GENERAL JONAS ŽEMAITIS
MILITARY ACADEMY OF LITHUANIA

THE DIESEL ENGINES RELIABILITY IN THE DIFFICULT CONDITIONS OF AFGHANISTAN

PART V

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Agenda

Subject: STUDY OF RELIABILITY OF ENGINES OPERATING IN DIFFICULT CONDITIONS AND ESTABLISHING ENGINES RELIABILITY IMPROVEMENT MEANS

Engine reliability study

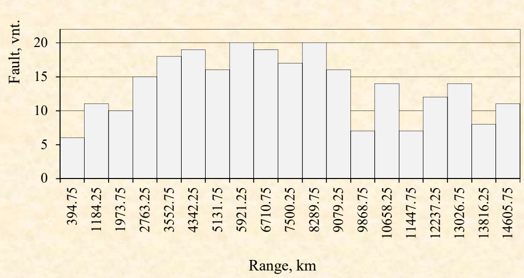
MAP OF GEOGRAPHICAL LOCATION OF AFGHANISTAN. REGIONS OF DESERTS

Oxus basin Amu Darja (1A), Kara-Kum Garagum, Badghyz and Karabil (1B). Clay deserts: Seistan, Dasht-e-Margo and Dasht-i-Arbu South, South-West Afghanistan desert (1C), Registan, South-East Afghanistan Sandy Desert (1D). Regions of semi-deserts: Khorassan (2A), part of Persian Iran) desert (2B), valleys of semi-deserts of the Afghan Mountains (2C). Regions of hills, semi-deserts and lower mountains that can be passed through: regions of Safedhok and Circum Oxiani-Hill (3A), and Siahkok (3B). Mountainous regions: Chorat (4A), Paropamiz and Hazarajat Mountains (4B), alpine plain surface Hindu Kush (4C), Pamir high-mountainous region (4H). (Michael A. Mares 1999, 2003).

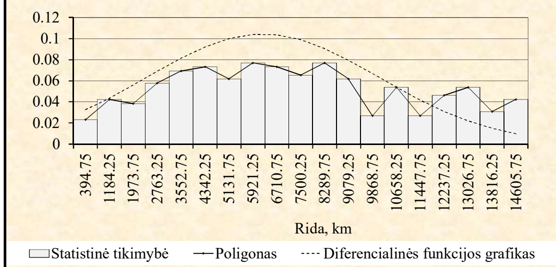
The period of 2005-2013 years recorded by Air Traffic Management Centre of Chaghcharan Airport using Vaisala TacMet Tactical Meteorological Observation System MAWS 201M with the software MIDAS IV Tacmet extremes

- The lowest temperature was recorded (of -46.1°C at Chaghcharan, -52.2°C at Shahrak)
- The highest temperature was recorded (of +41.1°C at Chaghcharan, of +49.6 °C – at Zaranj) July, 2006
- The maximum wind speed over amounted for 65.5 m/s (May 3, 2008). **of 91.1 m/s was recorded on August 14, 2008** in Ab-Paran city, Ghowr Province, Afghanistan.
- The Dust and sand concentration highly varies during sand storm, and may achieve values of 10.4 g/m^3
- The maximum duration of a sand storm was 62 days.

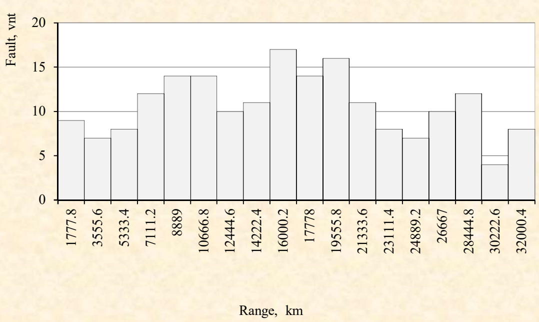
Engine reliability study (GM6.5L)



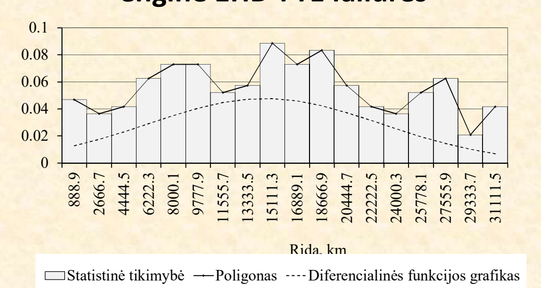
Determining probability distribution of ICE engine GM6,5L failures



Engine reliability study (1HD–FTE)



Determining probability distribution of ICE engine 1HD-FTE failures



Engine reliability study

• Accidental quantities distribution law depends on the origin of failure occurrence, it is characterized by individual features that are difficult to determine. Thus, having the hypothesis derived and parameters of the distribution law set, it is absolutely necessary to verify if the hypothesis matches experimental findings. Assessment of the conformity with the distribution law for engines GM6.5L and 1HD–FTE was carried out using χ^2-Pearson's goodness of fit measure. Based on the available data, $P_c(\chi^2>u)$ = 0.001 for both engines was calculated, and a low probability was found, thus function $F(x)$ was rejected as unfit and unacceptable. Based on the selected lengths of engine operation – i.e., 15,000 km for the engine GM6.5L, and 32,000 km for the engine 1HD-FTE – histograms of accidental quantity distribution and their polygon graphs were obtained. In summary of obtained findings, statistical distributions (normal, Weibull's, exponential) typically used in engine reliability theory is suitable.

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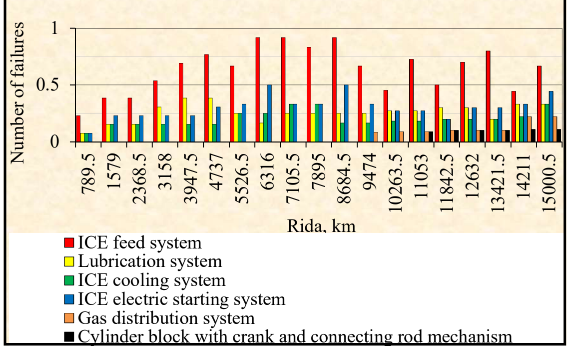
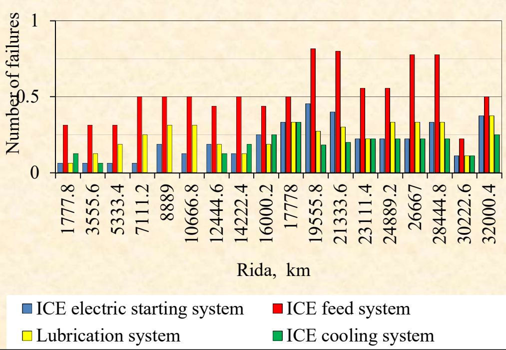
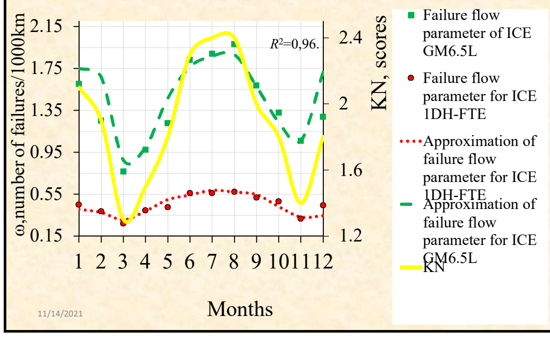
ENGINE GM6,5L



ENGINE 1HD-FTE



Research into reliability of engines operating under difficult conditions, and establishing reliability improvement means



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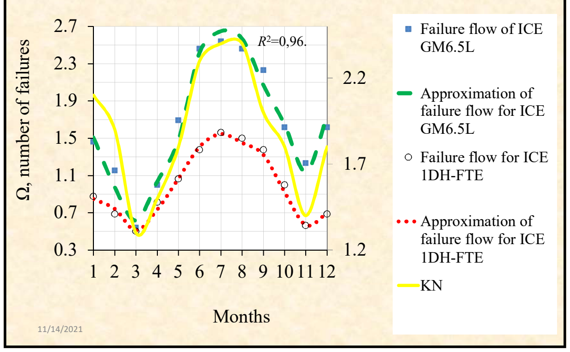

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Research into reliability of engines operating under difficult conditions, and establishing reliability improvement means

- In case under consideration, the failure flow parameter depends on the following **three factors: climatic adversity, road conditions, and operating intensity.** Given research findings and the equation (10) of proposed hypothesis, a system of linear equations can be constructed which is further expressed in the matrix form.

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Research into reliability of engines operating under difficult conditions, and establishing reliability improvement means

- To find out coefficients of polynomial approximation, the system of linear equations was solved in the matrix form. When solving the system of equations, the coefficients of mathematical simulation of the approximation are calculated such as relationship between the engine failure flow, weather adversity for ICE operation, rolling resistance coefficient, and operating intensity, which results in the following regression function:

$$\omega_{1HD-FTE}(\tau) = 0.026 + 0.06 K_N^2 + 0.6 f + 0.002 l_{ei}$$

$$\omega_{GM\ 6,5L}(\tau) = 0.01 + 0.28 K_N^2 + 2.4 f + 0.005 l_{ei}$$

Research into reliability of engines operating under difficult conditions, and establishing reliability improvement means

- As research shows, the failure flow parameter is variable, not constant, whereas the reliability function differs from the exponent. Assessing engine reliability requires taking into account deviation of the distribution of number of failures from Poisson distribution.

Research into reliability of engines operating under difficult conditions, and establishing reliability improvement means

Determining engine reliability includes calculation of the function $R_n(l,u)$ which is treated as the reliability of failure of the engine with K_{se} components for m times in range under investigation (Konarchiuk B., 1991):

$$R_n(L,u) = \frac{(\overline{\omega} L)^{m_n}}{m_n!} exp^{-\omega L} + \varepsilon\delta^2 \frac{(\overline{\omega} L)^{m_n}}{m_n!} exp^{-\omega L}$$

where – the average failure flow parameter; m_n – number of failures in length under investigation; – offset (deviation) from the approximation typical for Poisson distribution, ε – deviation of the dispersion of number of failures from Poisson flow dispersion; ω – ICE failure flow parameter; m_n – number of failures; L – length of engine operation.

$$\varepsilon = \frac{1}{2}(m_D - m_v),$$

where m_D – dispersion of number of failures in the interval; m_v – average number of failures in the interval.

Research into reliability of engines operating under difficult conditions, and establishing reliability improvement means

- Having established value of the parameter $R_n(l,u)$, which ensures continuous completion of tasks, and using equation , the intervals of periodic technical service *L* were estimated optimally ensuring ICE prevention against failure.
- Calculations resulted in the following technical service intervals of automotive engines operating in Ghor province of Afghanistan: **Toyota Land Cruiser 100 diesel engines 1HD-FTE – periodically after each 300 km to 500 km; M998A2 diesel engines GM 6.5L – periodically after each 100 km to 250 km;** more frequent intervals of technical service must be ensured in summertime, less frequent – in early spring, and medium intervals during other seasons.

Engine oil test

Engine oil test (GM6.5L)

Eil. Nr.	Automobilio spidometro rodmenys, km		VDV išdirbis nekeičiant alyvos, km	Alyvos rodiklis						
	Keičiant alyvą	Mėginio paėmimo		Klampumas	Tankis	Dilimo produktai	Korozinis aktyvumas	Klampumo kitimo greitis, s	Pliūpsnio temperatūra, °C	Dėmės testas, balai
1.	8463	13792	5329	0,70	±1	yra	B	45	194	5
2.	7971	11637	3666	0,9	±1	yra	B	67	171	7
3.	9892	11632	1740	1,0	±1	yra	B	64	168	7
4.	11019	12900	1881	0,95	±1	yra	B	43	213	5
5.	5475	10326	4851	0,71	±1	yra	B	40	199	6
6.	6353	10835	4482	0,9	±1	yra	C	42	184	5
7.	7132	11107	3975	0,92	±1	yra	B	39	191	5
8.	4587	10764	6177	0,78	±1	yra	C	57	176	7

Engine oil test

Eil. Nr.	VDV Nr.	Automobilio rida	Kompresijos slėgis cilindruose, MPa							
			1	2	3	4	5	6	7	8
1.	Nr. 2	11 637	2,76	2,76	2,69	2,62	2,76	2,69	2,21	1,45
2.	Nr. 3	11 632	2,21	2,14	2,14	2,14	2,07	2,07	2,07	2,07

The maximum compression pressure of engine GM6.5L engine cylinders shall not exceed 3.45 MPa and the minimum allowable shall be 2.62 MPa. The allowable difference in compression pressure between different engine cylinders is 0.1 MPa.

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Engine oil test (GM6.5L)

Eil. Nr.	Automobilio spidometro rodmenys, km		VDV išdirbis nekeičiant alyvos, km	Alyvos rodiklis						
	Keičiant alyvą	Mėginio paėmimo		Santikinis Klampumas	Tankis	Dilimo produktai	Korozinis aktyvumas	Klampumo kitimo greitis, s	Pliūpsnio temperatūra, °C	Dėmės testas, balai
1.	17375	21748	4373	0,76	±1	yra	B	50	190	5
2.	15745	20973	5228	0,77	±1	yra	B	59	177	6
3.	22987	27241	4254	0,76	±1	yra	B	48	182	5
4.	17332	22941	5609	0,74	±1	yra	B	57	176	5
5.	24756	26946	2194	1,03	±1	yra	B	35	205	4
6.	10666	17193	6527	0,75	±1	yra	C	63	168	7
7.	11220	17787	6567	0,65	±1	yra	B	66	165	7
8.	23463	28792	5329	0,79	±1	yra	B	58	173	5

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Engine oil test

- Analysis of research results obtained on engine operation under difficult conditions leads to observation that components of different types of automotive engines under investigation tend to fail, and their failure intensity is different.
- The pace of changes in characteristics of the oil used in ICEs under difficult conditions is also discussed leading to the observation that engine oil SAE 15W-30 (API CF-4) when used in technically fit engine for more than 5,000 km fails to preserve reserves of its neutralizing, detergent and dispersive properties, and viscosity improving oil additives do not show resistance to destruction, and for this reason engine oil loses its characteristics more rapidly than assumed, meaning that oil change intervals of 8,000 km of the engine oil SAE 15W-30 (API CF-4) used in diesel engines VDV 1DH–FTE, GM6.5L, and OM 366 LA of Toyota Land Cruiser 100, M998A2, and Mercedes Benz Unimog operated in Afghanistan are inappropriate and must be reduced to 5,000 km.

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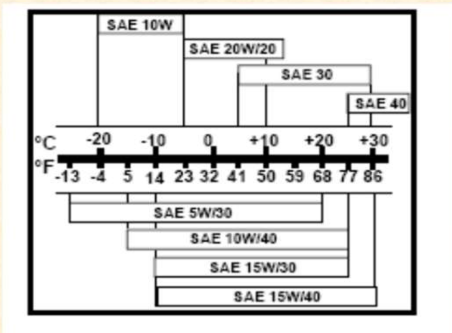
Engine oil test



Identification of measures to increase the reliability of engines

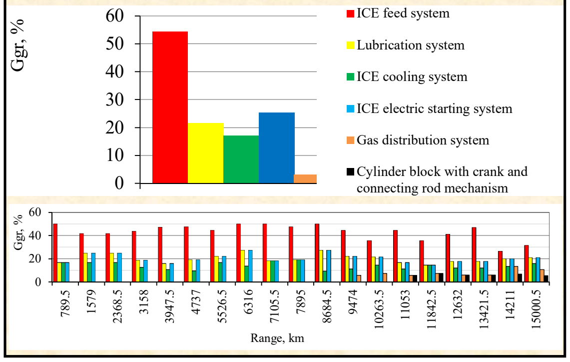
Research into reliability of engines operating under difficult conditions, and establishing reliability improvement means

- Analysis of research results obtained on engine operation under difficult conditions leads to observation that components of different types of automotive engines under investigation tend to fail, and their failure intensity is different.
- Engine components should be considered as reducing ICE reliability when their failure/fault flow accounts for at least 16 % compared to the total number of ICE failures:

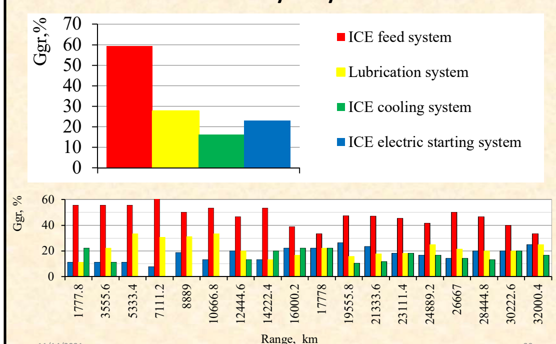
$$G_{gr} = \frac{G_{ssk}}{G_s} 100$$

- where G_{ssk} – number of failures or faults of the particular engine system or engine mechanism, G_s – total number of failures or faults of engine systems and/or engine mechanisms.

Failure flow of faults reducing ICE reliability of the engine GM6.5L by its systems



Failure flow of faults reducing ICE reliability of the engine 1HD-FTE by its systems



Research into reliability of engines operating under difficult conditions, and establishing reliability improvement means

- According to the research completed in this context, there are four weak points of an engine that can be unambiguously blamed for reducing ICE reliability: ICE power, cooling, electric starting, and lubrication systems. Reliability of ICE cooling, electric starting, and lubrication systems might be improved by appropriately selecting technical personnel and using passive reservation of components prone to failures (replacing faulty component with the new one).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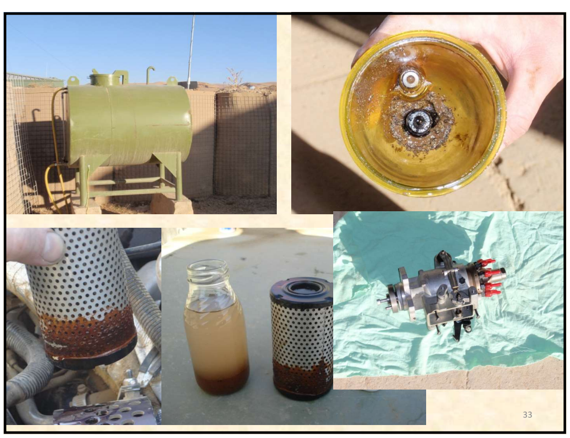
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SUGGESTIONS AND RECOMMENDATIONS

- FAILURE PREVENTION MEASURES
- CONSTRUCTION REQUIREMENTS FOR VEHICLES OPERATED IN AFGHANISTAN
- ASSEMBLY OF REPAIR KITS
- PREPARATION OF TEACHING BOOKS AND MANUALS
- IMPROVEMENT OF THE TECHNICAL OPERATION SYSTEM

GENERAL CONCLUSIONS

- Determining probability distribution of ICE failures is complicated by too low mileage of engines (GM 6.5L – 15,000 km and 1HD-FTE – 32,000 km), for this reason using χ^2-Pearson's goodness of fit measure and making research calculations, a low probability was found, thus function *F(x)* was rejected as unfit and unacceptable.
- The failure flow parameter of Toyota Land Cruiser 100 and M998A2 diesel engines 1HD-FTE, GM6.5L operated under difficult conditions has been investigated. ICE failure flow parameter was found to be dependent on weather adversity for ICE operation, road conditions, operating intensity, and varied depending on the type of engine: for 1HD-FTE – 0.3 to 0.6 failure/1000 km; for GM6.5L – 0.7 to 2.0 failures/1000 km; ICE failures were found to be less frequent in autumn and spring seasons. The fluctuation amplitude of failure flow parameter amounted for two times depending on the season.

GENERAL CONCLUSIONS

- Thermodynamic environment of mountains and fuel properties have a negative influence on diesel engines that run on non-traditional fuels. The analytical mathematical model was used enabling to assess ICE performance under conditions of the highlands. The theoretical assessment of combustion rate of the fuel F-34 (F-35) substitute in diesel engines in high-altitude conditions, resulted in finding that its use is complicated, i.e., operation of the engines is accompanied by too fast fuel combustion – above $(dP/d\varphi)_{max}$< 1.5 MPa, which is evidenced by noisy engine work, an increase of fuel's ignition delay to 7 degrees, and a decrease in effective pressure of combustion cycle by 20 MPA and more. Fuel properties may be improved using appropriate fuel additives.

GENERAL CONCLUSIONS

- Mountainous terrain of Afghanistan and its characteristic climatic factors have a negative effect on ICEs. The climatic factor of this region varies over year, and weather adversity for ICE operation ranges from 1.3 to 2.4 times over year, while achieving its maximum values in winter and summer times.
- Differently structured internal combustion engines offer different capabilities of their adaptation for operation under difficult conditions: diesel engines 1HD-FTE of Toyota Land Cruiser 100 offer twice better capabilities of their adaptation for operation under difficult conditions when compared to diesel engines GM6.5L of M998A2.

GENERAL CONCLUSIONS

- Recommendations were offered for the improvement of engine service system – i.e., to perform technical service and maintenance of internal combustion engines more frequently. Periodicity of technical service for Toyota Land Cruiser 100 diesel engines 1HD-FTE must be 300 to 500 km, whereas for M998A2 diesel engines GM 6.5L – each 100 km to 250 km, respectively.
- Differently structured ICEs offer different capabilities of their adaptation for operation under difficult conditions. Diesel engines 1HD-FTE of Toyota Land Cruiser 100 offer twice better capabilities of their adaptation for operation under difficult conditions when compared to diesel engines GM6.5L of M998A2.

GENERAL CONCLUSIONS

- The investigated internal combustion engines were found to have four weak points contributing to reduced ICE reliability in the system “ICE-environment”: ICE feeding, cooling, electric starting, and lubrication systems. The weakest point was found to be ICE feeding system as its failures accounted for more than 50 % of total number of ICE failures

GENERAL CONCLUSIONS

- Some recommendations were offered for the improvement of engine service system, namely to perform technical service and maintenance of internal combustion engines more frequently (each 300–500 km), to reduce engine oil change intervals (up to 5000 km), to adjust factory default settings of fuel injection (advance angle by 4–6°), to modify high-pressure fuel pumps used in M998A2 (Service Bulletin Nr. 484R4, Nr. 284R2, Nr. 125R4) based on the guidelines promoted by the company “Stanadyne Diesel Systems”, to modify fuels used in engines by adding multifunctional fuel additives (S–1750, S–1745, S–1747, Stadis 450), and to include specific technical requirements on engine designs of vehicles when arranging acquisitions thereof, etc.

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DISCUSSION

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