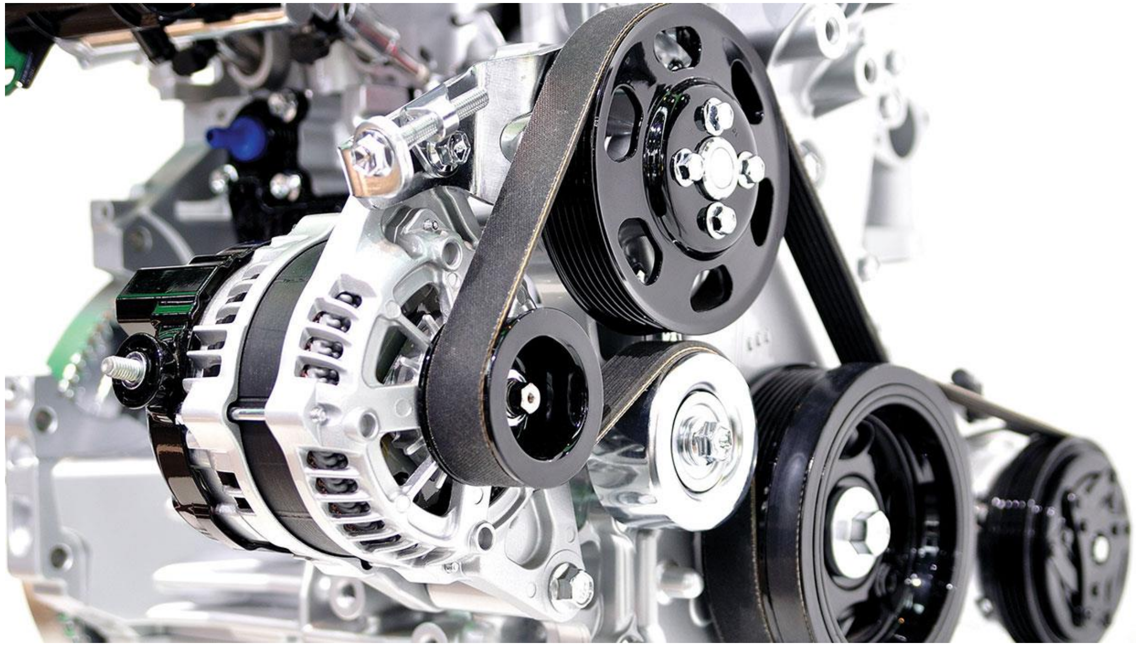
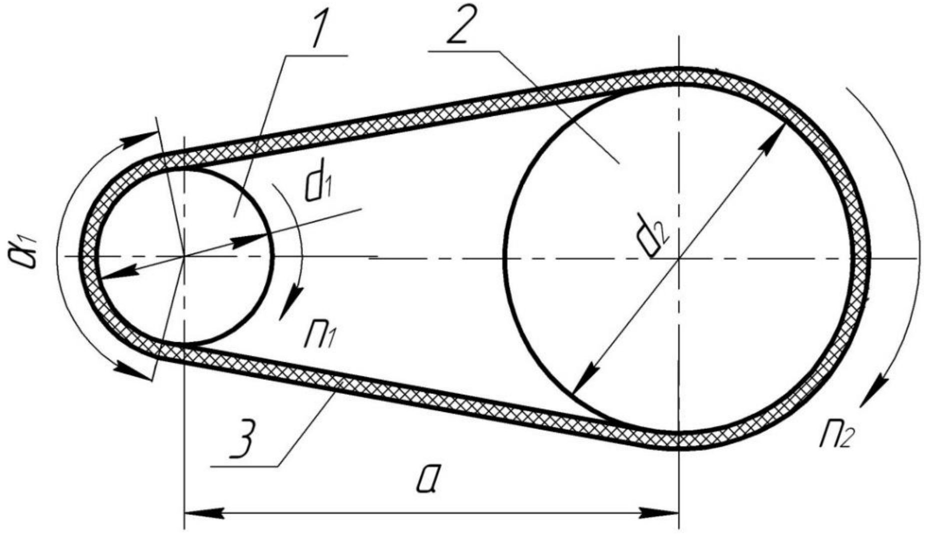
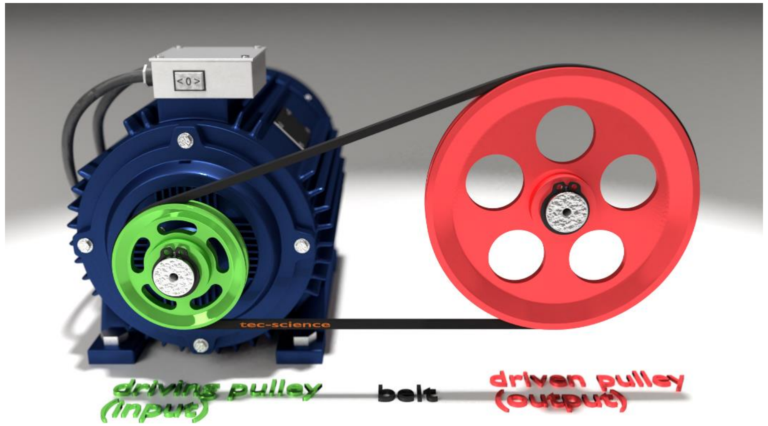
The belt drive
part 1



General information and classification of belt drives

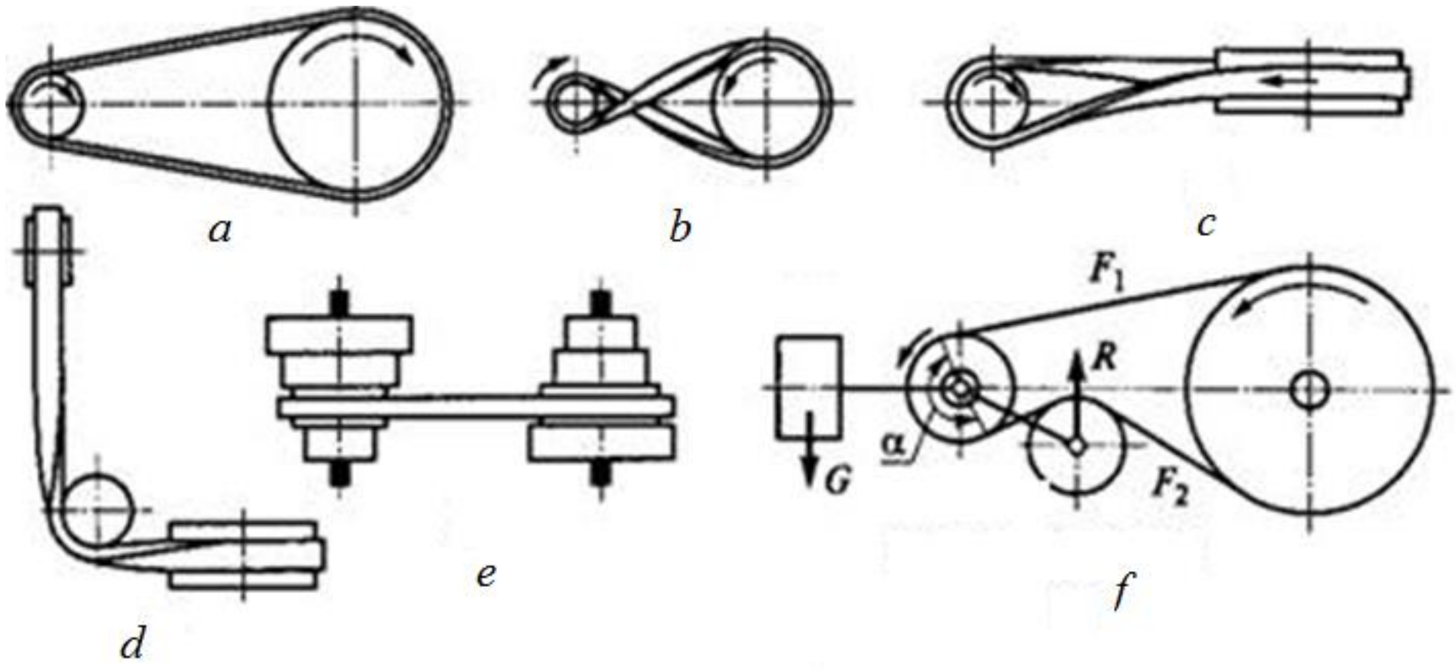




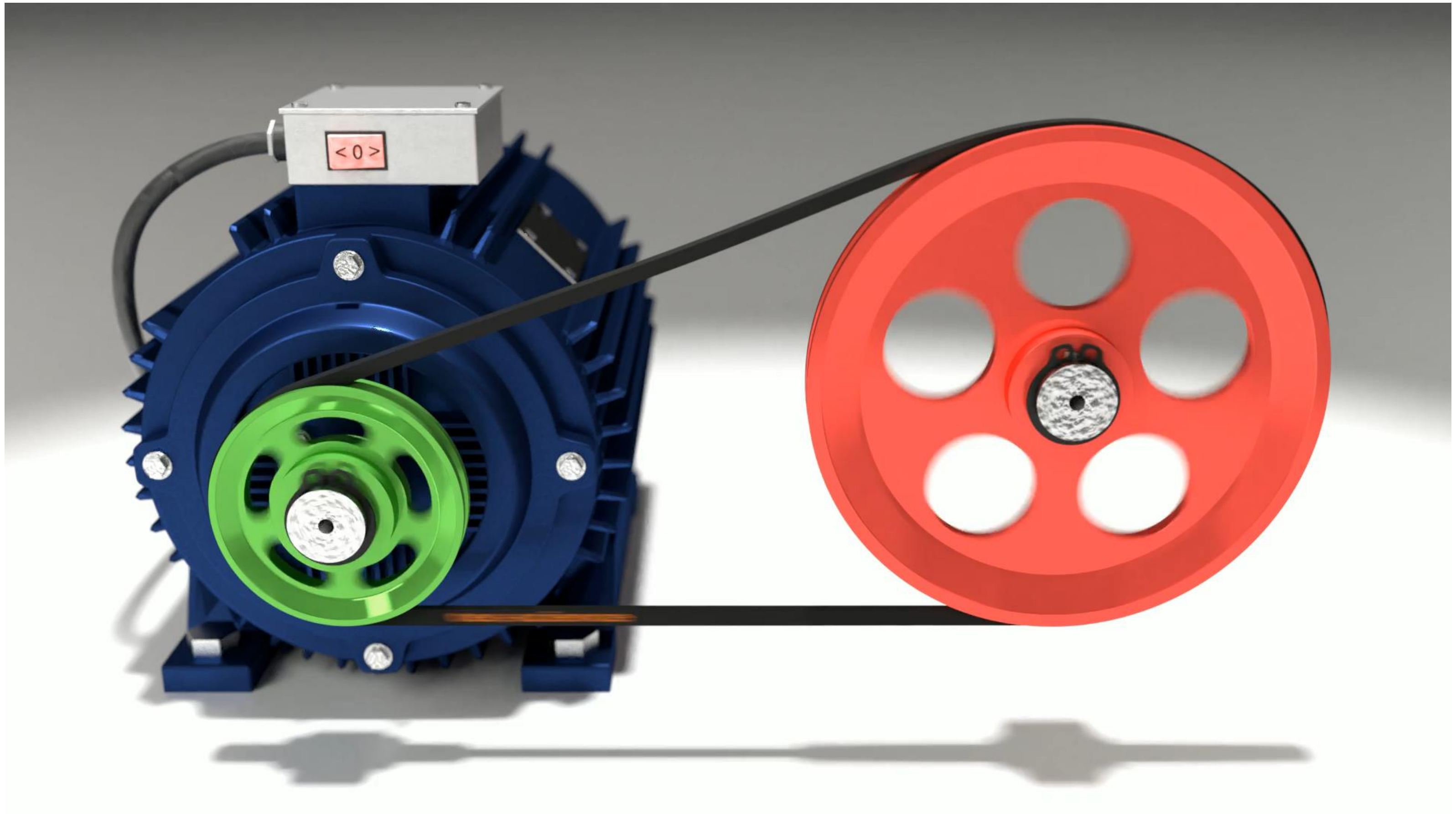
Belt transmission scheme

Belt transmission refers to friction transmissions with a flexible link. It consists of a driving 1 and a driven 2 pulleys and a closed form of the drive belt 3, which with some pre-tension is placed on the pulleys. During transmission, the belt transfers energy from the drive pulley to the driven pulley due to the friction forces that occur between the belt and the pulleys.

Belt drives can be classified by the shape of the cross section of the belt, the location of the shafts in space and purpose.

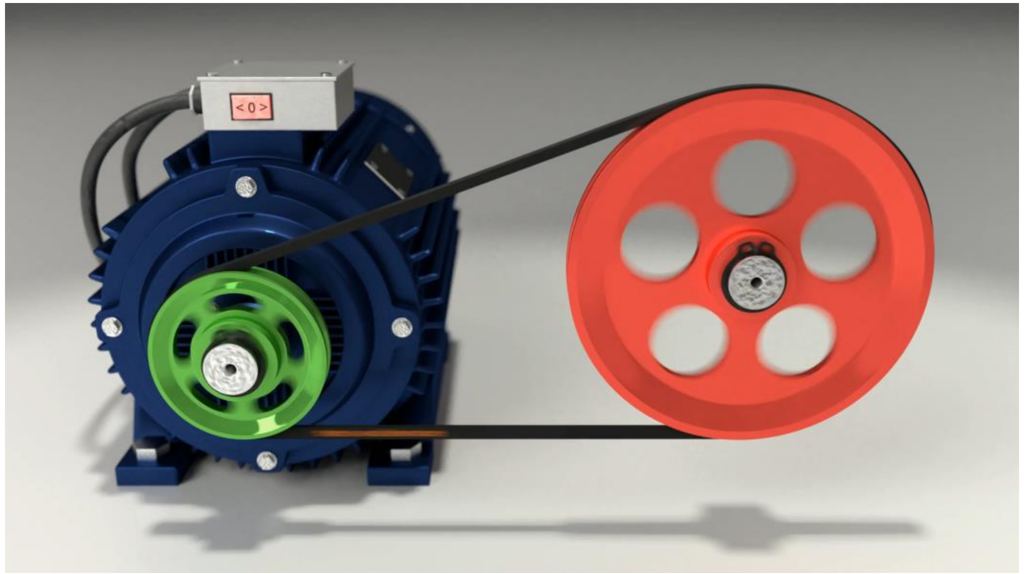


The main types of the belt: a) open, b) cross, c) semi-cross, d) angular, e) step drive f) with the ability to adjust the belt tension.



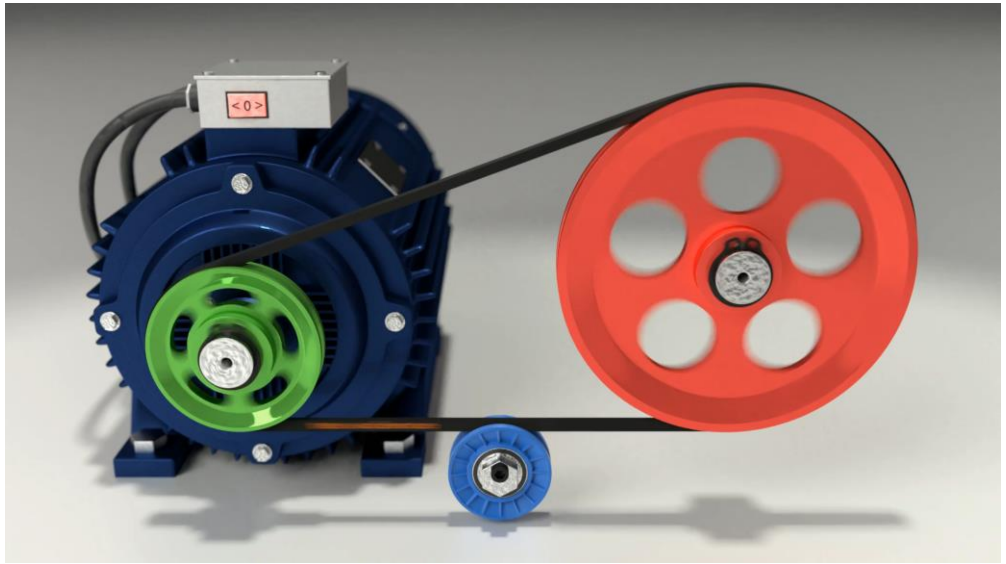
Drive with cross belt to change the direction of rotation

Belt tensioning systems

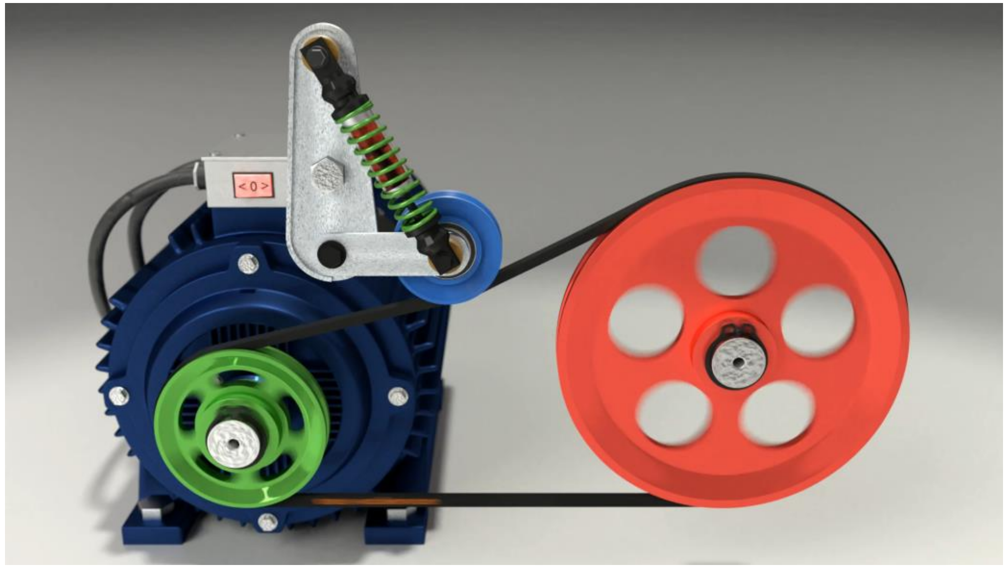


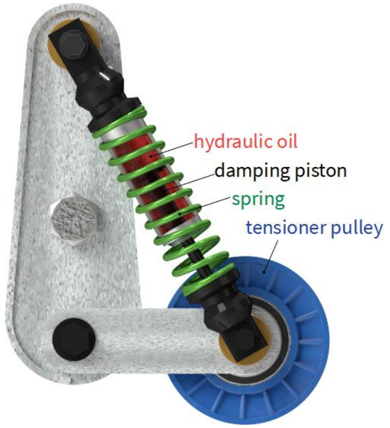
Tension pulley

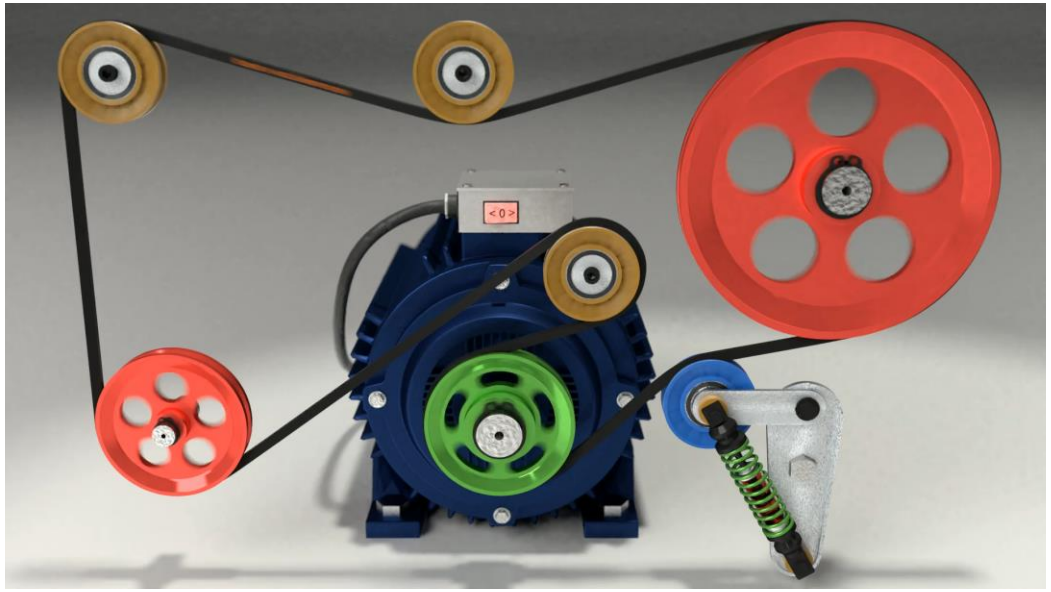
Eccentric tension pulley

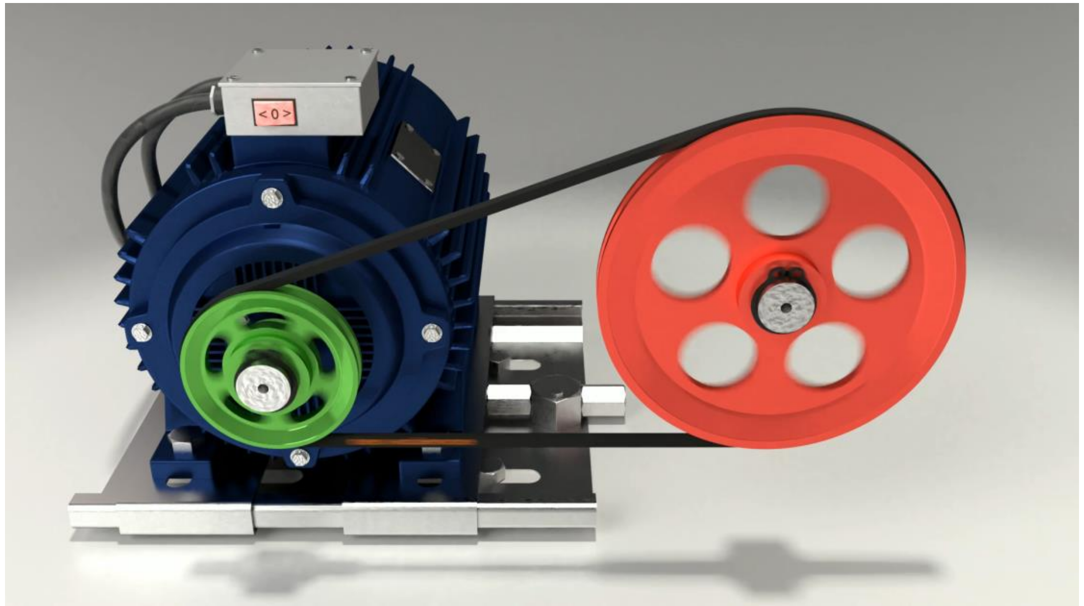


Hydraulic damping element

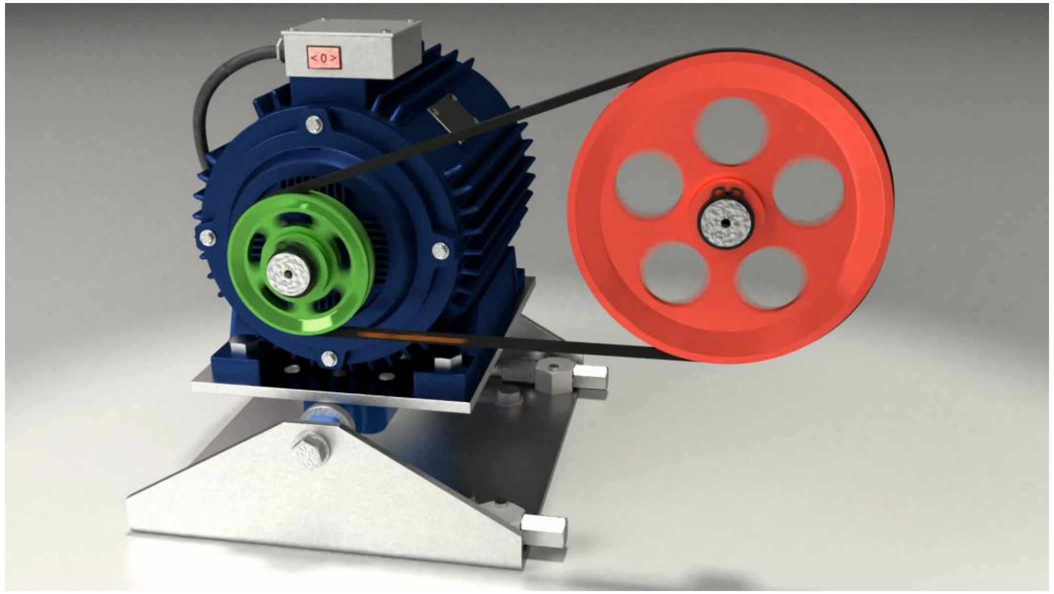






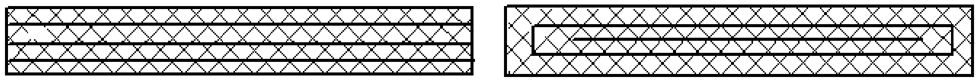


Mobile engine mount



Swivel engine mount

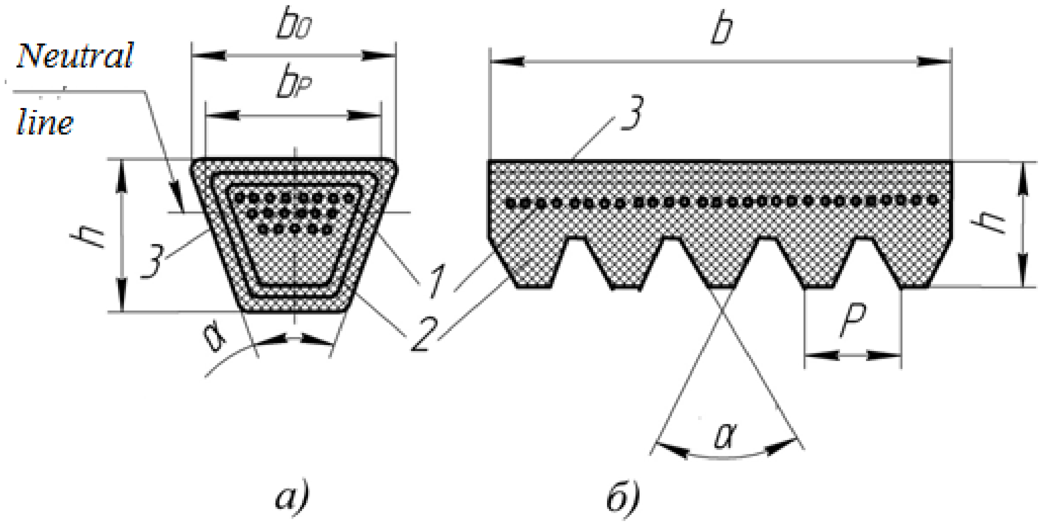
Types of belts



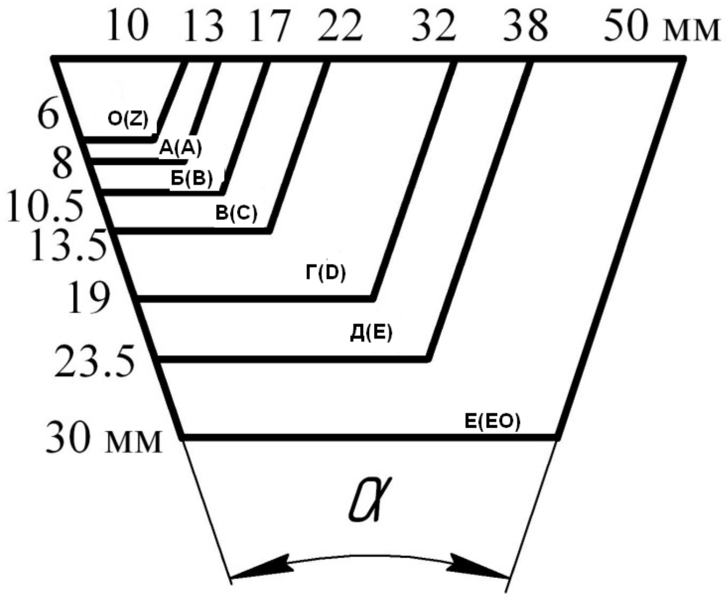
а) б)

Flat belts

a) - threaded; b) - with layered wrapped belting



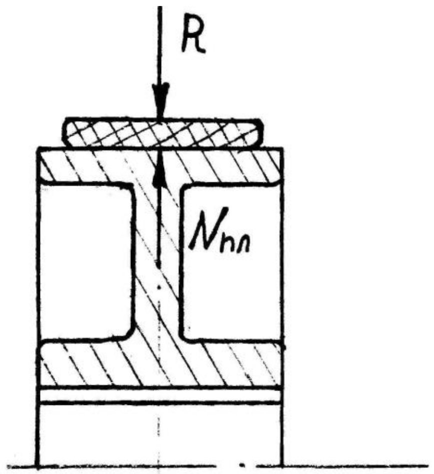
V-belt a) and poly V-belt b)



Dimensions of normal V-belts

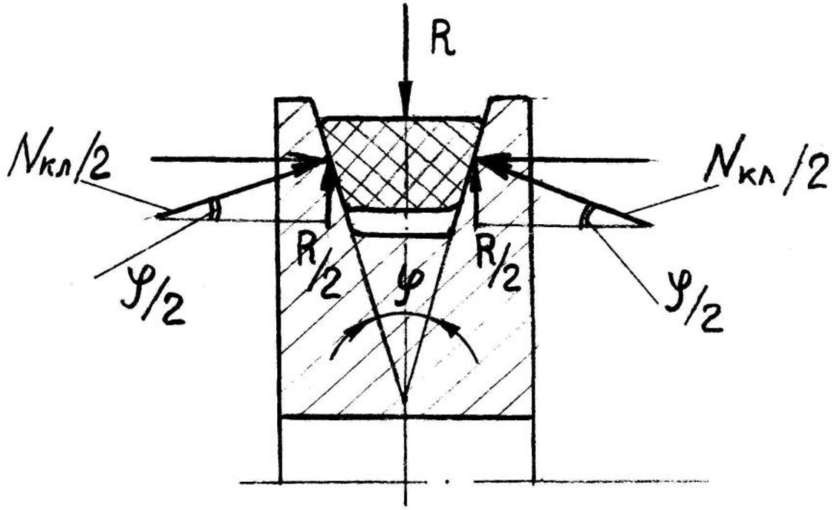
Friction forces

$$F_{fr} = f \cdot N$$



$$N_{пл} = R$$

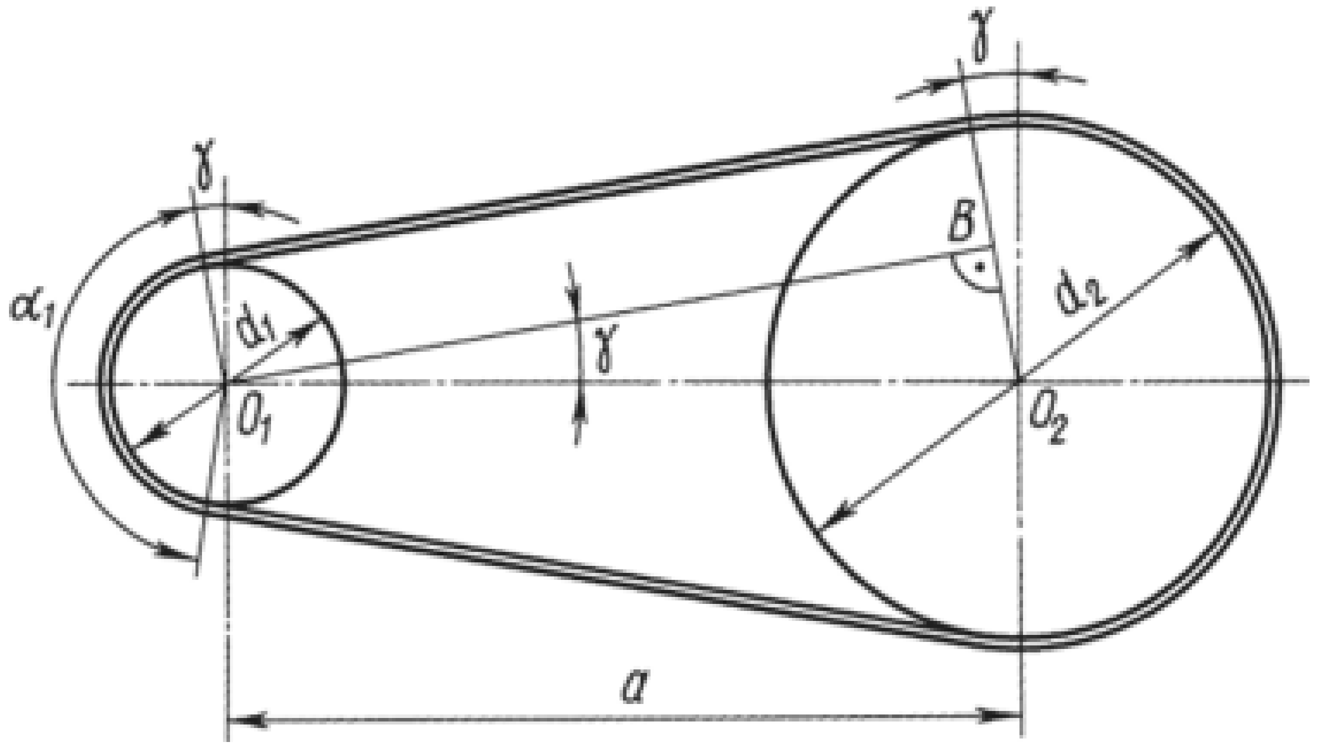
$$F_{fr}^{\ пл} = f \cdot R$$



$$N_{кл} = R / \sin\left(\frac{\varphi}{2}\right)$$

$$F_{fr}^{\ кл} = \frac{f \cdot R}{\sin\left(\frac{\varphi}{2}\right)}$$

Geometric parameters of the belt drive



Diameters of pulleys in flat belt transmission:

$$d_1 = (1100...1300)\sqrt[3]{\frac{P_1}{n_1}}; \quad d_2 = d_1 u(1-\xi)$$

Recommended wheelbase

for flat belt transmission: $$a \geq 1{,}5 \cdot (d_1 + d_2)$$

for V-belt transmission: $$a \geq 0{,}55 \cdot (d_1 + d_2) + h$$

Estimated belt length:

$$L = 2a + \frac{\pi}{2}(d_1 + d_2) + \frac{(d_2 - d_1)^2}{4a}$$

Specified wheelbase:

$$a=\frac{1}{8}\left\{2L-\pi(d_1+d_2)+\sqrt{[2L-\pi(d_1+d_2)]^2-8(d_2-d_1)^2}\right\}$$

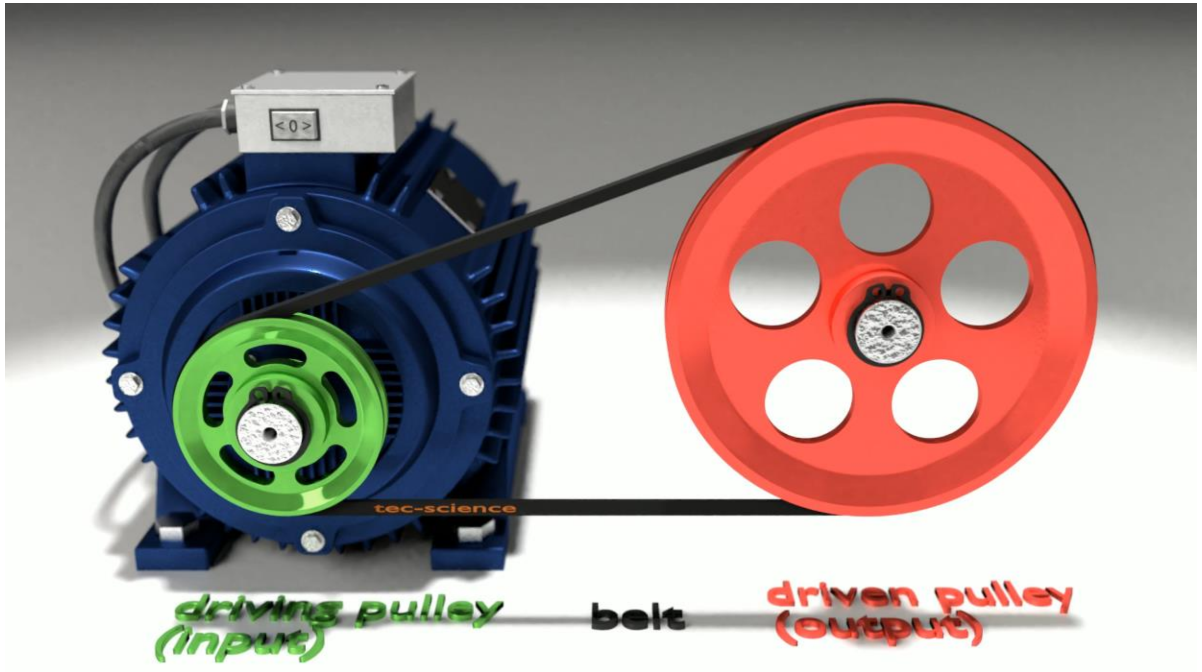
The angle of wrap on the small pulley :

$$\alpha=180^0-2\cdot\gamma=180^0-60\frac{d_2-d_1}{a}\geq[\alpha]$$

$[\alpha]=150^\circ$ for flat belt transmission;

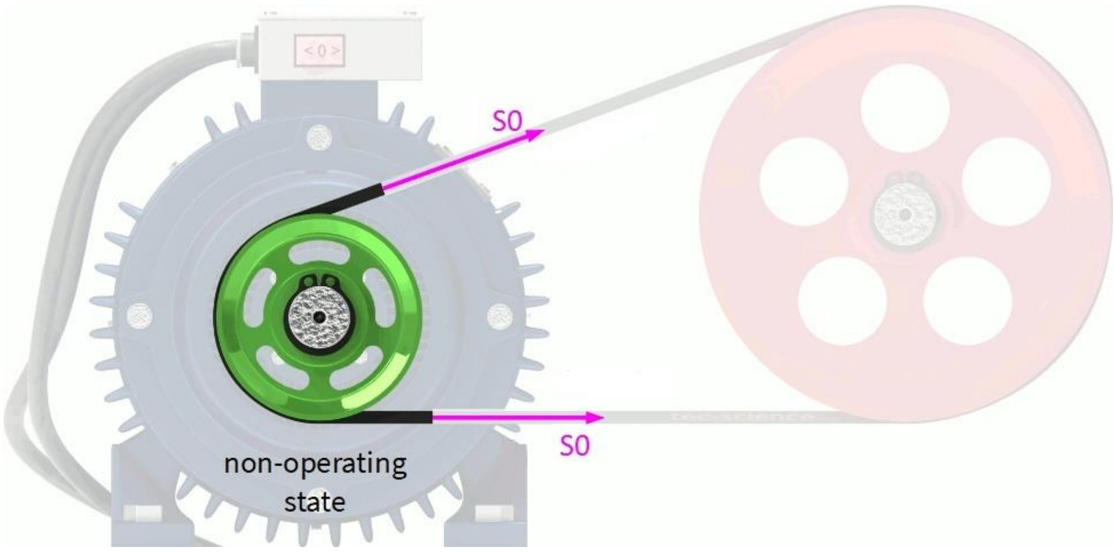
$[\alpha]=110^\circ$ for V-belt transmission.

Tight side and slack side of a belt drive



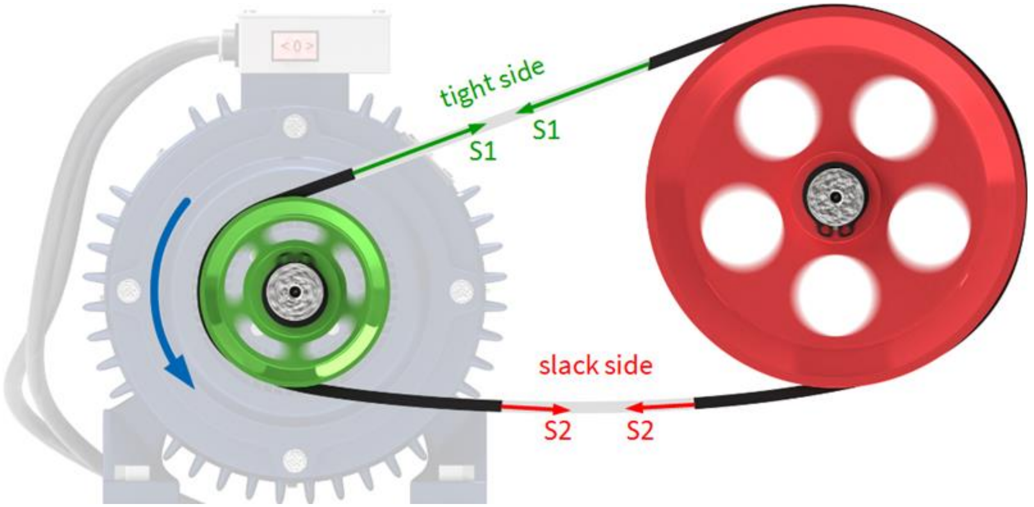
The section of the belt in which the belt is strongly pulled towards the driving pulley and is thus exposed to a large tensile load is referred to as the **tight side**. On the opposite section, the belt moves away from the driving pulley and is slightly relieved by its “pushing” effect. This belt section is called **slack side**.

Pre-load tension, tight side, slack side forces

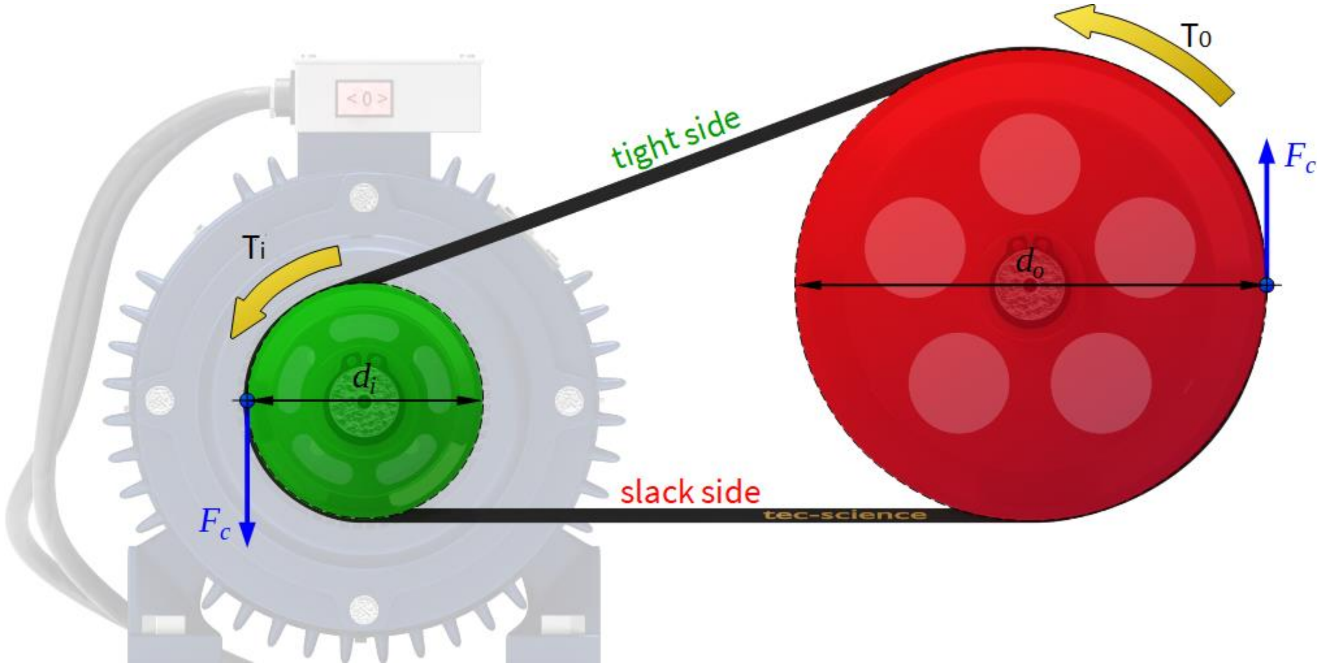


S0 - the force of pre-load tension

S1 - the tight side force
S2 - the slack side force



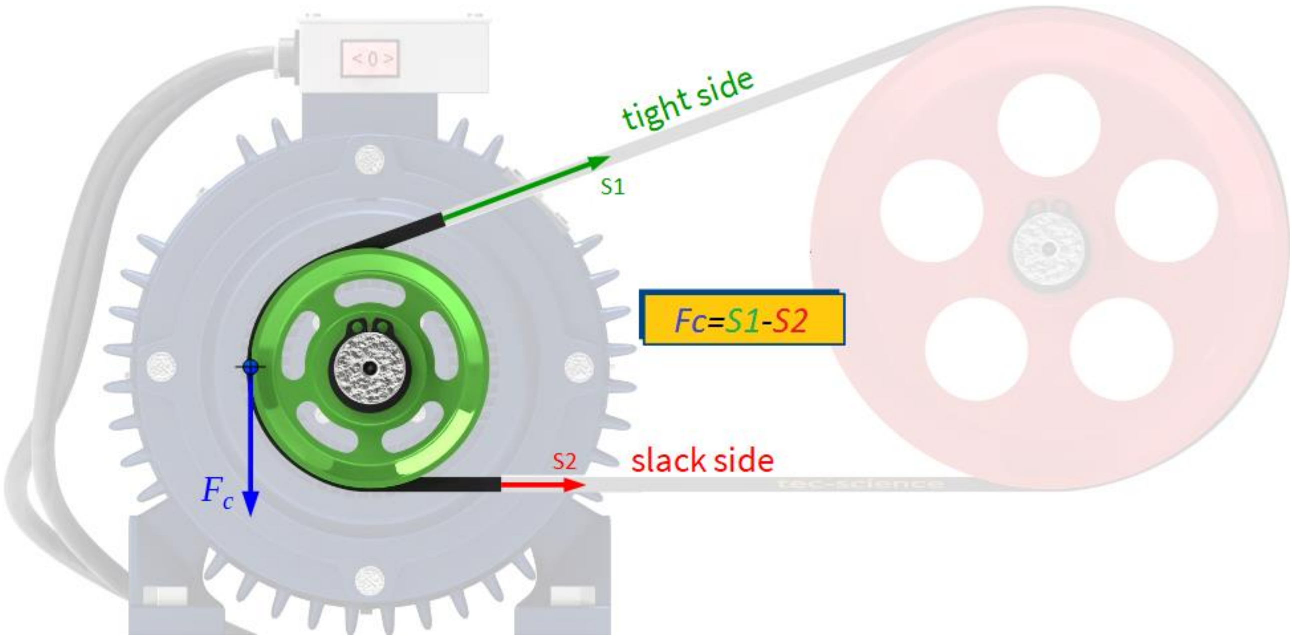
Circumferential force



The force to be transmitted from one pulley to the other is also referred to as the effective force or circumferential force *Fc*

$$F_C = \frac{2 \cdot T_i}{d_i} = \frac{60000 \cdot P_i}{\pi \cdot n_i \cdot d_i}$$

The balance of forces

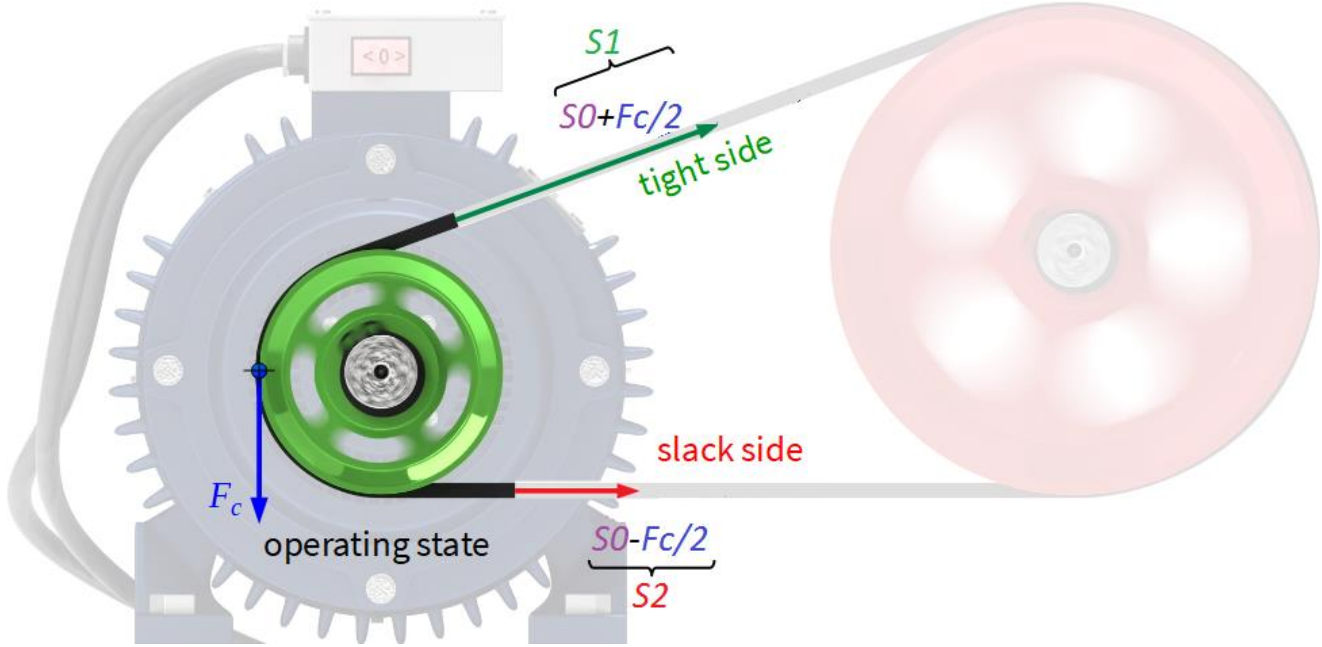


The balance of forces on a pulley generally shows that the difference between the tight side force *S1* and the slack side force *S2* corresponds to the transmitting circumferential force *Fc*

$$S1 = Fc + S2$$

$$Fc = S1 - S2$$

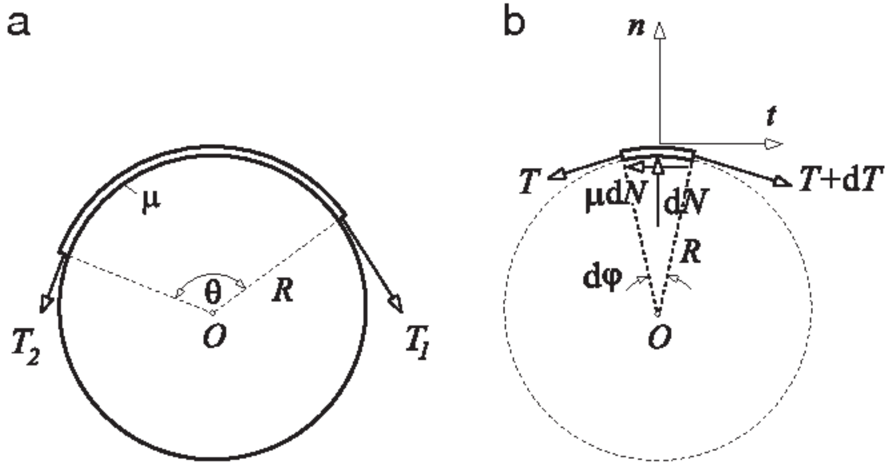
Preload with circumferential force



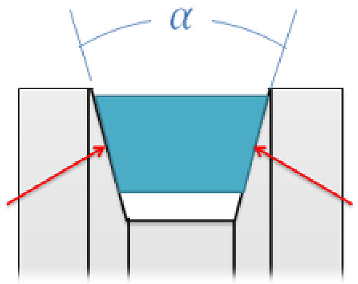
In the load-free idle state, only the pre-load *S0* in the belt initially acts. If a circumferential force *Fc* is introduced by the torque of the input pulley, the belt force in the tight side increases to *S1* and the slack side force decreases to the same extent to *S2*.

The tight side force increases by just half the circumferential force and the slack side force decreases by half the circumferential force.

Belt friction



$T_1 = T_2 e^{\mu_v}$ where... $\mu_v = \dfrac{\mu}{\sin\left(\frac{\alpha}{2}\right)}$



Coefficient of friction between surface and belt

Euler's constant ≈2.718

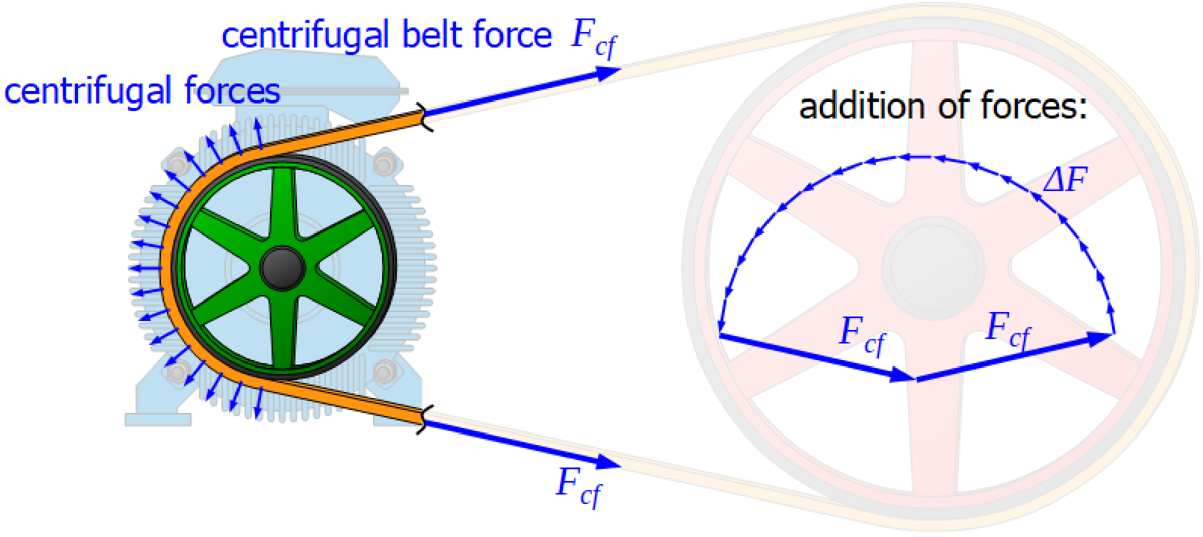
Angle of contact in radians

$$T_1 = T_2 e^{\mu \alpha}$$

Always the larger tension force

Always the smaller tension force

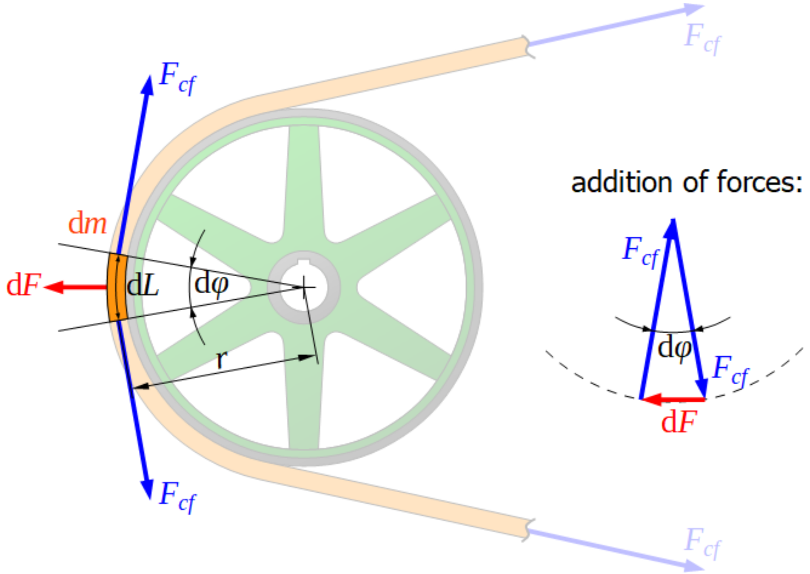
Centrifugal forces



At higher belt speeds, however, considerable centrifugal forces act on the belt sections which run around the pulleys. These centrifugal forces are trying to pull the belt outwards and lift it off the pulley. However, this would mean a reduction in the contact pressure and thus a reduction in the frictional force between belt and pulley.

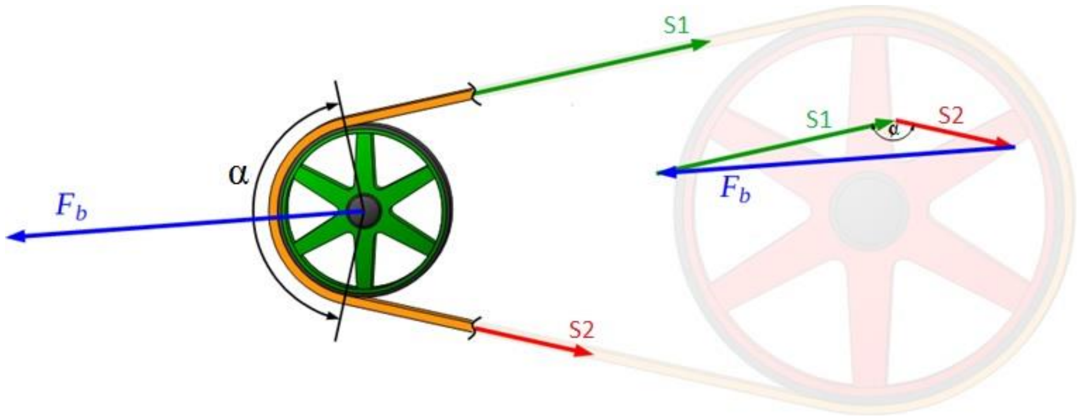
$$dF = dm \cdot a = dm \cdot \frac{v^2}{r}$$

$$F_{cf} = \rho \cdot A \cdot v^2$$



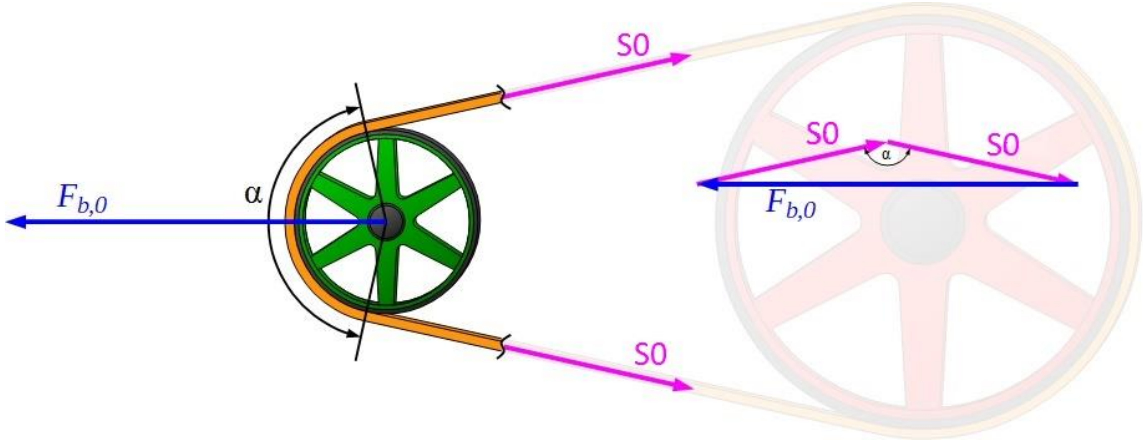
Bearing force

The forces acting in the belt press the belt onto the pulley and thus also act on the shaft bearings. The tight side force and the slack side force is thus balanced by the bearing force of the shaft.



By the law of cosines:

$$F_b = \sqrt{\left(S1^2 + S2^2 - 2 \cdot S1 \cdot S2 \cdot \cos(\alpha)\right)}$$



In a load-free standstill, i.e. when no circumferential force is transmitted (*Fc=0*), the bearing load is determined only by the total preload force *S0*

$$F_{b,0} = S0 \cdot \sqrt{2 \cdot \left(1 - \cos(\alpha)\right)}$$

Stresses in a belt

The resulting stresses σ are obtained by referring the forces to the cross-sectional area A of the belt:

$$\sigma_1 = \frac{S1}{A}$$ tight side tension

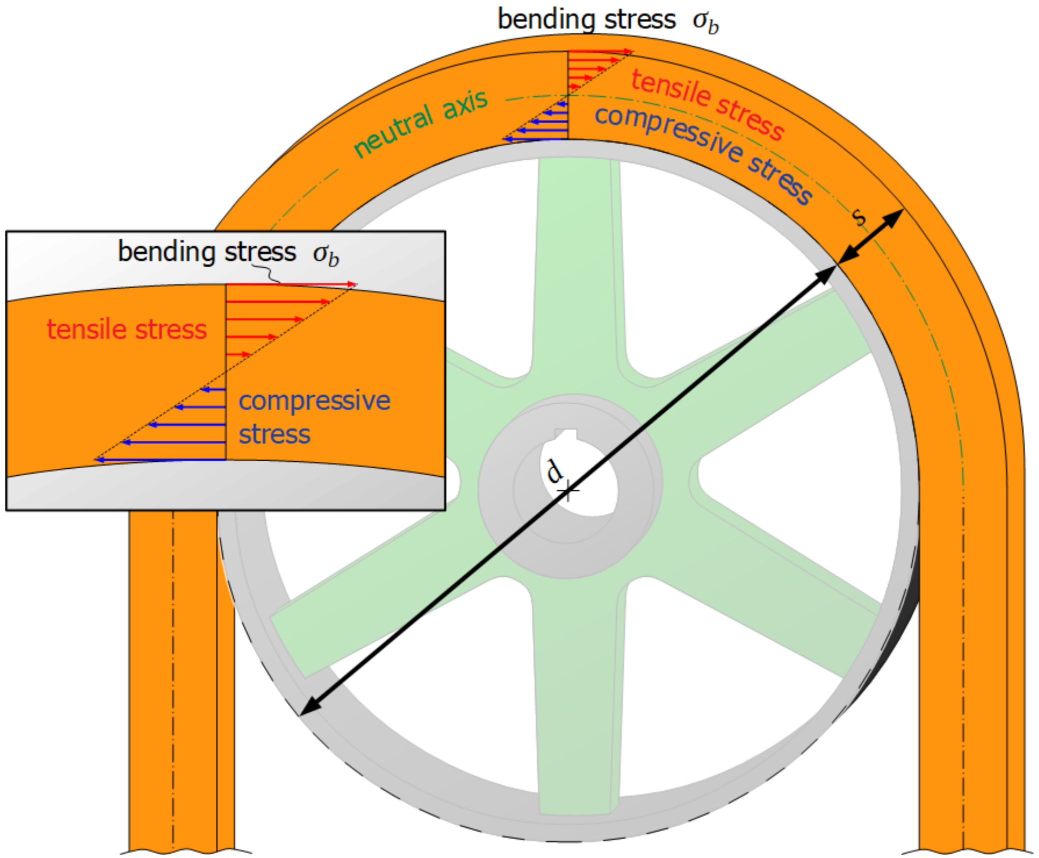
$$\sigma_2 = \frac{S2}{A}$$ slack side tension

$$\sigma_0 = \frac{S0}{A}$$ pre-load tension

$$\sigma_{cf} = \frac{F_{cf}}{A} = \rho \cdot v^2$$ centrifugal tension

$$\sigma_c = \frac{F_c}{A}$$ effective tension

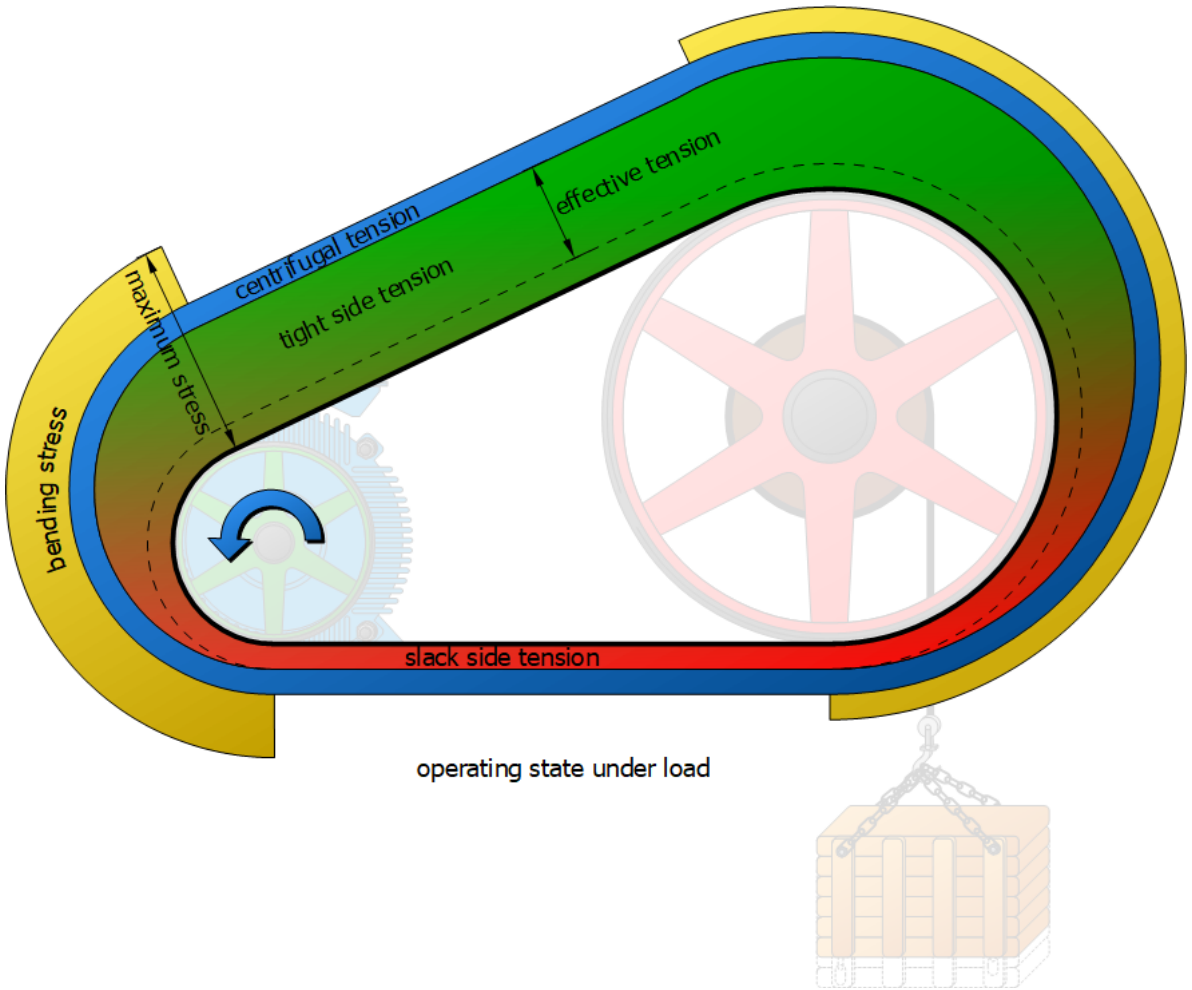
Bending stress



In addition to the above mentioned stresses, bending stresses *σb* must also be taken into account when rotating the belt around the pulleys. The belt is stretched in the outer areas and compressed in the inner areas; the neutral axis runs in-between and is neither stretched (necked) nor compressed (bulged).

$$\sigma_b = E \cdot \frac{S}{d}$$

Maximum belt stress



The figure schematically shows the distribution of the belt tension.

$$\sigma_{\max} = \sigma_{cf} + \sigma_1 + \sigma_{b1} = \sigma_{cf} + \sigma_0 + \frac{\sigma_c}{2} + \sigma_{b1}$$