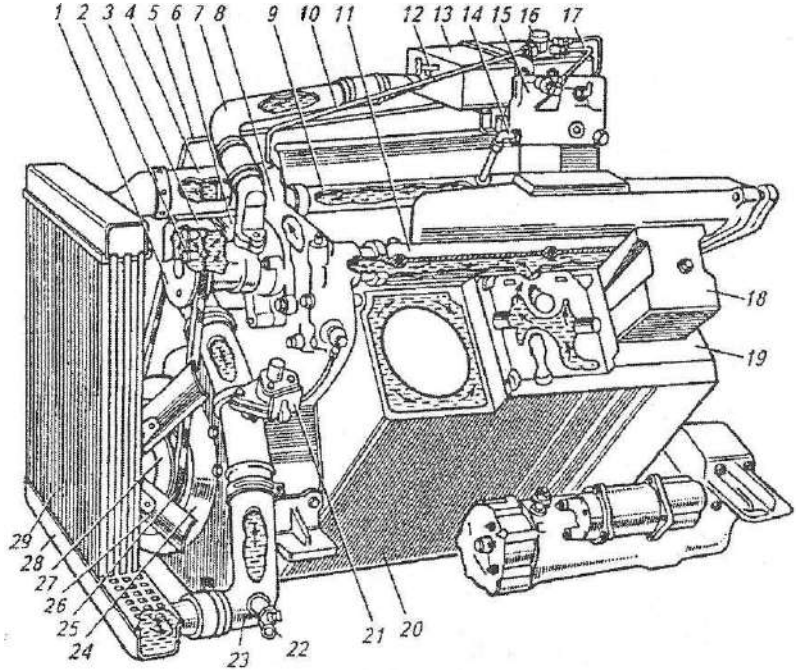


Figure 6.4 – Engine cooling system YaMZ-KAZ-642:
1– water pump drive pulley;*2*– thermostats;*3*- water pipe pump;*4*– outlet pipe;*5*– steam outlet pipe water pump to the expansion tank;*6*– water pump; *7*– connecting pipe;*8*– water pump bracket;*9*,*11*– accordingly, left and right water pipes;*10*– air exhaust tube from the bracket water pump to the expansion tank;*12* – level control valve; *13*– expansion tank;*14*– connecting tube from the water pipe to compressor;*15*– compressor;*16*– cork;*17*– connecting tube from compressor to expansion tank;*18*– cylinder head cover; *19*– cylinder head;*20*– cylinder block;*21*– hydraulic clutch switch; *22*– drain cock;*23*– radiator outlet pipe elbow;*24*– pulley generator drive;*25*– belt drives of units;*26*– fan; *27*– fan drive hydraulic coupling;*28*– radiator; *29*– radiator shutters

However at excessive assigned warmth occurs engine hypothermia, which is caused by a change in the viscosity properties of the oil, increased clearances, and reduced engine power and efficiency.

The amount of heat (18...35%) that the cooling system must remove depends on the engine's power and operating mode.

It is necessary to maintain the optimal thermal regime of the engine, which is controlled by the temperature of the coolant within 85...95 °C, regardless of its load and ambient temperature. This contributes to obtaining maximum power, reducing fuel consumption and increasing the engine's service life.

Modern piston engines use liquid or air cooling systems. Liquid systems with forced circulation of the coolant are very common. Water or its mixtures with ethylene glycol are used as coolants - antifreezes Tosol A-40M and Tosol A-65M. These are concentrated ethylene glycols with anti-corrosion and anti-foam additives, having a density of 1.078...1.085 g/cm^3Antifreeze A-40M is a 50% mixture of water and ethylene glycol, which at a temperature of minus 40 °C does not turn into ice and does not cause damage to the cylinder block or radiators.

The air cooling system is used mainly on small displacement engines. With air cooling, excess heat is removed by a flow of air through the finned surfaces of the cylinders and cylinder heads. This flow is created by a blade fan with a device that regulates the flow intensity depending on the degree of cooling of the engine parts.

The amount of heat removed by the system is 25–30% of the total heat released in the working cycles during fuel combustion. When changing the engine operating mode, this percentage has remain constant to prevent the engine from overheating or overheating.

Violation of proper heat dissipation causes deterioration of surface lubrication, oil burnout, and overheating of engine parts.

Engine overheating causes:

– decrease in the strength of parts and even their burning;

– oil burning on the cylinder walls;

– violation of normal clearances, which leads to increased wear, seizure and even breakage;

– decrease in filling factor $\eta_{\text{there are}}$, premature ignition.

Supercooling leads to:

– to incomplete evaporation of fuel and deterioration mixture formation;

– fuel that has not evaporated washes oil from the cylinder walls, getting into the crankcase, it dilutes it, burns out during the exhaust stroke;

– increased wear of parts and reduced engine efficiency. The

cooling system is designed to maintain the temperature within certain limits that ensure the operation of the operating cycle $t_{\text{cool.ed}}$= 80–90 °C. In internal combustion engines, two types of cooling systems are used: air and liquid.

*By circulation method*fluids in the engine cooling system are divided into the following:

– thermosiphon;

– with forced fluid circulation.

*By connection method*with the atmosphere, a liquid system can be:

– open;

– closed.

An open cooling system is directly connected to the surrounding atmosphere. A closed cooling system has become widespread, where the internal space is only periodically connected to the

the surrounding atmosphere using special valves in the radiator cap.

The closed system ensures that the boiling point of the coolant is increased to 120 °C.

The influence of engine thermal conditions on its operation Not all of the heat is spent on the useful operation of the internal combustion engine (Fig. 6.5).

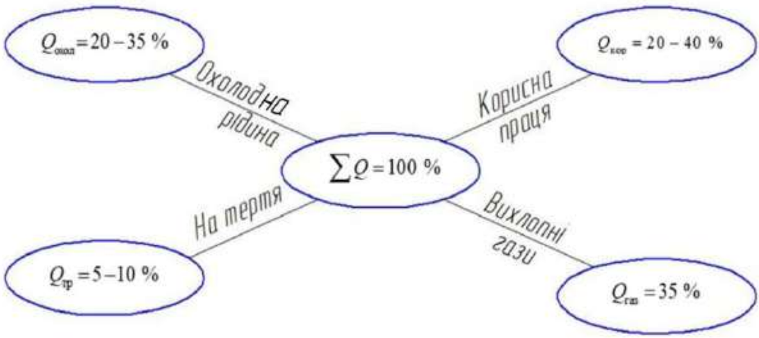


Figure 6.5 – Heat balance of an internal combustion engine

Effective efficiency:

– in gasoline engines $\eta_{\text{there are}}$= 0.20–0.28;

– in diesel engines $\eta_{\text{there are}}$= 0.27–0.4.

Only 20–40% of heat is converted into useful mechanical work, the rest of the heat generated during fuel combustion in the engine cylinders is spent:

– 35% of heat – with exhaust gases;

– 5–10% of heat – for friction;

– 20–35% of heat is removed by the coolant.

Heat transfer in the engine cylinder

The process of heat transfer from gases to the coolant can be depicted as follows (Fig. 6.6).

1. The heat flow from the main mass of gas passes through the gas film (boundary layer of gas) located near the cylinder wall.

2. After passing through the gas film, the heat flow overcomes the oil film.

3. Heat is transferred from the oil film to the cylinder wall.

4. From the cylinder wall, heat is transferred through a thin film layer (boundary fluid) to the main flow of the circulating fluid. cooler.

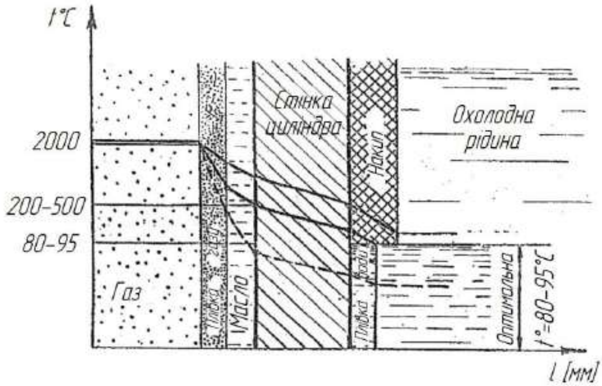


Figure 6.6 – Temperature change in the engine cylinder

As can be seen from the figure, the gas temperature in the combustion chamber is approximately constant. This is due to the chaotic motion of particles during combustion. In the boundary layer, which is characterized by the ordered motion of particles, the heat transfer process changes. Due to the low thermal conductivity of the gas, a sharp (by 1500–2000 °C) drop in temperature occurs at the wall. In the thin oil film and the cylinder wall, the temperature decreases slightly.

There is also a boundary layer on the cylinder wall on the liquid side, but since the thermal conductivity of the liquid is much higher than that of the gas, the temperature drop in this layer is of the order of 5–10 °C. Given these features, a temperature regime is established in the cylinder system at which the liquid has a temperature of 80–95 °C. At such a

At the liquid temperature, the temperature of the engine cylinder wall on the gas side is 200–250 °C.

Under such conditions, a thin film of oil, only a few microns thick, remains on the engine cylinder wall.

The film provides reliable lubrication and low friction losses when the piston moves in the engine cylinder.

A lower coolant temperature when operating an unheated engine leads to a decrease in the cylinder wall temperature (see Fig. 6.6, dotted curve). Therefore, the oil on the cylinder wall becomes more viscous, fuel vapors condense and wash away the oil film. As a result, friction losses and wear of the piston group engines increase. Even burrs on the cylinder wall are possible. It is also harmful to operate the engine at a coolant temperature higher than the recommended one. In this case, the cylinder wall temperature increases (upper curve Fig. 6.6). The oil film turns into a layer of carbon deposits, friction losses and wear of parts increase sharply, the strength of parts decreases, and self-ignition or detonation of the burning fuel occurs.

The same consequences are caused by a layer of insoluble calcium salts (scale) deposited on the cylinder wall. Having a lower thermal conductivity than the cylinder material, scale sharply reduces heat transfer to the coolant. The temperature of the cylinder mirror increases, given that the coolant has an optimal temperature of 80–95 °C.

Structure and operation of the cooling system (Fig. 6.7).

The closed, forced liquid cooling system includes the following elements: a cooling jacket for the block and cylinder head, a water pump, a fan, a radiator, a thermostat, blinds, a radiator cap, and drain cocks.

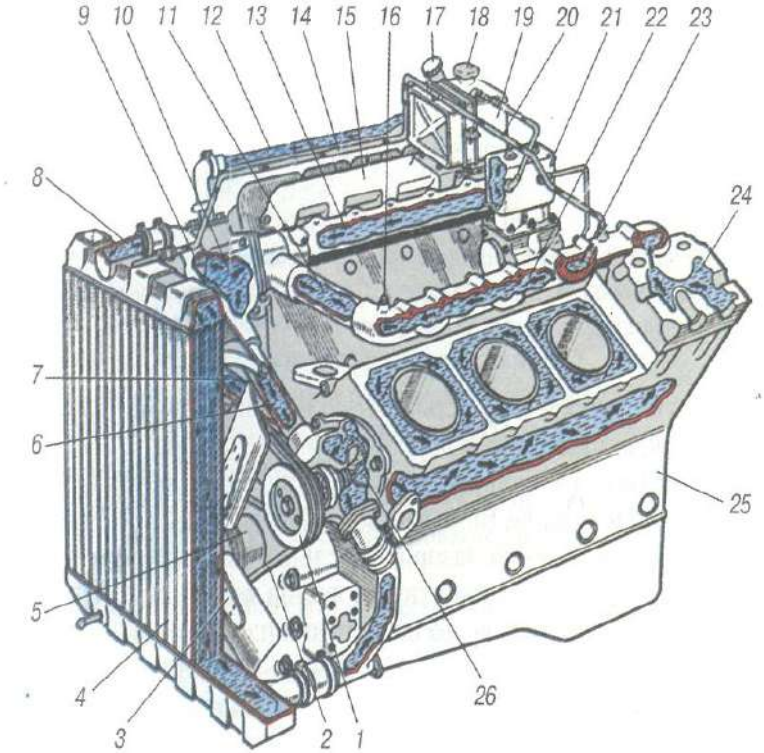


Figure 6.7 – Diagram of the KamAZ-740 engine cooling system:
1– fluid pump pulley; *2*– pump drive belt and generator; *3*– fan; *4*– radiator; *5*– fan pulley; *6*– bypass nipple; *7*– discharge pipe; *8*– upper branch pipe; *9*– thermostat; *10*– water distribution box; *11*– connecting tube; *12*– underwater tube; *13*– right tube; *14*– radiator outlet pipe; *15*– inlet pipeline; *16*– overheating warning lamp sensor engine; *17*– filler neck; *18*– plug with steam-air valve; *19*– expansion tank; *20*– outlet pipe; *21*– compressor; *22*– left outlet tube; *23*– left tube; *24*– head cylinder; *25*– cylinder block; *26*– centrifugal pump

Cooling shirtis an integral part of the block and head, i.e. the space between the block walls and the wet cylinder liners. The cooling jacket is connected to the radiator by pipes and connecting hoses.

Liquid pump– serves to create forced circulation fluid in the system.

Centrifugal pumps are used on engines (Fig. 6.8–6.9). Structurally, it is connected to the fan and has a common drive.

The pump consists of:from the housing; roller; drive pulley hub; drive pulley; self-sealing oil seal.

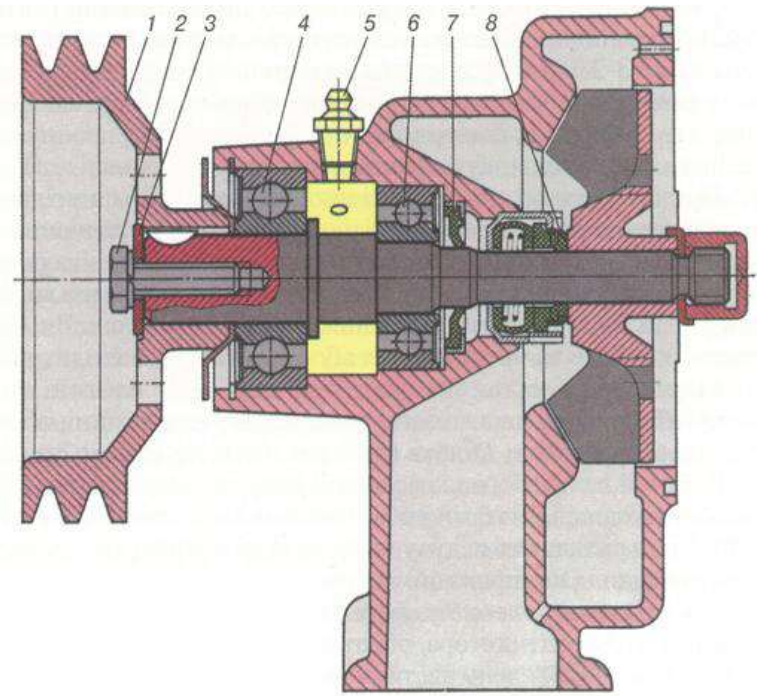


Figure 6.8 – Liquid pump of the KamAZ-740 engine:
1– pulley;*2*– bolt;*3*– washer;*4*,*6*– bearing;*5*– oil press;
7– cuff;*8*– oil seal

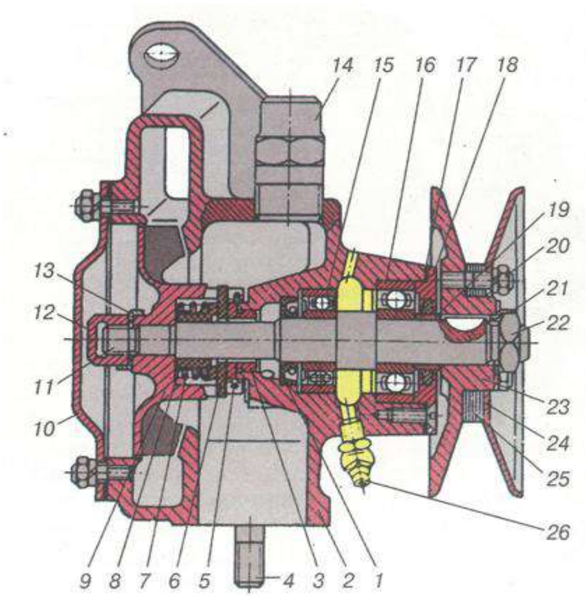


Figure 6.9 – Liquid pump of the YaMZ-238 engine:

1– oil seal;*2*– pump body;*3*– bushing;*4*– mounting pin inlet pipe;*5*– oil seal retaining ring;*6*– thrust ring gland;*7*– gland spring;*8*– gland seals;*9*– impeller; *10*– lid;*11*– shaft;*12*– nut;*13*– locking washer;*14*– bypass liquid thermostat tube nipple;*15*–*16*– ball bearings; *17*– gaskets;*18*– gland body;*19*– gland bushing; *20*– pulley sidewall fastening nut;*21*– lock washer;*22*– nut; *23*– pulley base;*24*– pulley sidewall;*25*– adjusting gaskets; *26*– oil press

Pump housingconsists of2 parts: the first part is the housing, cast from aluminum alloy and is one piece with the timing gear cover, the second part is the cover in which the pump is mounted, cast from gray cast iron and attached to the housing with studs.

There is a gasket between both parts. There is an inspection hole on the bottom of the cover for coolant to escape in case of a seal failure.*It is strictly forbidden to plug this hole.*There is also an inspection hole on the top of the cover for the release of fresh oil, which is pressed through a grease nipple to lubricate the bearings.

PlatenThe pump rotates in two ball bearings. The outer The more loaded bearing is larger, and the inner, less loaded one is smaller. Flats are made on both ends of the roller. A steel hub of the water pump and fan pulley is pressed onto the front end, and a plastic impeller with blades and a steel hub is pressed onto the rear end.

The pump is driven by a V-belt from the crankshaft pulley. The working part of the pump is sealed with a self-tightening oil seal.

The gland consists of a rubber cuff, a PCB washer, a spring, and two clips.

The seal rotates with the impeller.

Fan– serves to create air draft through the core radiator. Fans come in two types:

– stamped from sheet steel, blades attached to the hub;

– blades cast from light alloys as one piece with the hub.

Number of blades 3 – 4. Drive – belt drive.

Radiatorserves to cool the heated oil in the cylinder block liquid and consists of: an upper tank; a lower tank; a set of vertical tubes; cooling plates; a radiator cap; a control steam vent tube; a tap.

The upper and lower tanks are connected to each other by tubes soldered into them, forming the core of the radiator, as well as by side risers, forming the frame. Brass strips are soldered between the tubes, which increase the cooling surface.

On the inside, a casing is attached to the radiator frame, in which the fan rotates. The casing provides the direction of the air flow passing through the radiator core.

Radiator tanks have pipes that connect the radiator to the cooling systems with flexible hoses. The upper tank has a filler neck. The lower tank has a drain cock.

Thermostatserves to accelerate the warming up of cold engine and protects it from overheating while the car is moving. The thermostat is a single-valve thermostat located in the exhaust pipe. Thermostats are used with liquid and solid fillers.

Fillers:

– *liquid*– consists of a volatile liquid (mixture: 70% ethyl alcohol and 30% water);

– *firm*– they use wax with copper shavings, which has a large coefficient of volumetric expansion.

The thermostat consists of a valve, a cylinder, and a housing.

The thermostat valve operates automatically depending on the change in the length of the cylinder, inside which there is a volatile liquid. The lower end of the cylinder is fixedly fixed to the bracket of the thermostat housing. In the upper part of the cylinder there is a rod to which the valve is soldered. When the temperature of the coolant increases, the pressure inside the cylinder increases and the cylinder lengthens. The valve, rising, opens the access of the coolant through the outlet pipe to the radiator.

Valvestarts to open at coolant temperature 78 °C, and its full opening occurs at a temperature of 91 °C. To remove air from the engine water jacket when filling the cooling system with liquid, as well as for partial circulation of liquid through the radiator, there is a small round hole or extruded groove in the thermostat valve. It is necessary to monitor the cleanliness of the hole. So, if it turns out to be clogged with scale, then it will not be possible to completely fill the cooling system with liquid.

Jalousieare used to manually adjust the degree of cooling radiator. They consist of 16 galvanized steel leaf plates, which are located horizontally and hingedly in the frame. The shutter leaves are controlled by a handle on the removable floor of the car cabin. When the handle is pulled out, the leaves are open. When the handle is pulled up, the leaves are closed. The handle can be stopped by a latch in 9 positions depending on the ambient air temperature and engine operating mode. When starting, the blinds must be closed.

Radiator caphas two valves: steam and air. Steam The valve prevents the radiator from being destroyed by overheating. It opens at an excess pressure of 0.45–0.55 kgf/cm^{2}The liquid in the radiator at this pressure boils at a temperature of about 109 °C, which ensures the operation of the cooling system without boiling at elevated temperatures.

The air valve is adjusted for a vacuum in the system of 0.01...0.1 kgf/cm^{2}in order to prevent the radiator tubes and tanks from collapsing due to atmospheric pressure during the cooling of the liquid in the cooling system. The normal operation of the valves depends primarily on the serviceability of the gaskets. Therefore, their preservation and condition must be monitored.

Drain valve – bronze, cork. The liquid from the cooling system is drained simultaneously through four valves:

– tap on the lower radiator tank;
– a valve installed on the starting heater boiler;
– a tap on the right side of the engine cylinder block;
– tap on the cabin heating hose.

Since the system is sealed, it can only be completely drained of fluid when the radiator cap is removed.

The tap holes should be cleaned with a wire when draining the liquid. ***Coolant temperature control***

To monitor the temperature of the coolant in the cooling system, a temperature sensor is installed on the exhaust pipe, which is connected to the thermometer located on the instrument panel. In addition, a sensor for the emergency temperature warning lamp is located in the upper radiator tank. When the coolant temperature rises to 104–109 °C, the “Water” warning lamp with a red light filter lights up on the instrument panel. In this case, it is necessary to open the blinds, and if they are already open, immediately stop the car and eliminate the cause of overheating (add water, increase the tension of the fan drive belt, etc.).

Cooling system operation

The water pump pumps fluid through holes in the water jacket of the right and left banks of cylinders. From there, it enters the water jackets of the block heads through a hole in the cylinder gasket. From the left block head, the fluid is directed through two holes in its front and rear parts, and then through the left longitudinal and central channels of the water jacket of the intake pipe to the right longitudinal channel and exhaust pipe.

From the right head of the block through the right longitudinal channel of the water jacket of the intake pipe, the coolant enters the outlet pipe. From the outlet pipe, the liquid is directed to the upper radiator tank when the thermostat is closed.*(warm engine)*or with the thermostat closed through the bypass hose into the water pump suction cavity*(cold engine).*

Starting heaterserves to warm up the engine before starting in cold season. The engine starting heater includes:

– boiler;
– gasoline tank;
– electric fan;
– glow plug;
– solenoid valve;
– starting heater control panel;
– pipelines.

The boiler is installed on the left side of the engine and is permanently connected to the cooling system. The heater is controlled from the control panel, which is located on the removable floor panel behind the engine. The control panel contains a spark plug switch, a control coil, a push-button fuse, solenoid valve switches and a fan motor.

The switch can be in three positions for operation:

– 0 – all included;

– 1 – the fan motor is turned on;

– 2 – the fan motor and the electromagnetic switch are on valve.

Safety precautions when using

Safety precautions when using

1. While the heater is operating, the driver must not leave the car.

2. If smoke and flame appear at the outlet, the heater should be turned off. and fix the fault.

3. Not allowed to use in enclosed spaces.

4. Restarting the heater is only allowed after by blowing the gas ducts for 1–2 minutes.

Coolants

Water and special types of antifreeze are used as coolant in the engine.

Fluid requirements:

– the liquid must have a high heat capacity;

– good thermal conductivity;

– low viscosity;

– should not corrode metals and destroy rubber hoses;

– do not leave deposits in the system;

– the freezing temperature must be below the operating temperature engine.

*Water*has a high heat capacity, is well pumped, but has the following disadvantages:

– boiling point at the nominal thermal mode of the engine;

– boils away when atmospheric pressure drops (at an altitude of 4000 m t_{pile}= 87 °C);

– increases in volume upon freezing (this leads to defrosting of cast iron blocks and engine heads and radiators. Ice increases in volume by 10% and exerts pressure on the walls of the system*G*=250 MPa);

– scale and sludge reduce heat dissipation from the engine walls by 10–40%;

– it is necessary to use soft water.

Low-freezing coolant

Standard low-freezing coolant (antifreeze) is a mixture of dihydric alcohol - ethylene glycol and water. Technical ethylene glycol is an oily yellowish liquid with a boiling point of 197 ° C and a freezing point of minus 12 ° C. When mixing ethylene glycol with water, a decrease in the freezing point of the mixture is initially observed, which reaches a minimum at minus 70–75 ° C and with a water content of 33%.

Antifreeze of the brand "40" contains 52–55% ethylene glycol, the freezing point is not higher than minus 40 ° C. For northern regions, a mixture of the brand "65" is prepared with a freezing point not higher than minus 65 ° C, which contains 64–67% ethylene glycol. In addition to the considered low-freezing coolants, the following are produced: Tosol A; Tosol A-40; Tosol A-65. Tosol A-40 is green in color. These liquids have a large coefficient of volumetric expansion, so they are poured into the system 6–8% less than the nominal capacity of the cooling system (below 60–70 mm from the upper edge of the radiator nozzle).

Safety measures

*Ethylene glycol is a strong food poison, liquids of the brands "40" and "65" are also poisonous.*When it enters the body, it causes poisoning, which can be fatal.

It is prohibited:

– suck liquid with your mouth;

– eat food until hands contaminated with poisonous liquids are clean will be washed thoroughly with soap.

If it gets on your skin, wash with hot water and soap.

Maintenance, malfunctions of cooling systems and how to fix them When servicing the cooling system, the filling of the fluid is checked, the fluid level is checked for leaks, and

The fan belt tension is adjusted, the radiator mounting, its plug, louvers, fan, water pump, operation of the thermostat and the radiator plug air-vapor valve are checked, and scale and sludge are periodically removed from the system (Table 6.1).

During a control inspection(KO) the fluid level is checked in system, tightness of the connection, whether there are any fluid leaks, fastening of the radiator cap.

During daily maintenance(WHAT), except for WHO, the fan belt tension is checked, and during the winter period of belt operation, water is drained from the system if the car is parked in an unheated garage. Water is drained on a hot engine. To drain the water, all drain cocks and radiator plugs are opened. After draining the water, the drain cocks are left open.

*During technological maintenance*No. 1 (MAINTENANCE No. 1), in addition to MAINTENANCE, the fastening of the fan blades and bracket, the water pump, the radiator and its cladding, the fastening and operation of the blinds are checked. Fill the water pump bearing cavity with oil.

*During technological maintenance*No. 2 (MAINTENANCE No. 2) – in addition to the listed works, the operation of the thermostat and the steam-air valve of the radiator cap is checked.

During seasonal maintenance(CO) is drained from the system or Low-freezing fluid is poured into the system with preliminary flushing of the system from sediment and scale, and the engine starting heater and the car cabin heater are disconnected or connected to the system.

Flushing the cooling system. A solution of Chrompik (4–8 g per 1 liter of water) is used for flushing. The solution is poured into the system, and the engine is run on it for a month. Then the solution is drained, and the system is flushed with hot water.

Cooling system malfunctions and how to fix them Cooling system malfunctions can cause the engine to overheat or overcool, or coolant to leak.

Table 6.1 – Cooling system failures, malfunctions and ways to eliminate them

Causes of malfunction	Elimination methods
Engine overheating	
1. Insufficient fluid in the system	1. Top up to the level
2. Slipping of the fan drive belt due to weak tension or oil getting on it	2. Tighten the belt and remove oil from the fan belt
3. Faulty thermostat	3. Replace
4. Limescale build-up	4. Rinse with chromic acid solution
5. Malfunction of power and ignition systems	5. Adjust the power and ignition systems
Engine undercooling	
1. Faulty thermostat	1. Replace
2. Blinds stuck (blinds in open position)	2. Eliminate sticking and lubricate with TSIATIT-201
3. Supercooling measures	3. Cover the curtain, put on the insulating cover
Coolant leak	
1. Water pump seal wear: the leak is detected by fluid leaking through the inspection hole in the pump housing	1. Replace the oil seal with the water pump removed
2. Radiator damage	2. Eliminated during its repair
3. The clamps connecting the pipes have loosened.	3. Tighten the connection clamp
4. Poorly polished drain taps	4. Remove the taps and rub them with paste until a matte strip appears on the entire working surface. cork surface

Ignition system

The ignition system is designed to forcibly ignite the working mixture in the combustion chamber of gasoline engines at exactly the right moment.

*Classification.*By the method of spark synchronization – *contact and contactless*; by the method of energy storage –*inductive and capacitive*; by the method of breaking the primary circuit –*with mechanical rupture and transistor*; according to the method of distributing high voltage pulses –*with mechanical and electronic distribution*; according to the method of adjusting the ignition advance angle – with a mechanical automatic and electronic adjustment.

Fig. 6.10 shows a classic diagram of the ignition system.

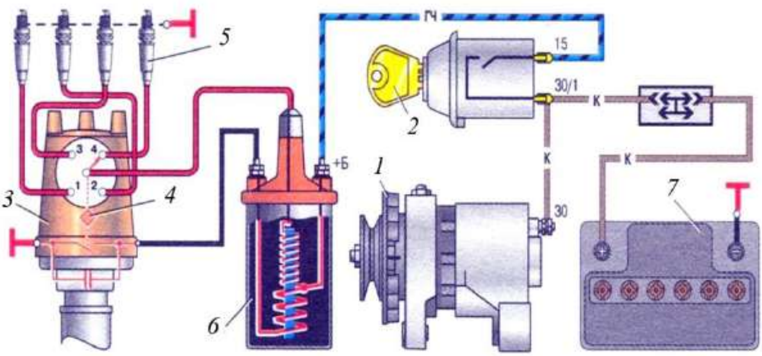


Figure 6.10 – Battery ignition diagram:
1– generator;*2*– ignition switch;*3*– ignition distributor;
4– breaker cam;*5*– spark plugs;*6*– coil
ignition;*7*– rechargeable battery

Starting system

To start the internal combustion engine, an electric starter system is used. The components of the system are shown in Fig. 6.11. The task of the system is to rotate the crankshaft when starting the internal combustion engine to the starting frequency using a starter. DC electric motors are used in starters.

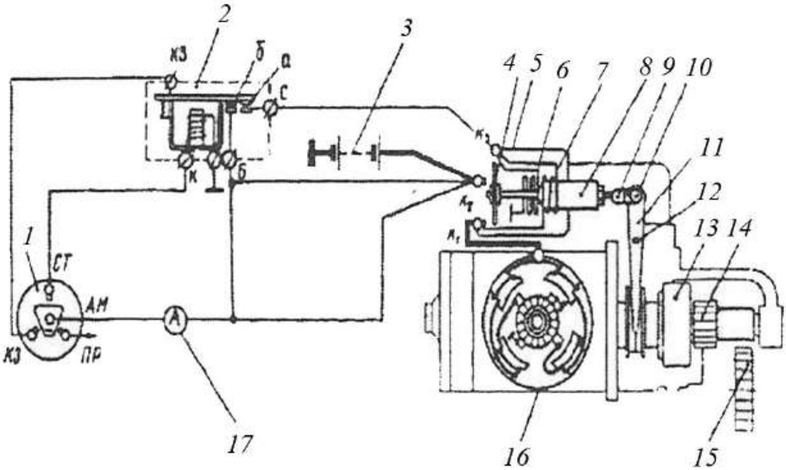


Figure 6.11 – Schematic diagram of the starter electrical connections: K_1, K_2, K_3– traction relay terminals; B, K, KZ and C – additional relay terminals relay,*and*and*b*– contacts;*1*– ignition switch;*2*– additional relay turning on the starter;*3*– rechargeable battery;*4*– contact disc;*5*– traction relay;*6*and*7*– holding and retracting windings;*8*– anchor;*9*– earring;*10*– finger;*11*– lever;*12*– axis;*13*– freewheel clutch;*14* – gear;*15*– flywheel ring gear;*16*– starter;*17*– ammeter

Review questions

1. Purpose and classification of engine power systems.
2. Power system structure.
3. Exhaust gas emission subsystem.
4. Purpose and structure of the engine lubrication system.
5. Purpose and structure of the cooling system.
6. Purpose and structure of the ignition system.
7. Purpose and structure of the engine starting system.
8. Purpose of the starting heater.
9. The influence of the thermal regime of the engine on its operation (thermal balance, heat transfer in the cylinder).

10. Construction and operation of the starting heater.

11. Construction and maintenance of a water pump.

12. Structure and operation of the thermostat and radiator cap.

13. The structure of the starting heater and safety measures when using it usage.

14. Coolants and safety precautions when using them.

15. Cooling system maintenance.

16. Cooling system malfunction and methods for its elimination.

17. How is the voltage increase in the system ensured? ignition?

18. Components of the ignition system.

19. What elements of the ignition system circuit are included in the circuit? low voltage?

20. What elements of the ignition system circuit are included in the circuit? high voltage?

21. Car electric energy generator for power supply ignition systems.

22. Purpose of the ignition system.

23. Which internal combustion engines use an ignition system?

24. What is included in the starting system?

25. How does the starter motor turn on?

26. What electric motors are used in the design? starter?

27. What does the starter gear connect to when starting an internal combustion engine?

Laboratory work 7
MODERN ICE LUBRICATION SYSTEMS

Purpose of work– study the purpose, design and operation modern lubrication systems used on various internal combustion engines of cars and tractors.

Visual aids:

- albums, instructions and posters on the design of car engines;
- electronic information material on the construction of modern engines;
- engine in section;
- car.

Tasks for work:

- identify and classify modern lubrication systems gasoline and diesel engines;
- study the components of modern engine lubrication systems internal combustion engine (ICE), identify the component mechanisms and devices. Determine their purpose;
- present in the report the structure of each internal combustion engine lubrication system accordingly to the task.

Lubrication system

*Lubrication system*designed to reduce friction between connected engine parts. In addition to performing its main function, the lubrication system provides:

– cooling of engine parts;

– removal of carbon deposits and wear products;

– protection of engine parts from corrosion.

Lubrication systemThe engine has the following structure (7.1):

– engine crankcase pan with oil receiver;

– oil pump;

– oil filter;

– oil radiator;

– oil pressure sensor;

– pressure reducing valve;

– oil main and channels.

When the engine is running, the oil gear pump, the shaft of which is driven by a gear on the crankshaft, supplies oil to the main line through a sequentially connected oil filter. The oil purified in the filter enters the central oil channel, and from there, through a system of holes in the cylinder block, to the main bearings of the crankshaft and camshaft and to external consumers (fan fluid couplings, NPT, compressor). The oil pressure at nominal speed should be within 0.4–0.55 MPa, but not less than 0.1 MPa.

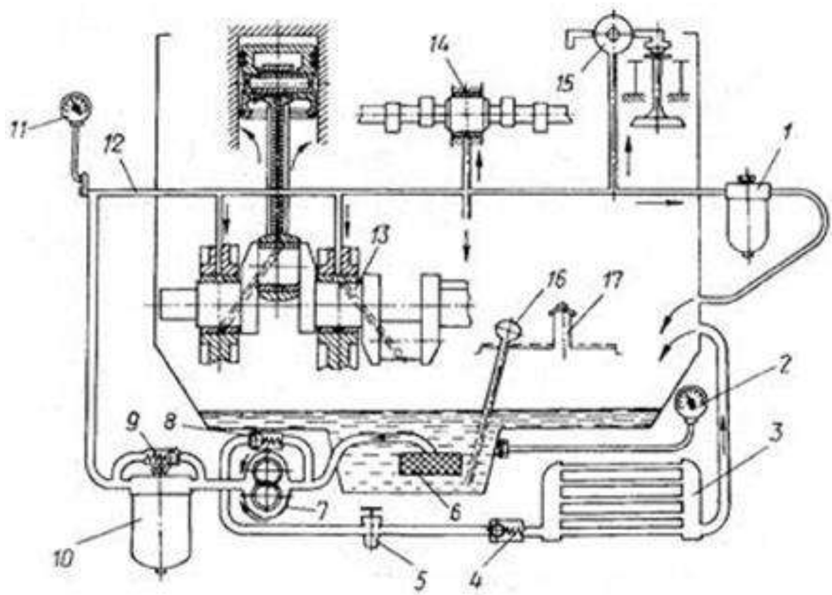


Figure 7.1 – General diagram of the engine lubrication system: *1*, *10*– filters; *2*– thermometer; *3*– radiator; *4*,*8*,*9*– accordingly safety, pressure reducing and bypass valves; *5*– crane; *6*– oil receiver; *7*– pump; *11*– pressure gauge: *12*– main highway; *13*– main bearing; *14*– camshaft bearing; *15*– axis rocker arm; *16*– oil dipstick; *17*– filler neck oil receiver *6*, filters *1* and *10*, main highway *12*, reduction *8*, bypass *9* and preventive *4* valves

The principle of operation of the lubrication system

In modern engines it is used*combined system lubrication*, in which part of the parts is lubricated under pressure, and the other part - by spraying or gravity.

Engine lubrication is carried out cyclically. When the engine is running, the oil pump pumps oil into the system. Under pressure, the oil is fed into the oil filter, where it is cleaned of mechanical impurities. Then, through the channels, the oil flows to the main and connecting rod journals (bearings) of the crankshaft, camshaft bearings, and the upper connecting rod support to lubricate the piston pin. Oil is supplied to the working surface of the cylinder through holes in the lower connecting rod support or using special nozzles.

The remaining parts of the engine are lubricated by splashing. The oil that flows through the gaps in the joints is splashed by the moving parts of the crank and gas distribution mechanisms. This creates an oil mist that settles on other engine parts and lubricates them. Under the influence of gravity, the oil flows into the sump and the lubrication cycle is repeated.

Some special purpose engines use a dry sump lubrication system, which includes all the parts and components of a wet sump system and operates on the same principle. The main difference is the way the oil is circulated. In a dry sump lubrication system, the oil is collected at the bottom of the engine, in an oil pan.

It is pumped into the oil tank by a suction pump, and then a conventional oil pump circulates the oil through the oil filter throughout the engine. An engine with this lubrication system does not have a sump, so the engine can be located lower. The oil tank can be installed in any place where it will be best cooled.

The filling capacity of a dry sump lubrication system is larger than that of a wet sump lubrication system (see Fig. 7.2).

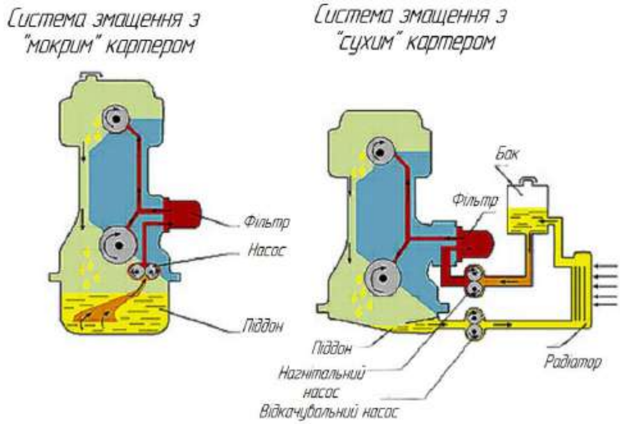


Figure 7.2 – Wet and dry sump lubrication system

Modern lubrication system using the example of a VW diesel engine

Using the example of a 2.5 liter diesel engine from *VW* can see how much more complex the lubrication system (Fig. 7.3) of a modern engine has become.

Design features

- Two-stage gear type oil pump with Internally meshed. Installed in the crankcase pan.

-Oil pressure control valve. By solenoid valve *ECU* (*Engine Control* with the help *Module*) directs oil into different channels, thereby switching the oil pump operating modes. When adjusting performance, the engine load, coolant temperature, crankshaft speed and signals from the automatic transmission are taken into account. When a control signal is given, the valve opens, passing oil into the first stage channels (system pressure about 1.8 kg/cm^2). In the absence of a control "mass", the return spring returns the valve to its original position, changes the direction of oil flow, raising the pressure in the system to 3.3–4 kg/cm^2.

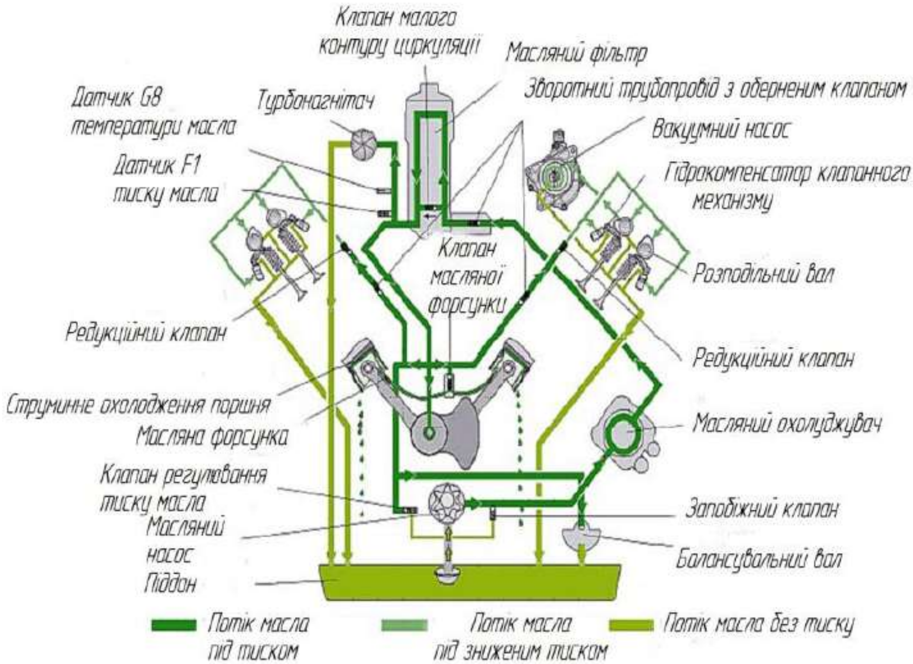


Figure 7.3 – VW diesel engine lubrication system

Changing the performance allows you to reduce mechanical losses spent on lubrication and cooling of the engine's friction pairs. This solution increases the overall efficiency of the engine, reducing the amount of harmful emissions.

Oil pump drive

1. From the camshaft through a pair of gears:

and) the drive gear is mounted on the distributor-breaker shaft;

b) the drive gear is installed in the cylinder block sleeve, the ignition distributor and oil pump are connected to the gear by splines.

2. On some engines, the pumps are driven by a separate circuit (*BMW*,*MAZDA*).

Oil pumps

An oil pump is a device necessary to create optimal pressure in the internal combustion engine lubrication system for constant oil circulation (Fig. 7.4, 7.5).

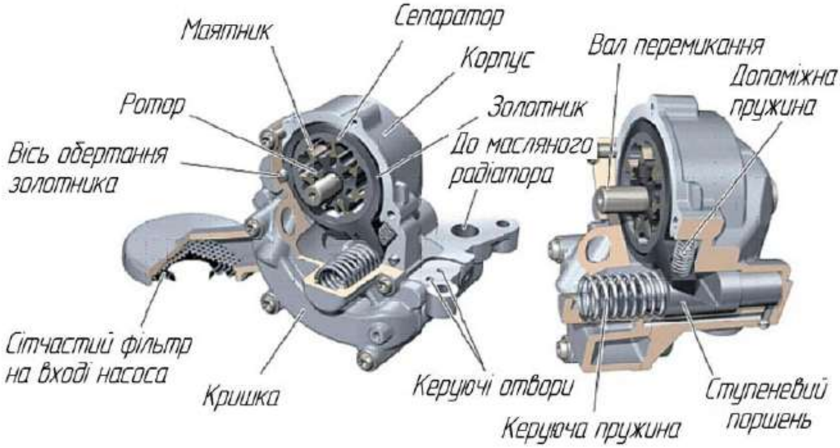


Figure 7.4 – Lubrication system pump with oil receiver

Design of an oil pump with gears

Such pumps are characterized by their simplicity. They consist of a small number of parts, including:

- driven and driving gears;
- drive;
- suction and discharge channels.

Gears mounted in the device body transfer oil from the suction to the discharge channel, from where it spreads throughout the system. The performance of such equipment depends entirely on the frequency of engine operation. If the pressure becomes excessive, it is necessary to drain oil from the system into the crankcase to reduce it. This operation is carried out automatically using a pressure reducing valve that reacts to pressure increase. It should be noted that it is impossible to manually adjust such an engine oil pump.

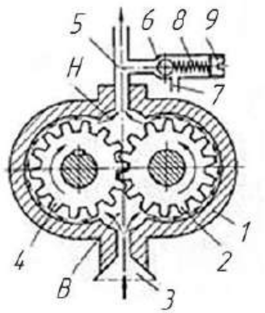


Figure 7.5 – Pump operation diagram:

1– body;*2, 4*– respectively, the driving and driven gears;*3*– mesh filter;*5*– discharge channel;*6, 8, 9*– respectively, a shut-off ball, a spring and the safety valve adjustment screw;*7*– hole for bypass oils;*N*,*IN*– respectively, the discharge and suction cavities

These pumps work as follows. When the gears rotate, one of which is the driving gear and the other is the driven gear, the oil moves through the gaps between the gear teeth and the pump housing. Increasingly, gear pumps with external gearing are used in lubrication systems, not with internal gearing, as shown in Fig. 7.6. The location of such a pump on the engine is shown in Fig. 7.1, and the features of its parts are shown in Fig. 7.7 and 7.8.

Rotary pump design.

The pump drive shaft is of small length and diameter. On one side, a sprocket or drive pulley is installed, and on the other side, a drive rotor is made, which has 4 protrusions (teeth), which, when rotated, alternately enter the five recesses of the driven rotor. The driven rotor rotates eccentrically relative to the drive rotor. The oil enters and exits through holes in the pump housing. The profile of the rotor protrusions ensures the sealing of the cavities due to small gaps between the protrusions and recesses, as well as the ends of the gears and the housing.

In lubrication systems, gear pumps with external gear engagement Fig. 7.6. They can be single-section (one pair of gears) Fig. 7.6,*and*, as well as two-section - Fig. 7.6,*b*,*in*and very rarely three-section (car engine*TATRA-815*).

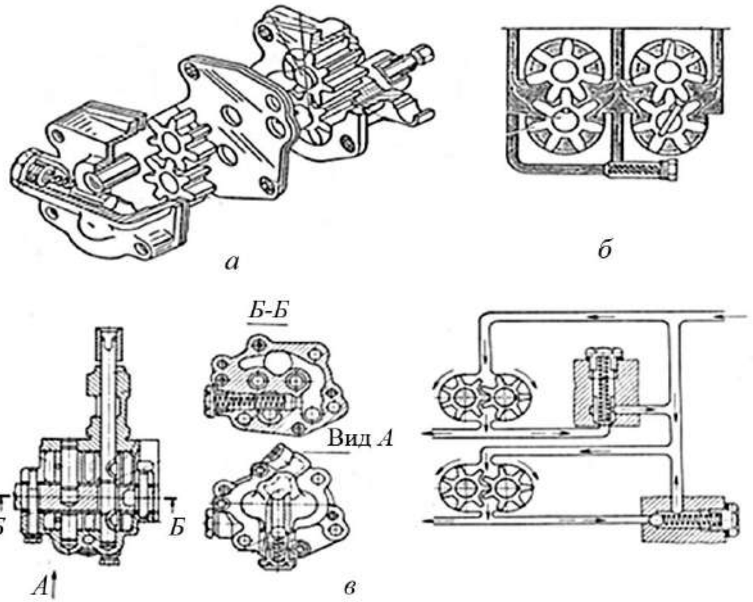


Figure 7.6 – Oil pumps with external gears:

and– single-section;*b*,*in*– two-section

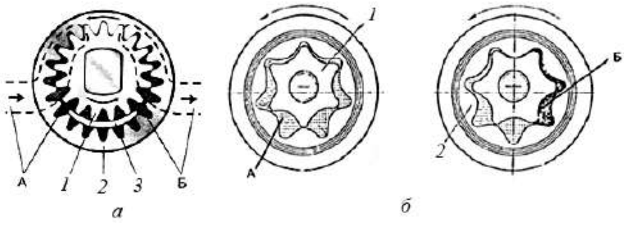


Figure 7.7 – Schemes of oil pumps with internal gearing: a – involute gearing; b – gerotor gearing;

1– drive gear,*2*– driven gear,*3*– jumper, A – suction cavity, B – discharge cavity

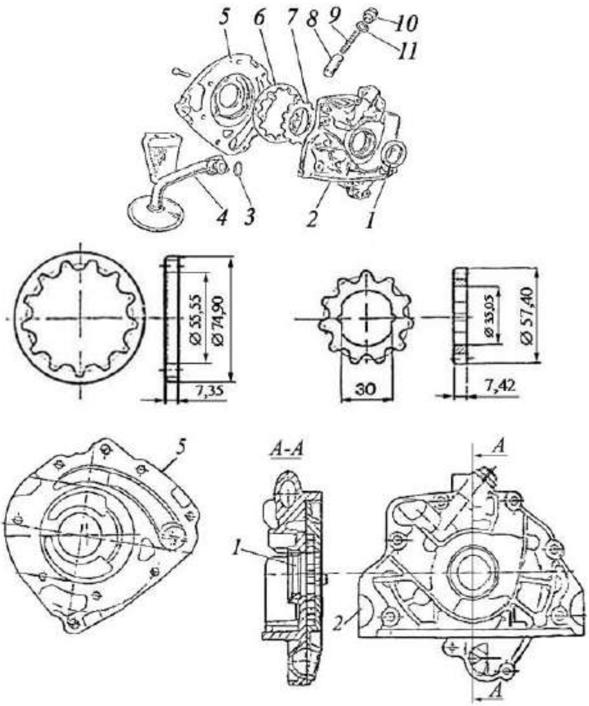


Figure 7.8 – Design of an oil pump with internal gearing: *1*– ring; *2*,*5*– lid; *3*– ring; *4*– intake; *6*– driven gear; *7*– drive gear; *8*– valve spool; *9*– spring; *10*– emphasis; *11*– washer

The main working parts of the pump (see Fig. 7.8) are the drive *7* and led *6* gears. The gears are located in the housing5, which has a protruding bridge that separates the gears. The housing has channels for oil movement. The pump is closed from the outside with a cover *2*, in which the pressure reducing valve is located.

In a wet sump engine, the oil is located in a pan. The pans can be stamped steel or cast from aluminum alloys with stiffening ribs and reinforcements (Fig. 7.9).

Sometimes cast pallets have ribs for cooling and increasing rigidity. Stamped pallets are more resistant to mechanical damage. A prefabricated pallet combines the advantages of cast and stamped pallets (see Fig. 7.9,*in*). Oil is collected from the sump by an oil receiver. There are two types of oil receivers – floating and fixed (fixed). The vast majority of lubrication systems use fixed oil receivers Fig. 7.10.

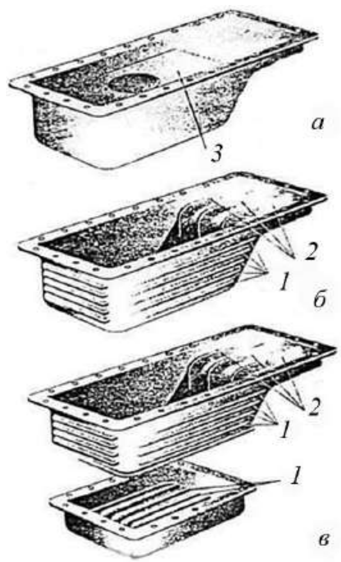


Figure 7.9 – Types of crankcase pans:
1– cooling fins,*2*– deflectors for directing oil flows,*3*– screen

Oil receivers are usually mounted on the pump and are a primary filter due to the installation of screens at the inlet. Through the oil receiver, oil enters the inlet of the oil pump (Fig. 7.10,*there are*,*w*).

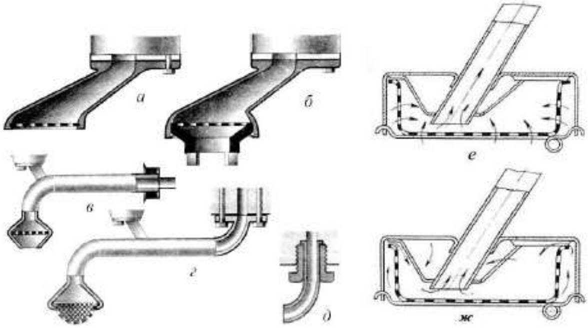


Figure 7.10 – Some common oil receiver schemes: *and*– cast aluminum oil sump – oil pump cover; *b*– the same, but the intake opening has a rubber deflector that allows deformation of the crankcase pan;*in*– oil receiver with a tube sealed with a rubber ring;*g*– flange mounting of the oil receiver tube allows for the greatest deformations in case of damage crankcase pan;*d*– fastening the tube with a fitting;*there are*,*w*– ways oil movement

Oil separatorprevents oil vapors from entering the chamber engine combustion, thereby reducing soot formation. There are labyrinth and cyclic methods of separating oil from gases. Modern engines are equipped with a combined action oil separator.

IN**labyrinth oil drain**(other name silencer) slows down the movement of crankcase gases, causing large drops of oil to settle on the walls and flow into the engine crankcase.

Centrifugal oil separatorperforms further oil separation from crankcase gases. Crankcase gases, passing through the oil separator, come into rotational motion. Oil particles under the action of centrifugal force settle on the walls of the oil separator and flow into the engine crankcase. To prevent turbulence of crankcase gases after the centrifugal

The oil separator uses a labyrinth type output still. It is where the final separation of oil from gases occurs.

Oil purification.

Filters are used to clean the oil. Depending on the method of installation of filters in the lubrication system, they are conventionally divided into full-flow and partial-flow. *Full-flow filter* is installed in series between the pump and oil consumers and all the oil supplied by the pump passes through it. *Partial flow filter* (Fig. 7.11) is installed parallel to the oil supply to consumers, and only part of the oil (10–15%) passes through it.

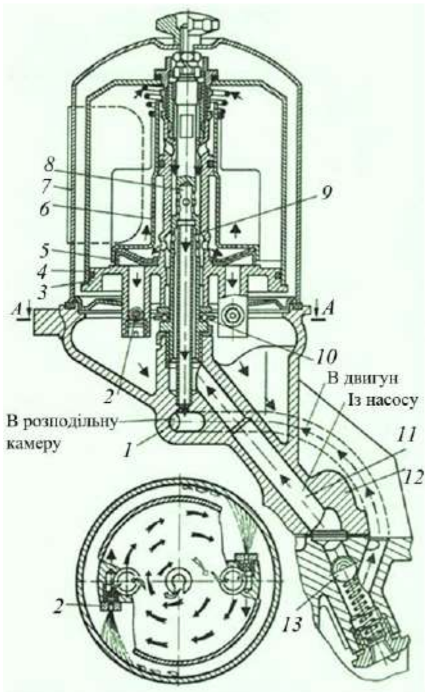


Figure 7.11 – Centrifugal oil filter:
1 – channel; *2* – jet; *3* – rotor; *4* – cap; *5* – mesh filter; *6* – insert; *7* – casing; *8* – rotor axis; *9* – tube; *10* – bearing; *11* – channel; *12* – body; 13 – bypass valve

According to the degree of purification, they are divided into coarse and fine filters. Coarse filters (mesh or plate-slot) are designed for purification from large impurities and are of limited use. By design, filters can be with a fixed element that filters in a collapsible or non-collapsible housing. Centrifugal filters with a movable filter element are mainly used on truck engines.

On most passenger car engines in lubrication systems non-separable filters are used, Fig. 7.12.

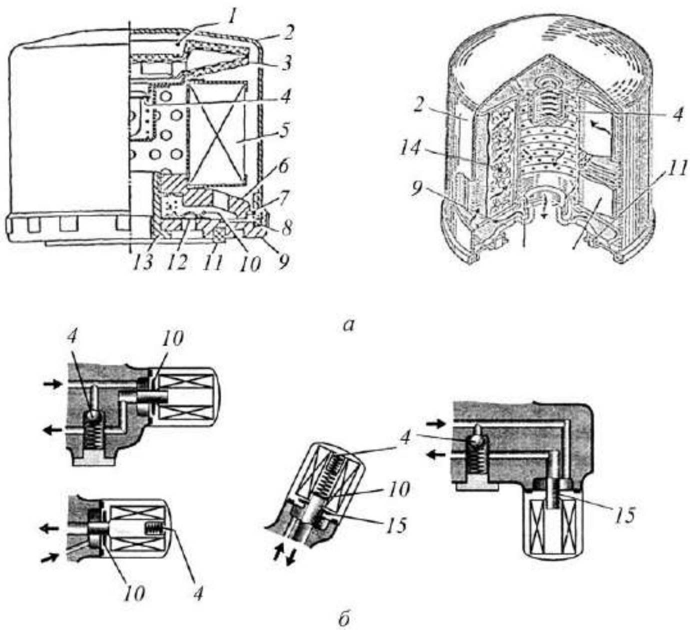


Figure 7.12 – Non-separable oil filters:

and– construction;*b*– installation methods in the lubrication system

Non-separable full-flow filter (Fig. 7.12,*and*) consists of a body*2*and lids*9,*united by rolling. In the body the main filter element is located*5*, bypass valve filter element*3*, fitted to the main spring

*1*The main filter element consists of a paper filter pack*5*Sometimes the paper filter element has a segmented insert*14*with less resistance to oil movement. Additional insert ensures the passage of oil on a cold engine. An additional filter also performs a similar function. In addition to filter elements, a non-separable filter can have three types of valves: anti-drainage, bypass and check. Anti-drainage valve *10* used to prevent oil from flowing from the filter into the crankcase when the engine is off. The anti-drainage valve is made in the form of an elastic rubber cuff adjacent to the inlet holes. Bypass valve*4*ensures oil movement past the filter element when it is clogged, as well as during cold start. Check valve *15* (see Fig. 7.12,*b*) prevents oil from leaking from the filter when it is removed from the engine. The combination of valves in the filter is determined by the design of the lubrication system. As a rule, the anti-drainage valve *10*required when installing a filter at the bottom of the system lubrication. The bypass valve is used when there is no such valve in the lubrication system line. The check valve is mostly used on filters with a vertical inlet from below. When the engine is running, oil enters the cavity around the filter element through the anti-drainage valve, passes the filter element and exits the system through the central fitting. The filter is replaced taking into account the vehicle's mileage.

Timely oil supply in a given direction with the required flow rate and pressure largely depends on the operation of the valves that regulate the oil flow. In the lubrication systems of the vast majority of engines, the pump supply is regulated by a reducing valve, which limits the maximum pressure by bypassing part of the oil from the pump outlet to the inlet. The pressure limitation at the pump outlet is also provided by a bypass (drain) valve. Protection of the system from pressure reduction when connecting to the oil radiator system is provided by a safety valve that works to reduce pressure. The valve design can have guide surfaces or be made without guides. Variants of valve schemes are shown in Fig. 7.13. Valves with guide surfaces have a small cavity to damp pressure fluctuations, but they are prone to jamming when particles get into

Wear. Valves without guides tend to have uneven wear on the seat or valve, which causes the valve to lose its tightness.

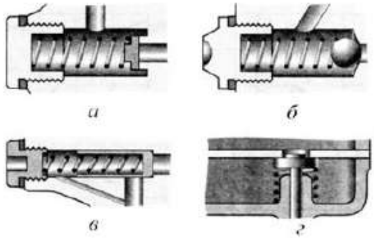


Figure 7.13 – Valve diagrams: *and*and*b*– without guides,*in*and*g*– with guides

The differential valve of the diesel engine lubrication system should be especially considered. The use of differential valves allows you to regulate the amount of oil supplied to the system depending on the degree of wear of the friction surfaces. With small wear, the oil leakage in the gaps is small. Taking into account the further increase in leaks, it is necessary to direct part of the oil to drain into the sump with small gaps. The use of the valves considered earlier leads to a blockage of the oil flow, What[N1]deteriorates its properties. Construction The differential valve (Fig. 7.14) provides controlled modes of its operation with oil flowing without resistance.

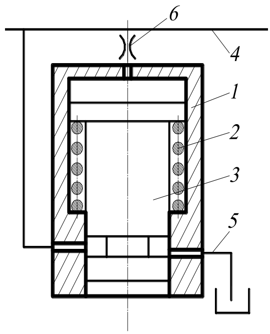


Figure 7.14 – Differential valve operation diagram:
1– body;*2*– spring;*3*– spool valve;*4*– main oil pipeline;
5– draining the oil into the sump;*6*– throttle

The scheme of oil supply to the rocker arm axis, as well as to the friction pairs rocker arm - axis and adjusting screw - push rod is shown in Fig. 7.15.

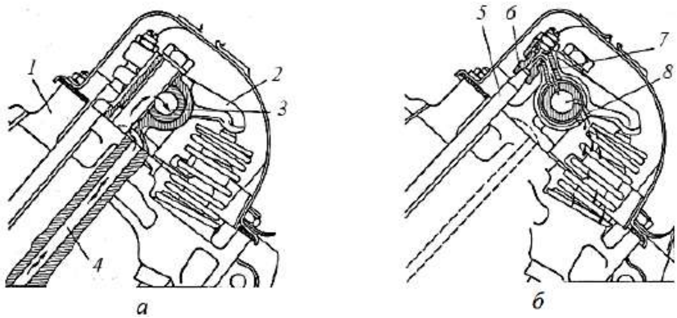


Figure 7.15–Rocker arm mechanism lubrication scheme: *and*– oil supply scheme to the rocker arm axis;*b*– lubrication scheme rocker mechanism;*1*– cylinder head;*2*– rocker arm; *3*– rocker arm axis cavity;*4*– channel in the cylinder head;*5*– barbell; *6*– adjusting screw;*7*– channel for supplying oil to the friction pair adjusting screw – rod;*8*– channel for draining oil from the axle rocker arm

From the channel*4*(rice.7.15) in the cylinder head, oil enters the cavity through the groove on the supporting surface of the axle strut and the gap between the strut and the rocker arm axle mounting bolt*3*From it, through the holes in the axle, oil flows to the rocker arm bushings.*2*, and through the channel*7*– to friction pair adjusting screw*6*- push rod*5*. Through the channel*8*the oil is dripping to the surface of the cylinder head, then along the rods to the pushrod cavity, and from there to the crankcase pan.

The valve stems in the guide sleeve and the exhaust valve rotation mechanism are lubricated by oil mist and oil leaking from the rocker arm mechanism.

Oil radiator(rice.7.16) is designed to dissipate the heat removed by the oil from the engine. The required temperature of the engine oil (80...110 °C) is maintained by two systems - cooling and lubrication, the work of which is closely interconnected.

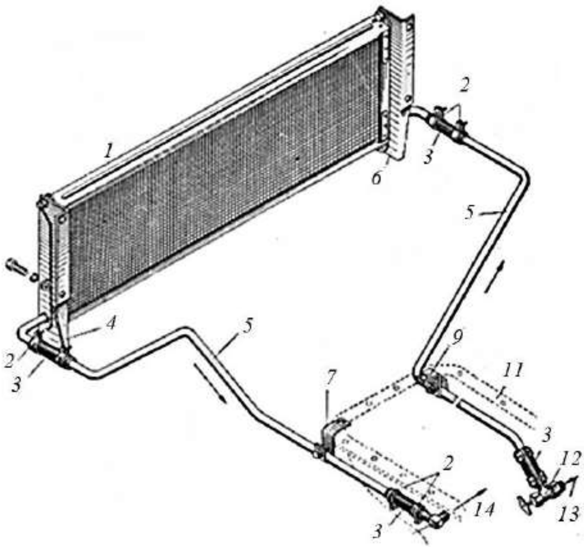


Figure 7.16–Oil radiator:

1– radiator frame;*2*– tie-down clamps;*3*– connecting hoses; *4*,*6*– radiator side brackets;*5*– pipeline that drains oil from radiator;*7*,*9*– pipeline mounting brackets;*8*– pipeline oil supply to the radiator;*10*– square root;*11*– crankcase pan engine;*12*– crane; *13*– direction of oil movement from the lower section of the oil sump pump;*14*– direction of oil flow to the sump

In low-power engines of cars moving at high speeds, it is sufficient to cool the oil in the sump by blowing it with a counter-current flow of air. In powerful engines with a busy working process installed on relatively slow-moving cars, it is necessary to provide forced cooling of the oil, for example in oil radiators.

Such radiators can be of two types: liquid-oil, which are installed in the engine's liquid cooling system, and air-oil with air flow generated by the movement of the car and created by a fan.

*Air-oil radiators*similar in design tube-plate radiators of the cooling system or made of finned tubes, they are installed in front of the radiator of the cooling system. The intensity of oil cooling in this case depends on the ambient air temperature.

*Oil-filled radiator*consists of a system of tubes in which circulating oil and which are washed by the engine cooling system fluid. They can be tubular or plate. Turbulizers are soldered inside the tubes (on the oil side) to improve heat dissipation from the oil to the walls. Liquid-oil radiators allow for a more stable oil temperature and accelerate its warming up after engine start. They are usually smaller in size than air-oil ones, since the heat transfer from the walls to the liquid is much higher than to the air. Radiators can be connected to the lubrication system in series or parallel to the main oil line. The most common is the parallel connection scheme, but it requires an additional section in the pump that pumps oil through the radiator. If the radiator is powered by a common section of the pump, then a safety valve is installed at the inlet, which prevents a dangerous decrease in pressure in the main line by turning off the radiator when the pressure in the system drops to 0.1 MPa. When the radiator is supplied by a separate section of the oil pump, it is equipped with a bypass valve adjustable to an excess pressure of 0.12 MPa.

Motor oils. Requirements for motor oils

The qualitative characteristics of the oils used in the engine lubrication system should most fully ensure that the system performs its main functions:

- reduction of friction between moving joints of engine parts;
- prevention of overheating of thermally stressed parts, to which it is difficult to supply the cooling system fluid;
- protection of engine parts from corrosion;
- washing away abrasive wear products from the surfaces of parts, dirt and mechanical particles. In addition, engine oil has a long

retain its useful properties in a wide range of operating temperatures, maintain constant viscosity at any ambient temperature, do not undergo significant chemical and physical wear during operation, since too frequent oil changes and topping up the lubrication system will negatively affect the cost of operating the engine and the car as a whole. Based on this, a number of requirements are imposed on motor oils:

- low pour point;
- minimal change in viscosity over a wide temperature range;
- long-term preservation of physical, chemical and lubricating properties properties during operation;
- prevent the formation of deposits on engine parts (carbon deposits, varnishes, sludges, etc.);
- reliably protect the working surfaces of engine parts from corrosion;
- not contain mechanical impurities and water;
- have minimal consumption.

These requirements are most fully met by synthetic motor oils, obtained artificially as a result of synthesis from various hydrocarbons and organic compounds. Petroleum products, natural gas and other hydrocarbon compounds are used as raw materials in the production of synthetic automotive oils. Synthetic motor oils, depending on their composition, are divided into polyalphaolefin, ether, hydrocarbon, polyorganosiloxane and others. By changing the conditions of chemical reactions (temperature, pressure, duration of the process) in the production of synthetic motor oils, the necessary quality characteristics are set, which distinguish synthetic oils with greater stability compared to mineral-based motor oils. Synthetic motor oil is less prone to thickening at low temperatures (facilitating engine start-up in winter), is less liquefied when heated and retains lubricating properties for a long time of operation. The main disadvantage of "synthetics" is their high cost compared to mineral motor oils. The variety of engine types and designs, as well as their operating conditions, necessitates the use of motor oils, which differ significantly in properties. At present, the world's industrial production has established the production of several hundred different types of motor oils, which are distinguished by their qualitative characteristics and purpose. This has led to the emergence of a large number of motor oil labeling systems, among which the most frequently used ones can be distinguished.

Classification of motor oils according to DSTU

In the designation of motor oil (for example, M-8V), the first letter indicates its purpose (M - motor), the number - the kinematic viscosity of the oil at 100 °C (in centistokes), the second letter - the oil group, which characterizes the type of engine and operating conditions for which this oil is intended. According to the engine's forced operation, the oil is divided into groups, which are indicated by capital letters:

- A – for unforced engines;
- B – for low-powered engines;
- B – for medium-powered engines;
- G – for high-speed engines;
- D – for high-performance diesel engines operating in severe conditions;
- E – for low-speed diesel engines operating on high-carbon fuel sulfur content (oils of this group are not used in automobile engines).

The numerical index following the group designation indicates the type of engine: if the oil is intended for a gasoline engine, the index “1” is used (for example, “G1”), for a diesel engine, the index “2” (for example, “G2”). If the oil is suitable for both gasoline and diesel engines, the index is omitted (i.e., it is not used). The oils of the listed groups are distinguished by the number and efficiency of additives introduced into them (Table 7.1).

The fewest additives are in group A oils.

Additives are complex organic or organometallic compounds that improve the properties of oils. For example, anti-corrosion additives create a protective film on the metal surface; viscosity additives stabilize the viscosity of oils in a wide temperature range; detergent additives prevent the deposition of carbon particles and oxidation products on

Table 7.1 – Quantity and efficiency of additives in the listed groups

Oil group	Number of additives, %
AND	3.5
B	5.5...6
IN	7...10
G	7...12.5
D	15...22

on the surfaces of parts and keep these particles in suspension, facilitating oil filtration, etc.

If the viscosity class designation contains the letter index "z" after the number, this means that thickeners have been added to the oil, which reduce the dependence of the oil's viscosity on temperature, i.e. the oil can be used as an all-season oil. Examples of full designations of motor oils:

– Oil M-10G2 – seasonal motor oil with a viscosity of at a temperature of 100 °C, equal to 10 cSt, intended for high-speed diesel engines;

– Oil M-6z / 10V – high-performance all-season motor oil viscosity, contains a thickener. Designed for medium-duty gasoline and diesel engines;

– M-8B2 oil – engine oil with a viscosity of 8 cSt (at 100 °C), intended for medium-powered diesel engines. The oil brand may contain an additional index in brackets indicating the special properties of the oil. For example, in the designation of oil M8-G2 (k), the letter "k" indicates that the oil is intended for engines of KamAZ cars; in the designation of oil M10-G1 (i), the letter "i" means that imported additives have been introduced into the oil; the index "t" indicates that the oil is also suitable for transmissions, for example - M16-B2 (t), the letter "t" indicates that the oil is low-ash. Oils M8-D (m) and M-Yu-D (m) with the index "m" are intended for turbocharged engines.

International classifications of motor oils

In recent years, motorists have increasingly used imported oils as engine lubricants (especially owners of foreign cars).

oils that have different markings from Ukrainian ones. Currently, leading world manufacturers most often use the following generally accepted classifications of motor oils:

• *SAE*– American Society of Automotive Engineers:

• *APIs*– American Petroleum Institute;

• *ASEA*– Association of European Automobile Manufacturers (joint American-Japanese classification);

• *MIL-L*– US Department of Defense specifications;

• *ILSAC*– International Committee for Standardization and Approbation motor oils.

In addition, leading car manufacturers test motor oils using their own programs and technologies, after which they approve oils that pass these tests as first-fill oils for all or certain types of their vehicles. Such specific oils are called approvals.

SAE classification of motor oils

One of the main properties of motor oils is viscosity, which varies depending on temperature - when heated, viscosity decreases, when cooled - increases. Currently, the generally accepted international system for classifying motor oils by viscosity is*SAE J300*, developed by the American Society of Automotive Engineers (*SAE*–Society of Automotive Engineers). The viscosity of the oil according to this system is expressed in conventional units - degrees of viscosity. The larger the number included in the SAE class designation, the higher the viscosity of the oil. The specification describes three series of viscosity of oils: winter, summer and all-season. But, before considering them, let's turn to the theory described by the science of hydraulics. The temperature range of motor oil is largely determined by two of its characteristics: kinematic and dynamic viscosity.*Kinematicviscosity*measured in capillary viscometer and shows how easily the oil flows at a given temperature under the influence of gravity in a thin capillary tube.

*Dynamic viscosity*measured in more complex installations – rotational viscometers. It shows how much the viscosity of the oil changes when the speed of movement of the lubricated parts changes relative to each other. With an increase in the speed of relative movement of the lubricated parts, the viscosity decreases, and with a decrease - it increases. According to the SAE classification, the viscosity-temperature characteristics of motor oils are regulated, that is, their practical viscosity. The operational properties of oils (quality) are determined by the classifications developed by*APIs*and*ASEA*.

SAE winter oils

A range of winter oils:*SAE 0W*,*5W 10W*,*15W*,*20W*,*25W*– are indicated by a number and a letter*W*(*Winter*– Winter). For winter classes Two maximum values of low-temperature dynamic viscosity and a lower limit of kinematic viscosity at 100 °C have been established. The main characteristic of winter oils is low-temperature viscosity, which is determined by the indicators of scrollability and pumpability.

Scrollability- shows the dynamic viscosity of the engine oil and temperature at which the oil remains liquid enough to start the engine. The temperature limit of pumpability determines the minimum temperature at which the lubrication system pump is able to supply oil to the engine parts without allowing dry friction between them. The viscosity that ensures normal operation of the lubrication system does not exceed 60,000 MPa·s. The maximum low-temperature scroll viscosity is measured according to the ASTM D5293 method on a CCS viscometer. This indicator corresponds to the values at which the crankshaft rotation speed necessary for starting the engine is ensured.

*Pumpability*is the dynamic viscosity of the oil at which the oil will be able to pump through the lubrication system and the engine will not run dry. The pump temperature is approximately 5 °C below the cranking temperature. The pump viscosity is determined by the ASTM D4684 method using an MRV viscometer.

The high-temperature properties of winter oils are characterized by the minimum kinematic viscosity at 100 °C - an indicator that determines the minimum viscosity of engine oil when the engine is warm.

SAE summer oils

A range of summer oils:*SAE 20, 30, 40, 50, 60*– are indicated by a number without letter designation. The main properties of the annual series of oils are defined as follows:

• by minimum and maximum kinematic viscosity at 100 °C is an indicator that determines the minimum and maximum viscosity of engine oil when the engine is warm;

• by minimum viscosity at 150 °C and shear rate 106 s^{-1}. *Shear rate gradient*is the ratio of the speed of movement of one friction surface relative to another to the size of the gap between them, filled with oil. As the shear rate gradient increases, the viscosity of the oil decreases, but it increases again when the shear rate decreases.

SAE multigrade oils

A range of all-season oils:*SAE 0W–20.0W–30.0W–40.0W–50.0W–60.5W–20.5W–30.5W–40.5W–50, 5W–60, 10W–20, 10W–30, 10W–40, 10W–50, 10W–60, 15W–30, 15W–40, 15W–50, 15W–60, 20W–30, 20W–40, 20W–50, 20W–60*. The designation consists of a combination of winter and summer series, separated by dashes. All-season oils must simultaneously meet the criteria of both winter and summer oils. The smaller the number before the letter W, the lower the viscosity of the oil at low temperatures, easier cold engine starting by the starter and better oil pumpability through the lubrication system. The larger the number after the letter W, the higher the viscosity of the oil at high temperatures and more reliable engine lubrication in hot weather. Thus, the SAE class reports the consumer range of ambient temperatures in which the oil will provide:

• cranking the engine with a starter (for winter and all-season oils);

• pumping oil through the lubrication system with an oil pump engine under pressure during cold start in a mode that prevents dry friction in friction units (for winter and all-season oils);

• reliable lubrication in summer during prolonged operation at maximum speed and load conditions (for summer and all-season oils). It should be noted that European standards are considered more stringent than American ones. This is explained by the fact that operating conditions and more compact engines on European models allow more power to be extracted from a unit of volume.

API classification of motor oils

Main indicators of oils according to classification*ARI*: engine type and operating mode, operational properties and conditions of use, year of manufacture. The standard provides for the division of oils into two categories:

• Category*S*(*Service*) – oils intended for 4-stroke gasoline engines engines;

• Category*WITH*(*Commercial*) – oils for diesel engines vehicles, road construction equipment and agricultural machinery. The oil class designation consists of two letters of the Latin alphabet: the first (*S*or*WITH*) indicates the category of oil, the second - the level of operational properties. The further from the beginning of the alphabet the second letter, the higher the level of properties (i.e. the quality of the oil).

Diesel oil classes are further divided for two-stroke (*CD-2*,*CF-2*) and four-stroke diesel engines (*CF-4*,*CG-4*,*CH-4*). Most foreign motor oils are universal - they are used in both gasoline and diesel engines, such oils have a double designation, for example:*SF/ CC*,*CD/ SF*etc. Main purpose oils are indicated by the first letters, i.e.*SF/ CC*– “more petrol”,*CD/ SF*

– “more diesel”. Energy-saving oils for gasoline engines are additionally indicated by the abbreviation*EU*(*Energy Conserving*). At this time, the category*S*consists of12 classes of motor oils –*SA, SB, SC, SD, SE, CF CG, SH, SJ, SL, SM, SN.*

To category*WITH*includes 14 classes –*SA, SV, SS, SD,CD-II, SE, CF, CF-4, CF-2, CG-4, CH-4, CI-4, CI-4 Plus, CJ-4*.

Each subsequent category class is characterized by a later year of implementation. The numbers in the designations (for example,*CE-4*, *SR-2*) give an idea of the possibility of using oils in 2- or 4-stroke engines. As noted above, if the engine oil can be used in both gasoline and diesel engines, the designation consists of two parts. The first indicates the type of engine for which the oil is optimized, the second - another permitted type of engine. Example of designation:*API SI-4/ SL* Table 7.2 shows the operating conditions depending on the class.*APIs.*

Table 7.2 – Operating conditions depending on the class *APIs*

Class *APIs*	Operating conditions
Category *S*	
SH	Oils intended for gasoline engines of passenger cars, vans and light trucks. Class *SH* provides for improvement in class performance *SG*, which he replaced
SJ	Ensures compliance with requirements *SH*, and also introduces additional requirements for oil consumption, energy-saving properties and resistance to deposit formation when heated
SL	Provides improved antioxidant, energy-saving and detergent properties of oils
SM	Sets even stricter requirements for engine oils
SN	The standard applies additional requirements to ensure energy efficiency and wear resistance, and also provides for reduced wear of engine rubber products. Class oils *API SN* can be used in engines, that run on biofuel
Category *C*	
CH-4	Applies to oils used in high-speed diesel engines
CI-4	It is used for oils used in high-speed diesel engines, provides for the use of oils with a sulfur content in diesel fuel of up to 0.5%. Provides an increase in the service life of engines with an exhaust gas recirculation system (*EGR*). There are additional requirements for antioxidant properties, wear resistance, deposit formation, foaming, sealant degradation, shear loss
CJ-4	It is used for oils used in high-speed diesel engines. It is possible to use them with a sulfur content in diesel fuel of up to 0.05% by weight. Oils that meet the class *CJ-4*, work especially effectively in engines with particulate filters (*OFF*) and other exhaust gas neutralization systems. They also have improved antioxidant properties, stability over a wide temperature range, and resistance to deposit formation.

Today's classification*APIs*contains3 active category classes*S*and6 active category classes*WITH*But many manufacturers continue to produce oils of grades that were excluded from the specification because cars*CD*with old engines continue to be exploited, which means there is a need for these oils.

According to the recommendations*APIs*highest current category class*S* replaces lower operating class. For diesel oils, a higher operating class usually, but not always, replaces a lower class.

ACEA classification of motor oils

Classification*ASEA*was developed by the Association of European Automobile Manufacturers in 1995, the latest edition of the standard provides for the division of oils into three categories and 12 classes:*AND*/*IN*– gasoline and diesel engines of passenger cars, vans, minibuses (*AND*1/*IN*1-12,*AND*3/*IN*3-12,*AND*3/*IN*4-12,*AND*5/*IN* 5-12);*WITH*– gasoline and diesel engines with exhaust gas catalyst (*WITH*1-12,*WITH* 2-12,*WITH*3-12, *WITH*4-12);*THERE ARE*– heavy-duty diesel engines (*THERE ARE*4-12, *THERE ARE*6-12,*THERE ARE*7-12,*THERE ARE*9-12). In the notation for*ASEA,*in addition to the class of engine oil, the year of its introduction into force is indicated, as well as the edition number (if the technical requirements have been updated).

ILSAC classification of motor oils

International Committee for Standardization and Approbation of Motor Oils (*ILSAC*) has issued five engine oil standards:*ILSAC GF-1*,*ILSAC GF-2*,*ILSAC GF-3*,*ILSAC GF-4*and*ILSACGF-5*.

Review questions

1. Purpose and structure of the engine lubrication system.
2. Location of the main components of lubrication systems.
3. Combined lubrication system.
4. What types of drives are there?
5. Name the types of oil pumps.
6. Design features of oil pumps.

7. Purpose of the pallet.

8. Name the types of car internal combustion engine pallets.

9. Purpose, types, design features of oil receivers.

10. Which cars use the lubrication system? from dry sump?

11. What is the purpose of an oil cooler?

12. What types of oil radiators are there?

13. Motor oils.

14. Requirements for motor oils.

15. Classification of motor oils.

16. International classifications of motor oils according to*SAE*.

17. International classifications of motor oils according to*APIs.*

18. International classifications of motor oils according to*ILSAC*.

Laboratory work 8

MODERN INTERNAL ENGINE COOLING SYSTEMS

Purpose of work– study the purpose, design and operation modern cooling systems used on various internal combustion engines of automobiles.

Visual aids:

• albums, instructions and posters on the design of engines and cars;

• electronic information material on the construction of modern engines;

• engine in section;

• cars.

Tasks for work:

• define and classify internal combustion engine cooling systems;

• study the components of engine cooling systems internal combustion engine (ICE), identify the component mechanisms and devices. Determine their purpose;

• present in the report the structure of each internal combustion engine cooling system according to the task.

Cooling systems

The cooling system is designed to maintain the optimal thermal regime of the engine so that it does not overheat or overcool during operation, since both overheating and undercooling are harmful to the engine. Fig. 8.1 shows the cooling system.

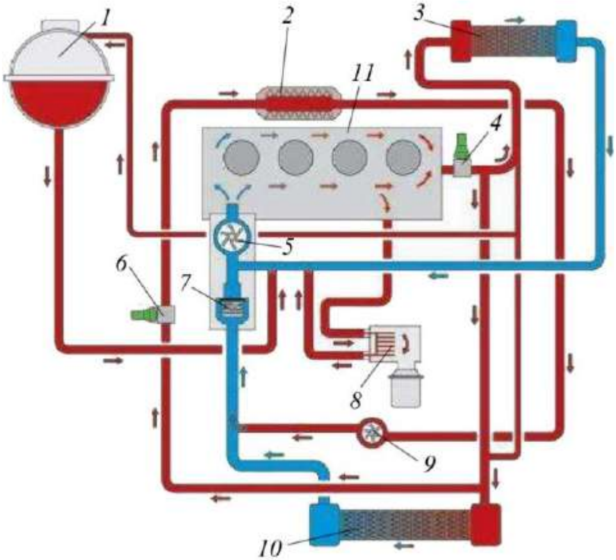


Figure 8.1 – Engine cooling system

The cooling system has the following **general structure** (see Fig. 8.1):

– cooling system radiators *3*, *10*;

– oil radiator;

– heater heat exchanger *2*;

– expansion tank *1*;

– centrifugal pump *5*, *9*;

– thermostat *7*;

– fan *8* interior heater radiator (cabin);

– sensors *4*, *6*;

– "cooling shirt" *11* engine;

– pipes.

On powerful engines it is installed **thermostat with electric heater**, which provides two-stage regulation of the coolant temperature. For this purpose, the thermostat design provides three operating positions: closed, partially open and fully open. When

At full engine load, the thermostat is fully opened using electric heating.

In this case, the coolant temperature drops to 90 °C, reducing the engine's tendency to detonate. In other cases, the coolant temperature is maintained within 105 °C.

By introducing an electronically controlled thermostat (Fig. 8.2–8.3), we achieved faster engine warm-up and raised its operating temperature from 85 to 110 °C. The efficiency of the engine increased, and accordingly, it began to consume slightly less gasoline.

Figure 8.2 – Electronically controlled thermostat

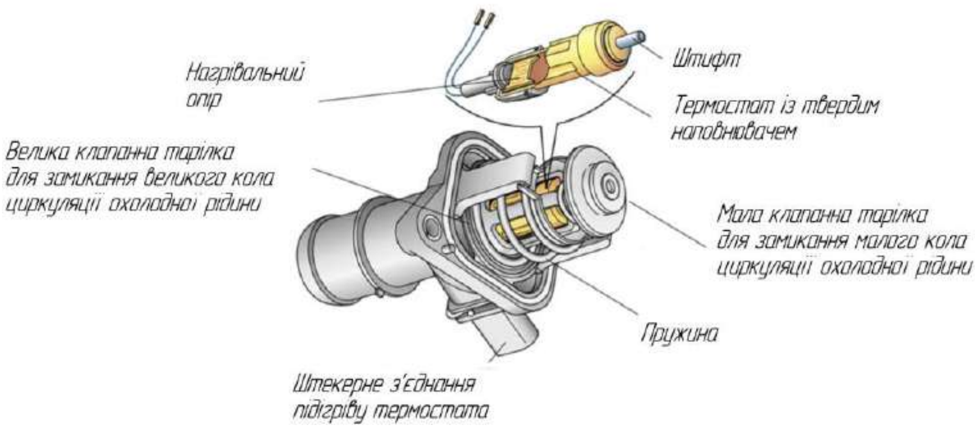


Figure 8.3 – Regulatory module (new generation thermostat)

Main structural elements:

– solid-filled thermostat;

– heating resistance in a solid filler;

– spring for mechanical closing of the coolant channels;

– one large and one small valve plates; *Action*

Coolant constantly flows around the solid-filled thermostat in the distributor.

In an unheated state, the filler behaves normally, but it is set to a different temperature.

With the help of the coolant, the filler is liquefied and expanded, which leads to the lifting of the pin.

When no current is supplied to the heating resistor, the thermostat operates in the usual way, but its operating temperature, according to the new control system, is 110 °C (the temperature of the coolant at the engine outlet).

The filler has a built-in heating resistor. When current is applied to it, it heats the filler, and the pin now moves not only under the influence of the heated coolant, but also under the influence of the heating of the resistor. The degree of its heating is determined by the engine control unit in accordance with the coolant temperature optimization program built into it.

Typical**controls**The cooling system consists of a coolant temperature sensor, an electronic control unit and various actuators.

Temperature sensor cooling liquids fixes value controlled parameter and converts it into an electrical signal. To expand the functions of the cooling system (cooling of exhaust gases in the exhaust gas recirculation system, fan operation control, etc.) an additional coolant temperature sensor is installed at the radiator outlet.

The sensor receives signals**electronic control unit**and transforms them into managerial influence on executive devices.

Typically, an engine control unit with installed and appropriate software is used.

The following actuators can be used in the operation of the cooling system:

– thermostat heater;

– additional coolant pump relay;

– radiator fan control unit;

– engine cooling relay after stopping. *The principle of operation of the cooling system*

The cooling system is operated by the engine control system. In modern engines, the operating algorithm is implemented based on **mathematical model**and, which takes into account various parameters (coolant temperature (Fig. 8.4), oil temperature, external temperature, etc.) and sets the optimal switching conditions and operating time of structural elements.

The coolant in the system has forced circulation, which is provided by a centrifugal pump. The movement of the fluid is carried out through the engine's "cooling jacket". This cools the engine and heats the coolant.

The direction of fluid movement in the "cooling jacket" can be longitudinal (from the first cylinder to the last) or transverse (from the exhaust manifold to the intake manifold).

Depending on the temperature, the fluid circulates in a small or large circle. When the engine is started, the engine itself and the coolant in it are cold. To accelerate the engine warming up, the coolant moves in **small circle**, bypassing the radiator. The thermostat is closed. As

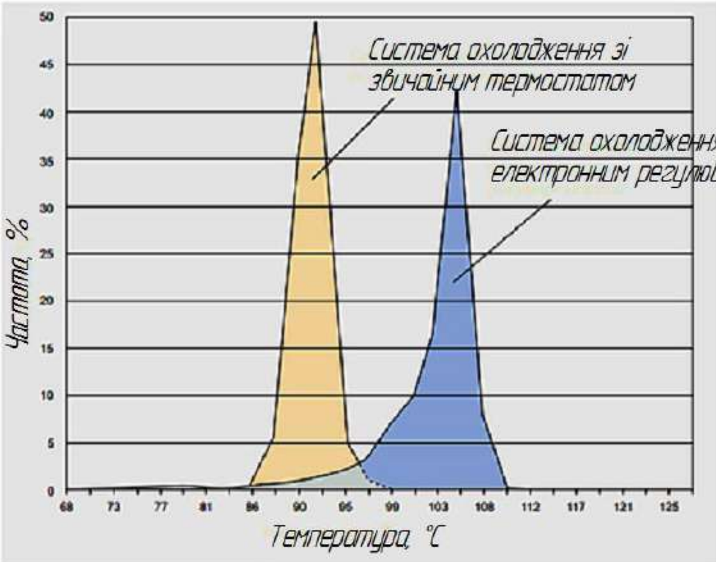


Figure 8.4 – Engine outlet coolant temperature

heating of the coolant, the thermostat opens and the coolant moves througha large circle– through the radiator. The heated liquid passes through the radiator, where it is cooled by a counter-flow of air. If necessary, the liquid is cooled by a flow of air from the fan. After cooling, the liquid enters the engine's "cooling jacket" again.

During engine operation, the coolant cycle is repeated many times. Turbocharged cars may use a dual-circuit cooling system, in which one circuit is responsible for cooling the engine, the other for cooling the charge air.

The structural features of the cooling system are shown in Fig. 8.5.

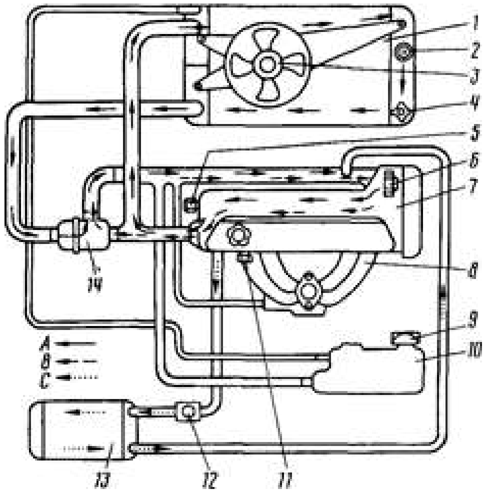


Figure 8.5 – Engine cooling system diagram: *1*– radiator; *2*– fan motor activation sensor; *3*– electric fan;*4*– radiator drain plug;*5*– sensor coolant temperature gauge;*6*– pump;*7*– engine;
8– intake manifold;*9*– expansion tank plug; *10*– expansion tank;*11*– engine drain plug;*12*– crane heater;*13*– heater;*14*– thermostat

A heat exchanger for crankcase gases is necessary to reduce their temperature so that when filling the engine cylinders with a fresh weight charge (air or combustible mixture), they occupy less volume, which increases the filling capacity of the engine cylinder, i.e. increases its filling coefficient.

The water distribution pipe, located in the lower part of the cooling jacket, ensures an even supply of coolant at an equal temperature to each engine cylinder.

Heat exchanger working for cooling oils in in high-speed and more powerful engines, it has a high temperature, which makes it difficult to cool it with a counter-flow of air, and also helps to reduce the length of oil lines.

Let's consider the structure of the fan clutch (Fig. 8.6) *Toyota* and which one the principle of its operation. Since this topic still sometimes raises questions, let's try to figure it out.

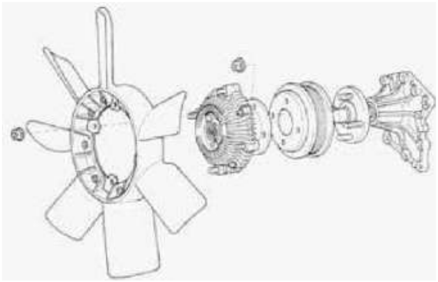


Figure 8.6 – Fan clutch

The fan is usually combined with a coolant pump, traditionally installed on most models with a longitudinal arrangement of the power unit. If the fan impeller were rigidly connected to the drive pulley, then its rotation frequency would be directly proportional to the crankshaft rotation speed - such cooling would be too effective, especially at high speeds and at low temperatures overboard. Therefore, to regulate the intensity of the air flow passing through the radiator, a coupling is installed between the pulley and the impeller.

At low temperatures, the fan speed is minimal, which allows the engine to warm up faster and at the same time reduces noise from the impeller. As the temperature rises, the fan speed will also increase.

Construction (see fig.8.7)

The clutch rotor is rigidly mounted on the coolant pump pulley. The rotor disk has bevel teeth cut around its circumference, which act as a pump for pumping oil. The clutch housing assembly (bearing housing and front cover) rotates around the rotor on a bearing.

On both sides of the rotor there are plates separating the working chambers from the tanks. The front one (with inlet channels A and B and rotating channel) is fixed on the rotor cover, the rear one (with rotating channel) is on the bearing housing.

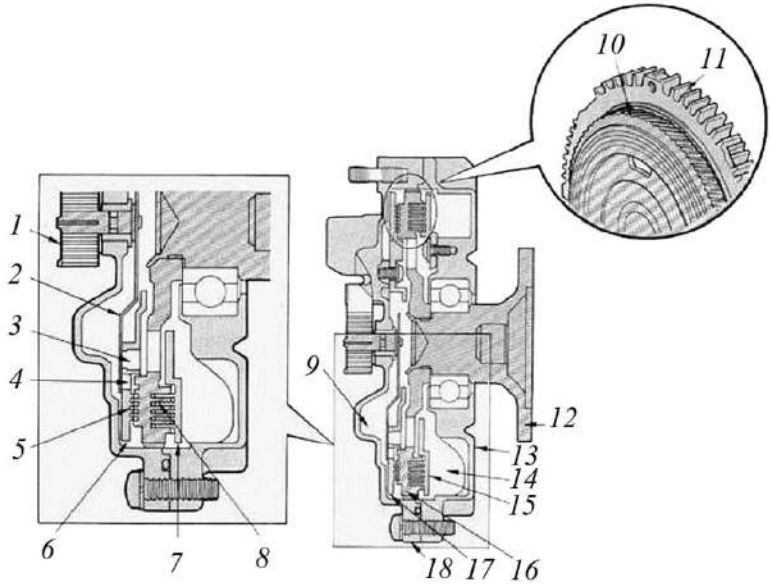


Figure 8.7 – Fan clutch:
1– bimetallic spring; *2*– bimetallic plate; *3*– intake channelB; *4*– intake channelA; *5*– front camera; *6*, *7*– return channel; *8*– rear camera; *9*– front tank; *10*– rotor teeth; *11*– body bearing; *12*– rotor shaft; *13*– bearing housing; *14*– rear tank; *15*– separating plate; *16*– rotor; *17*– front separating plate; *18*– front cover

The working chambers are “labyrinths” formed by ribs on the rotor and on the separating plates. The torque is transmitted from the rotor to the housing due to “internal friction” in the silicone oil.

A bimetallic spring mounted on the outside of the clutch housing moves the plate, opening and closing the inlet channels and regulating the oil flow depending on the air temperature.

Functioning

Cold air

As the rotor rotates, its teeth “pump” oil from the two chambers and the rear reservoir into the front reservoir through the return channels. As a result, its amount in the chambers decreases, the force transmission through the fluid decreases, and the fan rotation speed becomes significantly lower than the driving rotor rotation speed.

Warm air

Both inlet channels open, after which oil enters both working chambers. The volume of fluid in them and the "friction" are maximum, so the transmission of rotation through the clutch is also maximum.

Note: Since speed control occurs by changing the volume of silicone oil in the coupling cavities, its leakage inevitably leads to a decrease in fan speed and possible engine overheating.

Some early clutches did not have a rear reservoir. Since the oil flows into the lower part of the clutch after the engine is stopped, its level in the chambers increases significantly. Immediately after starting the engine, when the “friction” between the rotor and the plates is quite high, the fan speed increases too much. With a rear reservoir, the fluid level in the chambers is lower when the engine is stopped, and drops faster after starting - as a result, the noise level from the fan decreases.

The coolant pump provides forced circulation of fluid in the cooling system. In some sources of information, the coolant pump is called a water pump, which is not true. Water has long been out of use as a coolant.

The pump is usually installed in the front of the engine and can have two types of drive: mechanical and electric. The mechanical drive is made from the crankshaft or camshaft of the engine by using a belt drive. The electric drive involves the installation of an electric motor with a control system.

Centrifugal pumps are used as coolant pumps. The design of such a pump includes an impeller mounted on a shaft with a pulley and placed in a housing.

The structure of the pump for circulating the coolant is shown in (Fig. 8.8).

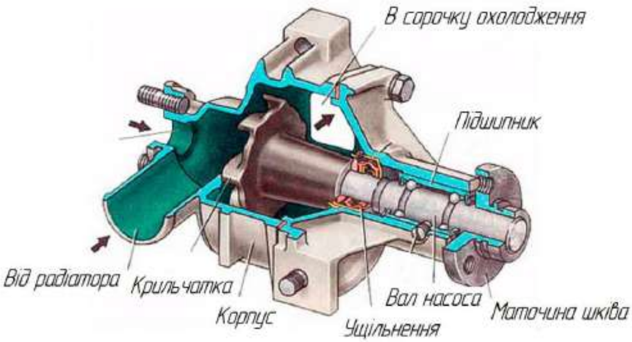


Figure 8.8–Centrifugal pump

The pump housing is made of cast iron or cast aluminum. The housing has channels for supplying and removing coolant to the impeller. A sealing gasket is installed between the pump housing and the engine cylinder block, which prevents coolant from leaking from the pump.

The impeller (common name - impeller) directly provides circulation of the cooling liquid. It is made in the form of blades of a special shape. The impeller is mounted on the drive shaft. The shaft is located in the housing on bearings. A drive pulley is installed on the opposite side of the shaft.

Coolant pump operation

When the impeller rotates, a vacuum is created at the pump inlet, due to which the coolant from the radiator enters the pump. The liquid is fed into the central part of the pump, moves along blades and is thrown out by centrifugal force at the pump outlet and then into the cylinder block cooling jacket.

The cooling system can be equipped with two coolant pumps – a main and an additional one. Depending on the engine design, the additional pump performs one of the following functions:

• additional engine cooling (operation in countries with hot weather) climate);

• ensuring the operation of the autonomous heater, turned on in engine cooling system;

• exhaust gas cooling in the recirculation system exhaust gases;

• turbocharger cooling on turbocharged engines;

• pumping the coolant after turning off the engine (for preventing engine overheating after stopping).

The additional coolant pump is usually electrically driven. The pump is included in the engine control system and, if necessary, is switched on (off) by a signal from the electronic unit.

On some engines of the concern *Volkswagen* is set to off coolant pump. The off-pump ensures rapid engine warm-up when starting by cutting off the coolant supply until the temperature reaches 30 °C. In this case, the coolant is constantly in the engine and warms up much faster. In addition to warming up, the use of the off-pump leads to reduced fuel consumption.

The coolant supply is stopped by means of an annular diaphragm (damper), which blocks the path of the fluid, while the impeller continues to rotate. The diaphragm is connected by levers to a membrane, which moves under the action of the discharge. The cavity in front of the diaphragm is connected by a line to the source of the discharge - the intake manifold.

The vacuum channel closes the control valve, which is included in the engine control system. When it opens, the diaphragm moves under the action of the vacuum, deactivating the pump impeller. When the valve closes, the diaphragm returns to its place under the action of the spring, and the diaphragm releases the impeller. The pump starts working.

Causes of water pump malfunction

The main reason for water pump malfunction is mechanical wear of friction parts: oil seal, bearings, shaft, pulley. When the oil seal leaks, antifreeze gets on the bearings and washes the oil out of them in a short time, after which they break and the pump shaft jams.

Dirt and impurities that get into the antifreeze accelerate pump wear. They can damage not only the friction pairs, but also the impeller.

Low-quality antifreeze without anti-corrosion additives causes oxidation of metal surfaces and damages rubber gaskets and seals.

Using water instead of antifreeze causes scale to form on parts of the cooling system, including the water pump. Modern cars are not designed to use water.

Rapid bearing wear can be caused by improper pulley tension – too tight (more load on one side of the bearing) or too loose.

Cavitation erosion is a consequence of the formation of bubbles in the coolant (low quality, production of anti-foaming additives, low level of coolant in the system). Small bubbles over time spoil metal surfaces, making round notches in them.

Troubleshooting The service life of the pump is affected by:

• quality of antifreeze, its timely replacement and level control. This, perhaps one of the main factors in the normal operation of the entire cooling system: from the engine jacket to the radiator;

• cleanliness in the cooling system. Absence of solid particles and the impurity will slow down the wear of the pump;

• timely replacement of gaskets of pipe seals that deteriorate ("harden" and crack) under the influence of coolant and high temperatures.

One of the most serious consequences of a water pump malfunction is the boiling of the coolant and overheating of the engine, especially in hot traffic jams. When standing in city traffic jams in the summer, you need to monitor the engine temperature and prevent critical heating, and on long trips always have a supply of antifreeze for topping up.

Self-diagnosis

Self-diagnostics for the electronic control of the engine cooling system are built into the engine electronics.

Sensors, actuators and the control unit are under the supervision of self-diagnostics.

If the control unit detects a fault, a backup value is calculated from other input signals and emergency operation is initiated. The fault is recorded in the fault recorder.

In addition, the measured parameters block, which is used when troubleshooting, displays the measured values.

Self-diagnosis detects the following malfunctions:

- coolant temperature sensor failure (at the outlet from engine);
- coolant temperature sensor failure (at the outlet from radiator);
- failure of both coolant temperature sensors;
- malfunction of electric fan stages;
- malfunction of the final stage of the thermostat.

Test questions

1. Purpose and general structure of the engine cooling system.
2. What is an electrically heated thermostat?
3. The principle of operation of the "new generation thermostat".
4. The principle of operation of the cooling system.
5. Fan clutch. Principle of operation. Purpose.
6. Coolant pump.
7. Causes of coolant pump malfunction.
8. Malfunction prevention.
9. Self-diagnosis of the cooling system.

Laboratory work 9
MODERN IGNITION SYSTEMS

Purpose of work– Study the design and operation of modern internal combustion engine ignition systems.

Visual aids:

• multimedia support;

• measuring and diagnostic equipment;

• car.

Tasks for work:

• identify and classify ignition systems;

• study the components of gasoline ignition systems internal combustion engine (ICE), identify components, devices and mechanisms. Determine their purpose;

• understand the advantages and features of modern ignition systems;

• present a structural diagram of the ignition system.

Theoretical data. Modern automotive systems Ignition. Electronic and microprocessor ignition systems

The ignition systems considered earlier (KTSZ, BTSZ) have limited application today, but are not used at all in imported passenger cars of high consumer class. They were replaced by fourth-generation ignition systems - these are systems with electronic computing devices without a high-voltage energy distributor for spark plugs in the output stage. Such systems are usually divided into electronic computing or simply electronic (ESZ) and microprocessor (MSZ). Electronic and

Microprocessor ignition systems have three important differences from previous systems:

1). their control devices (*VV*) are electronic computing blocks of discrete principle of operation, made using microelectronic technology (on universal or large integrated circuits) and designed to automatically control the ignition timing. These devices are called controllers;

2). application of microelectronic technology, in addition to obtaining advantages in reliability, allows to significantly expand the functions of electronic control. It became possible to introduce on-board self-diagnosis and principles of circuit redundancy into the automotive ignition system;

3). The output stages of these systems in the vast majority of cases multi-channel and, as a result, do not contain a high-voltage ignition distributor.

Electronic and microprocessor ignition systems differ from each other in the methods of generating the main ignition signal, that is, the signal that is supplied from the ECU to the accumulator trigger device.

In the ECU, the main ignition signal is formed using the time-pulse method of converting information from input sensors. This is when the controlled process is set by the time of its occurrence, with subsequent time conversion by the duration of the electrical pulse. Thus, the ECU controller contains an electronic chronometer and is controlled by analog signals. The component composition of a modern ECU is shown in Fig. 9.1 and 9.2.

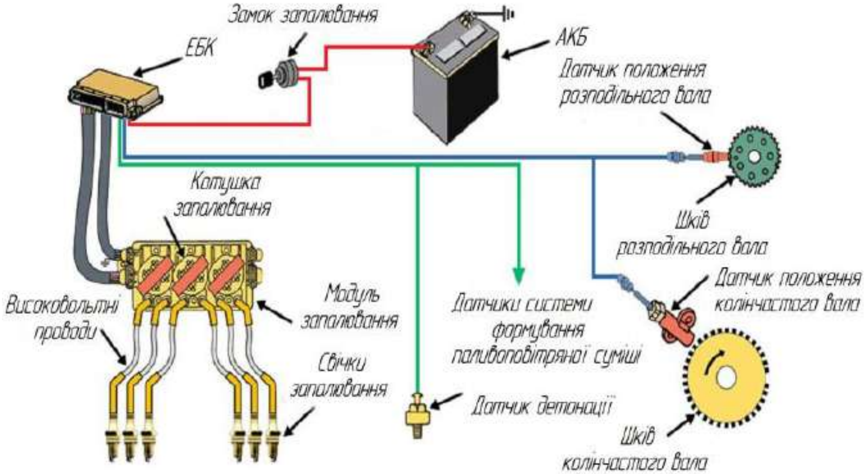


Figure 9.1 – Composition of the modern ESZ

In the MSZ, the block diagram of which is shown in Fig. 9.2, a number-pulse conversion is used to form the ignition signal, in which the process parameter is set not by the time of occurrence, but directly by the number of electrical pulses.

The functions of the electronic computer are performed here by a digital-pulse microprocessor, which operates on electrical pulses stabilized in amplitude and duration (from digital signals). Therefore, digital-pulse converters of analog signals to digital (CIPs) are installed between the microprocessor and the input sensors in the electronic control unit of the MSZ.

Unlike an electronic ignition system, a microprocessor ignition system operates according to a control program preset for a given internal combustion engine. Therefore, the microprocessor ignition system computer has electronic memory (permanent and operational).

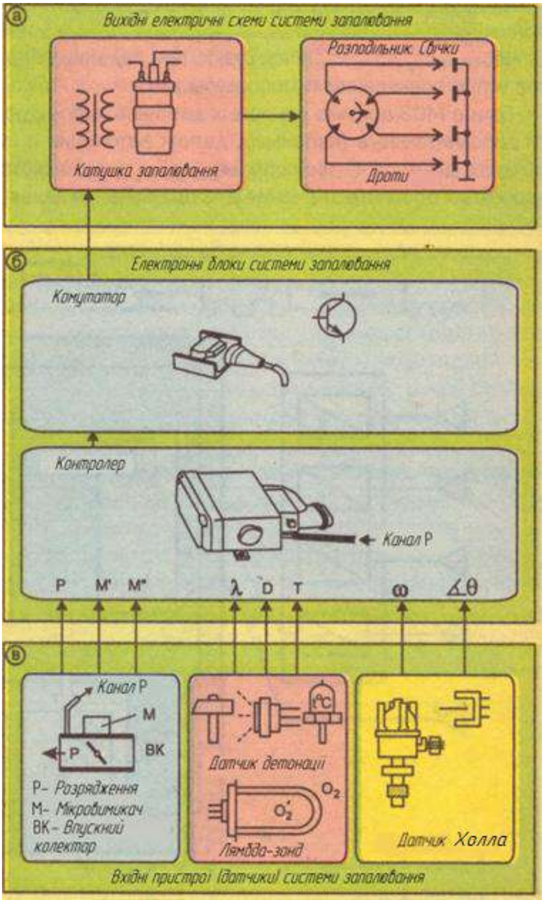


Figure 9.2 – Components of a modern EHS:

and– original electrical circuits; *b*– electronic blocks; *in*– input devices (sensors); P, M', M" – signals from throttle sensors; λ, *D*, *T*– signals from oxygen, knock, engine temperature sensors (respectively);

ω, P, θ – signals from the Hall sensor

The control program for a specific engine design is determined experimentally during its development. On the test bench, all possible engine modes are simulated under all possible operating conditions.

For each experimental point, the optimal ignition advance angle is selected and recorded. A set of numerous values of the ignition moment angle is obtained, each of which corresponds to a precisely defined set of signals from the input sensors. The graphic representation of such a set is a three-dimensional ignition characteristic, which is shown in the form of a matrix in Fig. 9.3. The coordinates of the three-dimensional characteristic are sewn into the permanent memory of the microprocessor and subsequently serve as reference information for determining the ignition advance angle in real operating conditions of the engine on a car. The change in the reference (taken from memory) ignition advance angle 9 is carried out automatically. The angle increases with increasing speed, with decreasing load and with decreasing internal combustion engine temperature. Reducing the angle θ occurs with increasing load, with a drop in speed and an increase in the temperature of the internal combustion engine.

θ – кут випередження (цифри)

n – оберти двигуна (об/хв)																
6400	32	32	35	38	45	40	46	46	46	50	54	56	56	56	56	56
5800	32	32	35	38	45	40	46	46	46	50	54	56	56	56	56	56
5200	32	32	35	38	45	40	46	46	46	50	54	56	56	56	56	56
4600	32	32	35	38	45	40	46	46	46	50	54	56	56	56	56	56
4000	31	31	35	38	45	48	48	46	46	50	54	56	56	56	56	56
3400	30	30	35	38	45	48	48	48	50	50	50	50	50	50	50	46
2800	26	27	31	35	41	36	36	36	36	36	36	36	36	40	45	45
2600	24	25	27	33	37	24	24	24	24	24	24	24	24	24	40	40
2400	23	24	26	31	35	23	23	23	23	23	23	23	23	23	40	35
2200	22	23	25	30	35	22	22	22	22	22	22	22	22	22	40	30
2000	21	22	23	28	33	21	21	21	21	21	21	21	21	21	32	21
1800	19	20	21	26	31	20	20	20	20	20	20	20	20	20	20	19
1600	18	18	19	23	27	17	17	17	17	17	17	17	17	17	18	18
1400	16	16	17	20	23	14	14	14	14	14	14	14	14	14	16	16
1200	14	14	15	17	20	14	12	10	10	10	10	10	10	14	14	15
1000	12	12	13	14	16	13	10	10	10	10	12	15	15	15	15	15
800	12	12	12	12	12	12	12	12	12	12	15	15	15	15	15	15
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75

Figure 9.3 – Three-dimensional ignition characteristic in the form of a matrix

If, in addition to the main sensors, additional sensors are used in the MSZ (for example, a detonation sensor in the internal combustion engine cylinders), then the microprocessor corrects the reference value of the ignition advance angle based on the signals of these sensors. In this case, the correction is carried out for each cylinder separately, except for functional and circuit-technical ones, which have important design differences.

Electronic control units for ESC and MC

In the ECU, the control unit is an independent structural unit and is called a controller (Fig. 9.4 and 9.5). The controller inputs are fed with signals from the input ignition sensors, and the controller outputs an electronic switch for the output stage (Fig. 9.4). All electronic circuits of the controller are low-level (potential), which allows them to be included in other onboard electronic control units (for example, the ECU of the fuel injection system).

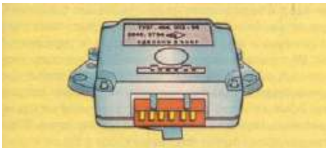


Figure 9.4 – Appearance of the microcontroller

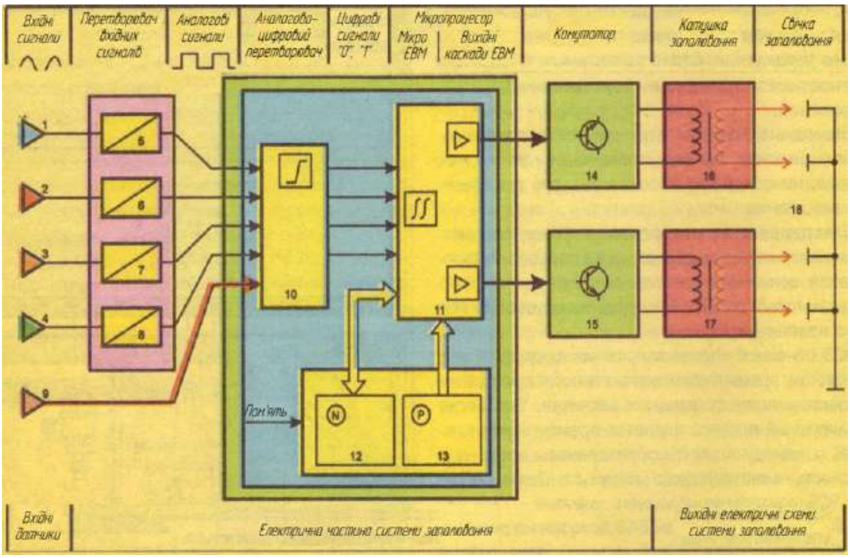


Figure 9.5 – Microcontroller as part of the ignition system

In the MSZ, all control functions are integrated into the central on-board computer of the car, and a personal ignition system control unit may be absent. The functions of the MSZ input sensors are performed by universal sensors of the complex automatic engine control system. The main ignition signal is supplied to the electronic switch of the MSZ output stage directly from the central on-board computer.

Despite significant differences electronic and microprocessor ignition systems, which, in relation to the control devices, the output stages of these systems have identical circuit and design, in which each spark plug on a multi-cylinder internal combustion engine receives energy for spark formation through a separate channel. Such a distribution is called static or multi-channel.

It should be noted that in addition to the usual disadvantages of a mechanical switch (low reliability and low failure time of rotating and friction parts), a classic ignition distributor also has a high-voltage energy switching, which is implemented in it through an electric spark. This, in addition to additional energy losses, leads to uneven burnout of the contacts in the insulating cover of the distributor and, as a result, the phenomenon of spark scattering across the cylinders and to low functional reliability of the ignition system. The spark scattering between the terminals of even a serviceable mechanical distributor can reach 2...3 angular degrees per rotation of the internal combustion engine crankshaft.

It is clear that in electronic and especially microprocessor ignition systems, highly reliable and highly precise in terms of functionality, in which the ignition timing is formed with an accuracy of 0.3...0.5° for each cylinder separately, the use of a high-voltage mechanical distributor is absolutely unacceptable. Here, electronic methods of switching channels at a low-potential level directly in the electronic control unit with subsequent static separation of high-voltage channels on multi-terminal or individual ignition coils are acceptable. This is inevitable leads to multichannel day off cascade systems ignition.

Output stages with multi-lead ignition coils Implementation of multi-channel energy distribution in ignition systems can be carried out in several ways. The simplest of them is the use of a two-terminal high-voltage output transformer or a two-terminal ignition coil in the output stage (Fig. 9.6). This method of channel division is acceptable for implementation in an ignition system with any type of accumulator.

It is known that in the ignition system, at the output of which a high-voltage distributor is installed, during the discharge of the accumulator there are two sparks: one main (working) in the spark plug and the other auxiliary between the distributor slider and the contact of one of its spark plug terminals. The secondary winding of the output transformer (ignition coil) is connected by a high-voltage lead to the central distributor slider, and the other lead of the winding is zero, since during the discharge of the accumulator it is connected to the vehicle ground (Fig. 9.7).

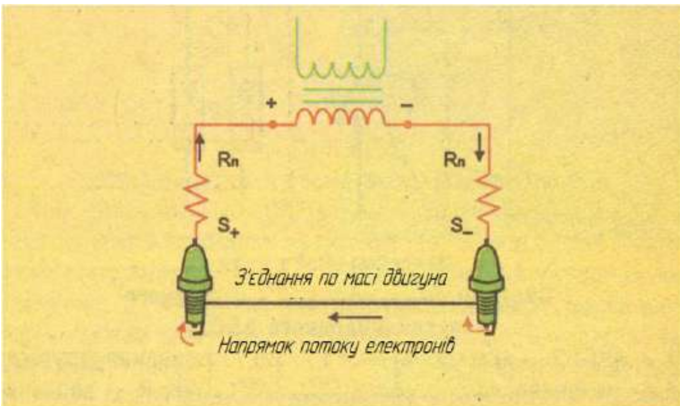


Figure 9.6 – Spark plug connection with a two-terminal coil

The energy of the auxiliary spark in the distributor is spent, and this spark is sought to be suppressed in every way. From this it is clear that the auxiliary spark from under the distributor cover can be transferred to the second spark plug, connecting it to the first through the mass of the cylinder head in series.

To do this, it is enough to turn off the distributor from the output stage, disconnect the ground terminal of the ignition coil from the vehicle's mass, and connect a second spark plug to it (Fig. 9.7).

With simultaneous spark formation (Fig. 9.8) in two spark plugs, one spark is high-voltage (12...20 kV) and occupies the fuel-air mixture at the end of the compression stroke (working spark). At the same time, the other spark is low-voltage (5...7 kV)..The phenomenon of redistribution of high voltage from the common secondary winding between the spark gaps in two spark plugs is a consequence of the profound differences in the conditions under which spark formation occurs. At the end of the compression stroke, shortly before the appearance of the working spark, the temperature of the fuel-air charge is not yet high enough (200...300 °C), and the pressure, on the contrary, is significant (1.0...1.2 MPa). Under such conditions, the breakdown voltage between the spark plug electrodes is maximum. At the end of the exhaust stroke, when there is spark formation in the exhaust gas environment, the breakdown voltage is minimal, since the exhaust gas temperature is high (800...1000 °C), and the pressure is low (0.2...0.3 MPa). Thus, with static distribution of high voltage using a two-terminal ignition coil (on two series-connected spark plugs - simultaneously), almost all the energy of the high-voltage electric spark discharge falls on the working spark.

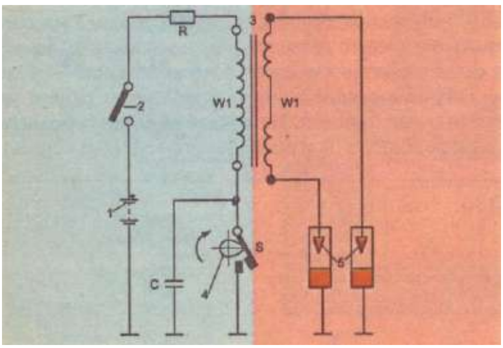
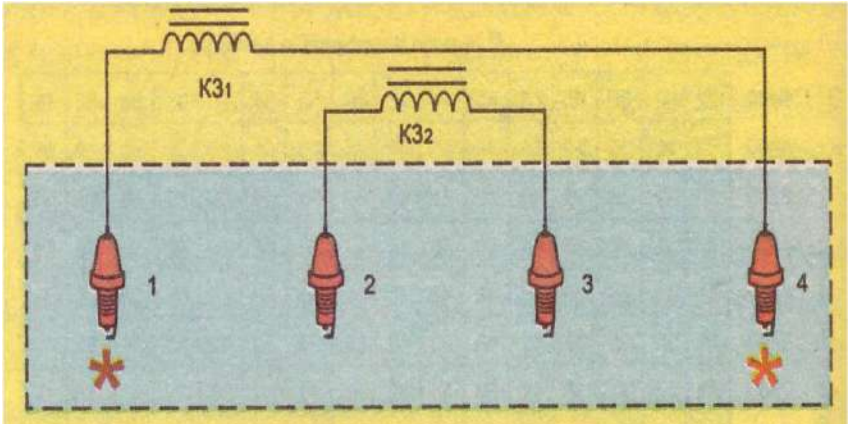


Figure 9.7 – Ignition system for a 4-stroke two-cylinder Internal combustion engine: *1*– battery; *2*– ignition key; *3*– two-lead coil; *4*– mechanical interrupter; *5*– candles; *R*– additional resistor; *S*– electromechanical contacts of the circuit breaker; *WITH*– capacitor



	1 Цилiндр	2 Цилiндр	3 Цилiндр	4 Цилiндр	
1 такт	Робоча			Холоста	от КЗ1
2 такт		Холоста	Робоча		от КЗ2
3 такт	Холоста			Робоча	от КЗ1
4 такт		Робоча	Холоста		от КЗ2
Робоча iскра 12...20 кВ. Холоста iскра 5...7 кВ.					

Figure 9.8 – Sparking sequence diagram

The first use of a two-terminal coil was in a contact battery ignition system for a two-cylinder, 4-stroke engine. An example is the ignition system for a Polish car engine.*FIAT-126P*An ignition system similar in principle of operation is installed on cars of a particularly small class (with electronic control).

If the internal combustion engine has four cylinders, two two-terminal ignition coils and two separate power switching channels in the output stage will be required (see Fig. 9.8). Fig. 9.8 shows a diagram of the spark formation sequence in the cylinders of a 4-cylinder four-stroke engine, equipped with an ignition system with two two-pin ignition coils. A six-cylinder engine will require three two-pin ignition coils and three energy channels.

At this time, a number of automotive ignition systems have been developed, in which two two-terminal ignition coils are combined. For example, in a W-shaped magnetic core, one 4-terminal ignition coil is formed. Such a coil has two primary and two secondary windings and is controlled by a two-channel switch. A four-terminal ignition coil can also have one secondary two-terminal winding with two primary ones. The secondary winding of such a coil is equipped with four high-voltage diodes - two for each high-voltage output.

The disadvantage of any ignition system with two-terminal coils is that in one spark plug the spark develops from the central electrode to the ground (side) electrode, and in the second spark plug – in the opposite direction (see Fig. 9.8). Since the central electrode is pointed and always much hotter than the side electrode, the flow of charge carriers from its tip and spark formation requires less energy than when ending with the side electrode (thermoelectronic emission begins at the central electrode). This leads to the fact that the breakdown voltage on a spark plug operating in the forward direction becomes somewhat lower (by 1.5...2 kV) than on a spark plug with reverse polarity. This is important for modern electronic and microprocessor ignition systems with a large reserve coefficient for the secondary voltage and with a controlled energy accumulation time.

Output stages with individual static distribution

In modern electronic and microprocessor ignition systems, output stages with individual ignition coils for each spark plug are widely used. An example is the ignition system of the company*BOSCH*, integrated into the electronic automatic control system (EAS) of the engine, which is known by the name *Motronic*(rice.9.9).

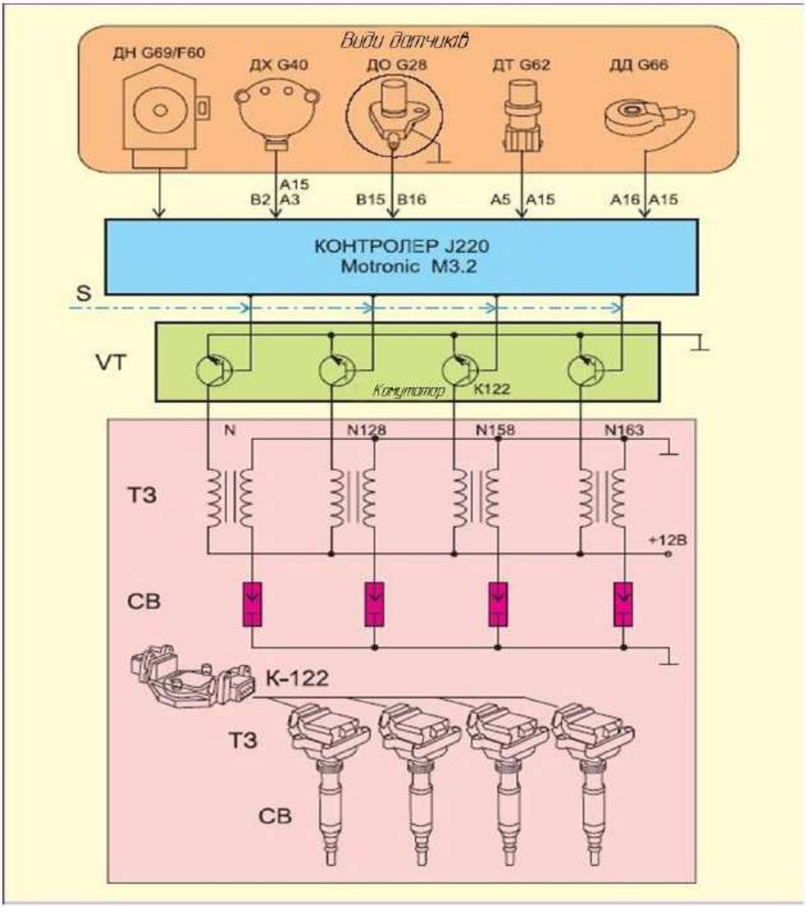


Figure 9.9 – Functional diagram *ESAUMotronic M-3.2*: DN – internal combustion engine load sensor (throttle potentiometer); DH – ignition advance angle sensor (Hall sensor); DO – speed sensor (magnetoelectric sensor on the crankshaft); DP – engine temperature sensor (thermistor); DD – knock sensor (piezoelectric); *S*– ignition signal, alternately supplied to the inputs switch; *AND*, *IN*– connector contacts; *VT*– power switch transistors; *N*– inductive storage devices; TK – ignition transformers; SZ – spark plugs

This scheme was installed on four-cylinder car engines.*AUDI-A4*.

The J220 controller contains a microprocessor with a memory block in which a three-dimensional ignition characteristic is stored. Based on this characteristic, as well as the signals from the DO sensor, *G-28*(frequency sensor engine rotation) and the DN sensor G-69 (engine load sensor) the initial angle is set*Q=F(n)*ignition advance. Further according to the signals of the DC sensors*G-40*, DT*G-62*and DD *G-66*in digital The microprocessor calculates the current (required for the given operating mode of the internal combustion engine) value of the ignition advance angle, which is supplied in the form of a main pulse using an electronic channel switching circuit.*S*ignition into the corresponding channel electronic switch*K-122*. Until now, this channel has an inductive storage*N*is in a charged state
(from the on-board network +12V) state and by signal*S*discharged to the appropriate spark plug. After 180° of crankshaft rotation, the described processes will be in the next (in order of engine operation) switch channel.

Main advantages of the ignition system integrated into the ECU *Motronic*, consist of the following:

– individual static distribution of high voltage across the spark plugs ignition;

– ignition coils with grounded secondary winding;

– all input sensors (Hall sensor, engine speed sensor,
internal combustion engine temperature sensor, throttle position sensors, knock sensor)
– these are electrical signal generators from non-electrical influences of a contactless principle of operation. Analog signals from these sensors are converted into digital signals in the controller;

– selective correction of ignition advance angle by detonation
(in each cylinder separately);

– disconnection of internal combustion engine cylinders in case of sparking failures (protection expensive components – oxygen sensor and catalytic converter of the car’s environmental system from damage);

– the controller has self-diagnostic and backup functions.

Review questions

1. Modern automotive internal combustion engine ignition systems.

2. Composition of the modern ESZ.

3. Components of a modern EHS.

4. How to use the three-dimensional ignition characteristic in in the form of a matrix?

5. Components of the microprocessor unit of the ignition system.

6. Explain the connection of spark plugs with a two-terminal coil, Give a definition.

7. Explain the principle of operation of the functional diagram of the ESAU *Motronic M-3.2*.

8. Advantages of modern ignition systems.

9. What is the difference between electronic and microprocessor systems? inflammation from each other?

10. How is the control program of a specific design determined? Internal combustion engine?

11. What sensors are used?

12. Where are all the management functions of the MSZ integrated?

13. When two spark plugs spark simultaneously one spark is high voltage and occupies the fuel-air mixture at the end of the compression stroke (working spark), and the other spark is low voltage. What voltage is applied to each of them?

14. What are the advantages and disadvantages of using a two-lead coil? ignition?

Laboratory work 10

ICE FUEL SYSTEM

Purpose of work– Study the design and operation of modern internal combustion engine power systems.

Visual aids:

- multimedia support;
- measuring and diagnostic equipment;
- presentations;
- animations of the power system operation
- car.

Tasks for work:

- define and classify internal combustion engine power systems;
- study the components of a gasoline engine's power supply systems internal combustion engine (ICE), identify the component mechanisms and devices. Determine their purpose;
- submit structural diagrams of the power system components.

Main provisions

The power system is directly involved in the conversion of energy, the source of which is hydrocarbon fuel.

To obtain thermal energy as a result of oxidation (combustion) of fuel, timely combination of two components is required - fuel and air. The following are mainly used as fuel for automobile engines:

– natural gas methane CH_4in a compressed state;

– liquefied gas consisting of propane $C_3H_8$and butane C_4H_{10};

– various grades of gasoline with pentane C fractions$_5H_{12}$, benzene C_6H_6, hexane C_6H_{14}, heptane C_7H_{16}, octane C_8H_{18};

– diesel fuel with cetane fractions $C_{16}H_{34}$, methylnaphthalene $C_{11}H_{10}$.

Sometimes gas and diesel fuel are used together (gas-diesel).

Possible use of alternative fuels:

– alcohols: ethanol C_2H_5OH, methanol CH_3ON;

– biofuels based on vegetable oils.

Hydrogen is of greatest interest, but its use is hampered by problems of production and storage.

Thus, the power supply system of automobile internal combustion engines should consist of subsystems that provide: air selection, purification and supply; fuel storage, purification and supply; organization of the working mixture and its dosage, as well as exhaust gas removal.

Air extraction and purification

Air enters the power supply system through air intakes. Depending on the purpose of the car, air intakes can be located at the entrance to the engine compartment or in the form of a special device. Variants of air intake to the power supply system are shown in Fig. 10.1.

Air directly from the atmosphere moves through channel A (Fig. 10.1, *and*and*b*) or through an external intake*5*(rice.10.1,*in*). Air intake from the engine compartment is carried out by a channel*B*(Fig. 10.1,*and*and *b*).

The incoming air is cleaned. A diagram of a system with pre-cleaning of the air is shown in Fig. 10.1,*in*. With significant clogging, air first enters the ejector*3*, in which preliminary dust cleaning and removal is performed, then into the exhaust pipe*6*The practical implementation of this scheme is shown in Fig. 10.2.

According to Fig. 10.2,*and*after the air intake, air enters the inlet *3* filter*2*After pre-cleaning, large dust particles are removed by a pipeline *7*into the ejector*8*.

In areas with high dust levels, a pre-separator is attached to the filter. It separates the coarse fraction of large dust and thus reduces engine wear.

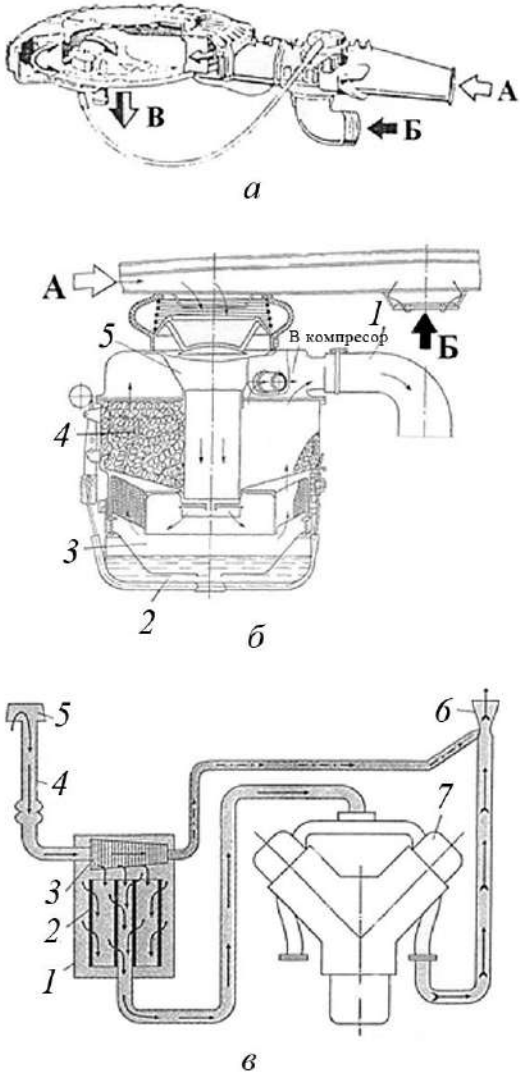


Figure 10.1 – Air supply options to the power system:
and– passenger car;*b*– cargo;*in*– SUV

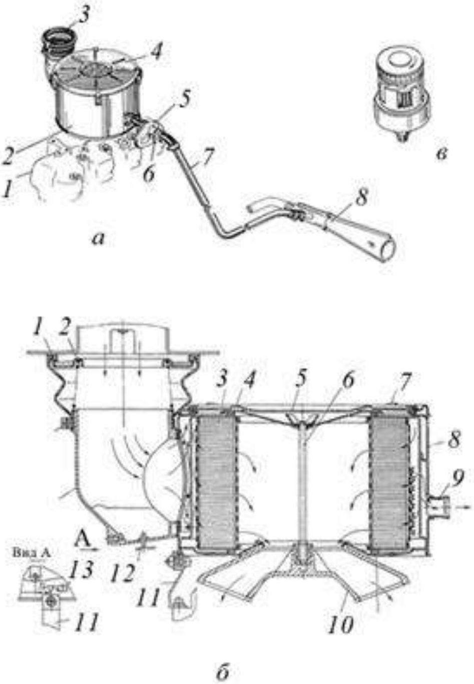


Figure 10.2 – Ejector air purification system

Sometimes a cyclone filter is used - a freely rotating multi-bladed crown. The air passing through it, thanks to the special shape of the blades, spins the crown, swirls, and the separation of coarse particles occurs as a result of the action of centrifugal forces. Most often, a clogging indicator is used in such systems. It is installed on the inlet pipeline. At a rarefaction of 0.007 MPa, a red area appears in the indicator's viewing window.

The main air purification is performed by a filter element.*3*(see fig. 10.2,*b*). The complete air cleaning module of the fuel system of the gasoline injection engine is shown in Fig. 10.3.

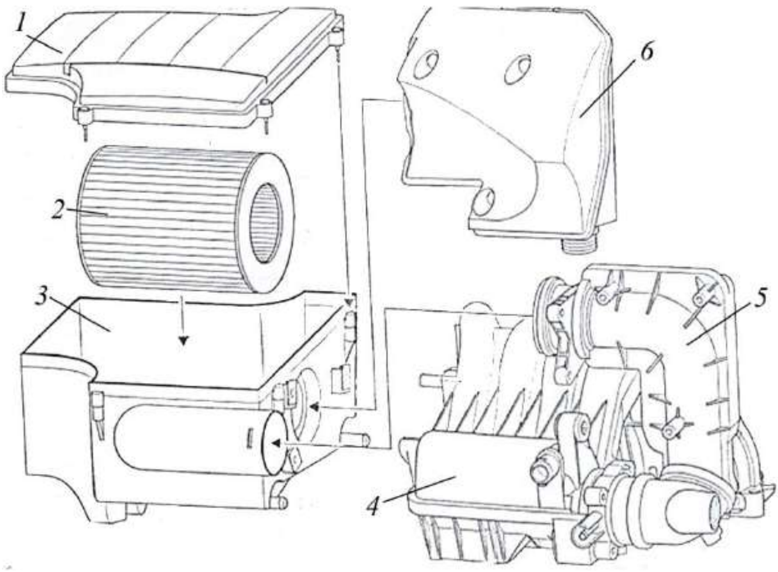


Figure 10.3 – Air purification module:
1– lid;*2*– filter element;*3*– body;*4*– intake module;
5,*6*– inlet pipes

Between the supply pipes*5*and*6,*as well as the intake module*4*(see Fig. 10.3) is a resonator and an acoustic pipe. With the help of this complex system, it is possible to coordinate the individual components of the filter and meet the requirements for reducing the noise level. However, there is a tendency to separate the filtration and noise resonators, which allows the filter housings to be reduced, made quite flat, and convenient to place.

For optimal use in the compact space of the engine compartment, filters of conical, oval, stepped or trapezoidal shape are used.

A filter with a dust-collecting cyclone is shown in Fig. 10.4.

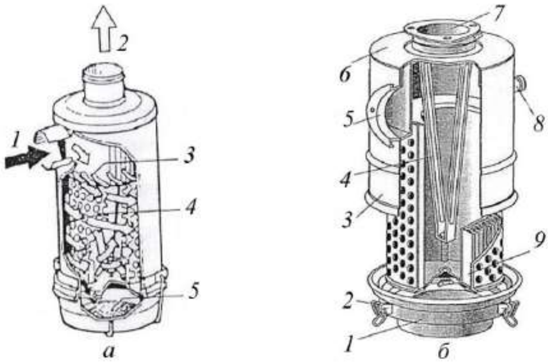


Figure 10.4 – Air filter with paper filter element
element and dust collection cyclone: *and* – cyclone, *b* – filter

Air inlet into the housing *6* filter is carried out by channels *1* and *5* respectively (Fig. 10.4, *and* and *b*). Clean air outlet – through channels *2* and *7*. In Fig. 10.4, *and* and *b* shoulder blades are shown *3* filter – cyclone, dust collector in the lid *5* and 1 (see Fig. 10.4, *b*). Dust is sucked into the ejector through the nozzle *8* (see fig.10.4, *b*). Filter *9* is installed in case *6* and is sealed with a lid *1* using latches *2*.

Air cleaners are connected to the cylinder via pipes. The placement and length of the intake pipe channels affect the filling of the cylinders.

The suction work at the inlet when the intake valve opens leads to the formation of a backpressure wave. At the open inlet manifold, this pressure wave encounters the mass of stationary ambient air, is reflected from it and moves towards the intake manifold. The resulting pressure fluctuations in the intake manifold can be used to increase the filling of the cylinders with a charge of fresh mixture. This effect of dynamic supercharging in the intake manifold depends on the geometry of the manifold and the crankshaft speed.

Dynamic supercharging options – inertial and resonant – usually improve torque characteristics in the low engine speed range. To expand the range of use of dynamic

Inlet manifolds with variable geometry are used for supercharging, when, depending on the engine operating mode, it is possible to produce:

– adjusting the length of the resonator intake pipes;

– changing the length or diameter of resonator pipelines;

– disconnection of individual pipelines per cylinder according to the system pipelines to the cylinder;

– changing the volume of resonance chambers. ***Mechanical air inflation***

In mechanical supercharging, the air supercharger, regardless of its design, is driven directly from the engine shaft. Superchargers (compressors) with a mechanical drive can be positive displacement superchargers of various designs: superchargers*Roots*(screw), rotary piston (Fig. 10.5), piston, centrifugal, with sliding blades, spiral, wave.

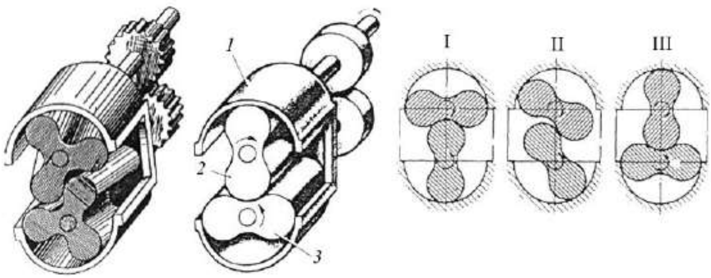


Figure 10.5 – Scheme and principle of operation of rotary-screw compressors*Roots*(without air compression)

Turbocharging

Any internal combustion engine can be equipped with a turbocharger: diesel, gasoline or gas-powered.

According to the principle of supercharging, constant pressure and pulse supercharging systems are used. According to the number of turbochargers - with one or two separate turbochargers. According to the design of the compressor - with a radial or axial compressor or turbine. Supercharging can be multi-stage, usually two-stage with sequential location of the low pressure supercharger, then the high pressure supercharger (over 0.35 MPa).

The operating principle of a turbocharger with pulse pressure at the turbine inlet is shown in Fig. 10.6.

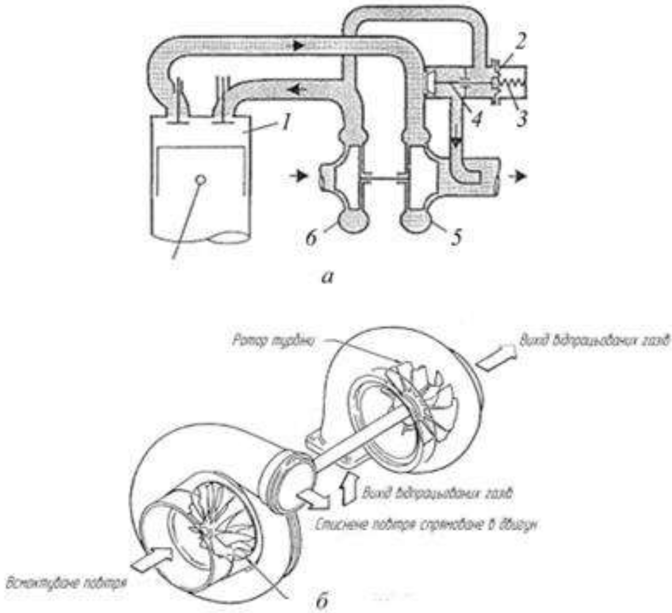


Fig. 10.6 – Principle of operation of a turbocharger (turbocompressor): *and*– scheme of the turbocharger system;*b*– interaction of components turbocharger;

1– engine cylinder;*2*– safety valve control membrane;
3– safety valve spring;*4* –valve;*5*– turbine;*6*– compressor

Since the air heats up when compressed by the compressor, its density decreases, and accordingly the filling of the cylinders will deteriorate. Installation of a charge air cooler after the compressor in the range from 180 to 30–40$_0$C increases the amount of oxygen entering the cylinders engine. An intercooler is used for intermediate air cooling – mainly air-to-liquid cooler. ***Mixture formation***

The main task of the fuel system is to create a combustible mixture and control its quality and quantity depending on the engine operating mode. The combustible mixture includes two components: air and fuel. However, due to the constant presence of a small amount of exhaust gases in this mixture, the mixture is usually called working.

Gas power system

For any amount of liquid gas in a cylinder, the pressure in it will always be equal to the saturated vapor pressure of the fuel for ambient conditions. The saturated vapor pressure of the main components of liquefied petroleum gas (LPG) propane and butane when the temperature changes from -40 to + 40_0C varies from 0.12 to 1.7 MPa and from 0.18 to 0.39 MPa, respectively. The

system includes a filter for trapping solid particles (scale, etc.) and a heat exchanger, which is located separately or in a common housing with the reducer. For liquefied gas, the heat exchanger is an evaporator at the outlet from the cylinder, and for compressed gas, a heater.

A heater is necessary in a compressed gas system, since a sharp decrease in pressure during its expansion at the outlet of the cylinder leads to a significant decrease in temperature, and if there is moisture in the gas, it can cause it to freeze and disrupt the normal operation of the system due to clogging of the main pipes with ice.

To heat compressed gas, the heat of exhaust gases passed through a heat exchanger is usually used, and to heat liquefied gas, liquid from the engine cooling system is most often used.

Automotive gas cylinders installations always foresee the ability to power the engine with traditional fuel (Fig. 10.7).

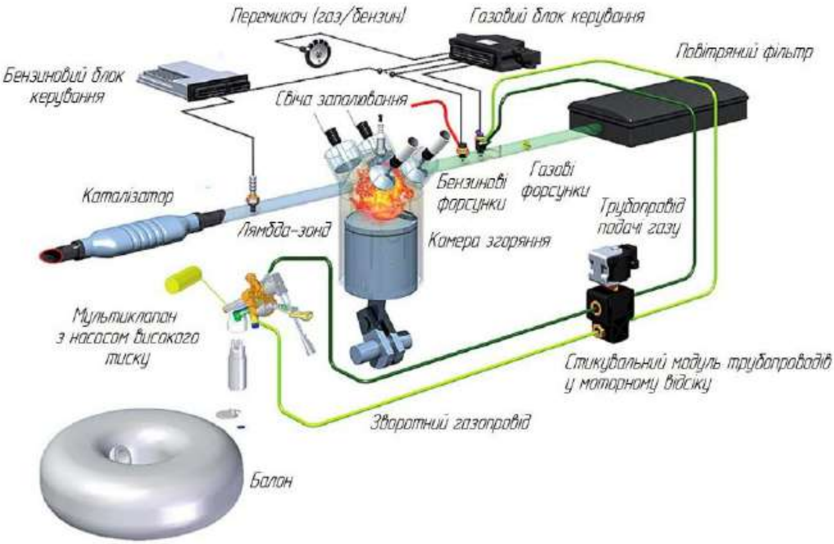


Fig. 10.7 – Combined power supply system

Gasoline systems

Since the beginning of the use of the automobile engine with spark ignition (Otto engine), gasoline has been successfully used as a fuel. The gasoline power system is continuously being improved. For a long period, until the end of the twentieth century, systems using a carburetor were used (Fig. 10.8,*and*). With the development and use of electronics in cars, the possibility of successfully using various injection systems has arisen, almost completely replacing carburetor systems.

Injection systems (Fig. 10.8,*b–g*) of gasoline are classified as follows.

By injection method:

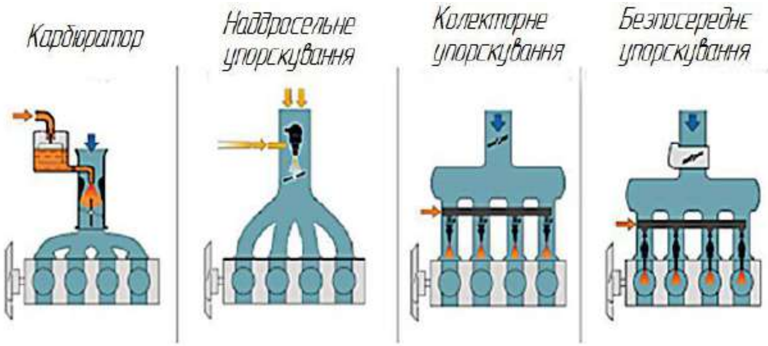
– with continuous injection;

– with discrete (cyclic) injection. At the injection site:

– into the intake manifold with central injection;

– into the intake manifold, distributed injection at the inlet to cylinders;

– distributed injection directly into the cylinder.



and *b* *in* *g*

Figure 10.8 – Gasoline fuel system options

At the moment of injection:

– coordinated (synchronized);

– uncoordinated (asynchronous).

Gasoline Direct Injection (GDI)

The system provides for the supply of gasoline through separate nozzles directly into the combustion chambers of each cylinder under high pressure, where air is simultaneously supplied. This injection system provides the most accurate concentration of the fuel-air mixture, regardless of the engine operating mode. In this case, the mixture burns almost completely, which reduces the volume of harmful emissions into the atmosphere.

Such an injection system has a complex design and is sensitive to fuel quality, which makes it expensive to manufacture and operate. Since the injectors operate in more aggressive conditions, for the correct operation of such a system it is necessary to ensure high fuel pressure, which should be at least 5 MPa.

Structurally, the direct injection system includes:

high-pressure fuel pump; fuel pressure regulator; fuel rail; safety valve (installed on the fuel rail to protect system elements from pressure exceeding the permissible level); high-pressure sensor; injectors.

This type of electronic injection system from the company *Bosch* was named *MED-Motronic* (see fig.10.9). The principle of its action depends on the type of mixture formation:

• *layered* – is implemented at low and medium engine speeds. Air is supplied to the combustion chamber at high speed. Fuel is injected into the spark plug and, mixing with the air along the way, ignites;

• *stoichiometric* When you press the gas pedal, the throttle valve opens and fuel is injected simultaneously with air supply, after which the mixture ignites and burns completely;

• *homogeneous*. Intense air movement is provoked in the cylinders, when This is when gasoline is injected on the intake stroke.

Their operating principle is based on the fact that fuel is sprayed directly into the engine cylinder using an injector. This is important for achieving fuel efficiency.

At the same time:

• a piston pump supplies fuel to the rail connected to the injectors;

• the fuel pressure regulator maintains a stable operating pressure in fuel rail. Fuel rail – this is where the process of fuel distribution to the injectors takes place;

• a safety valve protects the ramp from extreme pressure;

• high pressure sensor measures the pressure in the rail, sends a signal to the unit engine control for pressure correction.

Coordination of the interaction of the nodes is carried out using the electronic engine control system, which enters commands to the actuators of the electronic control unit.

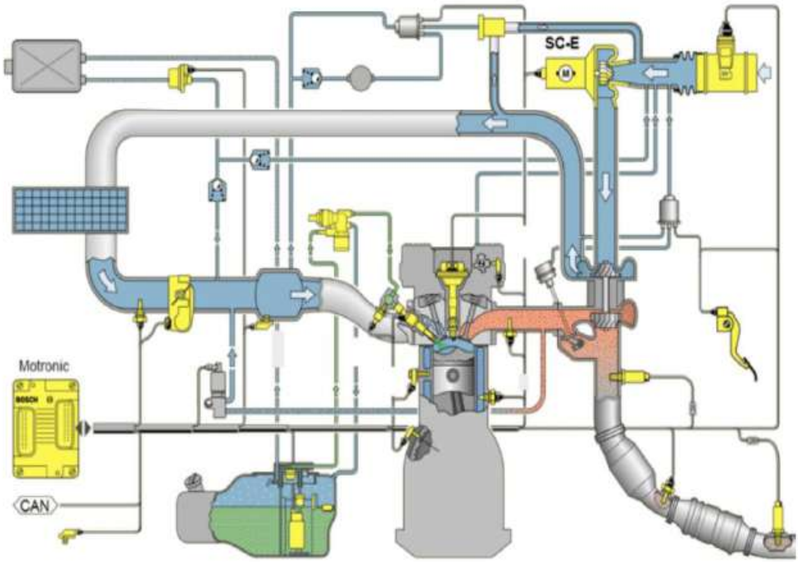


Figure 10.9 – Direct injection fuel system

Diesel engine power supply system

Initially, diesel engines were mainly used in trucks. However, later, for a number of reasons, diesel engines began to be actively used in passenger cars. The differences in the development directions of diesel engines for trucks, buses and passenger cars were fully reflected in the design of the power supply system. The development of the power supply system of powerful diesel engines is more conservative compared to the power supply systems of high-speed diesel engines for passenger cars.

The classic version of this system is successfully used on medium and high-power engines for trucks, as well as on a number of passenger car engines. The main unit in this power system is an in-line high-pressure fuel pump (HPF), which supplies fuel under pressure to the injectors of the engine cylinders. Fuel to the injection pump comes from the tank through a filter using a fuel injection pump.

Inline PNVTs successfully operate in the range of outlet pressure to the injectors within 20–60 MPa.

To accelerate (improve) mixture formation, it is necessary to increase the injection pressure. For this purpose, the following are used:

– distribution PNVT with axial movement of the plunger (pressure up to 70 MPa);

– distribution PNVT with radial movement of plungers (pressure up to 120 MPa);

– battery system *Common Rail* (pressure to140 MPa);

- individual PNVT (pressure up to 160 MPa);

- pump-nozzle (pressure over 180 MPa).

One such highly developed injection system is the accumulator system. *Common Rail* (*CR*), the main advantage of which is a wide range of changes in fuel pressure and the moment of injection start. This principle in the system *CR* is implemented by separating the pressure creation and ensuring injection.

System *CR* used on diesel engines with direct fuel injection. System *CR* allows to provide wider, unlike mechanically driven NPT, injection requirements. System design *CR* (rice.10.10) consists of the following:

– low-pressure circuit with fuel supply units;

– high-pressure circuit, including PNVT, fuel accumulator high pressure, nozzles and high pressure lines;

– electronic diesel engine control systems.

In the system *CR* high pressure and injection processes The electronic control system controls the operation of all components separately (Fig. 10.10).

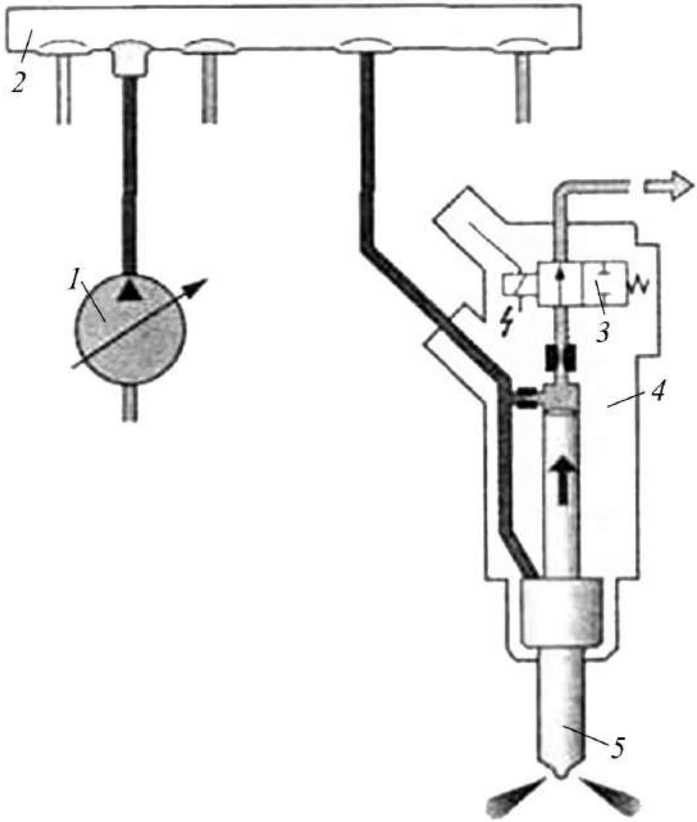


Figure 10.10 – System schematic diagram *Common Rail*: *1* – autonomous fuel injection pump; *2* – pressure accumulator; *3* – electromagnetic high pressure valve; *4* – nozzle; *5* – spray nozzle

System pressure *CR* is created and regulated independently of engine shaft speed and cyclic fuel supply. It is maintained in the accumulator for subsequent injection. System diagrams *CR* shown in Fig. 10.11. The system includes the main components (Fig. 10.11, *and*): *1* – mass air flow sensor; *2* – control unit; *3* – PNVT; *4* – high-pressure accumulator (*Rail*); *5* – injectors; *6* – crankshaft speed sensor; *7* – sensor

temperatures cooling liquids; *8* – fuel filter;
9– pedal position sensor.

In the high-pressure circuit (Fig. 10.11,*b*) is located: *1*– fuel injection pump; *2*– plunger section shut-off valve; *3*– pressure control valve; *4* – high-pressure main; *5*– high-pressure accumulator; *6*– sensor fuel pressure; *7*– pressure limiting valve (bypass valve); *8*– bandwidth limiter; *9*– nozzle; *10*– control unit.

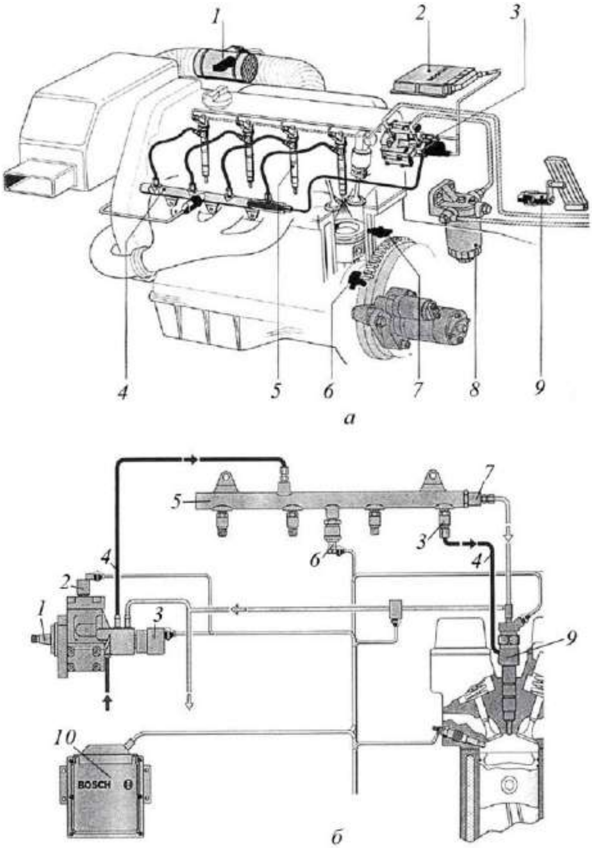


Figure 10.11 – Injection system diagrams *Common Rail*: *and*– location on the engine; *b*– high-pressure circuit of the system

PNVT systems *CR* devoid of distribution functions and serves only to create a fuel reserve and quickly increase the pressure in the fuel accumulator. It creates a constant pressure for the accumulator up to 160 MPa.

In systems *CR* passenger cars use a plunger radial PNVT (Fig. 10.12). The three pump plungers provide a uniform load on the pump drive shaft.

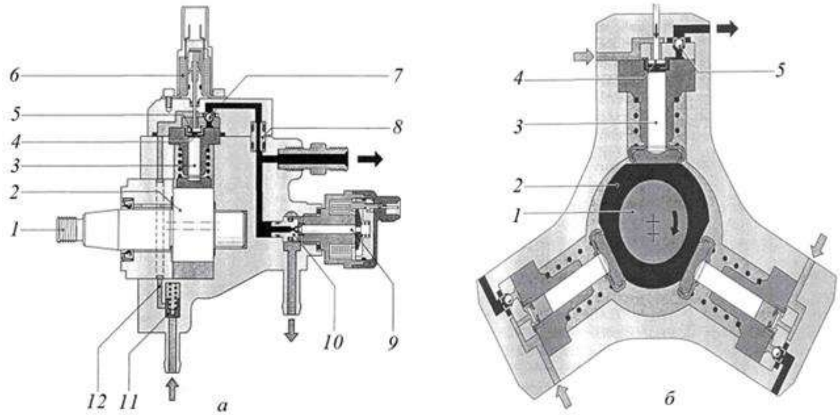


Figure 10.12 – Design of the PNVT system *CR*:
and – longitudinal section; *b* – cross section

At the entrance *13* PNVT fuel comes from the fuel pump pump with a pressure of 0.05–0.15 MPa through the filter. The inlet pressure is determined by the valve resistance *14* (see fig.10.12, *and*). At the outlet of the pump sections there are exhaust valves *7* When the fuel supply decreases, one of the pump sections is turned off by a solenoid valve. *6* and inlet valve *5*.

Pressure control valve *10* sets the pressure value battery depending on the engine load. The pressure control valve has two circuits:

– the slow (electrical) loop regulates the average variable the pressure in the accumulator;

– fast (hydromechanical) circuit smoothes high-frequency pressure fluctuations.

The high-pressure accumulator is mainly in the form of a pipeline with a considerable volume of fuel.

System injectors*CR*connected to the battery with short high-pressure mains.

System nozzle*CR*(rice.10.13 and Fig. 10.14) consists of the following functional blocks: pinless atomizer; hydraulic servo system; solenoid valve or piezo element. Fuel at the input*9*(rice.10.13,*and*) comes from the battery.

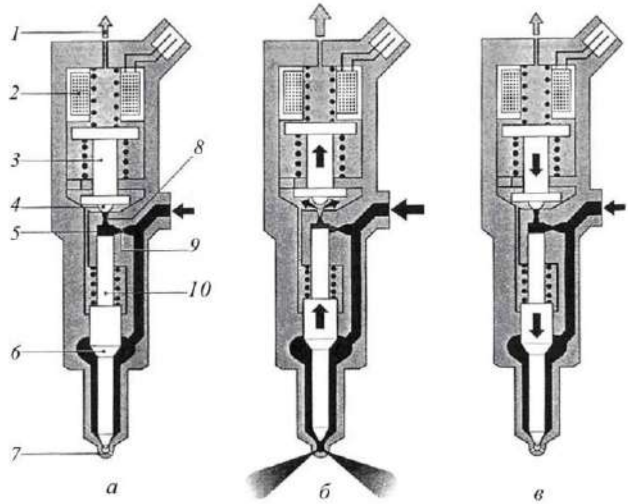


Figure 10.13 – Principle of operation of the system nozzles*CR*:*and*– output position;*b*– injection;*in*– stopping injection

Then the fuel under pressure enters the atomizer*6*and through throttle*10*into the cavity*5*control valve. Through the throttle hole withdrawal*8*fuel, which can be opened by a solenoid valve, cavity*5* connects to the highway*1*fuel drain.

With the throttle closed*8*(see fig.10.13,*and*) pressure from above on the piston *11*the control valve creates a force that exceeds the force that acts on the needle from the bottom of the sprayer. The sprayer is securely closed.

When opening the ball valve*4*pressure in the cavity*5*decreasing and the sprayer opens (see Fig. 10.13,*b*).

Closing the valve *4* turns off the injector. So, the cycle of operation Nozzles can be divided into four processes:

– the nozzle is closed (with high pressure supplied to the inlet);

– the injector opens (injection begins);

– the nozzle is fully open;

– the injector closes (end of injection).

The design of the system nozzles *CR* shown in Fig.10.14. The positions in Fig. 10.14, *and* marked: *1* – fuel drain line; *2* – electrical connector; *3* – solenoid valve; *4* – high-speed highway pressure; *5* – ball valve; *6* – fuel outlet throttle; *7* – fuel supply throttle opening; *8* – control valve cavity; *9* – control valve piston; *10* – fuel supply channel to sprayer; *11* – sprayer needle.

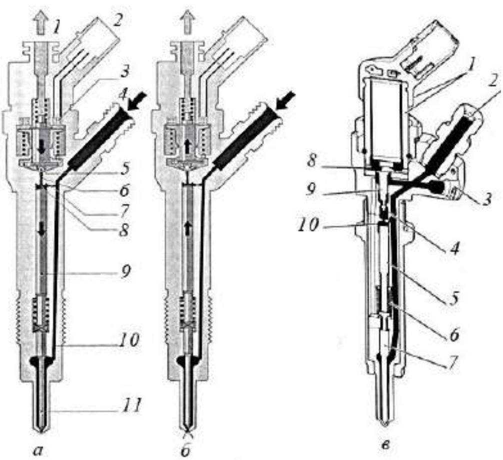


Figure 10.14 – System nozzle design *Common Rail*: *and* – the nozzle is closed; *b* – the nozzle is open; *in* – piezo injector

In Fig. 10.14, the piezo injector includes: *1* – piezoactuator; *2* – high-pressure fuel supply; *3* – drain channel; *4* – control valve; *5* – multiplier piston; *6* – spring injectors; *7*– sprayer needle; *8*– control cavity; *9*– pusher control valve; *10*– control valve drive lever.

The piezo nozzle operates twice as fast as a solenoid valve. Its operation time is less than 0.001 s thanks to the piezo actuator, which consists of a multitude of piezo plates located as close as possible to the atomizer. The piezo actuator plates are a ceramic solid solution of lead titanate-zirconate.

When a voltage pulse is applied to the piezo actuator, it expands and acts against the fuel pressure, pressing the needle against the injector seat. When the voltage is removed, the injector opens.

The piezoelectric effect allows you to divide a single injection cycle into several (up to seven or more separate doses with high delivery accuracy).

Emission, use and treatment of exhaust gases The main task of the exhaust system is to effectively remove exhaust gases from the engine cylinders, reduce their toxicity and noise level. The structure of a standard exhaust system depends on the type of fuel used, as well as on the applicable environmental standards. The exhaust system (Fig. 10.15) may consist of the following elements.

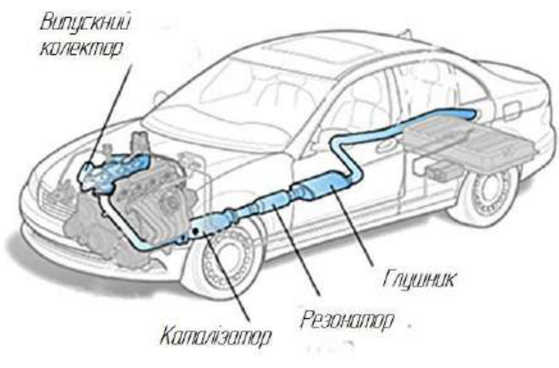


Figure 10.15 – Location of the release system exhaust gases

Exhaust manifold– performs the function of removing gases and cooling (blow-out) of the engine cylinders. It is performed with heat-resistant materials, since the temperature of exhaust gases varies on average from 700 to 1000 °C;

Receiving pipe– is a pipe of complex shape with flanges for mounting to the manifold or turbocharger.

Catalytic converter(installed in gasoline engines) engines of the environmental standard Euro-2 and higher) eliminates the most harmful components CH, NO from exhaust gases$_x$, CO, converting them into water vapor, carbon dioxide, and nitrogen.

*Flame extinguisher*installed in car exhaust systems instead of a catalyst or a particulate filter (as a budget replacement). It is designed to reduce the energy and temperature of the gas flow leaving the exhaust manifold. Unlike a catalyst, it does not reduce the amount of toxic components in the exhaust gases, but only reduces the load on the mufflers.

*Lambda probe*serves to control the oxygen level in the composition exhaust gases. The system may have one or two oxygen sensors. On modern engines (inline) with a catalyst, two sensors are installed.

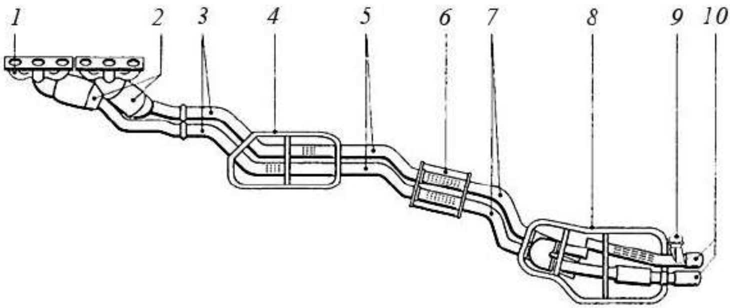


Figure 10.16 – Exhaust gas system: *1*– graduation collector; *2*– catalytic converter; *3*– front pipe; *4*– front muffler; *5*– intermediate pipe, *6*– central muffler; *7*– rear muffler; *8*– damper, *9*– rear exhaust pipe

Diesel particulate filter(mandatory part of the diesel engine system) removes soot from exhaust gases. Can combine the functions of a catalyst.

Resonator(pre-silencer) and*main silencer*reduce exhaust noise level.

*Pipelines*connect individual elements of a car exhaust systems into a single system. A variant of the system is shown in Fig. 10.16.

The exhaust gas exhaust system should ensure acceptable noise levels and, if possible, reduce emissions. Variants of traditional exhaust systems are shown in Fig. 10.17.

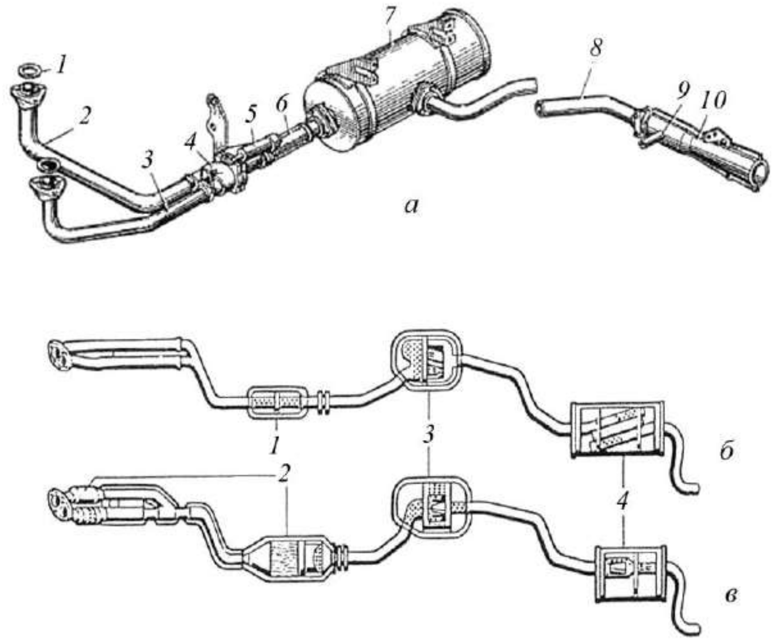


Figure 10.17 – Exhaust gas systems: *and*– a truck;*b* and*in*– passenger car

In particular, in the system (see Fig. 10.17,*and*) include:*1*– ring sealant;*2*,*3*– receiving pipes;*4*,*5*– motor mechanism (auxiliary) brake;*6*– flexible metal sleeve;*7*– muffler;*8*– exhaust pipe;*9*– nozzle of the ejector; *10*– ejector.

In the exhaust system of a passenger car (see Fig. 10.17,*b*) are located:*1*– front muffler;*3*– central muffler;*4*– rear muffler; catalytic converter installed*2*.

The exhaust noise level is reduced by a silencer. According to the principle of operation, silencers are divided into active (Fig. 10.18,*and*,*b*) and reactive (Fig. 10.18,*in*,*g*).

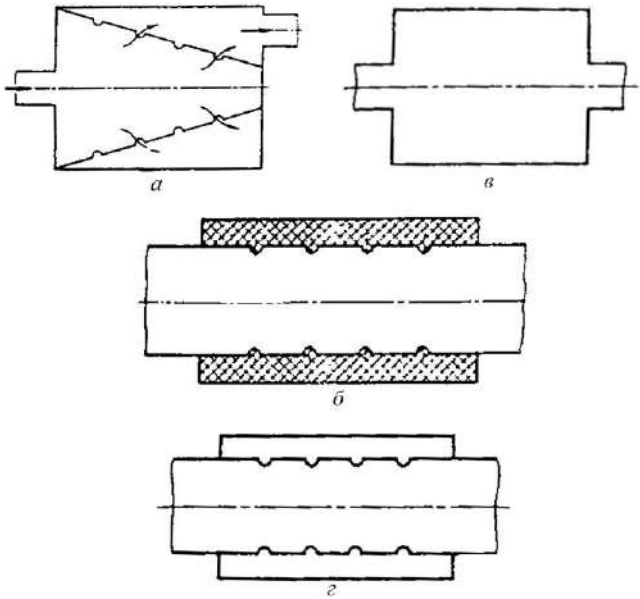


Figure 10.18 – Muffler diagrams:
and– active with perforated cone;*b*– active with sound-absorbing material;*in*– reactive with expansion camera;*g*– reactive with resonant chambers

For decrease individual spectral components frequencies Devices are used that set the acoustic parameters of the mufflers: Helmholtz resonator, perforated tubes, Venturi nozzles.

In addition to noise, exhaust gases contain harmful substances, products of incomplete combustion: carbon monoxide; soot CO_2; hydrocarbons CH; oxides nitrogen NO_x; sulfur dioxide SO_2(diesel engines). Nitrogen dioxide decomposes into nitric oxide and molecular oxygen, which in the air turns into ozone O_3, and is harmful at high concentrations.

To reduce the level of NO formation$_x$use*recycling exhaust gases* Recycling is based on reducingandoxygen concentration in the combustion chamber; reduction of exhaust gas flow; reduction of temperature in the cylinder due to the higher heat capacity of inert gases. For this purpose, exhaust gases in an amount of up to 10% of the volume of the fresh charge are taken from the exhaust manifold, cooled and directed into the intake system.

To reduce the concentration of toxic substances in the exhaust pipe, purifiers and neutralizers are installed. Chemical reactions occur in thermal and catalytic neutralizers. Mechanical purifiers are used to clean exhaust gases from mechanical particles (soot). They are rarely used, mainly on powerful diesel engines. To remove solid particles from the exhaust gases of diesel engines, soot filters are installed: with metal, ceramic and other filter elements. A filter with ceramic elements has channels with alternating open and closed channels (Fig. 10.19).

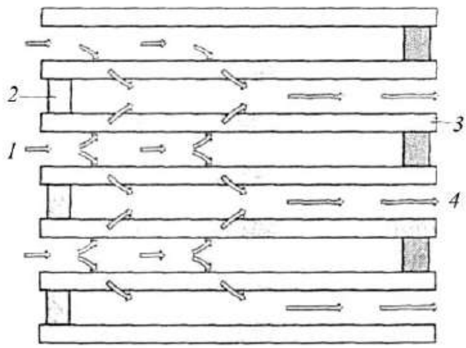


Figure 10.19 – Principle of operation of a ceramic particulate filter: *1*– gas inlet;*2*– ceramic tube;*3*– dividing wall; *4*– gas release

Regeneration (restoration, cleaning) of this filter can be performed thermally or chemically. Variants of filter designs are shown in Fig. 10.20.

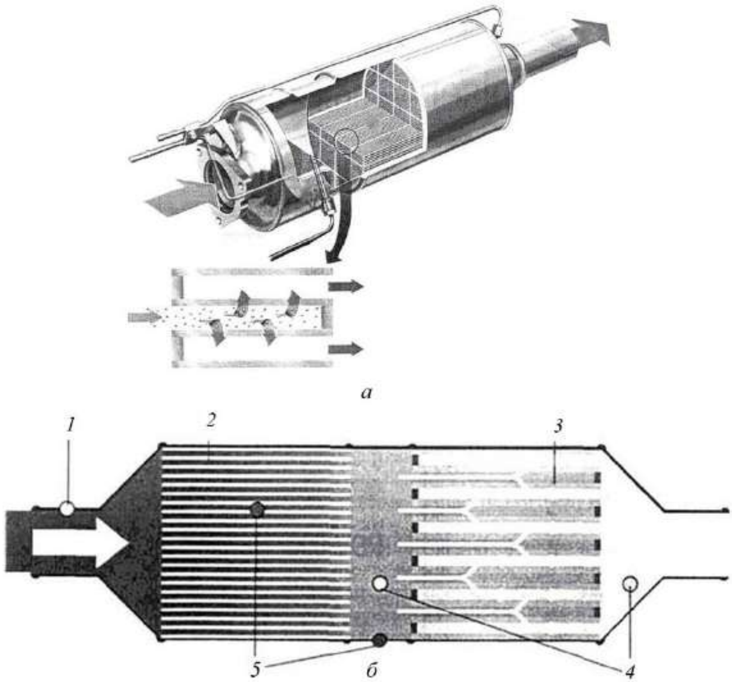


Figure 10.20 – Filter designs

and– soot filter: *1*- Exit; *2*– filter element; *3*– pressure sensor; *4*– temperature sensor; *5*- Entrance; *b*– combined filter: *1*– oxygen sensor; *2*– oxide neutralizer; *3*– particle filter soot; *4*– pressure sensor; *5*– temperature sensor

The thermal neutralizer (Fig. 10.21) is a combustion chamber located in the exhaust pipeline for burning CH and CO. It consists of a housing with inlet pipes and flame tube inserts.

In catalytic oxidation neutralizers, a high oxidation rate is achieved. To increase the total surface area, the catalyst is applied to the surface of the ceramic filler. In

Platinum and palladium are used in catalytic converters for passenger car engines. The design of a combined catalytic converter with ceramic filler is shown in Fig. 10.22,*and*.

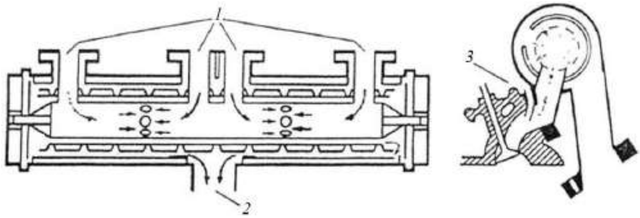


Figure 10.21 – Thermal neutralizer-afterburner: *1*– engine exhaust pipes;*2*– gas release;*3*– air supply

In the design of the neutralizer in the NO reduction chamber$_x$*3*(rice. 10.22,*and*) filler separated by partitions *1*To ensure the oxidation process to the nozzle*4*air is supplied. In the chamber*5* oxidation of CH and CO occurs.

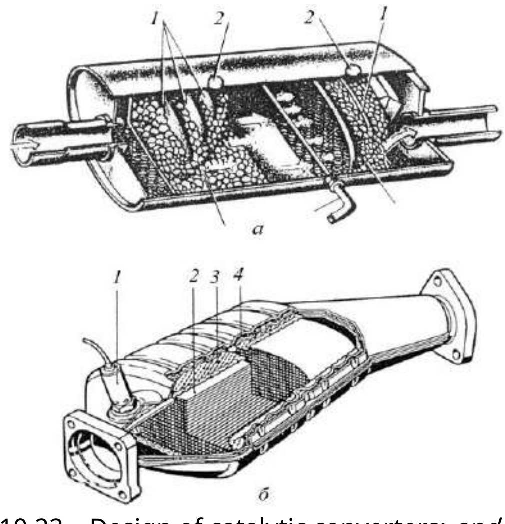


Figure 10.22 – Design of catalytic converters: *and*– combined catalytic converter;*b*– two-layer three-component catalyst

In the design of the neutralizer (see Fig. 10.22,*b*) are located: *1*– oxygen sensor;*2*– monolithic ceramic porous monoblock with platinum or palladium plating;*3*– mounting element (mesh);*4*– thermal insulation.

Catalytic neutralizers from renewable environment used in systems to reduce nitrogen oxide emissions. A catalytic converter with a reducing medium is advisable to use in combination with an oxidative catalytic converter for the oxidation of CH and CO.

If the neutralizer reduces the toxicity of three components: CH, CO and NO_x, then such neutralizers are called three-component. Combinations of thermal and catalytic neutralizers are also possible in two variants: 1) the catalytic one is installed first to neutralize NO_x, and the second is thermal for afterburning CH and CO; 2) the first is thermal, and the second is oxidative catalytic.

Review questions

1. Purpose of the power system.
2. Air extraction and purification. Design features.
3. The principle of operation of the ejector air purification system.
4. Mechanical air inflation.
5. Turbocharger supercharging. Purpose. Principle of operation.
6. Gas-powered system. What is included in the system?
7. What are the options for a gasoline fuel system? Principle of operation.
8. Diesel engine power supply system.
9. Injection system diagrams*Common Rail.*Principle of operation.
10. Emission, use and treatment of exhaust gases.

Laboratory work 11

CLASSIFICATION OF ICE STARTING SYSTEMS. DESIGN, PRINCIPLE OF OPERATION OF AN AUTOMOTIVE ELECTRIC STARTER

Purpose of work– study launch systems and the principle of operation car starter, design and purpose of its main components.

Visual aids:

• multimedia support;

• measuring and diagnostic equipment;

• cars.

Tasks for work:

• study the classification of internal combustion engine starting systems and establish the reasons using the most common method of starting an internal combustion engine;

• familiarize yourself with the purpose and principle of operation of the automobile starter;

• study the structure, purpose of components and elements of automobiles starters and provide an electrical diagram of the starting system;

• get acquainted with the main technical characteristics of the starter according to the individual task.

Classification of engine starting systems

Piston internal combustion engines can be started by spinning the crankshaft in various ways to starting speed.

The following methods of starting an internal combustion engine are possible. ***Muscle launch***

Muscle starting is carried out manually using a starting handle (or other similar device) or by scrolling the suspended drive wheel when the second drive wheel is braked (rests on the road and does not rotate due to the differential).

In this method, the source of energy for rotating the engine crankshaft is human muscle power.

Muscle starting is used on modern cars only in the event of a failure of the standard starting system. It is quite dangerous in terms of injury to a person, so it requires special care when using it. Starting a diesel engine using muscle starting is much more difficult and dangerous than a spark-ignition engine, due to the high level of compression in the cylinders.

Recently, manufacturers have not provided standard devices for muscle starting the engine on passenger cars.

Tow-launch

By towing, the engine can be started using another vehicle or using the muscular power of a group of people or animals (horses, mules, etc.).

By towing, the car accelerates to a certain speed, after which the driver engages the manual transmission gear (usually 3rd gear) and smoothly engages the clutch, causing the crankshaft to rotate.

This method of starting the engine does not apply to vehicles equipped with an automatic transmission.

Starting from an electric motor

Starting from a DC electric motor – a starter that uses the energy of the car battery for its operation. This method is the most convenient and practical, therefore it is used in the vast majority of starting systems of modern car engines.

The starter structurally combines a DC electric motor, a drive with an overrunning clutch, a starter with a connecting flywheel ring, and an electric relay for turning on the electric motor. Starting is carried out using an auxiliary motor - a "starter".

Starting the main engine from an auxiliary low-power internal combustion engine, which is started from other energy sources, in particular manually. This method is often used in tractor engines, as it allows you to easily start a high-power engine with a high compression ratio, typical of diesel engines, does not depend much on the battery charge level, so it is used in any conditions, including far from populated areas.

Small gasoline engines, called "starters," are usually used as starter motors.

Pneumatic start

Pneumatic starting is carried out using the energy of compressed air, which accumulates in special cylinders during the operation of the main engine. This method of starting an internal combustion engine has not been used in road transport; it is more often used to start ship and diesel locomotive engines, as well as diesel engines of heavy armored vehicles.

Inertial start

Inertia starting, using the energy of a rotating flywheel that has accumulated energy during engine operation, can be used to start the engine after a short stop. However, inertial starting systems are known in which a heavy flywheel is first spun manually, after which the energy is used to start the engine even after a long stop.

Inertial starting includes starting an engine that has stalled while the vehicle is moving - engaging any gear of the transmission while smoothly engaging the clutch allows the crankshaft to be unwound from the rotating wheels. This method of starting the engine is sometimes also called rotational starting.

Direct launch

Direct launch (*Direct Start*) – a promising method of starting an internal combustion engine without the use of external sources of mechanical energy, proposed by a well-known company*Bosch*.

The originality of this starting method lies in the fact that the on-board computer determines which of the engine cylinders is most suitable for performing the power stroke (the piston is slightly beyond top dead center), after which a small portion of the combustible mixture is fed into it and ignited - the engine starts working.

For a number of reasons, this method can be used in engines with at least four cylinders.

Work on the implementation of this idea is currently underway, and it is quite possible that the electric starting system will be replaced by a more efficient and convenient direct start.

Pyrotechnic launch

Another rare way to start an engine. Pyrotechnic starting is a method using pyrotechnic substances, for example, gunpowder, which has not been used in cars. This method is technologically similar to pneumatic starting and differs in that it does not require a supply of compressed air - the starting pressure is provided by powder gases formed during the combustion of a pyrotechnic cartridge, which can be ignited by an electric spark or by hitting the primer with a conventional hammer.

Currently, pyrotechnic starting is used on some models of snowmobiles and motor boats, as it is convenient because in some conditions other energy sources are not available to start the engine.

The main requirement for engine starting systems is to ensure sufficient crankshaft rotation speed, which requires a certain torque. At the same time, the starting system must function reliably in any operating conditions of the internal combustion engine and consume the vehicle's own energy sources as little as possible.

Engine starting aids

The starting system also includes devices that facilitate starting a cold engine, especially at low ambient temperatures. Such devices, when starting a cold engine, allow for improved spark formation (in engines with forced ignition of the mixture), ensure the supply of the combustible mixture to the cylinders of the required quality and quantity, perform cylinder purging, as well as preheating the combustible mixture, lubricant, coolant, and parts of the main engine mechanisms.

Starting a cold engine equipped with a gas and diesel fuel system is especially difficult in winter. Here, in addition to the reasons listed above, there are also specific starting problems caused by the characteristics of the fuel and the type of fuel system.

Thus, gas fuel needs to be heated (gaseous) or evaporated (liquid gas) when it leaves the cylinders. In order for the heater or evaporator to start functioning, it is necessary to first start and warm up the engine, since the heater uses exhaust gases, and the evaporator uses hot liquid from the cooling system. Obviously, in a cold state, the engine systems cannot provide normal heating of the gas before feeding it to the reducer and mixer. Therefore, the engine in gas-powered cars is usually started on gasoline, and after some warming up of the engine, the power system is switched to gaseous fuel.

For diesel engines, an additional reason for the difficulty of starting is cold air. Since a diesel engine uses strong air compression to ignite the combustible mixture, it is obvious that cold air at the same compression ratio will heat up less than warm air, and ignition of the mixture will be difficult or even impossible. In addition, the high compression ratio in diesel engines, characterized by significant compression resistance, creates an additional obstacle to the operation of the starting system (starter or starting motor), and during start-up it is difficult to spin the crankshaft to the required frequency.

To eliminate the described reasons for the difficult start of diesel engines, such design solutions as preheating the air in the intake manifold using special electric glow plugs, as well as decompressors - devices that reduce engine compression at the moment of cranking the crankshaft before starting the engine, are used. Decompressors usually open a valve (intake, exhaust or both), which makes it easier for the starter to crank the crankshaft to the desired frequency, and after the decompressor is turned off, the engine starts.

In addition, the decompressor can be used for emergency engine shutdown if necessary - reducing compression in the cylinders prevents ignition of the combustible mixture and the diesel engine stalls.

Structurally, the decompressor is a system of rods and levers with a manual or electromagnetic drive that act on the pushrods and open the timing valves.

In conditions of very low temperatures, ether-containing fluids are often used to facilitate engine starting, which are injected in small quantities into the intake tract of the power system.

In the cold season, the most convenient and reliable way to make starting engines easier is with pre-starting heaters.

Electric start

The amount of electrical voltage at the starter affects the power developed by the starter motor. On cars with gasoline internal combustion engines, the on-board voltage is 12 V, the same electrical voltage is applied to the starter.

On cars with powerful diesel engines, the on-board voltage is 24 V. This is because a diesel with a large displacement and a high compression ratio requires a powerful electric starter. Two 12-volt car batteries are installed, connected in series.

With equal electrical power and a doubling of electrical voltage, the current strength is correspondingly halved:

$$P = I \cdot U,$$

where I – current strength, and U - High-voltage.

Increasing the voltage allows you to reduce the discharge current of the battery, as well as reduce the heating of the electrical wires.

Passenger cars, vans, and light trucks with diesel engines use 12-volt starters. The starter can use various electric motors.

Classification of electric motors

Electric motors are classified according to the method of connecting the excitation winding (Table 11.1). The most common type of electric motors is series-excited motors. Mixed-excited motors are also often used for operation in severe conditions.

In a series-excited motor, the field winding is switched in series with the armature winding. This is the most common type engine for passenger cars, such an engine provides high starting torque, decreasing as the speed increases. This characteristic is ideal for overcoming the high resistance when rotating the crankshaft from a standstill.

Along with electrically excited motors, permanent magnet excited motors are also in operation, which have good weight characteristics.

Permanent magnet motors are small in size and simple in design. Since they do not have an excitation winding, the voltage drop in them is determined only by the resistance of the armature winding. To extract high power from the shaft, such motors may have a built-in mechanical transmission from the armature to the output shaft.

Mixed-excitation motors are used where high power is required. These motors have both series and parallel windings, which are switched on in two stages:

a) when the engine is turned off, the parallel winding is first switched on in series with the armature and acts as a ballast resistance. Due to this, the armature current is limited and the engine develops a small torque necessary for smooth engagement of the starter gear;

b) in the second stage, the windings correspond to their name: the parallel winding is connected in parallel with the armature, and the series winding is connected in series.

After the engine starts, the starter gear disengages from the flywheel, and the starter is disconnected from the power source. At this time, the inertial armature begins to generate current, which is dissipated in the parallel excitation winding. Due to this, the starter armature stops quickly - the effect of an electric brake.

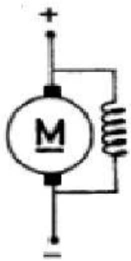
Electric starter system

The starter is designed for remote starting of a car engine. It is a DC electric motor with an electromagnetic traction relay and a drive mechanism.

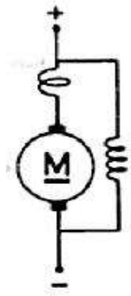
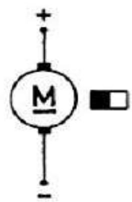
When the ignition switch is turned off, the traction relay is activated (Fig. 11.1 and 11.2), as a result of which the drive gear engages with the engine flywheel ring gear, and the power contacts of the electric motor power supply circuit are closed (Table 11.1). The starter armature through the drive mechanism rotates the crankshaft and gives it the speed necessary to start the engine independently. The minimum starting speed is 60...90 rpm, and for diesel engines - 100...200 rpm.

When starting the starter, the battery discharge current is 100...1500 A, so the starter operating time is limited. According to existing standards, the duration of an attempt to start a gasoline engine is 10 s, a diesel engine – 15 s, the interval between attempts is 60 s, and after three attempts – 3 min. After starting the car engine, the ignition key is released, the power contacts are opened, the traction relay and the electric motor are disconnected from the battery and the starter drive is disengaged from the flywheel ring gear.

Table 11.1 – Classification of DC motors

Engine with **parallel excitement**		General purpose electric motor. Not used as starters. The field winding has many turns and significant resistance
Engine with **consistent excitement**		High starting torque, ideal for cranking a piston engine. The field winding has a small number of turns of thick wire or metal low resistance strips

Continuation of Table 11.1

Engine with mixed excitement		Sometimes used for high-power starters. It is activated in two stages: 1. The parallel winding is connected in series with the armature to provide the small torque required to engage the starter gear with the flywheel ring gear. The series winding is disconnected. 2. Turns on as shown in the figure – full armature current
Engine with permanent magnet		Used as starters due to advances in the field of permanent magnets, which allowed for a more efficient electric motor with good weight performance.

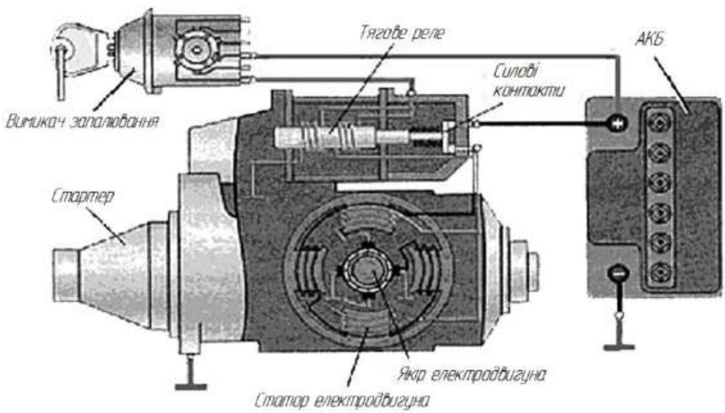


Figure 11.1 – Starter activation electrical diagram and components electric starter systems

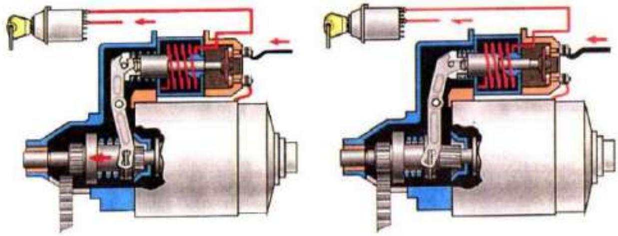


Figure 11.2 – Gear engagement with the engine flywheel ring gear

Starter structure

The starter consists of a housing in which the excitation coils are mounted with poles; an armature with a winding and a collector; covers (on the collector side and on the drive side); a drive consisting of a drive gear lever and a freewheel clutch; a traction relay consisting of a coil, a yoke, an armature, a rod with a contact plate, a cover with contact bolts (Fig. 11.3). The electric starter housing is made of a pipe or a steel strip ST10 or ST2 with subsequent butt welding. The housing has a hole for the output bolt of the excitation winding, but there are no windows for access to the brushes (in order to improve sealing).

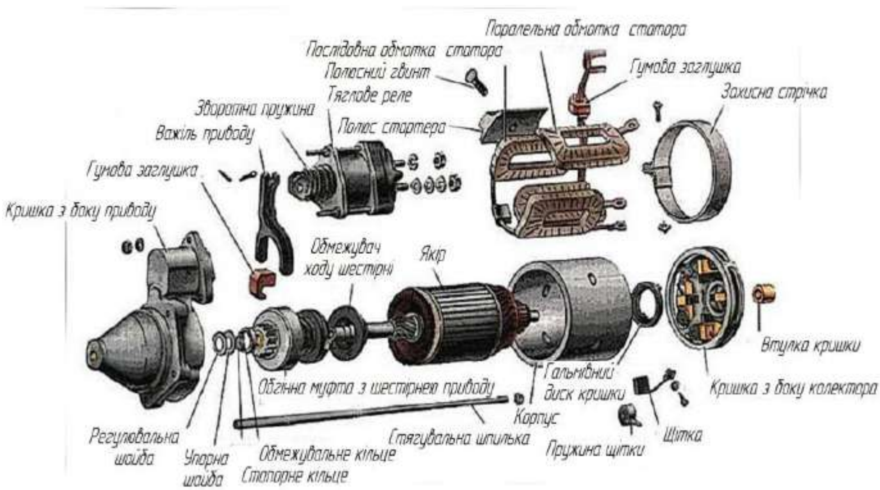


Figure 11.3 – Starter structure

The poles with the excitation winding coils are attached to the housing with screws. All automobile starters are four-pole. The coils of the series (series) and parallel (shunt) excitation windings are installed on separate poles, so the number of coils is equal to the number of poles. The series winding coils have a small number of turns of uninsulated copper wire of rectangular cross-section of the GSM brand. Between the turns of the coil, an insulating cardboard 0.2...0.4 mm thick is laid. The parallel excitation winding coils are wound with insulated round wire of the PEV-2 or PETV brands. The coils are insulated externally with a tape of insulating material (cotton taffeta tape, batiste tape B-13). The outer insulation after impregnation with varnish and drying has a thickness of 1...1.5 mm.

Promising use of polymer materials in coil insulation, which can be used to obtain coatings that are uniform in thickness and resistant to aggressive environments and elevated temperatures.

The starter armature is a stacked core, in the grooves of which the winding sections are placed. In a stacked core, eddy current losses are lower. The armature package is pressed onto a shaft that rotates in two or three supports with bronze-graphite bearings, bearings made of other powder material or with rolling bearings. The armature package is made of steel plates (ST0.8 KP or ST10) 1...1.2 mm thick. The end plates of the package made of electrical insulating cardboard EV 2.5 mm thick protect the insulating material of the front parts of the armature winding from damage.

Copper-graphite brushes with lead and tin additives are used in electric starters. There is more graphite in brushes for powerful starters and starters for heavy-duty use. The size of the brushes and the voltage drop under them depend on the permissible current density. Typically, the current density in electric starter brushes is in the range of 40...100 A/cm^2.

The traction relay ensures that the gear engages the flywheel ring gear, which connects the starter motor to the battery (Fig. 11.4). On most starters, the traction relay is located on

The relay cover is connected to the flange of the relay cover directly or through additional fastening elements.

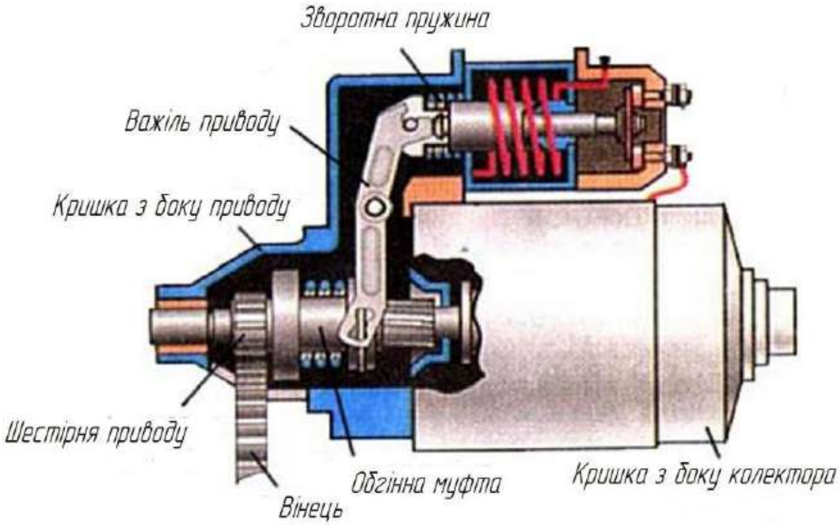


Figure 11.4 – Structure of the starter traction relay

The relay may have one or two windings wound on a brass sleeve, through which a steel armature moves freely, which acts on the rod with a movable contact disk (Fig. 11.5). Two fixed contacts in the form of contact bolts are fixed in a plastic cover.

In a two-winding relay, the holding winding is designed only to hold the relay armature in a state pulled to the core, is wound with a wire of a smaller cross-section and has a direct output to "ground". The pulling winding is connected in parallel to the relay contacts. When the relay is turned on, it acts in accordance with the holding winding and creates the necessary gravitational force when the gap between the armature and the core is maximum. During operation of the starter motor, the closed contacts of the traction relay shunt

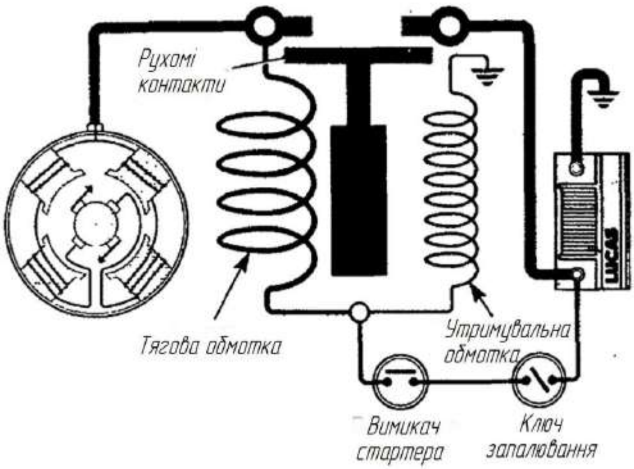


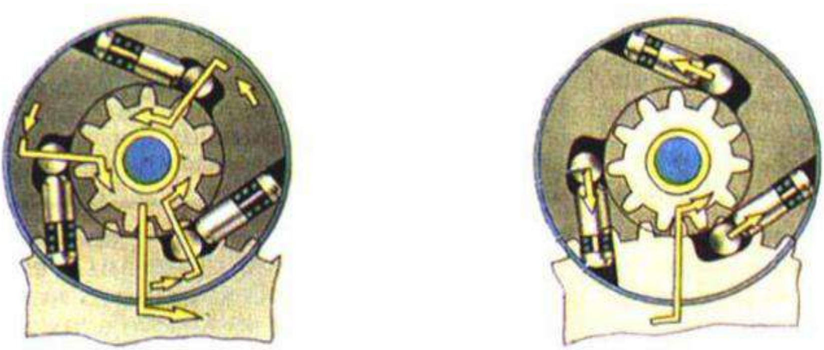
Figure 11.5–Electrical diagram of the starter traction relay

the retracting winding and turn it off.

Traction relay linked by lever with mechanism drive, located on the splined part of the shaft. The lever acts on the drive through a clutch. It is cast from a polymer material or made of two stamped steel parts connected by riveting or welding.

To transmit torque from the armature shaft to the crankshaft, a special drive mechanism is used. According to the type and principle of operation of the drive mechanisms, starters with electromechanical movement of drive gears with inertial or combined drive are distinguished. To prevent the armature from moving apart after starting the engine, roller, ratchet or friction-ratchet freewheel clutches are installed in automobile electric starters. The most widespread in electric starters are electromechanical drive gears and roller freewheel clutches.

Roller overrunning clutches are technologically advanced in manufacturing, silent in operation and capable of transmitting large torques despite their small size. They are insensitive to contamination, do not require care and regulationinoperation. Such a coupling works in the following way (Fig. 11.6).



and *b*

Figure 11.6 – Diagram of the operation of a roller overrunning clutch:
at startup (*and*) and after start (*b*) car engine

When the starter motor is switched off, the outer driving ring of the freewheeling clutch, together with the armature, rotates relative to the still stationary driven ring. The rollers, under the action of the compression springs and the friction forces between the rings and rollers, move into the narrow part of the wedge-shaped space, and the clutch jams (see Fig. 11.6, *and*). The rotation from the armature shaft of the driving clutch cage is transmitted by a splined sleeve. After starting the engine, the rotation frequency of the driven cage with the gear exceeds the rotation frequency of the driving cage, the rollers move into the wide part of the wedge-shaped space between the cages, so the rotation from the flywheel crown to the starter armature is not transmitted (see Fig. 11.6,*b*).

Permanent magnet starter with reduction gear Work in the field of improving electric motors has made it possible to create a simple and fairly lightweight starter design with permanent magnet excitation and a reduction gear (Fig. 11.7).

The reduction gear is a planetary gear set, the sun (central) gear of which is fixed to the armature shaft, and the output power is taken from the carrier, on the axes of which satellites are mounted, which rotate freely. The gears of the planetary gear with external teeth are made of steel, and the epicyclic gear (with internal teeth) is made of a polyamide compound with mineral additives to increase wear resistance.

This starter is 40% lighter than a conventional starter and is designed for use with engines up to 5 liters.

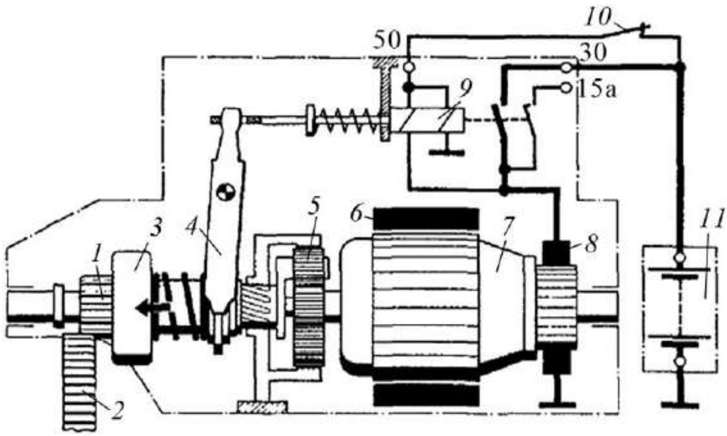


Figure 11.7 - Scheme of the starter *BoshDW* with permanent magnets and reduction gear:
1 – gear; *2* – flywheel crown; *3* – overrunning clutch; *4* – manager lever; *5* – planetary transmission; *6* – permanent magnet; *7* – anchor; *8* – collector with graphite brushes; *9* – electromagnetic drive with retracting and holding windings; *10* – starter key; *11* – battery

Review questions

1. What are the means of starting an internal combustion engine?
2. Give the classification of internal combustion engine starting systems.

3. What are the features of starting gasoline and diesel engines?

4. In what cases are the following means of starting an internal combustion engine used?

5. Why is an electric starter mostly used?
starting on cars?

6. What is the purpose of a starter?

7. What are the design characteristics that distinguish
starters?

8. What are the main elements of a starter and the functions they perform?

9. What type of winding switching do starters have and their
appointment?

10. How many windings are there in a starter? What are these windings and what is their purpose?
appointment?

11. What is the purpose and principle of operation of a roller clutch?

12. Design features of a permanent magnet starter
and planetary gear.

13. How does the minimum starting frequency and resistance torque change?
engine temperature?

14. What factors determine the choice of starter for a particular
engine?

Laboratory work 12
CLUTCH

Purpose of work– study of the design, principle of operation, operation and car clutch maintenance.

Visual aids:

• albums and posters on the design of friction clutches;

• components and parts of automobile clutches;

• slides, presentations and animations on clutch design cars.

Task:

• classify the clutches of GAZ-66, ZIL-130, MAZ-503A cars, KrAZ-257, VAZ-2110, Lanos,*ANDudi*,*Opel*according to the accepted system classification shown in the diagram in Fig. 12.1.

• using posters and models to study the designs of single-disk and double-disk clutches, perform the diagrams shown in Fig. 12.2 – 12.4, and write a brief description of them.

• study the purpose, principle of operation and design clutch torsional vibration damper using models and posters. Draw a schematic diagram of a torsional vibration damper using a poster.

• on the models, find and adjust the gap value δ, which decreases during operation due to wear of the friction surfaces of the driven disk.

• analyze the correspondence of the studied nodes to the main requirements

Purpose and principle of operation of the clutch

The clutch is an integral part of the car transmission. The clutch serves to disconnect the running engine from the transmission (during short stops and for shifting gears), for smooth starting, and to prevent transmission damage during overloads.

Most automobile clutches (Fig. 12.1) are frictional, i.e.

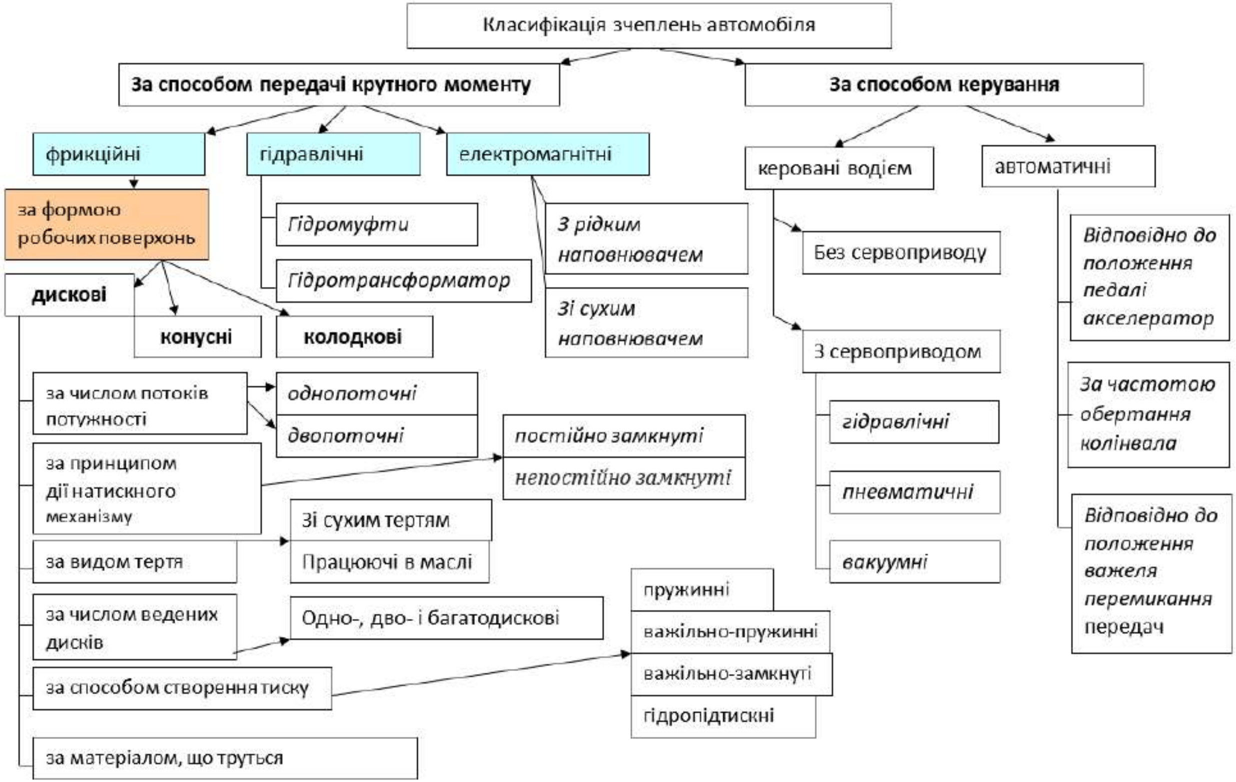


Figure 12.1 – Classification of couplings

those in which the transmission of torque is carried out due to friction forces between the contacting surfaces. The friction clutch consists of a driving and driven part, a pressure mechanism and a release mechanism. The parts of the driving group perceive the engine torque from the flywheel and are rigidly connected to it. The parts of the driven group transmit this torque to the gearbox input shaft. During the clutch disengagement process, these parts are disconnected from the engine. The pressure mechanism ensures tight pressing of the driving and driven parts of the clutch to create the necessary friction torque. The disengagement mechanism is designed to control the clutch. The clutch drive serves to facilitate clutch control.

The design features of a diaphragm spring coupling are shown in Fig. 12.2.

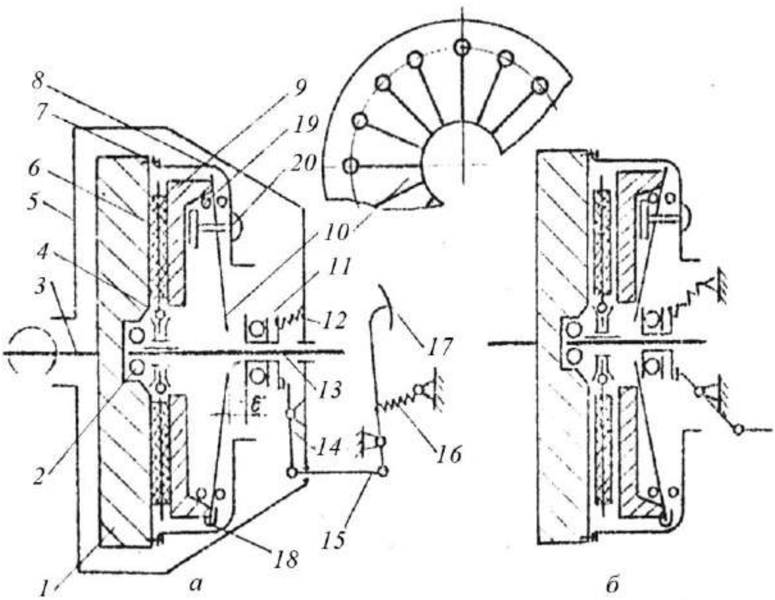
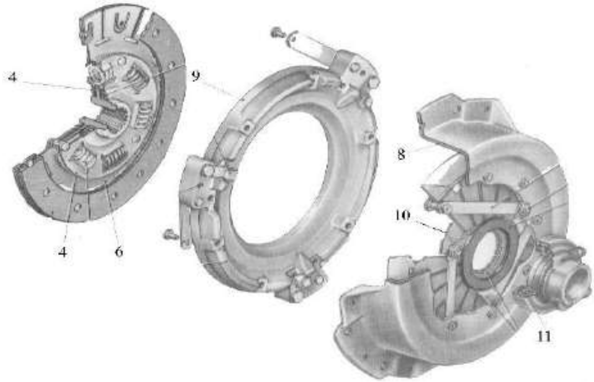


Figure 12.2 – Structural diagram of a diaphragm clutch spring: a – clutch disengaged; b – off;



Continuation of Fig. 12.2 – Structural diagram of the diaphragm clutch spring:
1– flywheel;*2*– bearing;*3*– crankshaft;*4*– damper assembly; *5*– crankcase;*6*– driven disk;*7*– bolts;*8*– casing;*9*– pressure disc; *10*– disc spring;*11*– shutdown bearing;*12*– pull-up spring;*13*– clutch shaft;*14*– power plug;*15*– traction; *16*– return spring;*17*– pedal;*18*– bracket;*19*– support rings; *20*– support pins

*To the leading part*clutch belongs to the flywheel*1*(see fig.12.3), casing *8*, pressure plate*9*,*to the slave*– disk*6*with friction linings, shaft clutch*13*. The pressure plate has spikes that fit into the windows of the casing bolted to the engine flywheel; this allows the pressure plate to rotate as one unit with the flywheel and at the same time move axially. The torque from the engine to the pressure plate is transmitted sequentially through the following parts: flywheel*1*, bolts*7*casing attachment, casing*8*clutch, pressure plate protrusions, pressure plate*9*. Pressure plate*9*may be associated with the casing not by means of pins, but by means of tangentially arranged plates, which participate in the transmission of torque. A thin steel driven disc is located between the flywheel and the pressure plate*6*from friction linings; hub*4*the slave disk has the ability to move on the splines of the driven shaft*13*in the axial direction. In

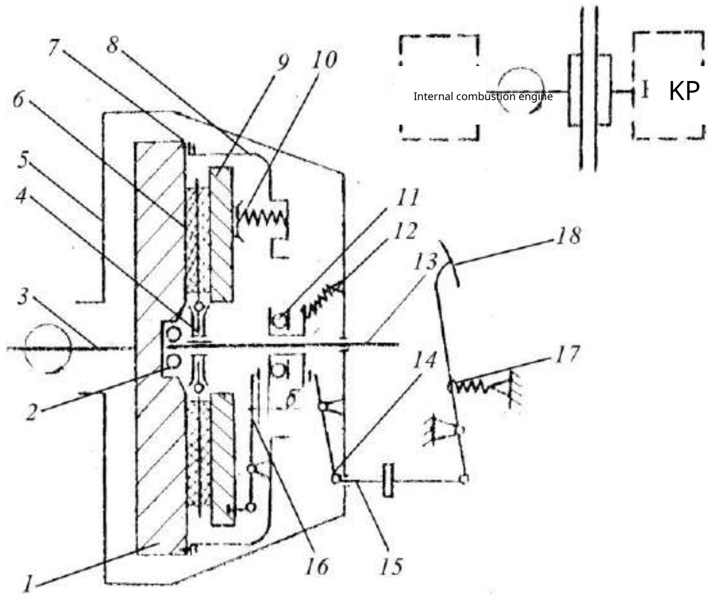


Figure 12.3 – Structural diagram of coupling with peripherals springs

In the operating mode of the permanently closed clutch, the driven disc is pressed against the flywheel by a pressure disc*9*using springs*10*, located in a circle between the clutch housing and the pressure plate; with the pedal free*18*clutch springs compress the discs and one piece, creating a rigid connection between the shafts*3*and*13*. Thrust bearing*11* moved by fork*14*; outer end of the fork with a pull rod*15*related to clutch pedal lever*18*. In the free state, the pedal is held by a spring*17*, the release bearing is pulled back by a spring*12*to the extreme right position (clutch disengaged); at the same time between the bearing*11* and release levers*16*a guaranteed gap δ = is formed3–4 mm. The presence of this gap eliminates the involuntary disengagement of the clutch and ensures complete engagement of the clutch in the event of partial wear of the friction linings; the gap corresponds to a certain pedal stroke*18*clutch (usually the pedal's idle travel is 30–45 mm).

When the clutch is disengaged by pressing the pedal, the release bearing moves axially. *11*,
the gap δ is selected, then under the action of the bearing force the pressure levers rotate, the pressure disc is moved away from the driven one, overcoming the resistance of the springs *10*(their compression occurs). The disks diverge, the driven disk under the action of resistance forces, the transmission stops, the connection between the shafts is interrupted. When the clutch is engaged, the drive discs slip relative to the driven one until their angular velocities are equalized; the car accelerates. When the clutch friction elements slip, a significant amount of heat is released, the temperature of the clutch parts increases. Most of the heat is removed through the flywheel and the pressure plate, so the latter is quite powerful. In addition, the clutch housing has special ventilation windows. To prevent the springs from heating up *10*and their release under each spring from the pressure plate side *9* a heat-insulating gasket is placed. To ensure that the clutch engages smoothly and the friction torque builds up gradually, the driven disc is often made elastic. The steel driven disc is divided into separate sections that are bent in different directions. One friction lining is riveted to the sections that are bent backward, the other to the sections that are bent forward; therefore, in the free state, there is a gap of about 1 mm between the linings and the disc itself. When engaged, the package is compressed, the gap is selected due to the deformation of the friction discs, the surfaces of which are in smooth contact.

To reduce the level of torsional vibrations in the powertrain, which arise due to uneven engine rotation, and to protect the engine from sharp shocks from the transmission, a torsional vibration damper (damper) is installed. In addition, the installation of a damper also ensures smoother clutch engagement. In this case, the driven disk *6* connected to its hub *4*not firmly, but with the help of springs, installed tangentially and circumferentially. The springs are installed in a compressed state in rectangular cutouts of the hub flange, driven disc and damper disc. The hub flange and damper disc are connected to each other by riveted pins. When the clutch is disengaged, the torque is transmitted through the friction linings to the driven disc *6*, and then through damper springs – on the hub of the driven disc and on the driven clutch shaft. Under the action of force, the damper springs are compressed, and the hub is slightly displaced relative to the driven disc: due to the deformation of the springs, the smoothness of the clutch engagement increases. The deformation of the damper springs is limited by the pins connecting the hub and the damper disc.

When adjusting the bearing, turn it off *11* moves to the right by due to change in rod length *15* clutch drive. Thus adjust the clearance during operation. For clutches with a central spring, it is necessary to check and adjust the spring compression force *10* (rice.12.4). This adjustment is carried out by moving the support flange *20* by removing the adjusting shims (P).

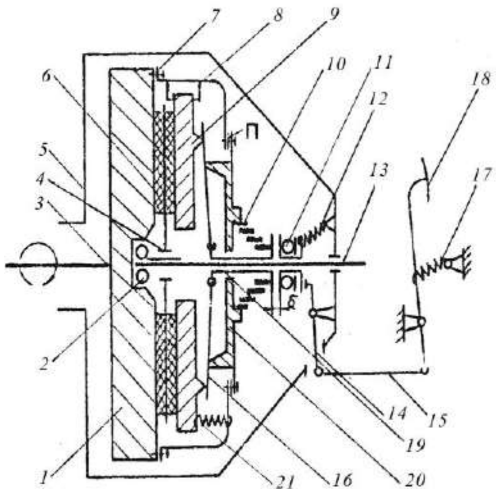


Figure 12.4 – Structural diagram of the clutch with the central spring:

1 – flywheel; *2* – bearing; *3* – crankshaft; *4* – hub; *5* – crankcase; *6* – driven disk assembly; *7* – bolts; *8* – casing; *9* – pressure disc; *10* – pressing spring; *11* – thrust bearing; *12* – extension spring; *13* – clutch shaft; *14* – power plug; *15* – traction; *16* – petal pressure lever; *17, 21* – extension springs; *18* – pedal; *19* – bushing; *20* – support flange

Double-disc clutches have their own characteristics. The diagram of a double-disc clutch is shown in Fig. 12.5.

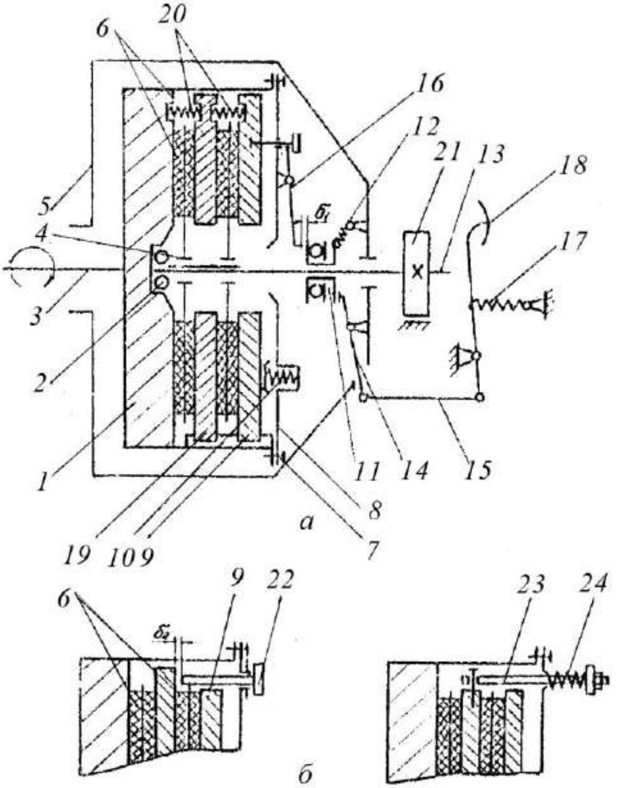


Figure 12.5 – Structural diagram of the clutch:*and*– with a mechanism for spreading discs by springs;*b*– disk spreading mechanisms stops and rods;

1– flywheel;*2*– bearing;*3*– crankshaft;*4*– hub;*5*– casing;*6*– driven disk assembly;*7*– bolts;*8*– casing;*9*– push-pull disc;*10*– compression springs;*11*– shutdown bearing;*12*– pull-up spring;*13*– clutch shaft;*14*– power plug;*15*– traction; *16*– shutdown levers;*17*– return spring;*18*– pedal; *19*– intermediate disk;*20*– flexible wiring;*21*– brake; 22 – stop screw; 23 – rod; 24 – extension spring

The main requirements for automotive clutches are as follows:

– reliable transmission of engine torque;

– cleanliness of shutdown (complete separation of friction surfaces);

– smooth switching on (without jerks and bumps in the teeth);

– minimum moment of inertia of the driven parts (for fast equalization of peripheral speeds and silent gear shifting in the gearbox);

– good heat dissipation from friction pairs;

– balance of clutch parts (no play);

– compliance of the force and travel of the drive pedal with the requirements of DSTU. For the considered clutches, special materials of the main parts are used. An approximate list of materials is given in Table. 12.1.

Table 12.1 – Materials of the main clutch parts

Part name	Material	Notes
Engine flywheel	Cast iron SCH 24	
Driven disk	Steel 65G	
Friction linings	Polymeric materials with additives	Asbestos friction materials
	Ceramet	Composite
		materials
Disc hub	Steel 40X	Hardening
Clutch cover	Cast iron SCH 24	
Pressure plate	Cast iron SCH 24	
Intermediate disk	Cast iron SCH 24	
Springs	Steel 65G	

Review questions

1. Purpose of the clutch, its place in the car's transmission.
2. Main features of the classification of clutches.
3. The most common types of automotive clutches.
4. Classification of the considered couplings.

5. Main components and parts of the clutch. Clutch drive and driven parts.

6. Sequence of torque transmission from the engine flywheel to the clutch shaft.

7. The concept of the coefficient of traction reserve; ensuring the necessary to transmit pressure torque on friction surfaces.

8. Disengaging and engaging the clutch.

9. Damping of engine torsional vibrations.

10. Coupling requirements and compliance with them studied clutch design. Changing clutch parameters during operation; adjustment.

11. Materials of the main clutch parts, hardening treatment.

12. Clutch control drive. Servo drive.

13. Advantages and disadvantages of the clutch considered in the task.

14. What are the types of clutches according to the method of torque transmission?

15. Why are the flywheel, pressure and intermediate discs made of cast iron?

16. How does the gap δ change during operation?

17. What are the advantages of using a diaphragm compression spring?

18. How is the temperature regime maintained? clutch and individual parts?

19. What are the features of a double-disc clutch?

20. What does dual clutch mean?

Laboratory work 13
CAR GEARBOXES. DISTRIBUTION BOXES

Purpose of work– study of the design, principle of operation, operation and maintenance of manual transmissions (MTBs) and transfer cases (RTs) of automobiles.

Visual aids:

• albums and posters on the design of MCP, RC cars;

• components and parts of MCP, RC;

• presentations, slides, videos;

• MCP, RK in section. *Task*:

• identify and classify MCP (list in the work materials);

• study the components of the MCP and RC and their purpose;

• submit kinematic diagrams of the CP and RC;

• study the kinematics of gearboxes of ZAZ-1102 cars, GAZ-66, ZIL-130, KAMAZ-5320. Determine the gear ratios of the specified gearboxes in all gears;

• using posters and models, independently compose kinematic diagrams of gearboxes of MAZ-503a and KrAZ-260 vehicles with the number of teeth indicated next to each gear;

• using the given kinematic diagrams, indicate the force flows when engaging different gears. Indicate the main positions on all kinematic diagrams;

• study the design features of the ZAZ-1102 gearbox.

Preparation for work

It is necessary to know that the gearbox is an integral part of the car's transmission and is located behind the clutch; often, the gearbox is structurally made in one unit with the clutch.*Box gears*designed to change the thrust and, accordingly, the speed of the vehicle, to ensure reverse movement and to permanently disconnect a running engine from the transmission.

Today, the most widespread are mechanical step gearboxes with the main arrangement of the primary and secondary shafts. The number of gears depends on the purpose of the car: the more difficult the operating conditions of the car, the greater the range of gear ratios and, accordingly, the greater the number of gears. Passenger cars usually have five gears, general-purpose trucks - four to five gears, the largest number of gears are tractors, heavy-duty trucks and off-road vehicles - up to ten gears.

The gearbox includes the following main components: a drive (primary) shaft, made in coordination with a permanent mesh drive gear, an intermediate shaft with fixed gears, a secondary shaft with freely sitting gears, equipped with synchronizers, a reverse axle or roller, a gearbox control mechanism (gear shifting mechanism), a lubrication system. The torque is transmitted from the clutch to the primary shaft of the gearbox, then - through a pair of permanent mesh gears - to the intermediate shaft, from the intermediate shaft - through a pair of gears of the corresponding gear - to the secondary shaft. A feature of automobile gearboxes is the presence of a direct transmission with a direct connection of the primary and secondary shafts. There are synchronizers on the secondary shaft: in passenger cars - on all forward gears, in trucks - only on working gears.

The transfer case is used to distribute torque between the drive axles of a car. The transfer case houses a device for engaging the front drive axle. In many cases, the transfer case is also used as an additional two-speed gearbox, thereby doubling the number of gears. The transfer case is installed behind the gearbox - separately or in one block with it.

Advantages of the MCP:

- can allow complete separation of the engine and transmission, therefore such a car is easily started “with a push” and can be towed at any speed for any distance;

- due to the rigid connection of the motor with the drive wheels, the driver can it is more efficient to use the car when driving off-road, in mud and on ice;

- easy to maintain and does not require expensive maintenance materials;

- proven and simple design, resulting in high reliability;

- high efficiency, acceleration dynamics and fuel economy;
- compared to other types of MCP, the lowest weight and cost;

Disadvantages:

- short clutch life; step change in gear
- ratio;
- gear shifting, which tires the driver, especially in city driving cycle and driving in traffic jams. To smoothly shift gears without jerks and select the right gear, you need to acquire skills.

Let us consider the classification of gearboxes (of ZAZ-1102, GAZ-66, ZIL-130, MA3-503a, KAMAZ-5320, KrAZ-260, VAZ-2121 vehicles) according to the accepted classification system shown in Fig. 13.1.

Types of manual transmission

Two-speed manual transmission

Two-shaft gearboxes (Fig. 13.2) are used in front-wheel drive and rear-wheel drive (rear-mounted engine) cars. Structurally, they are combined in one unit with the engine, clutch, final drive, and differential.

The transverse arrangement of the gearbox allows the use of a main gear with cylindrical gears. The longitudinal arrangement uses a main gear with bevel or hypoid gears; the latter is more difficult to manufacture and adjust.

Main advantages of dual-shaft gearboxes:

– simplicity of design;

– small mass;

– high efficiency in intermediate gears (when transmitting torque moment only one pair of gears is involved).

At the same time, there is no direct transmission in a two-shaft gearbox (when gears do not participate in the transmission of torque) and the maximum efficiency in the highest gear is lower than in the direct transmission of a long-stroke gearbox.

The maximum gear ratio of one gear pair of the gearbox should not exceed a certain limit, close to 4, exceeding which leads to an increase in dimensions and an increase in the noise level. This

Figure 13.1 – Classification scheme for automobile gearboxes

limits the scope of application of twin-shaft gearboxes to small passenger cars only. If the engines with such boxes are installed transversely in the front of the car, then for the designers of twin-shaft gearboxes, increasing the number of gears, and therefore the number of pairs of gears, presents certain difficulties. A longitudinal gearbox can easily be increased in length to accommodate additional gears. A transversely located engine and gearbox have a width limitation determined by the distance between the wheel arches of the car.

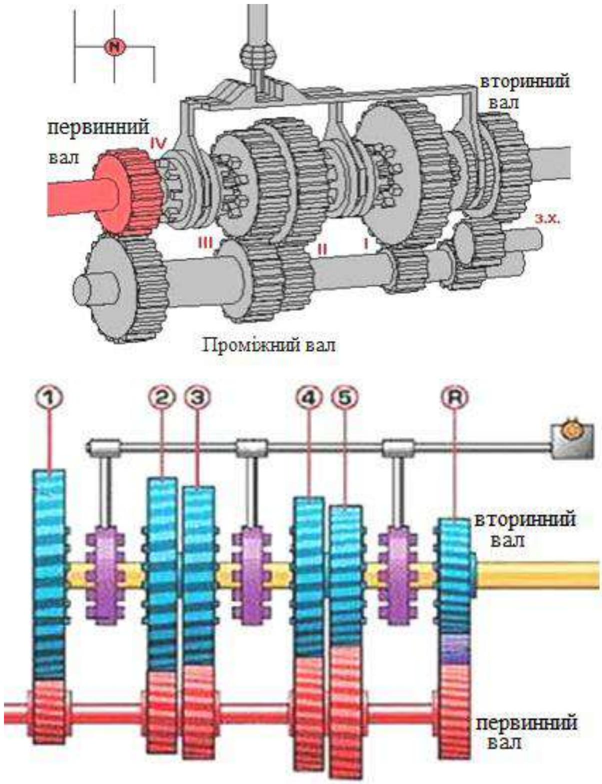


Figure 13.2 – Long-shaft and double-shaft gearboxes

Long-term MCPs

On cars with a classic layout, long-stroke gearboxes are usually used (Fig. 13.3–13.4). A feature of such cars is that it is almost always possible to distinguish the gear in which they travel most of the way. Therefore, the main advantage of long-stroke gearboxes is the presence of the so-called "direct" gear, which is obtained by directly connecting the primary and secondary shafts. Another advantage of long-stroke gearboxes is the relative ease of obtaining a large gear ratio in the lower (first) gear with a small center distance. This is explained by the fact that the gear ratio of all gears, except for the "direct" one, in such gearboxes is formed by two consecutively operating pairs of gear wheels, unlike one pair in two-shaft gearboxes.

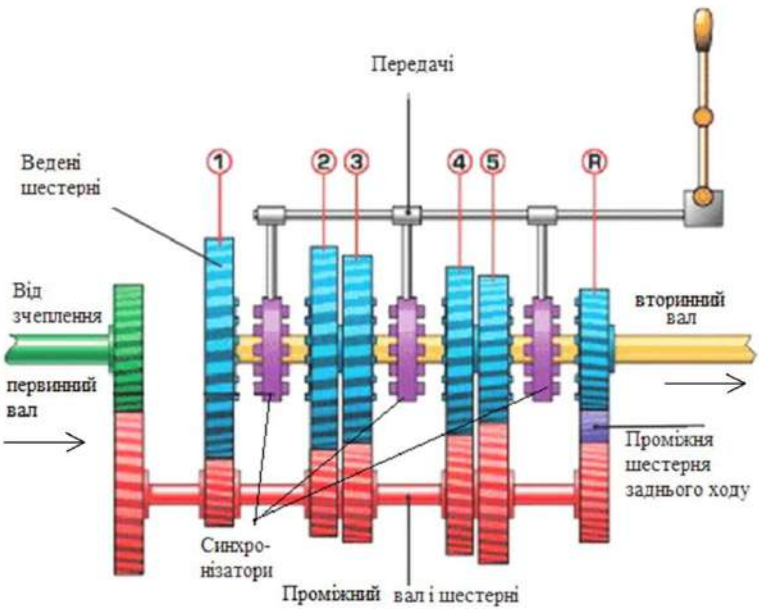


Figure 13.3 – Functional diagram of a long-range gearbox

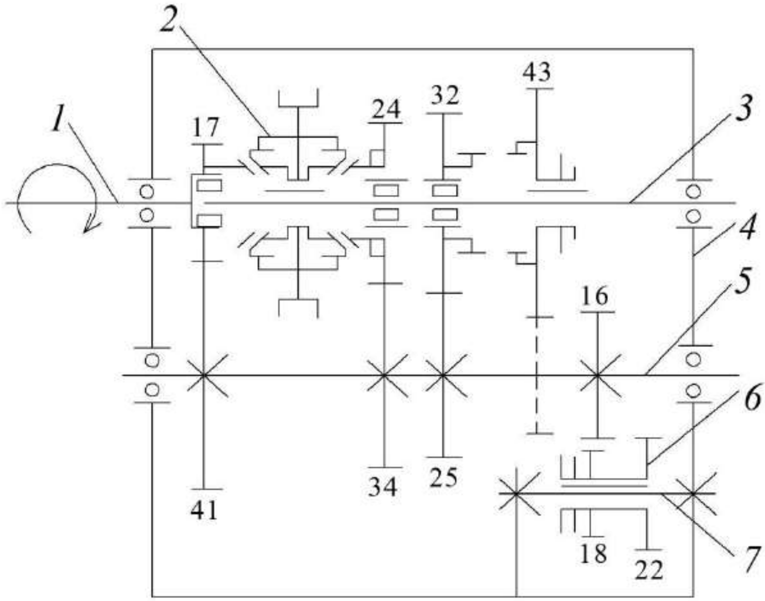


Figure 13.4 – Kinematic diagram of the GAZ-66 gearbox: *1*– input shaft; *2*– synchronizer and clutch for third and fourth gear; *3* – secondary shaft; *4*– crankcase; *5*– intermediate shaft; *6*– reverse gear unit; *7*– reverse axle

The ZAZ-1102 car is equipped with a mechanical, two-shaft, three-speed, five-speed gearbox with five forward gears and one reverse, made in one crankcase with the main gear (Fig. 13.5). All gears, except for reverse, are helical, with constant mesh. The driven gears of the first, second, third, fourth and fifth gears rotate freely on the driven shaft. The driving, intermediate and driven reverse gears are spur. All forward gears are engaged using sliding clutches and synchronizers. The clutches are moved using shift forks. The gearbox housing is cast from magnesium alloy.

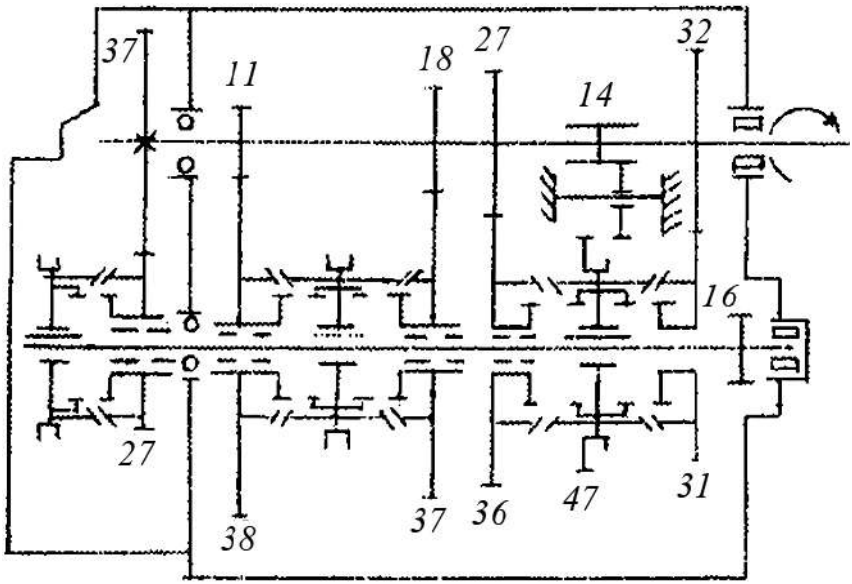


Figure 13.5 – Kinematic diagram of the gearbox of the ZAZ-1102 car

The drive shaft is made in the form of a welded non-separable structure with gear crowns of the drive gears of the first, second, third, fourth gears and reverse. At the rear end of this shaft, a fifth gear drive gear is installed on a key. At the front end of the drive shaft, splines are cut for the clutch driven disk hub.

The driven shaft is made as one unit with the main gear drive gear.

The driven gears of the first, second, third and fifth gears each rotate on two needle bearings, between which a polyamide spacer ring is installed; the fourth gear gear rotates on the journal of the driven shaft.

The gearbox has non-interchangeable synchronizers of the same device, but different in size.

A feature of the KAMAZ-5320 gearbox (Fig. 13.6) is the use of a demultiplier, which doubles the number of gears.

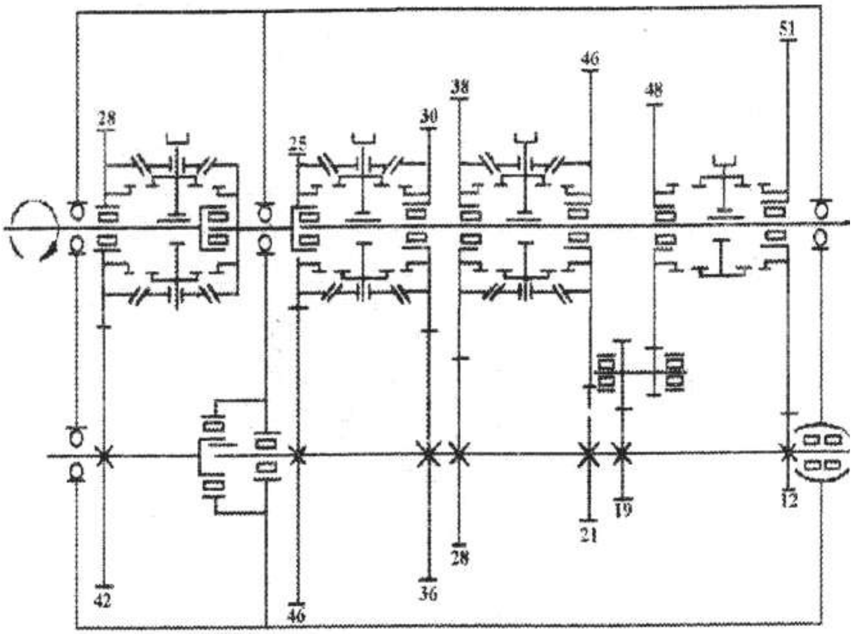


Figure 13.6 – Kinematic diagram of a car gearbox KAMAZ-5320

A feature of the ZIL-130 gearbox (Fig. 13.7) is that it is durable. The design provides for the possibility of installing a power take-off box. The kinematic diagram (see Fig. 13.7) indicates the number of teeth on each gear.

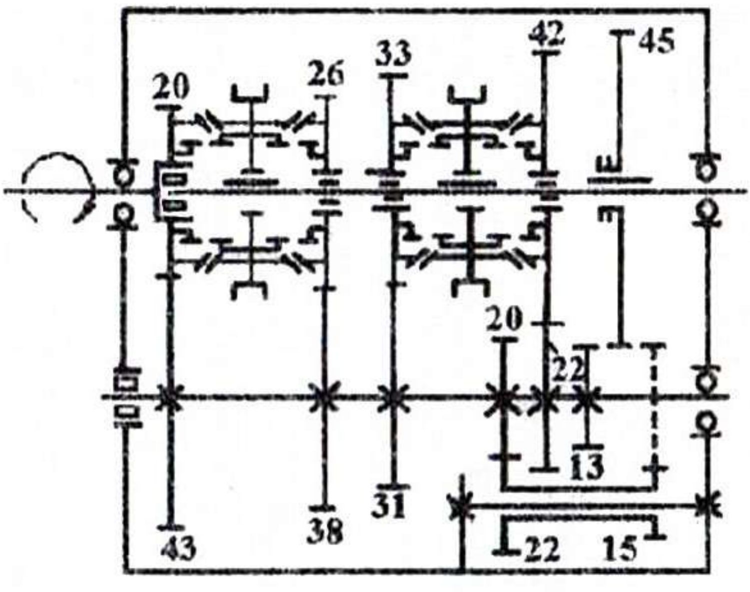


Figure 13.7 – Kinematic diagram of the ZIL-130 gearbox

Synchronizers are installed on the gearbox. The principle of operation of the inertial synchronizer (Fig. 13.8) is related to its purpose - equalization of the angular velocities of the connecting gear and shaft when the gear is engaged. This allows you to reduce noise when shifting gears, increase the durability of the gearbox, facilitate its control, and speed up gear shifting (shifting time 2–4 s). The ability of a simple synchronizer is that it allows, unlike the inertial synchronizer, to shift gears with incomplete alignment of the angular velocities of the connecting parts.

The synchronizer consists of a movable clutch *7*(see fig.13.8) with an external gear ring (involute splines) and an internal spline connection by which it is connected to the shaft *11*, retainer *9*, which connects the gear coupling to the housing *4* synchronizer. Housing The synchronizer has a conical friction surface, often with special with pads; the angle α of the cone is 7–10°. The conical surfaces with the same angle also have the engagement gears mounted on bearings; the gears also have internal gear rings 6 (involute splines). The synchronizer is controlled by a fork lever through the engagement clutch.

In the neutral position, the synchronizer gear clutch is held by a fork lever, and the synchronizer housing is held by a retainer. *9*, driven gears *10* and *8* with a driven shaft *11* are not connected. When When the gear is engaged, the fork lever acts on the finger *3* and moves gear coupling *7*.

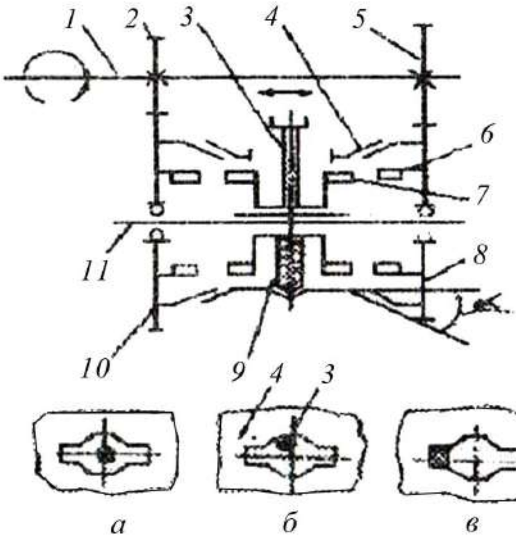


Figure 13.8 – Schematic diagram of an inertial synchronizer

At the initial moment, the coupling, through the retainer, also captures the housing. *4* with a friction cone; both parts will move as one unit until the housing with its inner conical surface comes into contact with the outer conical surface of the gear *10* or *8* Due to the friction between the conical surfaces, the angular speed of the engagement gear and the shaft synchronizer associated with the clutch *11* gradually level out. With further increase in effort on gear shift levers gear clutch *7* moves towards the past gear, overcoming the resistance of the retainers, and engages with the internal gear ring of the gear; the transmission is engaged. Torque from the drive shaft *1* transmitted through steam gears *2*, *10* or *5*, *8*, toothed connection *6* gear with clutch *7* synchronizer, and then through the splined connection of the synchronizer clutch with the shaft *11*.

The inertia synchronizer has a special locking device, made in the form of a figured window on the housing. *4* synchronizer; through This window is a finger pass. *3*, the neutral position of which is shown in Fig. 13.8, *and*. Until the angular velocities of the connected parts are equalized, the force from the friction moment in the slipping cones presses the finger against the bevel of the figured window and does not allow the finger to move further to engage the gear (see Fig. 13.8, *b*). After equalizing the angular velocities, the friction moment drops sharply, and it becomes possible to move the finger, and with it the gear clutch, to the position corresponding to the engaged gear (see Fig. 13.8, *in*), the detents in the inertial synchronizer play a supporting role.

The design of the inertial synchronizer of the gearbox is shown in Fig. 13.9.

Simple synchronizers

A simple synchronizer consists of two main elements:

– leveling – friction device that absorbs energy tangential forces of inertia of rotating masses;

– engaging – gear clutch that engages the transmission.

In a simple synchronizer, unlike an inertial synchronizer, there is no blocking element. It is installed, as a rule, on lower gears. The use of a simple synchronizer on these gears is due to the fact that large gear ratios are implemented on them.

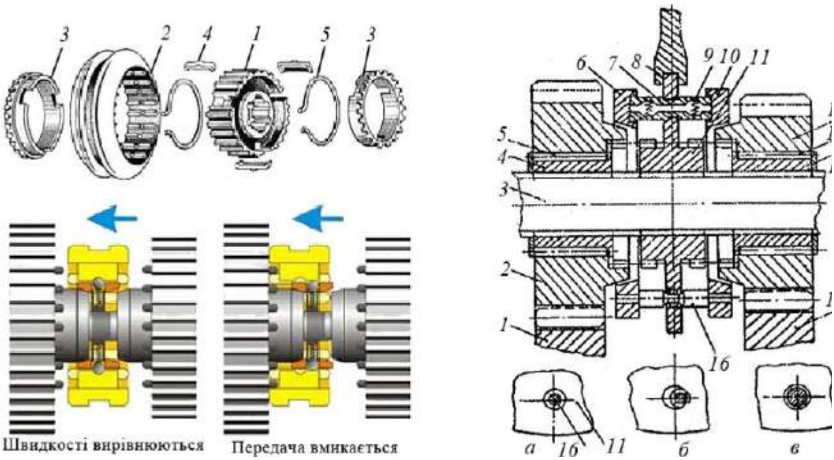


Figure 13.9 – Transmission synchronizer diagram:
and– the position of the locking finger relative to the flange of the gear coupling when the synchronizer is in neutral position;*b*,*in*– the initial moment of equalization of angular velocities;*and*– with equality of angular velocities engaging the transmission

In this case, the inertia moment and the clutch torque (in the case of its incomplete disengagement) brought to the synchronizer cones reach relatively large values, which significantly prolongs the gear shifting process due to the prolonged slippage of the above-mentioned cones. Under these conditions, a simple synchronizer allows you to engage the gear in a short period of time with incomplete alignment of the angular velocities of the connected parts.

Let's consider the design of a simple synchronizer. If, when the transmission is engaged, a force is applied to the clutch that immediately exceeds the resistance of the retainer balls, then it will approach the gear ring gear until their angular velocities are equalized, and the transmission will be engaged with a clash of teeth. It should be noted that in a simple synchronizer, the retainers are the main element of the design, since they set the force on the conical friction surfaces.

The synchronizer consists of a movable gear clutch *11* with with a flange in the middle, two conical rings *6* and *10*, three locking fingers *16* and three latches consisting of two half cylinders *7* and two springs *9* each.

The synchronizer gear coupling (carriage) has two gear rings (involute splines), holes for locking fingers and retainers are made in the coupling flange. The holes in the gear coupling flange have conical chamfers, and in the middle part of each finger there is an annular groove with the same chamfers. The locking fingers rigidly connect both conical rings together.

In the neutral position, the synchronizer carriage is located in the middle between the gears, the locking fingers occupy a floating position (see Fig. 13.9, *and*), the cone rings are held in the neutral position by the retainers. When the transmission is engaged, the fork lever *8* moves the gear coupling by the flange *11* to the gear *2* or *12* engaged gear; the conical ring is captured by the retainer and is brought into contact with the conical surface of the gear. Due to the difference in angular velocities of the gear and the shaft connected to it *3* carriages synchronizer, the conical ring moves relative to the carriage flange, the grooves of the locking fingers *16* contact the chamfers of the flange holes; locking fingers prevent further movement of the carriage (see Fig. 13.9, *b*). After equalizing the angular velocities of the gear and the conical ring (and the driven shaft, respectively) *3*) the chamfers of the locking fingers are “released”, the fingers take a floating position, the carriage is able to move further to the engaged gear; overcoming the resistance of the lock, the fork lever moves the carriage until its gear ring meshes with the internal teeth of the gear (see Fig. 13.9, *in*). Thus, smooth gear shifting is ensured. Using posters and models,

independently study the design and draw up a structural diagram of the synchronizers of gearboxes of MAZ, KrAZ, KAMAZ vehicles.

Using posters and bearing assemblies of models, to characterize the shafts of these gearboxes.

Using posters and models of gearboxes, study the gearbox control mechanism, the oscillating engagement lever mounted on a ball bearing, sliders (travel rollers), fork levers, latches, locking device, reverse safety device. Draw a diagram of the locking device and latches.

Using the posters, study the lubrication system of the provided gearboxes: splash, forced, combined. Describe the seals.

To analyze the compliance of the considered gearbox designs with the requirements: ensuring the required gear range, rational distribution of gear ratios, high efficiency, speed and ease of gear shifting, protection against self-disengagement and ensuring the impossibility of simultaneously disabling two gears, reliability, durability, ease of manufacturing, maintenance and repair.

For the gearboxes under study, characterize the materials of the main parts and justify the use of materials (Table 13.1).

Get acquainted with the features of the Borg-Warner-35 automatic transmission (Fig. 13.10).

Automatic transmissions:

– the main advantage of the machine is its ease of control.

Disadvantages:

– low efficiency (due to turbine slippage in the oil bath);

– increased fuel consumption;

– complexity of the device, which causes reliability to be lower than in "mechanics" and problems with repairs and maintenance;

– high cost;

– dynamic indicators are lower than those of the MCP;

– towing problems.

Nowadays, automatic transmission is widely used. It greatly simplifies driving. This is especially noticeable in heavy city traffic. The automatic transmission consists of a torque converter and a mechanical part. Gear shifting occurs automatically using a centrifugal regulator. *15,* depending on the speed of the vehicle and the degree of pressing the accelerator pedal.

The automatic transmission has three forward gears and one reverse gear. The transmission includes a torque converter and a mechanical part.

Torque converter designed for stepless changes torque (Fig. 13.10). It consists of a turbine wheel *1*, pump wheel*2*and reactor wheels*3*, connected by a bypass

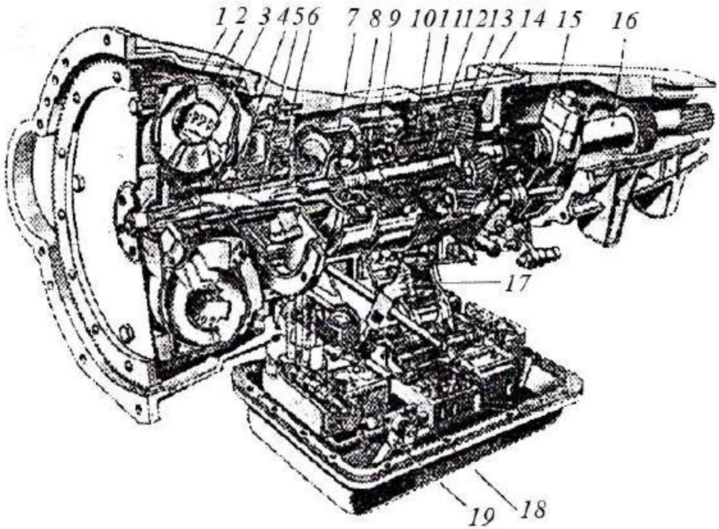


Figure 13.10 – Borg-Warner-35 automatic transmission:
1– turbine wheel;*2*– pump wheel;*3*– reactor wheel; *4*– reactor shaft;*5*– input shaft of the planetary gearbox;*6*– main oil pump;*7*– frictionII and III gears;*8*– brakeI and II gears;*9*– frictionIII gear and reverse gear;*10*– coupling freewheeling of 1st gear;*11*– reverse brake;*12*– the first countershaft;*13*– second intermediate shaft;*14*– drum with teeth crown;*15*– centrifugal regulator;*16*– secondary shaft; *17*– gear shifting mechanism;*18*– throttle valve; *19*– cam

couplings with fixed tubular shaft *4* gearbox. Pump wheel *2* rigidly connected to the engine flywheel and receives torque from it. Turbine wheel *1* attached to the front end of the primary shaft *5* planetary gearbox.

The mechanical part, consisting of a planetary gearbox, is designed for three-stage change and transmission of torque from the input shaft. *5* on the secondary shaft *16*. The brake is used to engage first gear. *8* and freewheel clutch *10*. To disengage second gear, a clutch is used. *7* and brake *8*. To disengage third gear, friction clutches are used. *7* and *9*. A clutch is used to disengage reverse gear. *9* and brake *11*.

The main materials of the box parts are given in Table 13.1.

Table 13.1 – Materials of main parts of gearboxes

Part name	Materials	Note
Casing	Cast iron SCh18, SCh21	
Gears	Steel 12KHN3L, 15KHGN2TA, 20KHGM, 25KHGM, 25KHGT, 25KhGNR	Cementation, hardening, HRC 60...62
Auxiliary gears	Steel 35X, 40X, 45	Hardening
Drive shaft	Steel 15KhGN2TA, 18KhGT, 20KhGNM, 30 KHT	Cementation, hardening
Intermediate shafts and secondary	Steel 25 KhGT, 35X, 38XS	
Rear axle	Steel 40X, 45	
Carriage synchronizer	Steel 15KHGN2TA, 25KHGT, 25 HGM, 40X	Cementation, hardening
Friction cone	Alloy LMTSSKA 58-2-2-1-1	

Junction boxes

Task:

• classify automobile transfer cases GAZ-66, KrAZ-255B, KrAZ-260 according to the adopted classification system (Fig. 13.11).

• study the kinematics of a car's transfer case GAZ-66 (Fig. 13.12). Indicate the power flows at different operating modes, determine the gear ratios.

• study the design of the transfer case using posters. Using posters and models, independently draw up kinematic diagrams of transfer boxes of KrAZ-255B, KrAZ-260 vehicles. Identify and describe the main components of the specified transfer boxes.

Figure 13.11 – Classification of transfer gearboxes

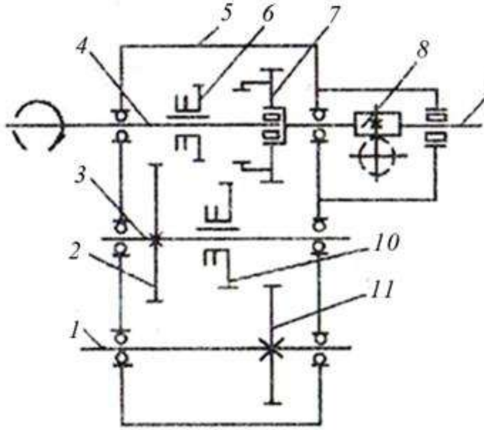


Figure 13.12 – Kinematic diagram of the transfer case GAZ-66 car:
1– front axle drive shaft;*2*– driven gear reduction gear;*3*– intermediate shaft;*4*– drive shaft (primary); *5*– crankcase;*6*– drive shaft gear;*7*– driven shaft gear;*8*– speedometer drive;*9*– driven shaft (rear axle drive shaft);*10*– movable gear of the intermediate shaft;*11*– driven gear of the drive front axle

The model of the RC with a locked drive is shown in Fig. 13.13.

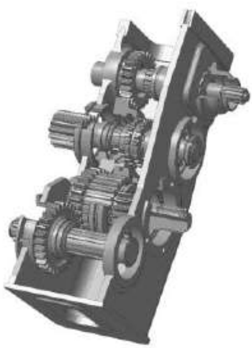


Figure 13.13 – 3D model of the LCD

Review questions

1. Purpose of gearboxes, their place in the car's transmission.
2. Main features of gearbox classification.
3. The most common types of automotive gearboxes.
4. Selection of range and number of gears depending on the purpose car.
5. Main components and parts of the gearbox.
6. Gear shifting mechanism. Locking device, latches, safety device.
7. Principle of operation, design, operation of the gearbox synchronizer.
8. Bearing assemblies.
9. Gearbox seal. Lubrication system.
10. Adjustment and maintenance.
11. Materials of the main parts of the gearbox.
12. Basic requirements and compliance with them of the CP for the task.
13. Promising design solutions for car gearboxes.
14. Purpose of the RC, its place in the car's transmission.
15. Main features of the classification of the RC and its development prospects.
16. Classification of the given RC, its kinematics. Gear ratios.
17. Main components and parts of the LCD. Design and operation.

Laboratory work 14
POWER TAKE-OFF BOX

Purpose of work– study the types of power take-off boxes (PTO), used in cars: general structure, purpose and operation of the mechanism.

Visual aids:

• albums, instructions and posters on the design of the control system;

• electronic information material on structures

modern control systems;

• KVP in section;

• cars.

Tasks for work:

• identify the types of control systems currently used in modern cars;

• study the components of the control system. Indicate their purpose;

• define and present schemes of control systems and their drives;

• study modern control systems of mechanical engineering.

General information

A power take-off box is an element of a truck and special equipment that serves to drive working elements using a hydraulic pump or cardan shaft.

The power take-off is a device by which the torque of the engine of the power plant is transmitted to the working equipment: pumps, winches, compressor units, etc. The purpose of the power take-off box is to move the working equipment through the box itself or an intermediate mechanism (cardan shaft or hydraulic pump). Such a device is not a mandatory component of the gearbox.

Power take-off boxes are distinguished by the following parameters:

– the number of stages in the device;

– the value of the gear ratio;

– number of shafts and their placement;

– with and without reverse;

– a type of control system.

The latter parameter, in turn, is divided into the following: electro-pneumatic, mechanical, or hydraulic.

In addition, there are dependent and independent gearboxes. The former are switched on only when the clutch pedal is depressed. They are essentially combined with the gearbox. This unit cannot be used when the equipment is moving. Among the positive qualities of this option, one can note the economy of engine power and the low weight of the device.

An independent power take-off box is necessary if it is to function properly on a moving or stationary vehicle with the clutch engaged or disengaged. The specified models are compatible with power plants and gearboxes of any type. The situation is similar with their control system, it may be different.

For example, on basic fire engines with special units (fire pump), in addition to the main transmission for driving the drive wheels, an additional transmission is installed. As a rule, on fire engines to drive special units, engines of the base chassis are used. Only on mobile pumping stations, fire engines of the airfield service (heavy type) and some PAs with ESU there is a separate engine for driving the pump.

For example, the following types of additional transmissions are installed on fire trucks:

– mechanical;

– hydraulic;

– electric;

– combined.

For driving a fire pump, the most common additional mechanical transmission is one consisting of a gearbox, cardan shafts, intermediate supports and transmission control system. The control unit according to the first variant is installed instead of the gearbox covers.

The gearbox according to the second variant is made in the form of a separate gearbox.

The gearbox is installed in transmissions according to the third option instead of the cover on the transfer case.

The use of gearboxes is common on many trucks for various purposes. The drive can be organized as follows.

Classification of KVP according to company data*ZF*are given in table.14.1.

Table 14.1 – Application of KVP

	N.../1	N.../4	N.../10	NMV	N.../PL	
	Taken from clutch			Given from engine	Synchronous-ny (dependent from regime	Debkoiltyk)a drives
Dump truck	-	-				
Cargo crane	-	-				
Articulated support	-	-				
Car-tank for loose cargo and fuel	-		-			(x)
Garbage can			-			
Fire department machine			-	-		(x)

Continuation of Table 14.1

Concrete pump			-	-		(x)
Cars for washing and pumping dirt			-	-		(x)
Concrete mixer				-		
Truck crane (some steered axes with and/or second contour steering wheel management)			-		-	(x)

There are 3 possible types of KVP drive options (Fig. 14.1).

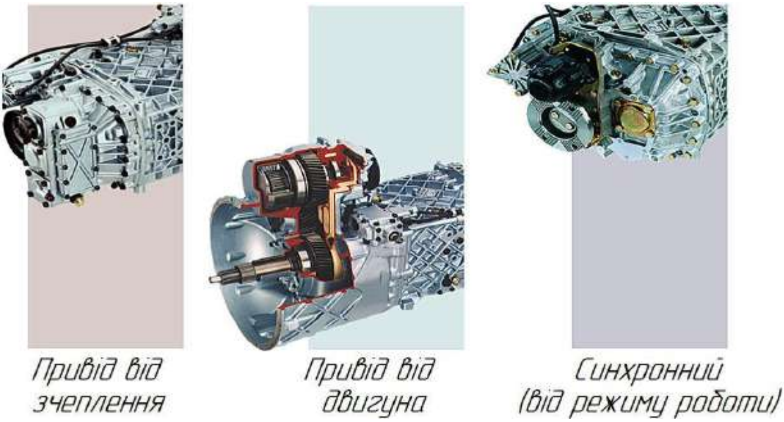


Figure 14.1 – Variants of KVP drive types

Types of KVP variants and their drives are shown in Fig. 14.2.

N.../1	Простий × економний × вантажопідйомний × безперервна експлуатація	Привід від зчеплення
N.../4	Зміщення осі (вільне місце для карданного вала) × більш висока кількість обертів × короткочасний режим роботи	
N.../10	2 приводи × кілька передаточних відношень × дуже вантажопідйомний × безперервна експлуатація	
N.../PL	При їзді відразу в експлуатації × економне місце × можна комбінувати з іншими КВП × ідеально для систем кермового керування з 2-ма контурами	Синхро-нний
NMV	Прямий електропривід × найвища вантажопідйомність × безперервна експлуатація × перемикається під навантаженням	Привід від двигуна

Figure 14.2 – Main characteristics of types (variants) of KVP

Usage examples:

– dump truck, loading crane, swap body (Fig. 14.3);

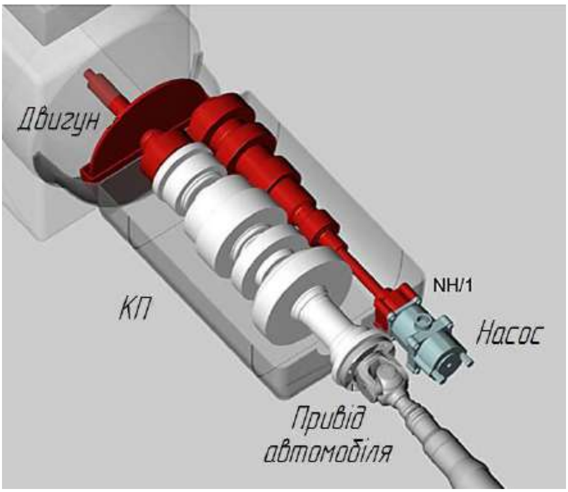


Figure 14.3 – Control system for dump truck, cargo crane, mobile container

– tank truck for bulk cargo (Fig. 14.4);

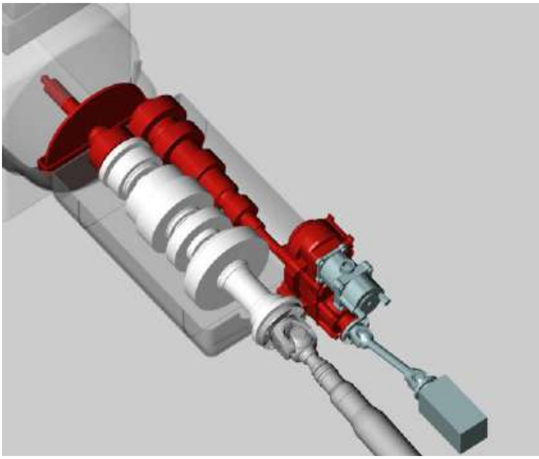


Figure 14.4 – Tank truck control system for driving pumps transportation of bulk cargo

– garbage collection (compression) (Fig. 14.5);

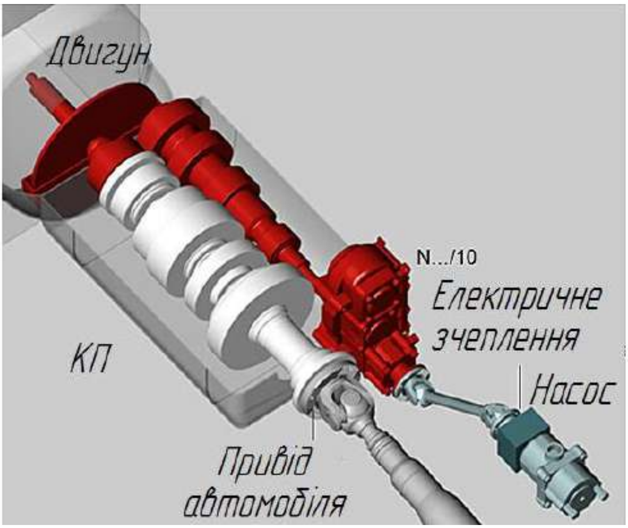


Figure 14.5 – KVP with drive for collecting (pressing) devices garbage – fire trucks for airfields

– for fire engines (Fig. 14.6);

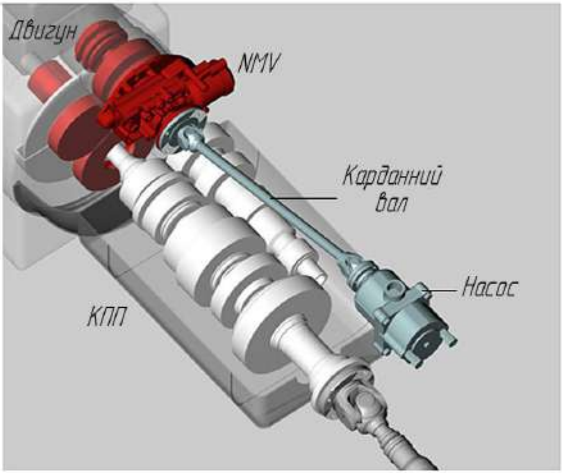


Figure 14.6 – Fire truck control systems for airfields

– concrete pump (Fig. 14.7);

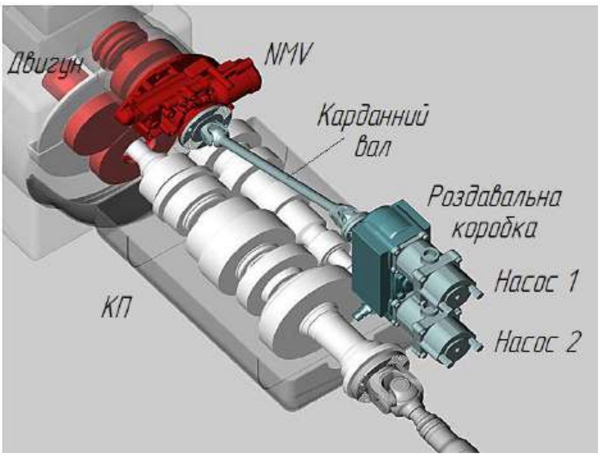


Figure 14.7 – Concrete pump control unit drive

– a vehicle for washing/pumping out dirt (Fig. 14.8);

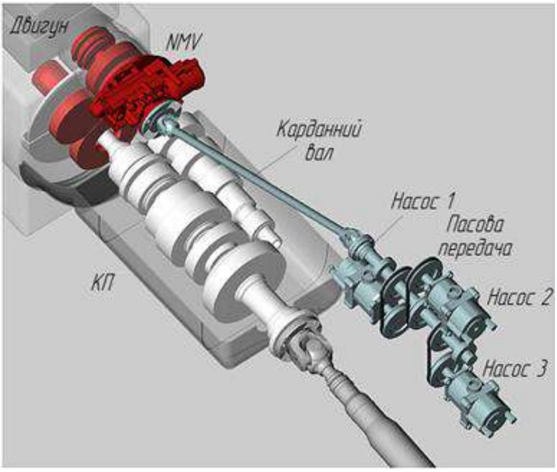


Figure 14.8 – Vehicle with a pump drive mechanism
for washing/pumping out dirt

The operating diagram of a clutch-driven gearbox is shown in Fig. 14.9.

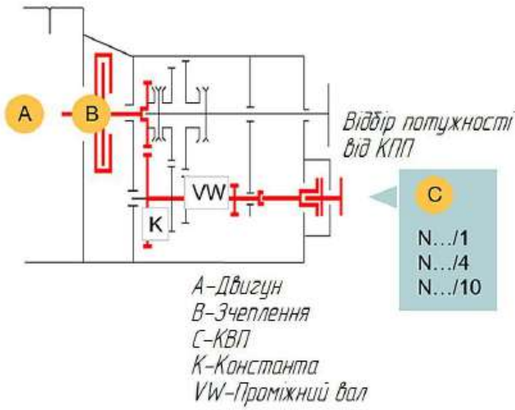


Figure 14.9 – Scheme of the drive for the operation of the control unit

Clutch driven gearboxes N.../10

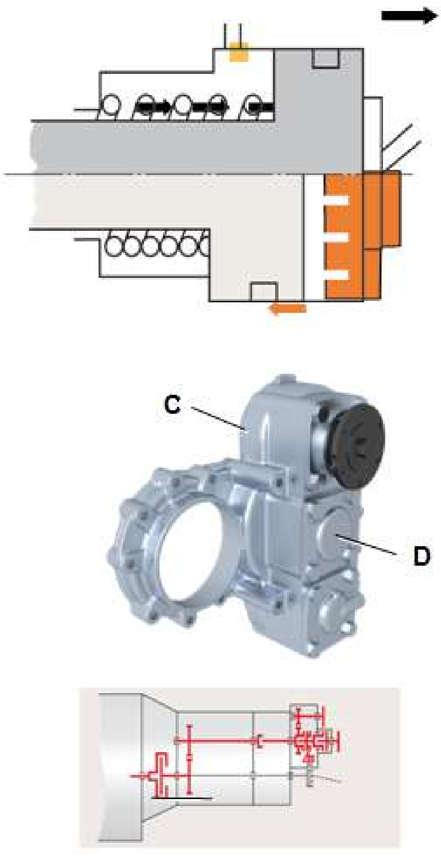


Figure 14.10 – Clutch-driven gearbox

Possible option for using the drive *WITH* or *D* This changes the direction of rotation.

Synchronous KVP

Type *N...PL* active while the car's wheels are turning. It can actuate the power steering pump.

– Type: *N...PL* for a synchronous drive (Fig.14.11):

– steering pump (e.g., truck crane), spare pumps steering (special purpose vehicles, attachments);

– direction of rotation of the drive – as in the engine;

– operating mode – continuous operation;

– no switching, constantly rotates with the wheels;

– the rotation frequency depends on the speed of movement.

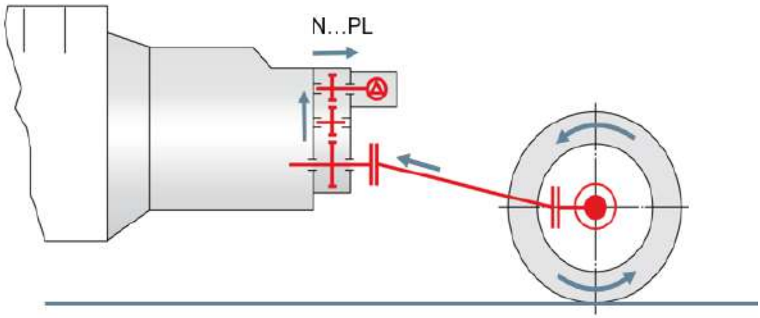


Figure 14.11 – Synchronous KVP

Operation of engine-driven control equipment (NMV 221) – special clutch with direct through drive for *NMV* (Fig. 14.12).

Design features:

– multi-plate clutch controlled by a hydraulic drive, which switches under load;

– pneumatic control valve;

– oil pump (with filter for hydraulic multi-disc clutch);

– power take-off flange *NMV*;

– hollow shaft with a cylindrical gear wheel.

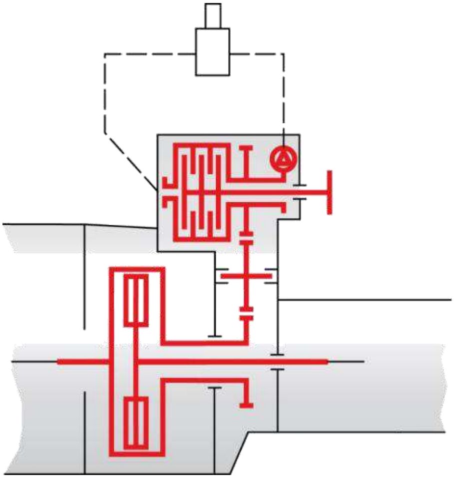


Figure 14.12 – Operation of the control unit during drive from the engine (*NMV*221)

Variants of the specified execution and the main parameters of the control system are shown in Fig. 14.13.

КВП	Допустимий крутний момент	9 S 1110 TD	9 S 1310 TO
		12,91-1,0	9,62-0,75
Тип	Нм	Коефіцієнт f	
NH/1	800	0,72	0,97
NH/4	430	0,92	1,24
N 109/10 „C"	410-630	0,88-1,42	1,19-1,90
N 109/10 „D" NL/1	600	0,72	0,97
N 109/10 „D" NL/4	430	0,92	1,24
N 109 PL	-	Коефіцієнт g=1,85	

Figure 14.13 – Execution options and KVP parameters

Italian company *OMFB* manufactures control units for many cars (Fig. 14.14). The designs differ in execution. This takes into account the parameters of gearboxes, transfer cases. The control systems also differ.

Figure 14.14 – Options for the firm’s KVP *ATFMB* for various cars

A variant of one of the company's KVP designs*OMFB*submitted in Fig. 14.15.

Figure 14.15 – Firm’s CPI*OMFB*

The operating range shown in Fig. 14.16 is specified in advance.

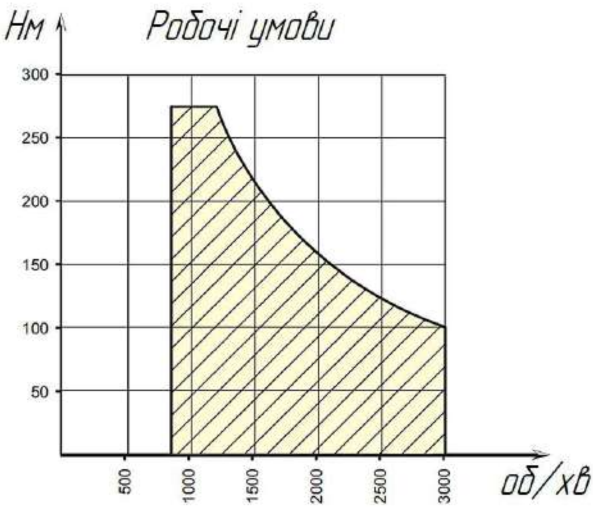


Figure 14.16 – Torque vs. RPM in the operating range

Example constructive parameters KVP depicted in Fig. 14.17.

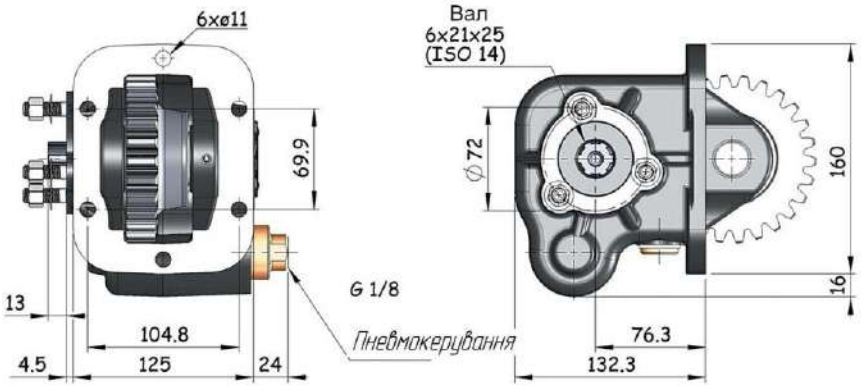


Figure 14.17 – Main structural dimensions of the control unit

The manufacturer's data for this version of the control unit is given in Table 14.2.

Table 14.2 – Manufacturer's data on the KVP *YAMZ*236

Type KVP	Code KVP	Version	Rotation frequency KVP at 1000 rpm engine	Maximum moment, N m	Mont. flange	Entrance	Rotation	Mounting kit	Mass, kg
YAM Z 236	86-71-139	13	950	280	right	Behind	In an hour. arrow	154-3-3053	7.6

Breakdowns that periodically occur with the box are different. You need to understand how the power take-off box works in its original state in order to notice failures in time. Some can be detected and fixed independently, without sending the car to a service center. Here are some of these malfunctions:

– increased noise – the cause may be incorrect engagement gears;

– the mechanism does not turn on, poisons the air – you need to check whether the diaphragm in the pneumatic control chamber is not damaged;

– the node cannot be fully turned on – it is probably out of order return spring;

– leakage of working fluid on the flanges – a breather has been noticed or seals have developed.

For most other malfunctions, you need to seek the help of professional craftsmen who use special equipment for inspection and repair.

Review questions

1. Purpose of the KVP.
2. By what parameters are KVPs distinguished?
3. Give the classification of KVP according to the company data*ZF.*
4. What other companies manufacture KVP?
5. What types of KVP drives are there?
6. Give the main characteristics of the types (variants) of KVP.
7. What examples of using KVP do you know?
8. Describe in detail the scheme of operation of the control unit.
9. Variants of control systems for automation.
10. List the main design parameters of the control system.
11. How is the switching on of the control unit controlled?
12. What does synchronous drive of a gearbox mean?
13. What are the possible failures of the KVP?
14. How to connect the gearbox and transfer case?

Laboratory work 15
AUTOMATIC CLUTCHES

Purpose of work– study the purpose, design and operation modern automatic clutches used in automobile transmissions.

Visual aids:

• albums, instructions and posters on the construction of automatic clutches;

• electronic information material on the designs of automatic clutches;

• automatic clutch in the section;

• car.

Tasks for work:

• study the design and operation of automatic clutches;

• determine the design features and operating procedure of dual clutches;

• determine the torque that the clutch of a given cars and trucks.

General information

Automation of the operation of friction disc clutches is carried out in order to simplify and facilitate the processes of starting a car and shifting gears while driving. The frequency of use of the clutch is quite high. In urban conditions, in heavy traffic, a passenger car makes more than 100 stops per 100 km of run, the driver makes more than 1000 gear changes. On city buses, gear changes occur with greater intensity: up to 3000 shifts per 100 km of run.

The relevance of automating the clutch operation is also due to the constant improvement of the car design, which is accompanied by an increase in the indicators of dynamic properties, an increase in passenger capacity and load capacity of vehicles.

The automatic clutch provides the following basic components of clutch control without driver intervention:

– selection of clutch engagement moment and friction torque adjustment in the T clutch$_{zch}$when the car starts moving;

– selection of switching off moments – engagement of the clutch during gear shift;

– selection of the moment of shutdown when the car stops.

In each of the above cases, the driver does not participate in the processes of selecting the rate of change of the clutch friction torque and the moments of clutch engagement and disengagement. Sensors and instruments of the automatic control system allow to evaluate and take into account various factors: speed and driving conditions, engine operating mode, engaged gear, and others.

The following additional requirements apply to the operation of the automatic clutch:

– fast (less than 0.25 s) clutch disengagement and smooth, according to the legally specified change T_{zch}, switching on after shifting gears;

– clutch disengagement when angular speed decreases crankshaft to idle speed ω_{xx}.

Modern automatic control systems (ACC) for clutch operation are characterized by a division according to the degree of automation of the workflow, the justified feasibility of using the ACC, and the design features of the vehicle.

In a fully automatic clutch, the law of change of $T_{zch}$is formed depending on the combination of engine, transmission and vehicle driving parameters using control systems that include sensitive elements (sensors), a processor, switching and actuators. In some cases, clutch operation automation may apply to individual operating modes, for example, when shifting gears.

Most often, when solving problems of automating clutch operation, several constructive types of clutches are used.

A centrifugal disc clutch (centrifugal clutch) provides a significant simplification of control. The car starts from a standstill without pressing the clutch pedal, automatically, with an increase in the engine crankshaft speed. When the engine speed decreases, the clutch automatically disengages and prevents the engine from stalling. In a centrifugal clutch (Fig. 15.1), the friction torque is adjusted depending on the engine crankshaft speed. The engine crankshaft is rigidly connected to the casing *1*, on which the hinged supports are located *5* cargo *4*. Centrifugal force of loads *4* is transmitted to the jet disk clutch *8*.

When the engine is idling ($\omega_{there\ are}= \omega_{xx}$) compression springs *7* overcome total centrifugal force of the loads *4*, jet disk *8* shifts right and acts on the pin *6*. Simultaneously shifts to the right rigidly connected to the pin *6* pressure plate *3*. The clutch is disengaged.

As the engine speed increases, the centrifugal force F_c cargo *4* is transmitted to the jet disk *8*. Disk *8* shifts to the left, overcoming force F_0 pressure springs *7*, resting on a fixed rigidly connected to the casing *1* resistance. Compression springs *9* are compressed.

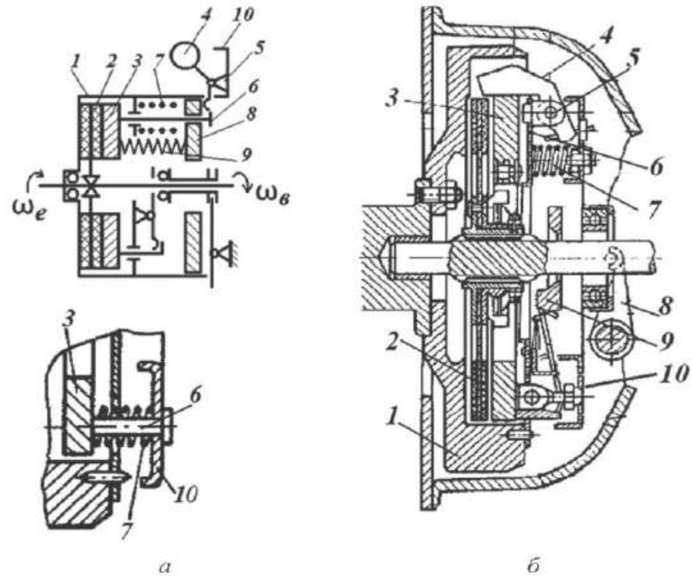


Figure 15.1 – Disc clutch with centrifugal mechanism:
and – scheme; *b* – construction

Pressure plate *3* presses the driven disk *2* to the flywheel. Moment clutch friction T_{zch} increases in proportion to the square of the angular velocity of the crankshaft:

$$T_{zch}=f(\omega_e^{2}).$$

Maximum value of T_{zch} is determined by the maximum value of the elastic forces of the springs *9*, the deformation of which is limited by the movement of loads *4* to the stops *10*.

A disc electromagnetic clutch with a rotating core ensures the implementation of any law of change in the friction torque T_{zch}, which is set by changing the power signal - the magnitude of the current or voltage in the excitation winding. Despite the increase in energy consumption, the simplicity of the clutch design and the method of forming the given characteristic T_{zch} provide the possibility of its use on cars with a small mass. Electromagnetic clutch with a rotating (moving) core (Fig. 15.2, *and*, *b*) consists of a flywheel *1* with casing *4* and rigidly fixed on with a fixed armature of an electromagnet *5*.

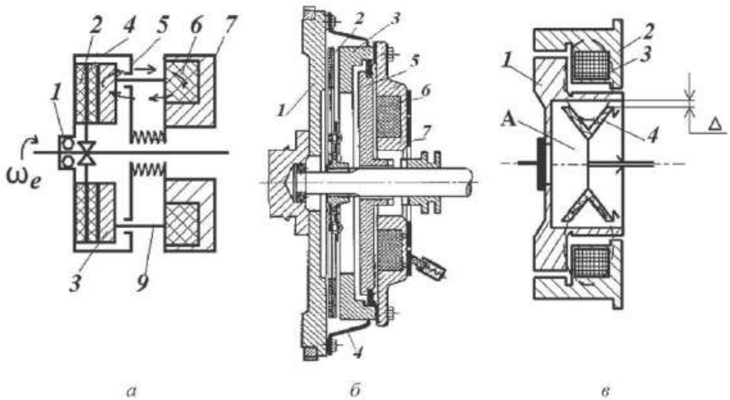


Figure 15.2 – Electromagnetic clutch:
and – scheme with a rotating core; *b* – design with a rotating core;
in – with powder ferrofiller

Moving core *7* with a ring located inside it excitation winding *6* attached to the pressure plate *3* by means of pins *9* When applying excitation to the winding *6* supply voltage an electromagnetic field arises, and the core *7* is attracted to the anchor *5*, and the pressure plate *3* presses the driven disk *2* to the flywheel *1* The magnitude of the friction torque depends on the magnetic flux density *IN* and from the magnitude of the active area of the poles of the electromagnet *S*:

$$T_{zch} = 0.0406 \cdot IN^2 \cdot S.$$

The electromagnetic clutch with a powder ferrofiller (Fig. 15.3) consists of a fixed housing *2*, mounted on the clutch housing. In the housing *2* excitation winding installed *3*. Clutch drive part *1* connects to the engine crankshaft, and the driven part – rotor *4*, fixed at on the driven shaft. Cavity *AND* The coupling and the gap Δ are filled with chemically pure iron powder. When the current is excited in the winding *3* iron powder particles form "hard threads", connecting the driven part of the clutch *4* with the leading part *1* The strength of the threads determines the friction moment of the coupling T_{zch} and depends on the magnitude of the magnetic field strength created by the excitation winding *3* The magnitude of the clutch friction moment T_{zch} is regulated by the current strength of the excitation winding using a control system that provides the required intensity of change in T_{zch} .

Electromagnetic powder clutch(Fig. 15.3) has become somewhat common on small cars.

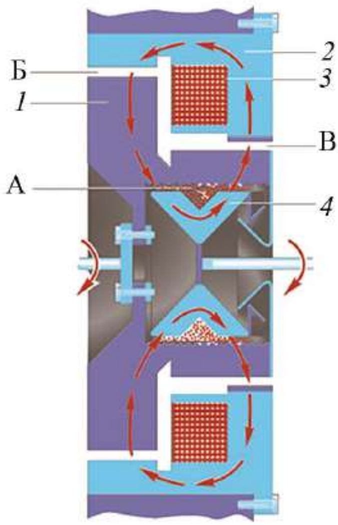


Figure 15.3 – Electromagnetic powder clutch: *AND*, *B*, *IN* – gaps; *1* – the leading part; *2* – fixed body; *3* – excitation winding; *4* – driven part

The clutch drive element is a flywheel with magnetic circuits with excitation windings fixed to it. The driven disk is fixed to the drive shaft of the gearbox. There is an air gap between the magnetic circuits and the driven disk, into which a special friction powder with high magnetic properties is introduced. In the absence of current in the excitation windings, there is no force connection between the driving and driven clutch elements - the clutch is turned off. If an electric current is supplied to the excitation windings, then due to the formation of a magnetic field, the powder particles line up along the lines of force of the magnetic field, and a force interaction is created between the driving and driven clutch elements. The force connection depends on the strength of the current entering the excitation winding. The main advantage of this design is that the clutch control can be transferred from the clutch pedal to a manual, push-button control option, which is relevant for drivers with limited physical abilities.

Automatic electronic clutch control system Electronically

controlled clutches are used on vehicles equipped with robotic or manual transmissions. When using an automatic clutch with an electronic control system (ECS), the driver shifts gears but does not depress the clutch pedal. The clutch pedal may be absent.

The clutch is engaged and disengaged when starting, shifting gears, and stopping the vehicle automatically, using electro-hydraulic or electro-mechanical actuators (EMAs). The EMAs operate in accordance with the power signals of the electronic control unit (ECU), which reads and processes information from sensors recording parameters of engine and transmission unit operating processes, brake pedal position, gearshift lever position and speed, etc. Sensor signals are processed using special control system programs.

Important advantages of the considered clutch with ESC are the relative simplicity of the design and reduction of costs for the manufacturer. When using it, it is practically not necessary to change the design of the clutch release mechanism and drive, gearbox and gearshift mechanism.

The automatic system with electronic control provides for the use of designs of disc clutch mechanisms of a permanently closed type with central or peripheral pressure springs. The schematic diagram of the ESC clutch with a pneumatic actuator (VM), operating from a discharge created in an external energy source, is shown in Fig. 15.4.

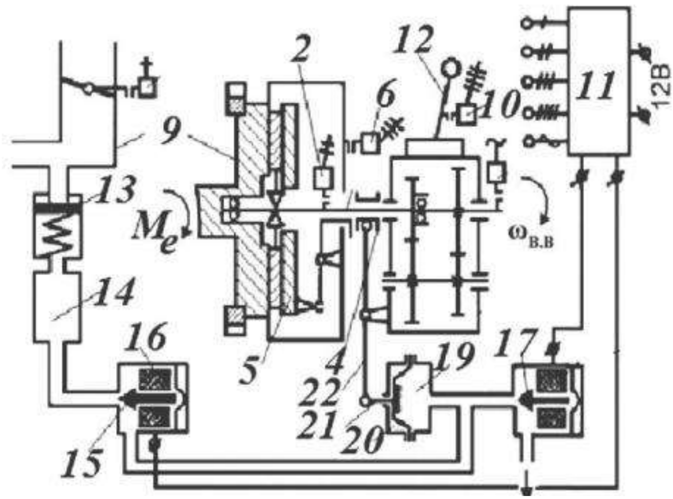


Figure 15.4 – Electronic control system

The VM of the automatic control system is a vacuum chamber*20*, for the operation of which a discharge created in a vacuum receiver is used*14*. Vacuum receiver*14*powered by the intake manifold*9* through a check valve *13*, which provides a discharge in the IM drive for several clutch disengagements when the engine is not running. Depending on the pressure in the cavity*19*VM changes the position of the diaphragm and associated stock*21*, acting on the clutch release fork, and the value of the clutch friction torque T is regulated$_{zch}$.

The vacuum chamber is controlled by two solenoid valves. The inlet (vacuum) normally closed valve*15*with electromagnetic coil *16* connects the vacuum receiver cavity *14* with pressure-controlled cavity *19* VM *20*. Exhaust (atmospheric) normally open valve stem *17* connects the cavity *19* with atmosphere. Valve operation *15* and *17* depends on sensor signals *6*, *2* and *24* (according to the speed of the crankshaft, driven disk and secondary shaft of the gearbox). With the valve open *15* and closed valve *17* pressure in the cavity *19* decreases and the shutdown process begins clutch, friction torque T_{zch} decreases. With the valve open *17* and closed valve *15* pressure in the cavity *19* gradually, according to given law of change, increases to atmospheric, the clutch engagement process occurs. Rod *21* vacuum chamber *20* through the fork shutdown *22* affects the thrust bearing *4*, which moves the clutch pressure plate *5*.

Microprocessor electronic control unit (ECU) *11* carries out processing information from all elements of the control system and is connected to a programmable read-only memory (ROM), which stores the algorithm program, standard programs and other data. Random access memory (RAM) is used to store the results of intermediate calculations, current values of variables and other data. The system operation in time mode is supported by a timer, which ensures the implementation of time delays and timely supply of power and control signals. Communication between the system control elements and actuators (solenoid valves) is carried out through the "ports" of input-output information and amplifier cascades. The RAM, ports and timer are structurally designed in the form of a large integrated circuit.

When the gear lever is operated *12* forced clutch disengagement as a result of sensor contact closure *10* To eliminate unclear clutch operation at this moment, a delay of the circuit breaking device is applied.

Fig. 15.5 shows a diagram of an automatic clutch drive from an English company *Automotive Products*, which responds to the opening size engine throttle. This system is based on the following concept - the clutch is disengaged as soon as the driver takes the gearshift lever, and is engaged again when the next gear is changed. The law of clutch torque change is formed on the basis of signals from sensors that provide information about the state of the fuel pedal and the stroke of the clutch slave cylinder rod.

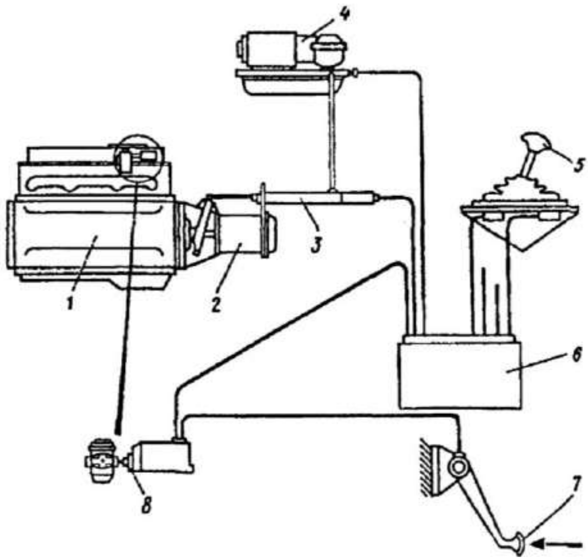


Figure 15.5 – Diagram of the company's automatic clutch drive *Automotive Products*:
1– engine;*2*– mechanical gearbox;*3*– working cylinder;
4– hydraulic power unit;*5*– gear shift lever;
6– EBC;*7*– fuel pedal; *8*– throttle position regulator

An example of a system that responds to the crankshaft speed is an electro-hydraulic system.*ACTS*(rice.15.6), which was developed by the company*Automotive Products*.

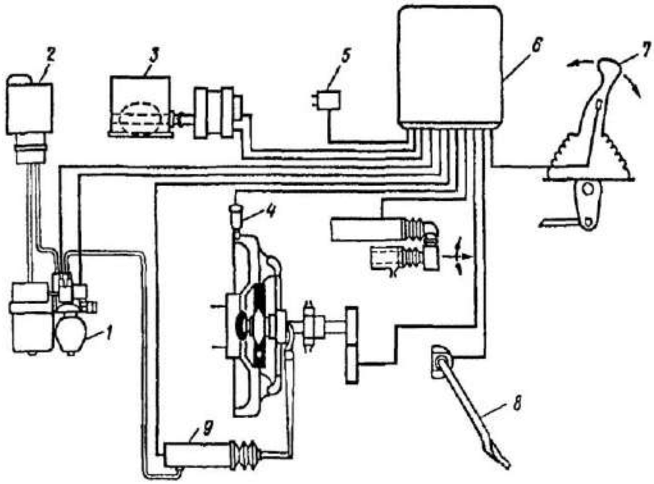


Figure 15.6 – Electro-hydraulic system*ACTS:*
1– hydraulic block;*2*– hydraulic system tank;*3*– electric motor; *4*– crankshaft speed sensor;*5*– position sensor throttle valve;*6*– EBC;*7*– gear shift lever;*8*– pedal
fuel supply;*9*– clutch release lever drive

System*ACTS*has quite broad functionality, which To some extent, it brings the driving comfort achieved with its help closer to that of fully automatic transmissions. However, both this and similar systems significantly increase the cost and complexity of the vehicle design.

Clutch in the DSG automatic transmission and its analogue PSG

Automatic transmission design*DSG*, which is installed on the Audi TT car, and its analogue*PSG*shown in Fig.15.7. It combines two conventional gearboxes, each with its own clutch. The “First” gearbox is responsible for engaging odd gears (first, third and fifth), the “Second” gearbox is responsible for engaging even gears: second, fourth and sixth, which makes it possible to engage two gears simultaneously. During acceleration in first gear, the gears of the second are already engaged, but rotate at idle. When the computer determines the time to shift, two hydraulic actuators simultaneously release the first clutch and engage the second. Now the second is active gear, and the gearbox engages the gears of the next, third gear in advance. And so on – up to sixth. Moreover, simultaneously with sixth gear, the gearbox will also engage fifth gear – in case the engine speed drops and more traction is needed. Press the gas – and in 0.2 seconds the synchronous “dance” of the two clutches will shift the traction back, from sixth to fifth. All this avoids jerks, since with two clutches, the switching occurs without interrupting the flow of power from the engine to the wheels.

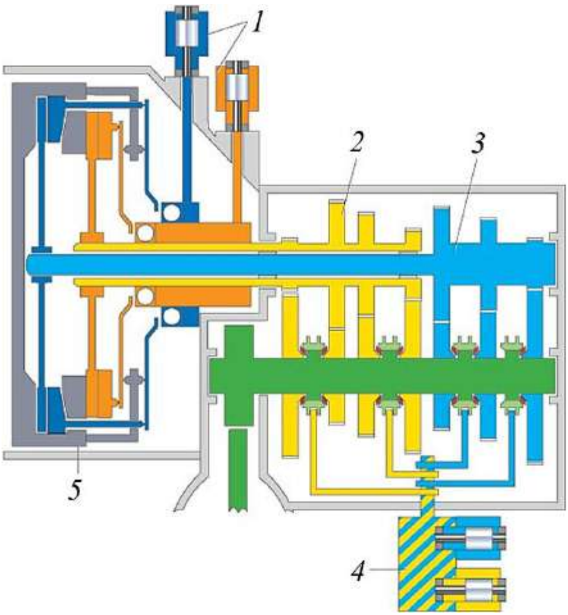


Figure 15.7 – Transmission *PSG*:
1– clutch actuators; *2*– gears of paired gears; *3*– gears odd gears; *4*– shutdown drive; *5*– double clutch

In cars, it is advisable to use a dual clutch, which provides switching without interrupting the flow of power. The minimum costs when changing the design of the prototype will be in the case of using a dry friction clutch.

Automated dual-clutch transmissions Finally, the classic automatic transmission has a competitor – the “Sequential Shift Transmission” *DSG* (*Direct Shift Transmission*). It is possible that the feeling of comfort from gear changes is somewhat behind that of a classic automatic transmission, but the efficiency is much higher with full automation of all processes taking place. Due to the fact that the gear shifting speed in a car with a dual clutch is very low, it is primarily of interest to sports cars. At the same time, the overall dimensions of the dual clutch are quite small, they can be compared with the dimensions of a conventional clutch, so the use of this mechanism makes sense in all cars, as they say, from small to large. The box is designed for all types of cars, from economical to sports cars, while a large market volume is covered, and the cost of production is no longer as high as it was in the first test samples and prototypes. However, the development and production of a dual clutch is a very technological and precise process. For example, software control must regulate the degree of clutch engagement when starting from a standstill and moving in reverse. Modern engines are designed in such a way that they produce a fairly large torque at the start of movement. In order for the acceleration of the car to be not too large and at the same time controllable, the engine output shaft must rotate with slippage relative to the gearbox input shaft.

There are clutches with completely dry friction surfaces and those that operate in an oil bath (they are called wet). As a rule, to transmit the same torque, the friction surface in wet clutches, despite the smaller diameter, is larger than in dry ones, due to the presence in the clutch of a set of several friction and steel discs. Until recently, multi-plate clutches were used only in automatic transmissions. Gradually, they are beginning to be introduced into other segments of the automotive industry.

Dual clutch is mainly used for automatic gear shifting. In cars, dual clutch works together with automated transmission, and sometimes is used in a fully automatic transmission instead of a torque converter.

(wet clutch only). It responds to commands from the transmission control unit and moves by means of a hydraulic drive (wet clutch) or an electric drive (dry).

Modern wet clutches

Wet clutches have proven themselves well, because the oil circulation in them more actively removes heat from the friction surfaces. In this case, new oil is supplied to the contact area only at the moment of clutch closure. The principle of operation of a wet double clutch is shown in Fig. 15.8. When driving in one gear, oil flows out of the clutch surfaces, and due to this, power losses are reduced. In this mode of use, a wet clutch can compete with a dry clutch in terms of efficiency. Naturally, the friction surfaces of these two different systems are not the same, but the friction coefficient of the wet layer is sufficient to transmit engine torque in the closed state without slipping (Fig. 15.9).

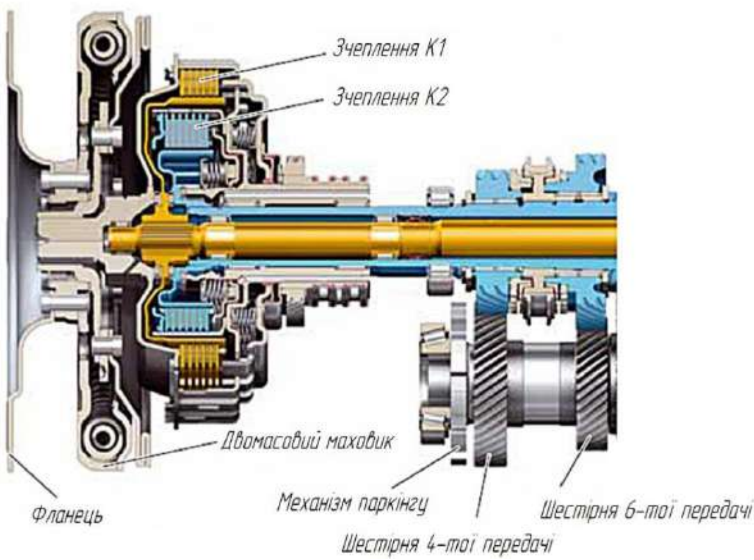


Figure 15.8 – Working principle of a wet dual clutch

Figure 15.9 – Wet dual clutch

Modern dry dual clutches

The principle of operation of a dry double clutch (Fig. 15.10) is based on the transmission of torque from the engine of the machine to the transmission system using dry friction. It is formed during the operation of the driving and driven discs.

Figure 15.10 – Dry double clutch

The torque is transmitted to the dual clutch by a dual-mass flywheel mounted on the crankshaft. For this purpose, the dual-mass flywheel has an internal gear ring. It meshes with the external gear ring on the dual clutch carrier ring. From there, the torque is transmitted to the dual clutch mechanism. The dual clutch is located in the clutch housing. It consists of two conventional clutches combined into a dual clutch.

Diaphragm springs are used as the driving power transmission element of the dry friction double clutch (Fig. 15.11). *8*,*9*In the literature they are also sometimes called disc springs.

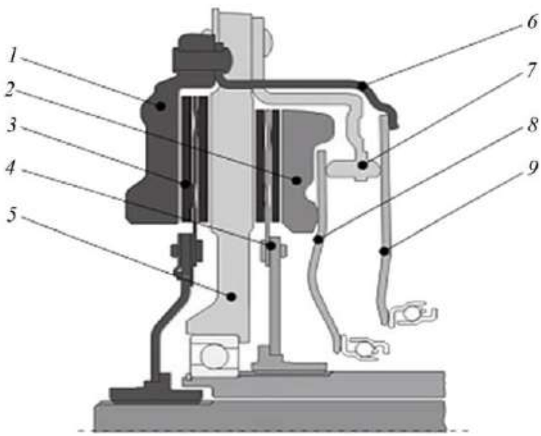


Figure 15.11 – Schematic representation of the SPZ

Diaphragm springs have the shape of a truncated cone and consist of a solid ring with petals located on it, which perform the function of elastic release levers. Clutch housing*6*and casing clutch*7* fixed on the pressure plate *1*and the central plate*5* respectively. Thrust discs *1*,*2*designed for pressing friction disks*3*,*4*to the central plate*5*, which rotates synchronously with engine. The operation of the SPZ is based on the use of tangential friction forces that arise in the contact zone of the driving and driven elements during their relative angular displacement.

In this case, the friction force that arises is proportional to the normal force that compresses these elements. To return the pressure plates to their original positions when the clutches are opened, i.e. to ensure the minimum required air gap when the transmission is disconnected from the running engine, leaf spring assemblies (not shown in the figure) are used.

The principle of operation of a dry double clutch is shown in Fig. 15.12. It is clearly seen that the clutch K1 transmits torque through a spline to the input shaft *1*. From the input shaft *1*twisty moment for *1*and *3*gear is transmitted to the secondary shaft *1*, and for*5*and *7* gears – on the secondary shaft*2*.

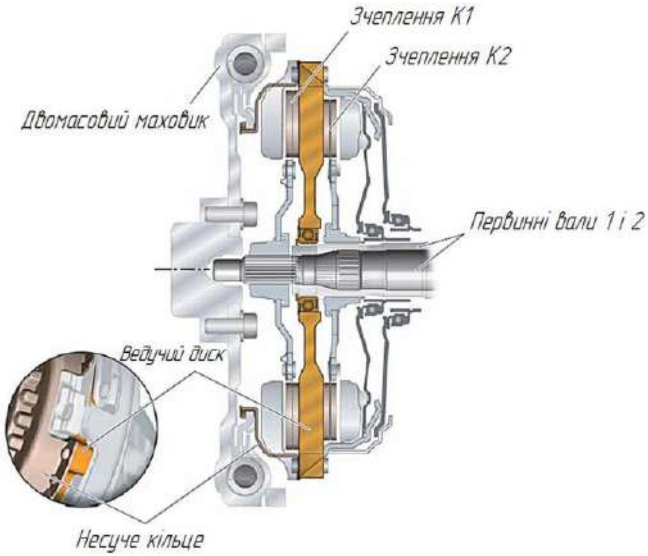


Figure 15.12 – The principle of operation of a dry clutch

Clutch*K2*transmits torque through a spline to the input shaft *2*. From there the torque for*2*and*4*gear is transmitted to the secondary shaft

1, and for *6* transmission and reverse gear – on the secondary shaft *2*. Through the reverse gear idler gear *R1* further progress is taking place torque transmission to the reverse gear *R2* secondary shaft. All three secondary shafts are connected to the gear wheel of the main differential gear.

The torque is transmitted to the dual clutch drive plate via a ring. For this purpose, the ring and the drive plate are firmly connected to each other. The drive plate is mounted on the input shaft *2* like a wheel that rotates freely.

When one of the two clutches is engaged, torque is transmitted from the drive disk to the corresponding clutch disk and then to the corresponding input shaft.

To operate the clutch, use the clutch release lever.
presses the release bearing against the diaphragm spring. Due to the presence of several support points, the pressing force is converted into a force displacement. Due to this, the pressure plate is pressed against the clutch disc and the drive disc. In this way, the torque is transmitted to the input shaft. The clutch release lever is driven via a valve *3*, located in the dividing mechanism *1 N215*, from the hydraulic clutch actuator *K1*
The first clutch engagement diagram is shown in Fig. 15.13.

The second clutch engagement diagram is shown in Fig. 15.14. When the clutch disengagement lever is actuated, the thrust bearing moves, overcoming the force of the diaphragm spring.

Since the diaphragm spring rests on the clutch housing,
the pressure plate is pressed against the drive plate and ensures the transmission of torque to the input shaft *2*.

The clutch release lever is actuated via a valve *3* in dividing mechanism *2 N216* from the hydraulic actuator clutch drive *K2*.

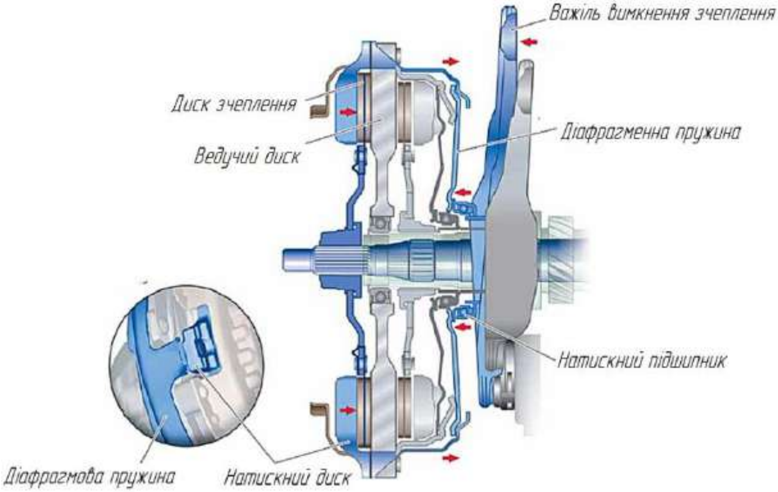


Figure 15.13 – First clutch engagement diagram

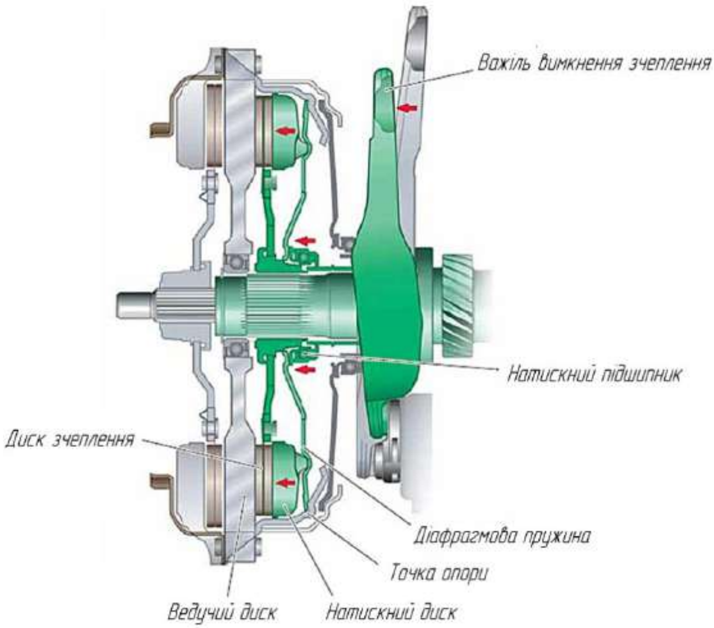


Figure 15.14 – Second clutch engagement diagram

Control unit *Mechatronics* – this is the central control module of the gearbox. It collects signals from all sensors and all signals from other control units, and it controls and carries out all actions.

The control unit has 11 sensors built in, only the gearbox input shaft speed sensor *G182* located outside the block control. The control unit hydraulically controls and regulates the solenoid valves for engaging the 7th gear and the clutch drive.

The control unit adapts the clutch positions and the positions of the gearshift mechanism elements when the gear is engaged and takes into account the adaptation values during the subsequent operation of these parts (Fig. 15.15).

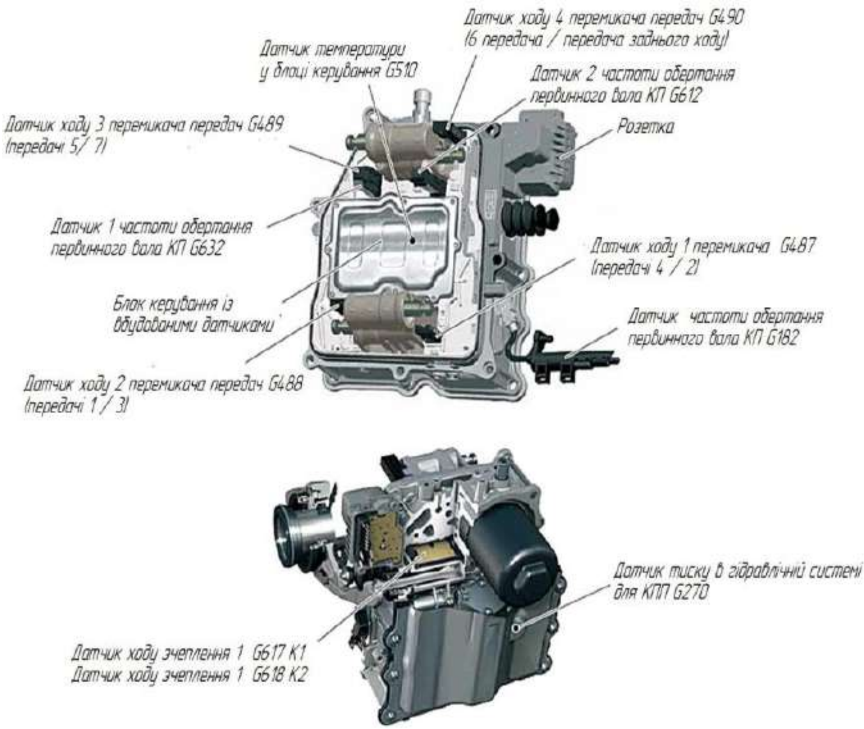


Figure 15.15 – Clutch and gearbox control system sensors

Let's expand the comparative table of dry and wet clutches (table. 15.1).

Table 15.1 – Comparison of dry and wet clutches

	Dry clutch	*Wet grip*
Economy	Best fuel economy, even compared to a manual transmission	Average consumption 6% more than dry clutch due to viscous friction oils and work oil pump
Maximum transmitted power	The maximum torque transmitted from the motor is limited due to the slow cooling of the contacting surfaces	Can transmit large rotary moment. Better cooling by oil bill flow
Development and management	The development of dry double clutches requires special software control costs, since the inevitable long-term wear of the clutch must be taken into account and must change over time. clutch closing and opening control strategy	No significant costs for development through lack of wear and tear
Speed switching	Comparable to wet clutch, greater than in manual transmission. Shift time from 0.12 to 0.05 s	Comparable to dry clutch, greater in Manual gearbox management. Time switching from 0.12 up to 0.05 s

Advantages and disadvantages of dual clutch dry and wet types A dual-clutch transmission behaves similarly to a standard manual transmission: it has an input and countershaft for gearing, a clutch, and synchronizers. The only difference is that there is no clutch pedal, as the pedal function is performed by a computer, a hydraulic control actuator, and solenoids.

The advantages of using a dual clutch of dry and wet types are the speed of upshifting, which takes about 8 ms, which provides the car with dynamic acceleration; the ability to independently control gear shifting or switch to automatic mode; increases fuel efficiency by up to 10%.

The disadvantages of dual clutches of dry and wet types are a significant increase in the cost of the car. Unsuitability for repair due to the complexity of the design; on cars with a gearbox *DSG-7* some users note jerks and vibrations when accelerating in 1st gear and when shifting from 1st to 2nd gear, due to the design features of the unit. On *DSG-6* this problem now not noted; expensive oil change procedure (for *DSG-6*); delays before sharp acceleration when driving at medium speeds, associated with the pre-selected adjacent lower gear, for example, 6th when driving in 7th, while for sharp acceleration it is necessary to turn off 4th or maybe even 2nd. The complexity of the dual clutch design compared to a manual gearbox. Also in the dual clutch there are energy losses in the hydraulic control drive.

Clutch with reduced energy consumption for control

In the design of this clutch, the discs of each clutch (Fig. 15.16) are held alternately in the pressed state by means of springs alone. When the clutch is engaged, the force of the pressure springs, acting through the levers on the pressure disc, creates pressure on the friction pairs and creates the necessary pressing force on the friction pairs to transmit torque. When the clutch is disengaged, the spring is compressed, and the pressure disc ceases to act on the driven disc of this clutch. Then the clutches are disengaged and the second clutch is engaged.

This dual-clutch design provides higher drive efficiency, fuel economy, and reduced gear shifting time, which reduces the load on the internal combustion engine and on the driver when driving.

The use of a dual clutch ensures torque transmission with virtually no interruption in the power flow, which is extremely important for trucks and other vehicles.

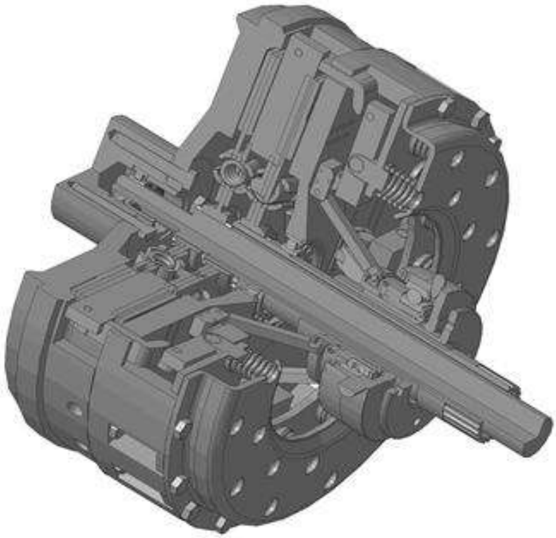


Figure 15.16 – Dry dual clutch with reduced energy costs for control

Review questions

1. General information. Classical and automatic clutch designs.
2. What does an electromagnetic powder clutch consist of?

advantages and disadvantages?

3. The principle of operation of the electromagnetic powder clutch.
4. What does an automatic electronic control system consist of? clutch?
5. The principle of operation of the clutch in an automatic transmission*DS*G and its analogue*PSG*.

6. Automated dual-clutch transmissions.
Advantages and disadvantages.

7. Modern wet clutches. Design, principle of operation, where are applied.

8. Modern dry dual clutches. Design, principle of operation, where are applied.

9. Purpose of the control unit *Mechatronics?*

10. Clutch with reduced energy consumption for control.
Main advantages.

11. How can energy consumption for clutch control be reduced?

12. What are the advantages and disadvantages of a dry dual clutch?

13. Wet clutches. Structure and operation.

14. Disadvantages and advantages of dual wet clutches.

Laboratory work 16
GEAR BOX *DSG*

Purpose of work – study the purpose, design and operation modern *DSG* gearboxes and clutches used in car transmissions.

Visual aids:

• albums, instructions and construction posters *DSG*;

• electronic information material on structures *DSG*;

• clutch and gearbox *DSG* in section;

• car.

Tasks for work:

• study the design and operation of the dual clutch and gearboxes *DSG*;

• determine the design features of clutches and gearboxes *DSG*;

• provide a kinematic diagram of the clutches and gearbox.

General information

Gear box *DSG* combines the strengths of automatic and manual transmissions, spontaneously choosing the optimal transmission mode. This gearbox allows you to achieve significant fuel savings, because it always “chooses” the least expensive and at the same time most efficient mode of operation of the power unit. The embodiment of ideal efficiency: when the engine output power is converted directly into speed.

Main advantage *DSG* – smooth acceleration without interruption power flow during gear shifting. *DSG* provides direct gear shifting, dynamic acceleration for sporty driving, and reduced fuel consumption.

DSG from *Volkswagen* there are6- or 7-speed gearbox for all classes of cars produced *Volkswagen*, and therefore arouses increased interest among buyers.

The dual dry clutch gearbox allows you to choose any driving style. *DSG* – it is more than

simple automatic transmission. It combines the advantages of automatic and manual transmissions. This is manifested in the fact that the driver can make a choice twice: first he selects the operating mode*DSG*
– normal or sporty. Then he makes a choice between automatic and manual gear shifting.

Normal DSG mode

When the gear lever is turned off, it is in the "*D*", "Motion", "normal mode" is selected*DSG*. In this case, the required gears are already selected in the box, which are automatically switched in a split second and without interrupting the flow of power. This is the best mode for comfortable driving, as the gears change imperceptibly and no additional actions are required from the driver.

DSG Sport Mode

When shifting the transmission to sport mode*S*(*Sports*) the electronic control unit holds the lower gears. The shift to a higher gear does not occur until the vehicle reaches a higher speed and the engine is revving.

Selection of gear ratios

The optimal moment switching is carried out thanks to the best selection of gear ratios. Precise selection of gear ratios allows you to achieve the best dynamic characteristics of the transmission. The gearbox control unit selects the optimal shift point, depending on the activated mode, engine speed, vehicle speed and accelerator pedal position.

As a result, power losses can be avoided and efficiency can be increased.

Reducing fuel consumption

*Volkswagen*developed an innovative gearbox*DSG*, which allows you to save fuel and reduce harmful emissions.

In combination with the engine*TSI*gear box*DSG*reduces costs fuel by 22%, thus reducing CO emissions$_2$Even compared to a classic manual transmission*DSG*provides significant fuel savings of up to 10%.

Benefits for car owners

Design solutions transmissions with two clutches offered for both small class cars and representatives of the "higher" segments: 7-speed gearbox *DSG* for engines with torque with a torque of up to 250 N m is more suitable for small and medium-sized cars, for example for *Volkswagen Polo* sedan in configuration *GT*, *Volkswagen Passat B8*, or *Volkswagen Golf* in packages Trendline and Highline. 6-speed gearbox *DSG* for engines with torque with a torque of up to 350 Nm meets the expectations of buyers interested in cars from higher segments with more powerful engines, for example, *Volkswagen Tiguan 1.4TSI BlueMotion*.

Having developed *DSG*, *Volkswagen* provided drivers with a dynamic, sporty driving style, acceleration without interruption of the power flow, and gear shifting is almost imperceptible.

Gear box *DSG*, which ensures reduced fuel consumption and CO_2 emissions, is an important factor for those who care about the environment.

Drivers who spend a lot of time behind the wheel can relax behind the wheel of their car with *DSG*, enjoying the ease of control.

New high-tech developments *Volkswagen* allowed to achieve *DSG* the best combination of operating advantages of mechanical and automatic gearboxes.

DSG 7 transmission

Seventh model *DSG* appeared three years after the sixth and was made specifically for budget cars. *DSG 6* is noted heavy weight (about 95 kg) and a large volume of transmission oil. *DSG 7* weighs about 70 kg and has a smaller oil volume, which has a positive effect on fuel consumption and the cost of regular maintenance. Fig. 16.1 shows a 7-speed dual clutch gearbox.

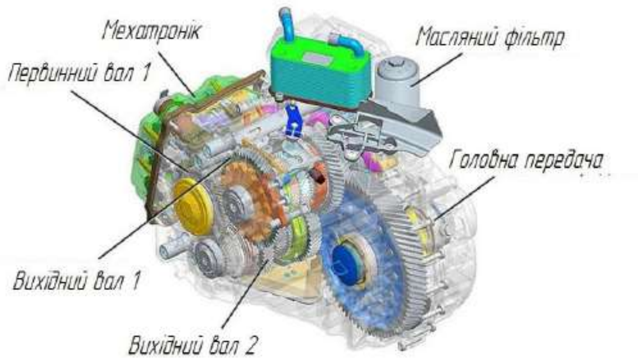


Figure 16.1 – 7-speed dual clutch transmission

*DSG 7*installed on a car, equipped with an engine with a torque torque up to 250 N m. These include the following models:

– *Volkswagen*(*Golf*,*Passat*,*Transporter*,*Caddy*);
– *Skoda*(*Fabia*,*Superb*,*Octavia*);
– Audi (*A3*,*Q3*,*TT*);
– *Seat*(*Ibiza*,*Leon*,*Altea*).

"Dry" in structure*DSG*(rice.16.2) is no different from the “wet” one. It is based on: the first and second secondary shafts, the main gear, the oil filter, the flywheel and the mechatronics unit. A feature of this automatic transmission is the presence of two dry friction clutches that do not operate in an oil bath. This technical innovation has significantly increased the efficiency of the gearbox.

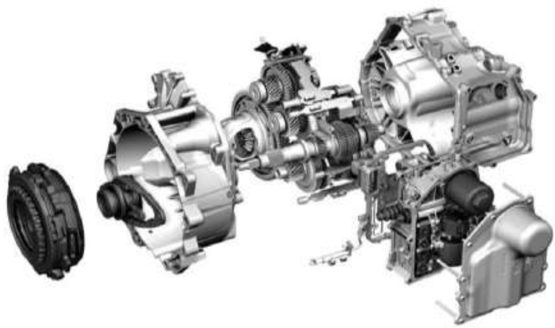


Figure 16.2 – “Dry”*DSG*

To ensure better operational and economic performance, a modern multi-speed, for example a six-speed (six forward gears and one reverse) gearbox is required. Box *DSG* is radically different from all the others. It seems to combine two ordinary boxes, each with its own clutch. One "box" is responsible for engaging odd gears (first, third and fifth), the other
– even: second, fourth and sixth, which makes it possible to engage two gears simultaneously. While acceleration is ongoing in first gear, the gears of second are already engaged, but are rotating at idle. When the time comes, they are switched: the first clutch is released at the same time and the second is engaged. Now the second gear is active – and the gearbox engages the gears of the next third gear in advance. And so on – up to sixth. Moreover, simultaneously with the sixth gearbox, the fifth gear will also be engaged – in case the engine speed drops and more traction is needed. Pressing the gas and the synchronous operation of the two clutches switches the traction back – from sixth to fifth. All this avoids unpleasant and unexpected bites, since with two clutches, switching occurs without interrupting the flow of power from the engine to the wheels.

DSG gearbox operation

The scheme of the box is shown in an expanded form in Fig. 16.3. The dual-clutch transmission consists of two independent dividing mechanisms. Each dividing mechanism functions as a mechanical transmission. Each dividing mechanism corresponds to one clutch. Both clutches, for example, are dry (can also be wet). The control unit regulates, opens and closes the discs of both clutches depending on the gear. Through the clutch *1*, respectively through the dividing mechanism *1* and secondary shaft *1* powering on *1*, *3*, *5* and *7* transmission. Transmissions *2*, *4*, *6* and reverse gear are engaged via the clutch *2* and respectively through the dividing mechanism *2* and secondary shafts *2* and *3*. At the same time, only one dividing mechanism is in the state of power locking. In the other dividing mechanism, the next gear can be engaged, since the clutch of this gear is open. For each gear, a synchronization and gear shifting mechanism standard for a manual transmission is provided.

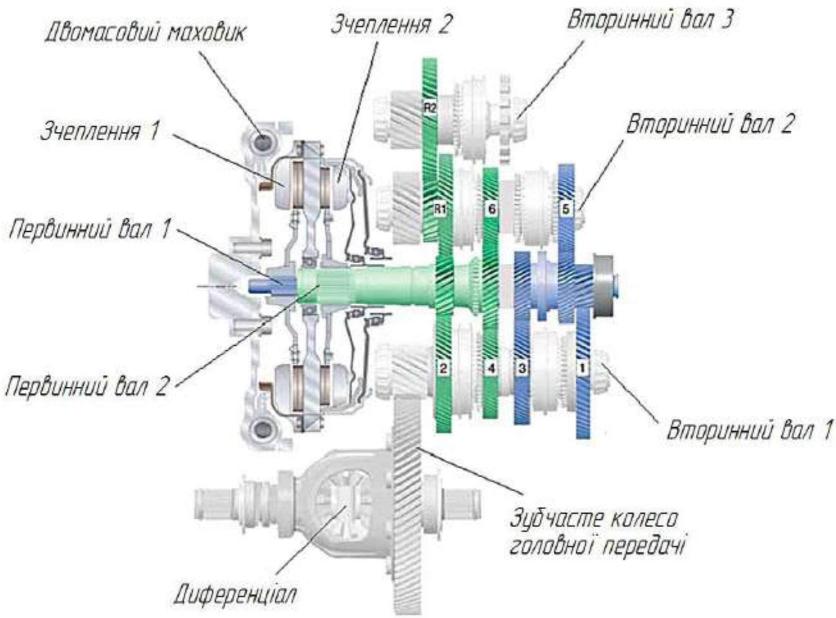


Figure 16.3 – Exploded diagram of the box operation:
1–6– transfers;*R1*– reverse gear intermediate gear;
R2– reverse gear

The operation of the gearbox in each gear, including reverse gear, is shown in Fig. 16.4–16.6. Torque is transmitted to the gearbox through the clutch.*1*or*2*. Each clutch drives one input shaft. Input shaft *1*is given from clutch*1,*and the input shaft*2*– from the clutch*2*.

When the gearbox is in 1st gear (Fig. 16.4), torque is transmitted in the following order: clutch*1*– input shaft *1*– secondary shaft*1*– final drive (GD) – differential.

When the gearbox is in reverse gear (Fig. 16.4), torque is transmitted in the following order: clutch*2*– input shaft*2*– secondary shaft*3*– GP, differential.

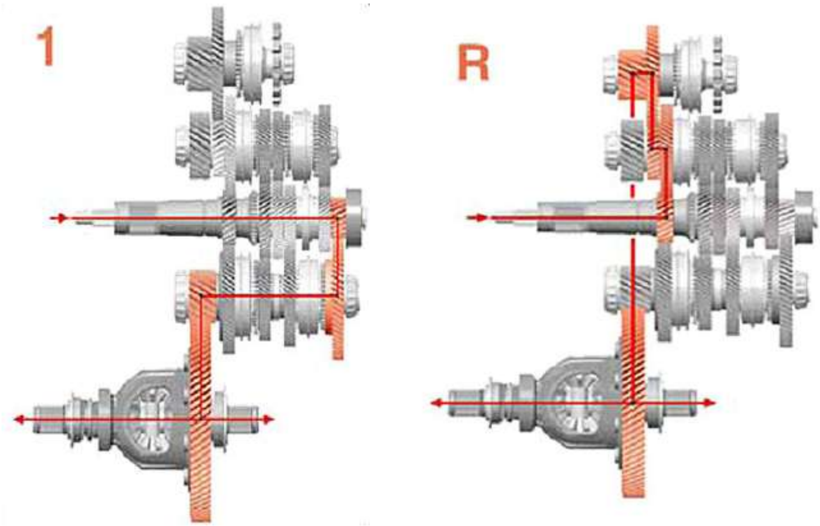


Figure 16.4 – Gearbox operation in 1st and reverse gears

When the gearbox is in 2nd gear (Fig. 16.5), torque is transmitted in the following order: clutch *2* – input shaft *2* – secondary shaft *1* – GP, differential.

When the gearbox is in 3rd gear (Fig. 16.5), torque is transmitted in the following order: clutch *1* – input shaft *1* – secondary shaft *1* – GP, differential.

When the gearbox is in 4th gear (Fig. 16.6), torque is transmitted in the following order: clutch *2* – input shaft *2* – secondary shaft *1* – GP, differential.

When the gearbox is in 5th gear (Fig. 16.6), torque is transmitted in the following order: clutch *1* – input shaft *1* – secondary shaft *2* – GP, differential.

When the gearbox is operating in 6th gear (Fig. 16.6), torque is transmitted in the following order: clutch *2* – input shaft *2* – secondary shaft *2* – GP, differential.

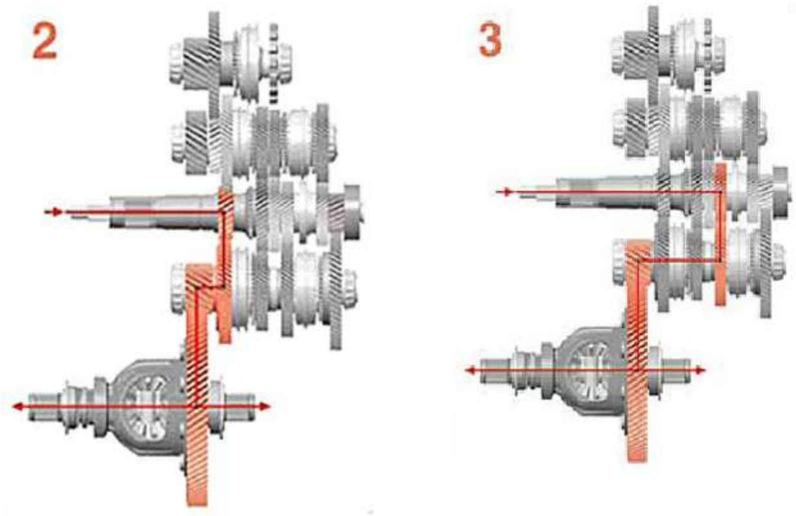


Figure 16.5 – Gearbox operation in 2nd and 3rd gears

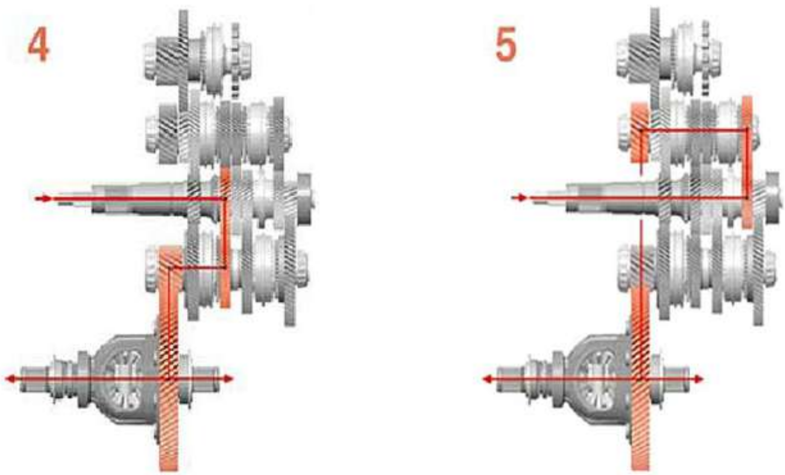


Figure 16.5 – Gearbox operation in 4th, 5th and 6th gears

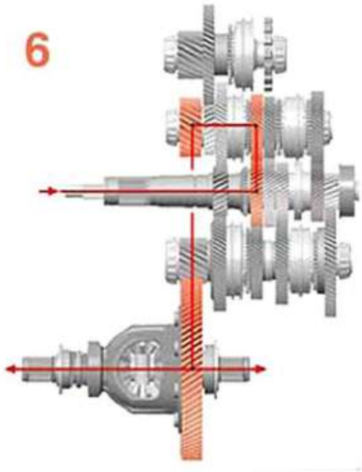


Figure 16.6 – Gearbox operation in 4th, 5th and 6th gears transmissions (continued)

Hydraulic circuit of the automatic transmission control system DSG 02E Volkswagen

All the functions of the gearbox are performed as a result of the operation of its components (Fig. 16.7), which are included in the general oil circulation circuit. In this circuit, including the oil intake, 7.2 liters of oil circulates.

The oil must meet the following requirements:

– be suitable for clutches and control systems gearbox;

– maintain sufficient viscosity throughout the entire operating range temperatures;

– withstand high mechanical loads;

– not foam. The oil should provide:

– lubrication and cooling of clutches, gears, shafts, bearings and synchronizers;

– operation of clutches and gearshift cylinders. The oil circulation circuit includes a cooler connected to the engine cooling system. It prevents the oil from heating to temperatures above 135 °C.

The hydraulic components of the circuit are shown in Fig. 16.7.

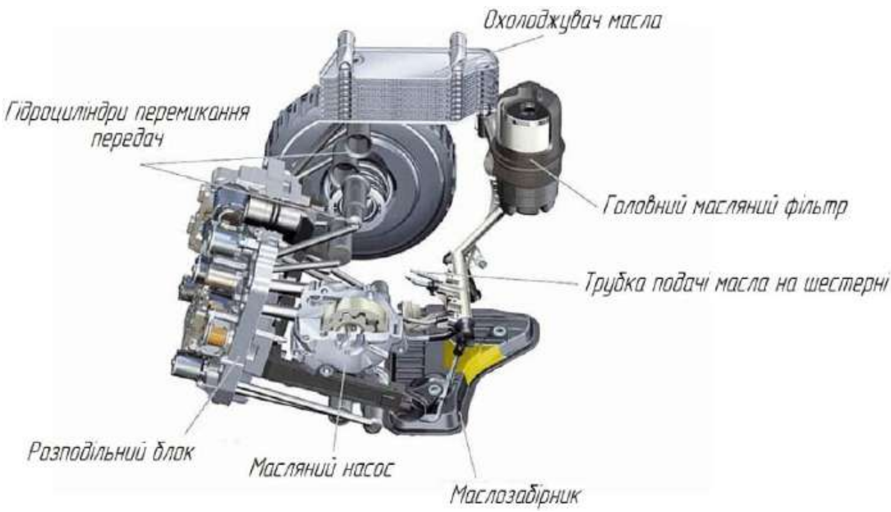


Figure 16.7 – Main components of the hydraulic circuit

Oil pump

The hydraulic system of the gearbox is served by an oil pump (Fig. 16.8) with internal gearing and a crescent-shaped partition between them. The pump sucks oil from the oil receiver and supplies it under pressure to the actuators. The pump capacity reaches 100 l/min at a main line pressure of 20 bar.

The oil pump provides:

– operation of multi-plate clutches;

– cooling of these couplings;

– operation of gearshift hydraulic cylinders;

– lubrication of gears.

The oil pump is driven by a shaft that rotates at the same speed as the crankshaft. This shaft runs inside the tubular input shaft. *1*, which in turn is located in the tubular input shaft 2 (Fig. 16.8).

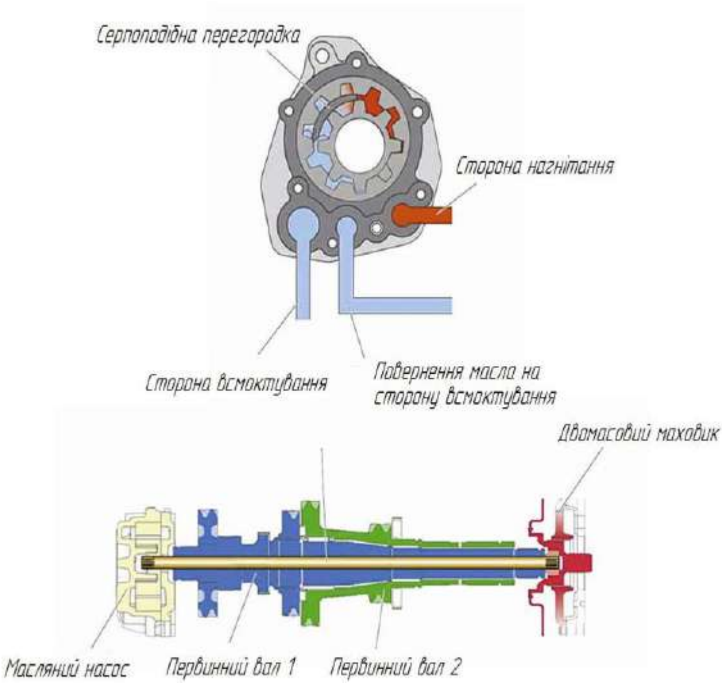


Figure 16.8 – Pump and its drive from an internal combustion engine

The oil circulation diagram and the connections of the elements are shown in Fig. 16.9.

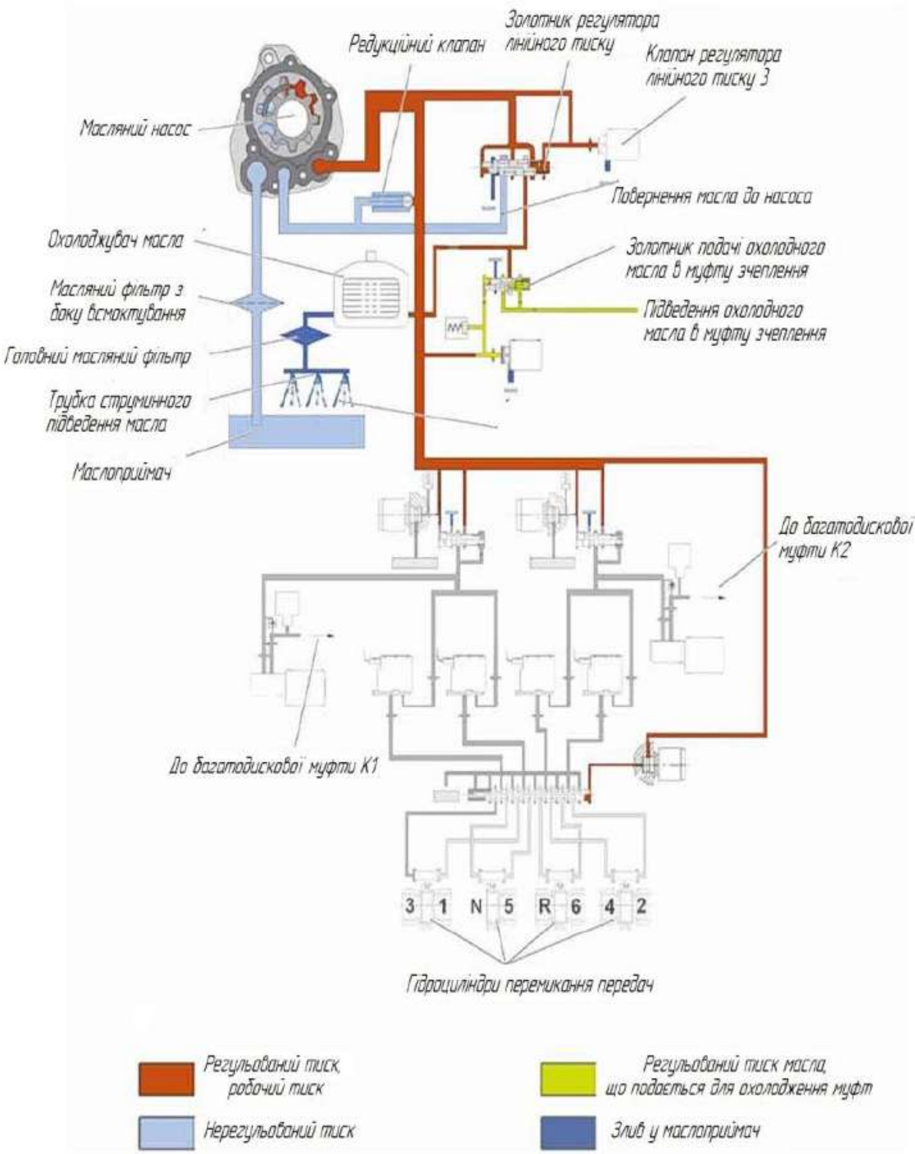


Figure 16.9 – Oil circulation diagram

Functions of the hydraulic circuit of the control system(rice.16.10)

The pump sucks oil from the oil receiver through the filter and supplies it under pressure to the linear pressure regulator spool. This spool is controlled by the linear pressure regulator valve, the pressure in the main transmission line depends on its movement.

A channel branches off from the spool of the linear pressure regulator, through which part of the oil returns to the suction side of the pump. Another channel from the spool branches into two channels. Through one of these channels, the oil goes to the cooler and then to the oil intake through the main filter, which is under pressure. The other channel serves to supply oil to the spool, which regulates the cooling of the clutches.

Oil, regulated by a linear pressure valve, is supplied to the hydraulic cylinders of the multi-plate clutch drive and the synchronizer sliding clutches. The oil cooler is connected to the engine cooling system. The main oil filter, which is under pressure, is mounted on the gearbox housing outside. The pressure reducing valve limits the oil pressure in the main line, preventing it from exceeding 32 bar. The gears are lubricated by oil flowing from the distribution pipes.

Diagram of switching on the hydraulic components of the control system Electro-hydraulic components of the control system(rice.16.10)

Line pressure regulator valve (N217)

This valve is switched by the electronic control unit gearbox. It serves to control the spool of the linear pressure regulator. Thus, the valve participates in regulating the oil pressure in the main transmission line.

The linear pressure regulator spool redistributes the oil flows:

– into the oil intake through the cooler, filter and distribution pipes oil supply to gears;

– to the pump on the suction side.

Operating in the main line (linear) pressure oils used to lock clutches *K1*and*K2*controlled by valves*N215*and*N216*, and hydraulic gearshift cylinders controlled by valves*N88*,*N89*,*N90*and*N91*.

*N92 Multiplexer Control Valve*This valve controls a multiplexer that enables eight gearshift cylinders to be controlled using only four solenoid valves.

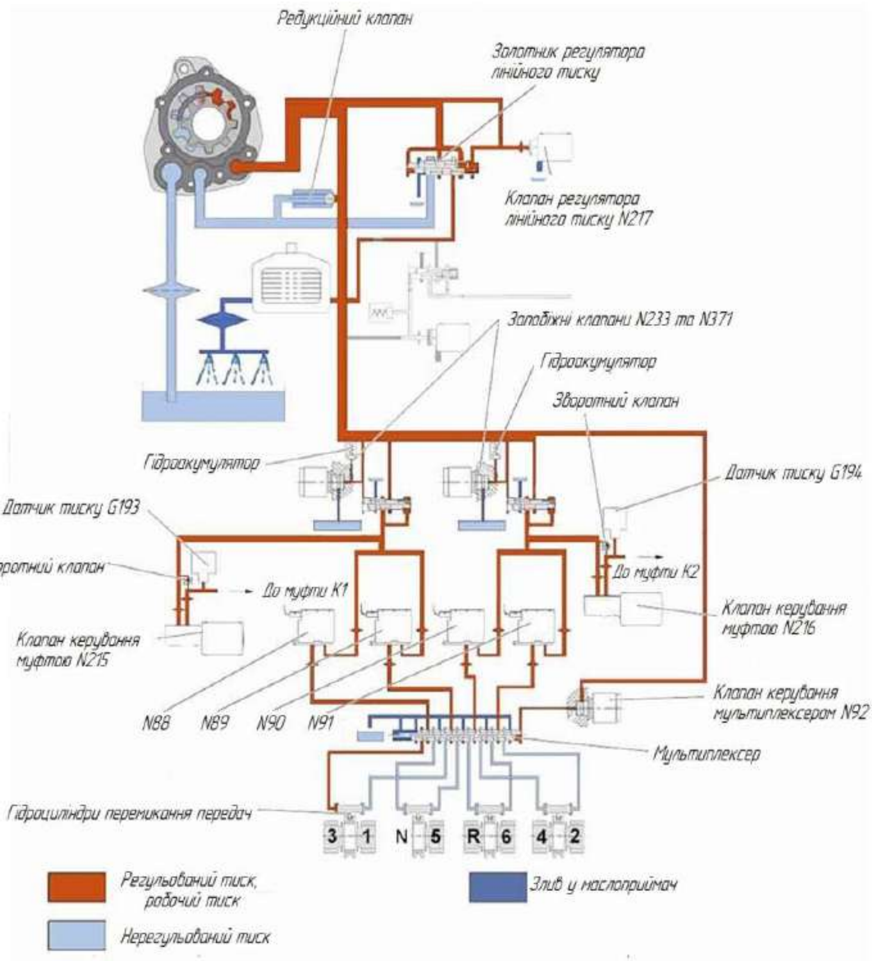


Figure 16.10 – Scheme of switching on the hydraulic components of the system management

The multiplexer moves to its original position under the influence of a spring. In the original position of the multiplexer, first, third, sixth and reverse gears can be engaged.

When voltage is applied to the valve winding*N92*opens, due to whereupon oil under pressure enters the multiplexer and moves it into the operating position, overcoming the force of the return spring. After that, second, fourth and fifth gears can be engaged, as well as neutral set.

Safety valves

Clutches*K1*safety valve corresponds*N233*, and the clutch *K2*– safety valve*N371*These valves provide accelerated opening of the couplings if the operating pressure exceeds a set value.

Pressure sensors (G193 and G194)

Pressure sensors*G193*and*G194*designed for pressure measurement oil in the clutches. The pressure reducing valve prevents excessive pressure build-up in the main line if the linear pressure regulator spool is faulty.

Clutch cooling system

Friction between the clutch discs leads to an increase in their temperature. Their overheating can be prevented only by applying forced cooling. The hydraulic system of the gearbox has a special oil circulation circuit for cooling the clutch discs (Fig. 16.11). This circuit includes a spool that distributes the oil flow and a valve*4*(*N218*), which regulates the pressure.

Principle of operation

Sensor*G509*serves to measure the oil temperature at the outlet from multi-plate clutches. Based on the signal from this sensor, the electronic control unit issues a command to the pressure control valve.

This valve changes the pressure acting on the distribution spool depending on the measured oil temperature. The spool moves according to the pressure acting on it, opening or closing the cooling oil supply channel to the clutches. Maximum flow rate cooling oil is 20 l/min. In this case, the pressure acting in the cooling circuit can increase to 2 bar.

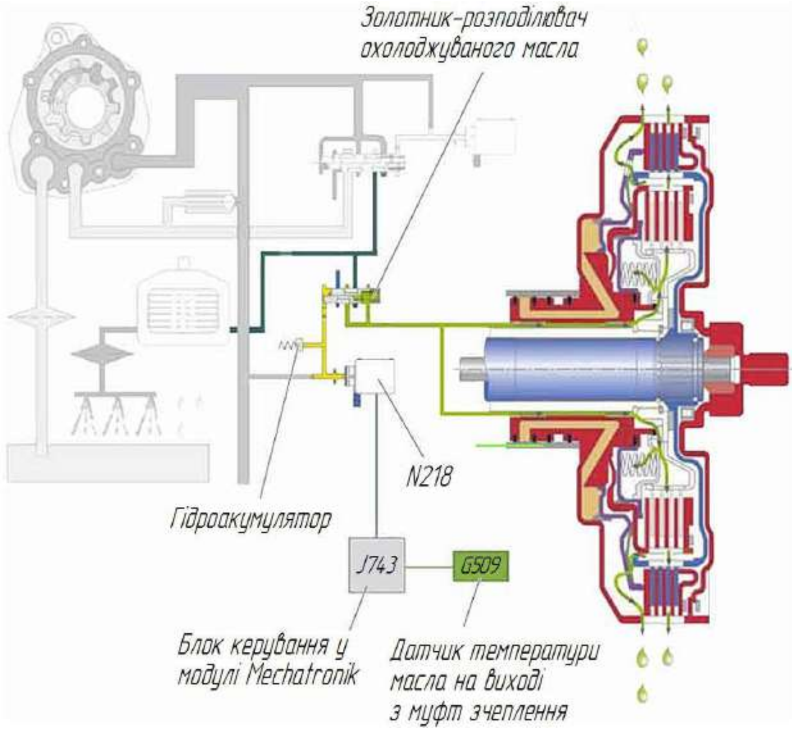


Figure 16.11 – Clutch cooling system

Gear shifting process

Gear shifting is carried out using forks and synchronizers (Fig. 16.12) of the same type as in conventional manual transmissions. Each fork is used to engage two gears. However, in a gearbox*DSG*hydraulic drive is used gearshift forks, rather than the drive using rods and levers, which is usually used in manual transmissions.

The shift fork rods are moved in ball-bearing hydraulic cylinders. The shift process begins with a system command.

Mechatronics for oil supply, for example, the left hydraulic cylinder of the drive fork. Since there is no oil pressure in the right hydraulic cylinder, the rod together with the fork moves to the right, dragging the synchronizer sliding clutch with it. As a result, the transmission is engaged.

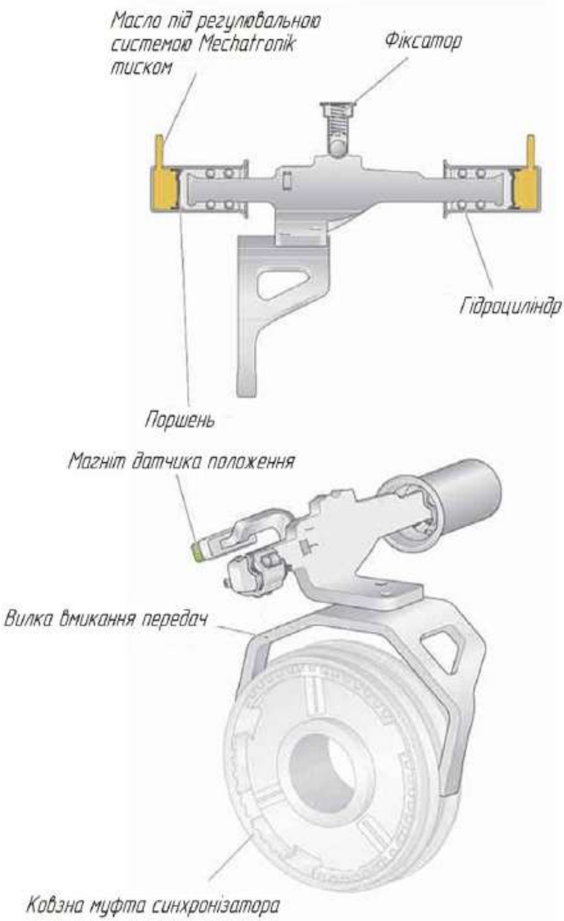


Figure 16.12 – Gear shifting process

After the gear is engaged, the hydraulic cylinder, which is under pressure, switches to drain. The synchronizer clutch is then held by the bevels on the teeth of the engaged gear ring and the detent acting on the fork stem. In the initial neutral position, the fork is held by a detent installed in the gearbox housing.

Each fork has a permanent magnet. This magnet is an element of the displacement sensor, according to the signal of which the system*Mechatronics* determines the exact position of the gear shift forks.

Review questions

1. General information about the gearbox*DSG*.
2. What are the operating modes?*DSG*Do you know?
3. What does the transmission consist of?*DSG 7*?
4. Explain the difference between “dry” and “wet” clutches*DSG*.
5. Tell us in detail about the operation of the gearbox.*DSG*.
6. What does the hydraulic circuit of the automatic transmission control system consist of? *DSG 02E Volkswagen*?
7. The role of the oil pump in the box*DSG*.
8. Describe in detail the oil circulation diagram.
9. What functions does the hydraulic circuit of the control system perform?
10. Electrohydraulic components of the control system, purpose.
11. Why is a clutch cooling system needed?
12. How does the gear shifting process work?