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SIMULATION MODEL OF THE CATERPILLAR DRIVE OF THE TRACTOR

Head of the Department BLR. Leskovets Igor, Head of the Department BLR. Melnikova Elena
Automechanical Faculty– Belarusian-Russian University, Belarus

1. Introduction

Modern tracked vehicles are used in different industries: construction, mining and agriculture. Depending on the conditions of operation and maintenance, these vehicles are supposed to meet different requirements. Tracked vehicles can be used as transport vehicles, tractive vehicles, vehicles with attachments. The speed of these vehicles, depending on the operating procedure, varies from 0.5 to 35 m/s.

Depending on the type of working operations, different types of loads with different dynamic factors act on the caterpillar drive (the caterpillar). One of the main tasks at the stage of the caterpillar development is to determine loads, to select strength and geometric characteristics of different elements to ensure maximum service life at minimal cost. One of the directions which enables us to solve these tasks is simulation of dynamic systems.

2. Problem discussion

The level of modern production assumes that the developed object is a component of higher level objects, on the one hand, and, on the other hand, it is a system consisting of lower-level objects. Currently, the process of development of tracked vehicles is divided into two stages: the external one, where the vehicle is presented as a part of a high order system, and the internal one, where the object is

a set of tools and systems that make up the vehicle - which determines the need for a system analysis of the vehicles.

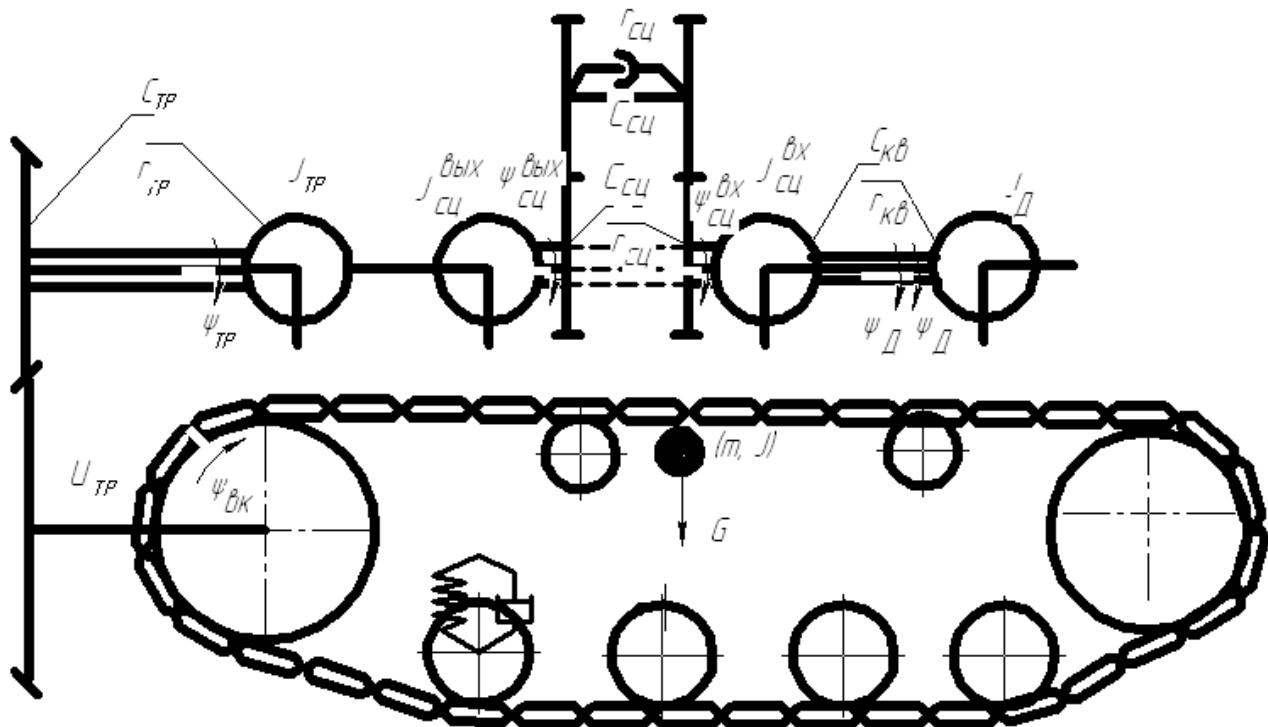
In order to substantiate and select parameters for developed vehicles, it is necessary to conduct not only static but also dynamic analysis, based on comprehensive consideration of interaction of main systems, such as OPERATOR – INTERNAL COMBUSTION ENGINE - TRANSMISSION - CATERPILLAR – BEARING SURFACE.

The problem can be stated as follows: to develop a simulation model of the caterpillar in order to determine at the development stage output characteristics during movement under varying input parameters.

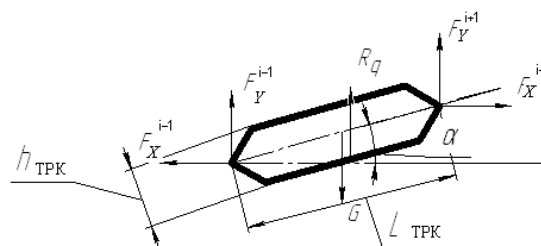
3. Objective and research methodologies

The main stages of this research are: to develop a dynamic model of the caterpillar, to develop a mathematical model, to develop a simulation model.

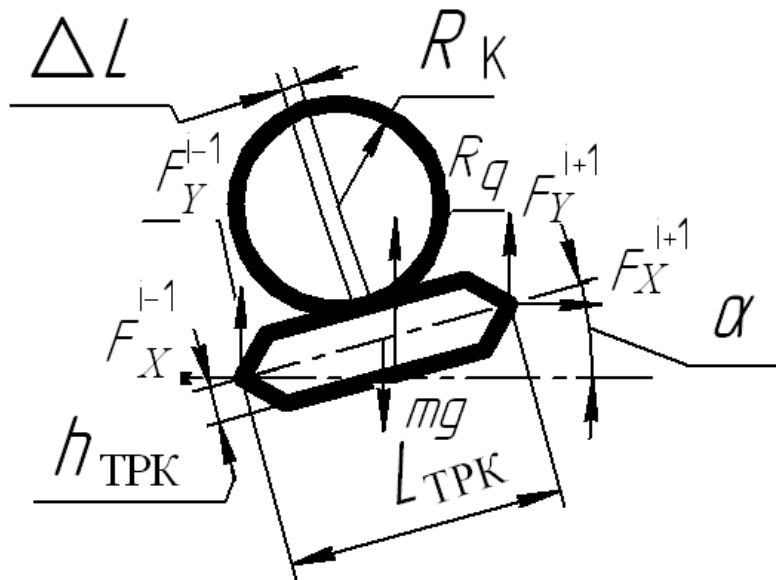
a) the dynamic model of the caterpillar is a graphical representation of the system, which includes all moving elements and the bearing surface. Each of the moving elements is presented in a separate dynamic model which reflects its interaction with neighboring elements.



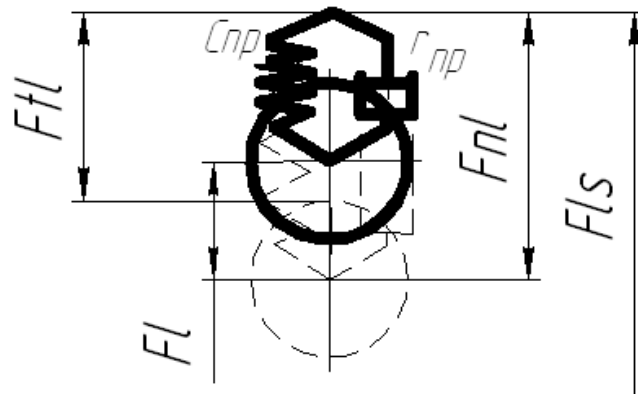
b) version of the dynamic model of the track



c) version of the dynamic model of the wheel



d) version of the dynamic model of the suspension



The mathematical model includes dependences for determining:

- the torque on the crankshaft $M_{\Delta} = a_1^{\Delta} \cdot q_H + a_2^{\Delta} \cdot p_K$;
- the feed of the fuel pump $q_H = b_0^H + b_1^H \cdot \omega_{\Delta} (b_2^H + \gamma_H) + b_3^H \cdot \gamma_H (b_4^H + \gamma_H)$
- the turbocharger boost pressure $p_K = c_0^{TK} + c_1^{TK} \cdot \omega_{\Delta} + c_2^{TK} \cdot q_H - c_3^{TK} \cdot \omega_{\Delta}^2$
- the torque produced on the output clutch disk $M_K = S_{\Pi P} R_{C P} \Phi_T K_{T P} / K_C$
- the torque on the shaft of the main gear $M_{\Gamma \Pi} = (c_{\Gamma \Pi} \varphi_{\Gamma \Pi} - r_{\Gamma \Pi} \frac{\varphi_{\Gamma \Pi}}{dt}) / J_{\Gamma \Pi}$;
- the equations on the basis of which the characteristics of the tracks are determined
- the equations on the basis of which the characteristics of running and supporting wheels are determined

$$\frac{d^2 Y_K}{dt^2} = (C_{\Pi P} \Delta L_{\Pi P} + R_{T P K} - m_K g) / m_K$$

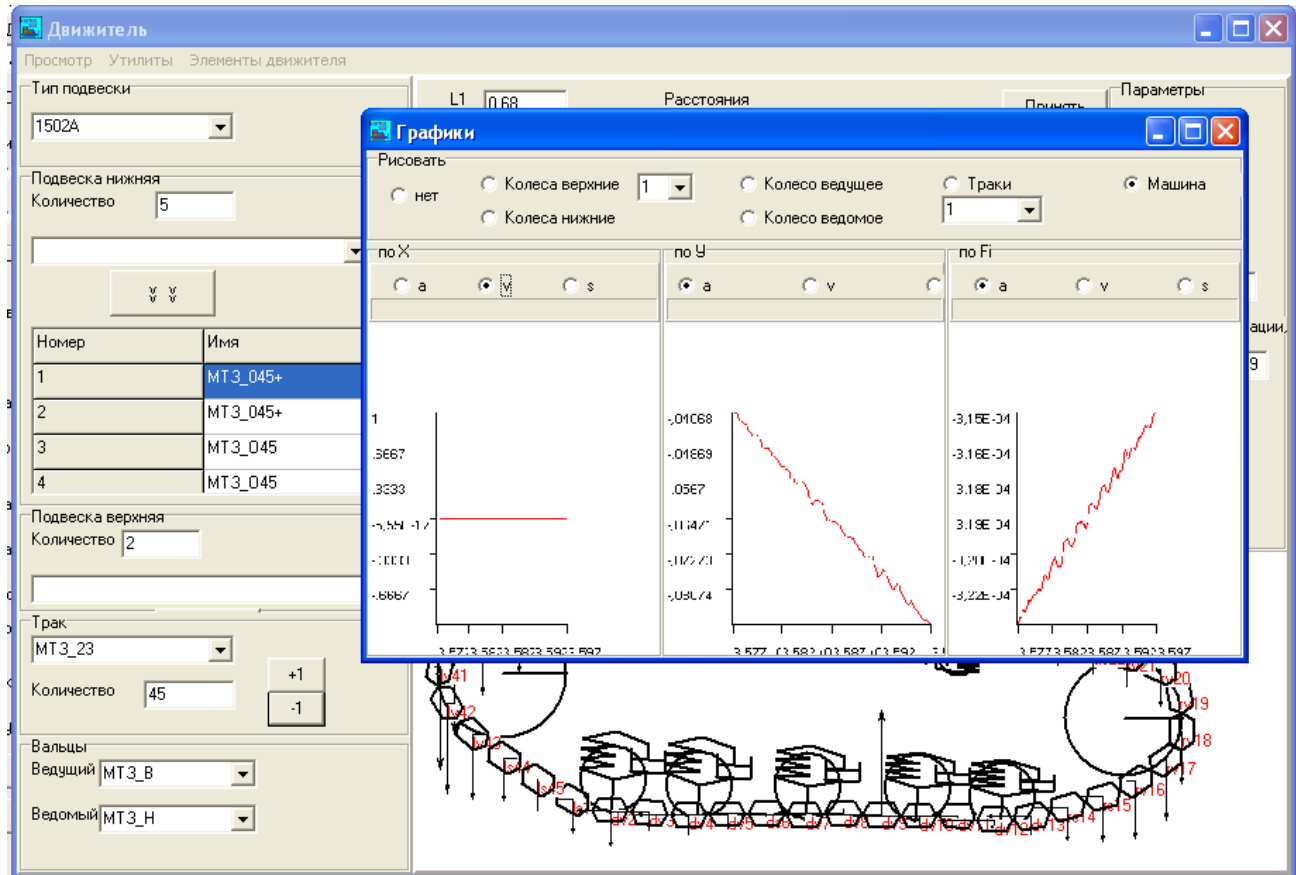
- the equations on the basis of which the characteristics of the whole vehicle are determined

$$\frac{d^2 Y}{dt^2} = (\sum F_{\Pi P} - m \cdot g / 2) / m$$

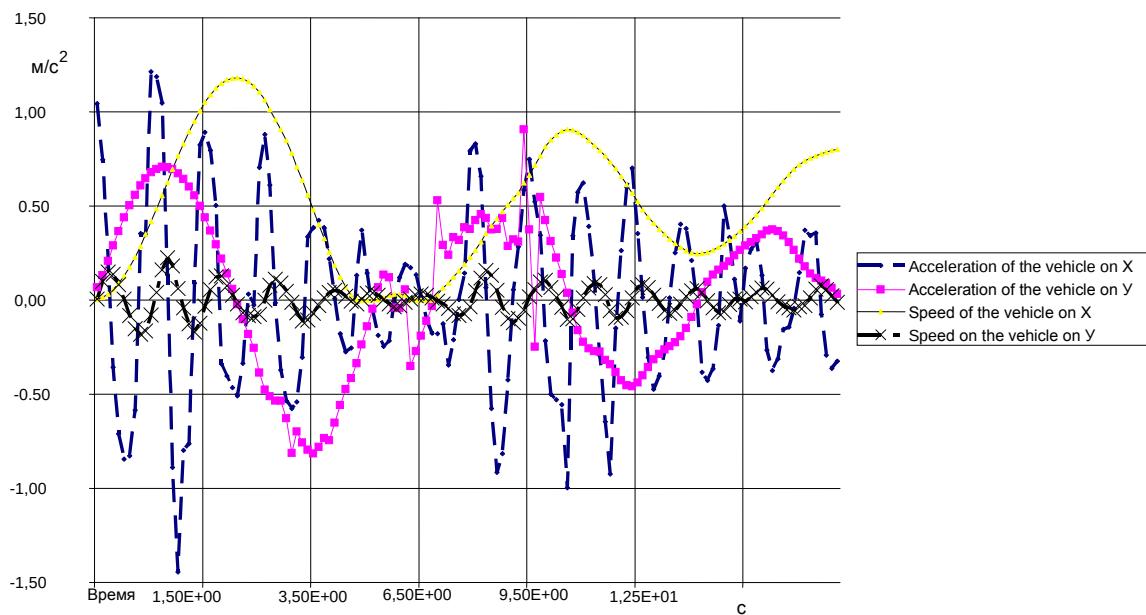
$$J_m \frac{d^2 \varphi}{dt^2} = \sum (F_{\Pi P} \cdot (L_i i - L_{cm}))$$

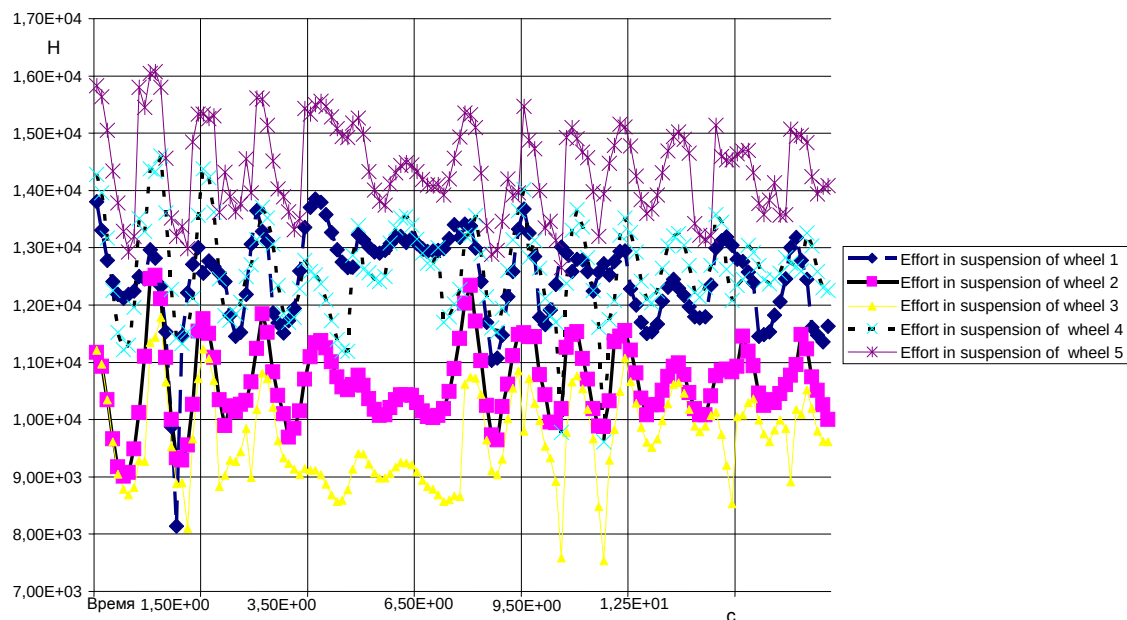
In order to determine the output characteristics of the tracked vehicle, we use a simulation model represented as the software, which combines the engine, the transmission and the caterpillar into a single set.

The software allows simulating the process of movement of the vehicle during acceleration, movement at a constant speed and engine braking.



The software allows us to obtain characteristics of individual elements during movement, process them in MS Office applications to get statistical dependences, and conduct a further analysis of metal structures for strength and durability.





3. Conclusion

A simulation model of the caterpillar based on information-logical functional elements: tracks, wheels and their suspensions, as well as the bearing surface, interconnected by means of mathematical and logical dependences, is developed.

It allows us to present the operation of the caterpillar as a single mechanical system and calculate characteristics of forces generated by interaction of tracks with the bearing surface and wheels, as well as torques on the driving wheel, linear and angular accelerations,

velocities and movements of the caterpillar and its components, pressure on the ground under each track, directions and values of the forces which occur when the vehicle is moving under different conditions.

The analysis of these characteristics at the development stage allows substantiating the choice of values of parameters of the caterpillar elements to meet the criteria determining values of pressure distribution on the ground, maximum traction, linear and angular accelerations of the vehicle, etc.

THE SYNTHETIC MINERAL ALLOYS AS MATERIAL FOR BOMB RESISTANT WASTE RECEPTACLES

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Abstract: *These results characterize synthetic mineral alloys as material with a good capacity for energy dissipation. In the process of a high velocity impact on synthetic mineral alloys, the kinetic energy is transformed into the wave energy, which is proof that structure of synthetic mineral alloys kinetic energy dissipated experiencing multiple conversions with transformation of structure. The present results prove that synthetic mineral alloys relates to the field of bomb resistant and specifically to methods and articles for protecting an object from kinetic threats. Although the material has been described in conjunction with specific embodiments, it is evident that many alternatives, modifications and variations thereof will be apparent to those skilled in the art.*

Keywords: BOMB RESISTANT, KINETIC ENERGY ABSORPTION, BULLET PROOF, SAFETY

Blast mitigation devices, such as bomb resistant waste receptacles, are being deployed to replace one of the softest terrorist targets- trash receptacles. Trash receptacles, which are a necessity for waste management pose a serious threat to public safety and infrastructure security, considering how easily they can conceal an explosive device planted by a terrorist. The trash receptacle becomes part of the attack and maximizes the intensity of the explosion by spraying shrapnel and fragmentation at great distances. It must also be understood that a terrorist attack using ordinary trash receptacles and remote activated or time delayed explosive devices can be easily coordinated to strike multiple places simultaneously or in stages without exposing the terrorist.

One of effective way to eliminate issues of potential dangers of waste receptacles is using especial materials for producing these products. We offer use as bomb resistant material the synthetic mineral alloys. Synthetic mineral alloys relates to the field of materials and including high hardness mineral-group crystal phase (approximately 10-12 GPa (Vickers)) and pyroxene phase, methods of making this materials and products are casting. This materials have high compressive strength (200-300 MPa), low thermal expansion ($(5-25) \cdot 10^{-6} \text{ K}^{-1}$ at temperature 100-1000°C), are impermeable to gases, liquids, biohazards and are resistant to thermal shock [1-2].

The goal of study is disclose possibility of use of the synthetic mineral alloys in bomb resistant and related applications, primarily as material for waste receptacles and products for protection an different objects.

The structure and composition of synthetic mineral alloys are similar to those of mafic and ultramafic igneous rocks. The structure contains a synthetic mineral alloys amorphous phase (2 to 30%) and two or more mineral phases. Siminals are not glass-crystalline materials because they are not crystallised using catalysts. Siminals contain an average of 50% SiO₂; therefore, synthetic mineral alloys melts often split into two liquid phases. The structure of siminals represents a special case of a condensed medium. Some studies noticed that the main part of material fore protection devices have untypical deformation mechanism in hypervelocity impact action - undislocation. Amorphous and composite materials with a heterogeneous structure, which include synthetic mineral alloys are most susceptible to deformation undislocation mechanism than others [3].

Some studies noticed that the synthetic mineral alloys can be similarly of a glass-ceramics having spinel-group crystal phases used for bomb and bullet protection, but the synthetic mineral alloys have a relatively low cost of production than prevalent materials, because these materials can be produce from a man-made raw materials. Products made from synthetic mineral alloys can be any size and any shape, because a raw materials is cheaper than traditional ceramic or glass raw materials and technology of casting permit make product any configuration. For disclose possibility use of the synthetic mineral alloys in bomb resistant and related applications we made experimental studies.

Experimental studies were held on pneumatic installation high-speed penetration (fig. 1), apparatus for dynamic compressive strength tests (fig. 2) (velocity of impact 60-650 m/s) [4-5], tests on landfill by shooting from different type of firearms and Electromagnetic Induction Launcher EML (railgun, velocity of impact 2800-3000 m/s). In experiments with pneumatic installation high-speed penetration and apparatus for dynamic compressive strength results were fixed heat the sample back surface by using an infrared camera CEDIP Silver 450M (tab. 1 and 2).

Table 1: Results of experiments on the high-speed destruction of synthetic mineral sample alloys by using pneumatic equipment

№ test	Parameters of the punch	Impact velocity, V m/c	Temp T _{max} , °C	The point of impact
1	cylindrical shape (L=50mm, Ø5mm, M=7,4g)	650	114	upper
2	cylindrical shape (L=45mm, Ø5mm, M=6,8g)	125	43	middle
3	cylindrical shape (L=45mm, Ø5mm, M=6,8g)	80,6	110	bottom
4	cylindrical shape (L=45mm, Ø5mm, M=6,8g)	49,5	70	middle
5	spherical shape (Ø6mm, M=1g)	65	121	bottom

Table 2: Results of experiments on the high-speed destruction of synthetic mineral sample alloys by using dynamic compressive strength tests equipment

№ test	Speed impact of the punch on the rod, V m/c	Temp T _{max} , °C	The point of impact	The maximum value of stress, Pa	The maximum strain rate, 1/s
1	22,7	185	upper	$3 \cdot 10^8$	$3,0 \cdot 10^3$
2	25	175	middle	$4 \cdot 10^8$	$2,5 \cdot 10^3$
3	23,1	101	bottom	$5,8 \cdot 10^8$	$2,8 \cdot 10^3$
4	24	195	middle	$4,3 \cdot 10^8$	$2,6 \cdot 10^3$

Result of study show that the parameters of fracture of sample depend of reference point. Found that at a strain rate $\sim 2,5 \cdot 10^3 \text{ 1/s}$, samples are destroyed into fragments smaller than 0.5-1 mm (it is approximately size of crystalline aggregates in the structure, aggregates contains from three type of mineral phase). Dependence of the strain rate on the value of stress has not linear character is predominantly parabolic curves. Temperature surface sample at the moment of fracture is 40 – 195°C. Heating of the back surface of sample was uneven, on the back surface of the sample was found

areas with the highest temperature, the higher the impact rate, the greater these areas [6].

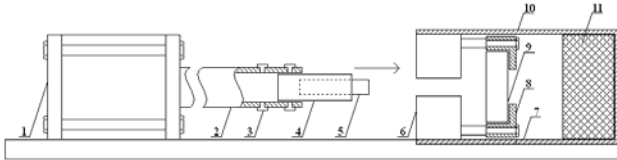


Fig. 1. The scheme of pneumatic installation of high-speed penetration: 1 – chamber of high pressure, 2 – gun, 3 – photosensor, 4 – holder for puncher, 5 – puncher, 6 – device for separating puncher from holder, 7 – stabilizing casing, 8 – holder for target, 9 – target (sample), 10 – receiving chamber, 11 – trap for particles of fracture

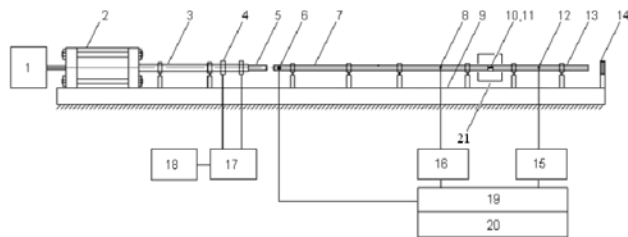


Fig. 2. The scheme apparatus for dynamic compressive strength tests (plate impact): 1 – compressor; 2 – accelerator; 3 – gun; 4 – photodiode speedometer; 5 – puncher; 6 – piezocrystal; 7 – load bar; 8, 12 – tensoresistors; 9 – stabilizing casing; 10, 11 – sample, mirror; 13 – support bar; 14 – buffer; 15, 16 – device for signal amplification with tensoresistors sensor; 17 – device for sensor of measurement velocity; 18 – device for frequency measurement; 19 – main sensor; 20 – PC, 21 – holder for mirror

The phenomena of heating on surface in the moment of impact can be due to exemption some of the energy of chemical bonds.

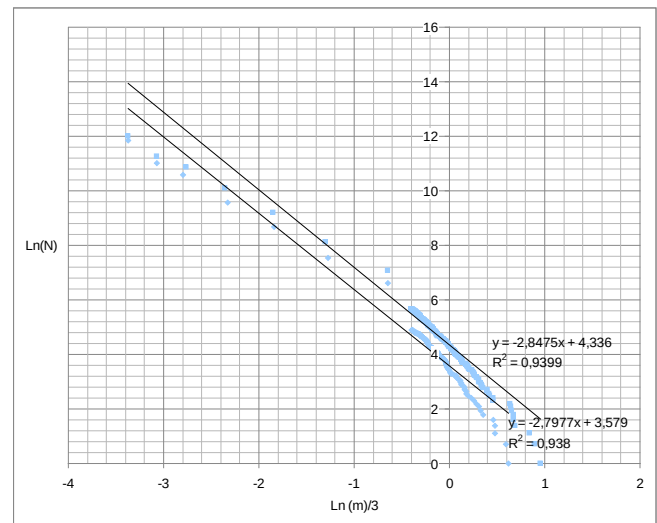
Practical tests on landfill by shooting from different type of firearms [7-8] was used for evaluation ability of using synthetic mineral alloys for bulletproof products. All the synthetic mineral alloys plates prepared as above were tested in accordance with Russian standards of Ballistic Resistance of Body Armor (GOSTs P 51136-98, P 51112-97, P 50941-96) likewise the NIJ 0101.04 and shown to effectively neutralize kinetic threats at the I-IV level. No penetration through the glass- ceramic plates was observed in most part of tests. The results of tests represented in table 3.

Table 3: The Results of shooting of samples from synthetic mineral alloys

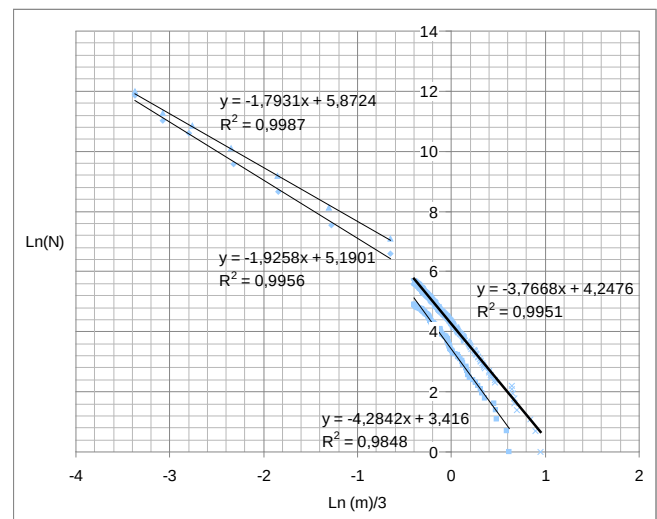
The characteristic of type weapons and condition of tests	The type of firearms			
	The PM (Pistolet Makarova - Makarov's Pistol)	AK-74	SVD Dragunov	SVD Dragunov
The type of cartridge	9-mm 57-H-181C	5,45-mm 7H6	7,62-mm 57-H-323C	7,62-mm 7-B3-3
The type core of cartridge	steel	steel	steel	hardened steel
Mass, gram	5,9	3,4	9,6	10,4
Velocity, m/s	305-325	890-910	820-840	800-835
Distance, m	5	7	7	7
The Result	stop or partial penetration	stop or partial penetration	stop or partial penetration	partial penetration or penetration

Hypervelocity impact made using a punch from Lexan with rate 2800-3000 m/s, rate of punch was accelerated by Electromagnetic Induction Launcher EML (railgun) [9].

Two types of samples of material were used, both types of samples had a disk shape with a diameter of 80 mm. The height of the first kind of samples was 33 mm, and the second - 100 mm. The target sample was placed at a distance of 0.45 m from the muzzle of the railgun.



a



b

Fig. 3. Cumulative distribution function of the target fracture fragments: a - sample D = 80 mm, h = 33 mm at a rate punch V = 2800 m/s, b - sample D = 80 mm, h = 100 mm at a rate punch V = 3000 m/s

For evaluation of the results was used by fractional analysis, scanning electron microscopy and X-ray microprobe analysis. Cumulative distribution functions of fracture fragments by size are shown in Fig.3 The study by scanning electron microscopy was revealed spherical particles (Fig. 4 [10]) among fragments of destruction. These spherical particles are composed of iron oxide according to microprobe spectrum analysis, the structure they are similar to the aerosol particles. Among the fragments of destruction have been found yet amorphous particles and fragments with signs of plastic deformation, while the plastic deformation isn't peculiar for synthetic mineral alloys[11-12].

Research by rate 2800-3000 m/s indicated that for these materials is typical ultrafine grinding and changing the crystal structure defects, aerosol formation, amorphization, and beginning mechanism of the plastic deformation.

A kinetic threat impacting ceramic armor is deformed and the kinetic energy dissipated by inelastic deformation of the armor through a combination of a pulverization energy mechanism and a fracture energy mechanism. In the fracture energy mechanism, kinetic energy is absorbed by the plate from synthetic mineral

alloys, distributed throughout the plate and subsequently expended by the shattering of the plate itself along many radial and circumferential cracks. In the moment of impact in structure of materials as synthetic mineral alloys can be local heating as one of stage of absorbed kinetic energy.

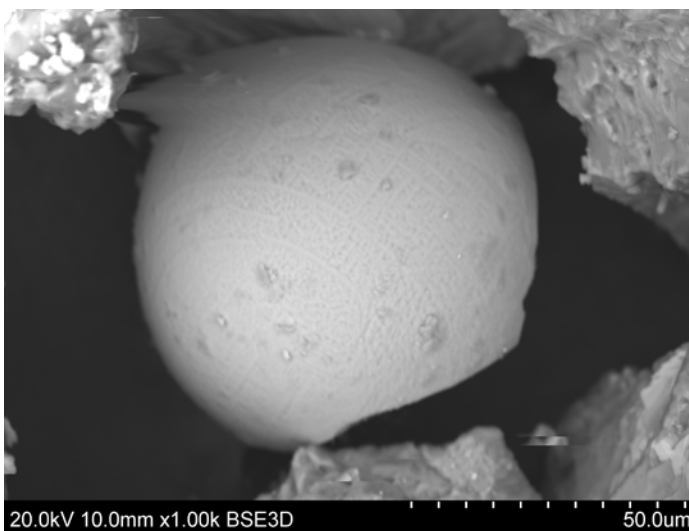
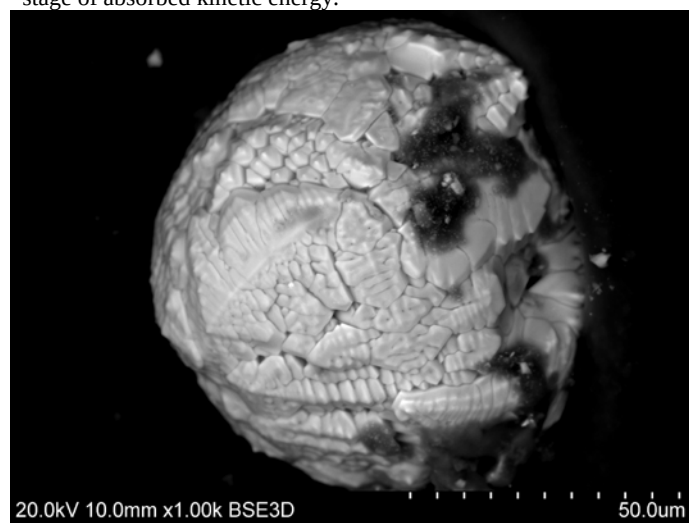


Fig. 4. Spherical fragments after shock wave action

These results characterize synthetic mineral alloys as material with a good capacity for energy dissipation. In the process of a high velocity impact on synthetic mineral alloys, the kinetic energy is transformed into the wave energy, which is proof that structure of synthetic mineral alloys kinetic energy dissipated experiencing multiple conversions with transformation of structure.

The present results prove that synthetic mineral alloys relates to the field of bomb resistance and specifically to methods and articles for protecting an object from kinetic threats.

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RESEARCH ON TEMPERATURE DEPENDENCE ON SURFACE TENSION OF CATIONS SURFACE ACTIVE SUBSTANCES

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Abstract: The object of this research paper is cation surface active substances, used for disinfection. The experiments were conducted in pure original laboratory conditions at different temperature and concentration intervals. The propounded methodology and experimental results are applicable to assess the operational qualities of disinfecting substances.

Keywords: SURFACE TENSION, SURFACE ACTIVE SUBSTANCES.

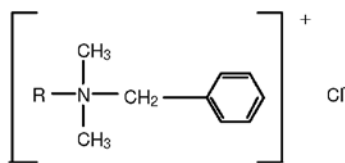
1. Introduction

Eliminating the consequences of biological contamination is often realized with the help of cationic surface active substances. Surface tension is a parameter directly connected with the quality of disinfection.

The objective of this research is to test the surface tension of the disinfecting components at different temperature and concentration intervals.

2. Objects of testing are the following cationic surface active substances:

1) n – Alkyl Dimethyl Benzil Ammonium Chloride /BTC-50E/- pertaining to the group of Ammonium compounds with the following graphic formula:



BTC- 50E possesses a wide specter of bactericidal, fungicidal and virucide activities and it is used to disinfect equipment in food industry, transportation vehicles etc. Its most important parameters are shown in Table1. [1, 3, 5, 6, 7]

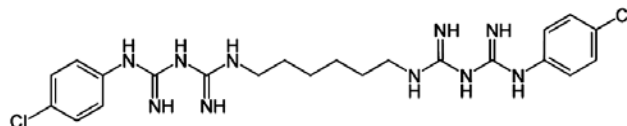
Table 1: Typical properties of BTC- 50E.

properties	amounts
Appearance at 25°C	clear liquid
pH, 5% aqueous	7.5
Colour, Klett value	max 150
Density, g/cm ³	1.000
Viscosity, (Brookfield LVT1, V60), mPa.s	130
Flash point, SETA, °C	>100
Amine + chlorhydrate, %	<1

2/Clorhexidine gluconate- it is used for producing pharmaceutical and cosmetic products with fast bactericidal activity and long-lasting bacteriostatic activity which is a result of adsorption on the surfaces. [1,3] Chlorhexidine is active against gram-positive and gram-negative organisms, facultative anaerobes, aerobes, and yeast. It is particularly effective against gram-positive bacteria (in concentrations $\geq 1 \mu\text{g/l}$). Significantly higher concentrations (10 to more than $73 \mu\text{g/ml}$) are required for gram-negative bacteria and fungi. In the presence of blood or protein the efficacy is reduced by a factor of 100 to 1000. Chlorhexidine is ineffective against polioviruses and adenoviruses. The effectiveness against herpes viruses has not yet been established unequivocally. [4]

Chlorhexidine, like other cation-active compounds, remains on the skin. It is frequently combined with alcohols. [2]

Its graphic formula is:



Its most important parameters are shown in Table2 .

Table 2: Typical properties of Chlorhexidine digluconate.

properties	amounts
Appearance at 25°C	Almost colorless or pale yellow, Clear liquid
pH, 5% aqueous	Between 5.5 - 7.0
Specific gravity, g/ml	Between 1.06 and 1.07
Assay by HPLC	Not less than 19.0% and Not more than 21.0% of C ₂₂ H ₃₀ C ₁₂ N ₁₀ ·2C ₆ H ₁₂ O ₇ (w/v)

Surface tension is determined with the help of conducting laboratory experiments which test the temperature dependence on surface tension. On Fig. 1 there is a laboratory apparatus for measuring a surface tension which we used.



Fig. 1 Laboratory apparatus for measuring a surface tension.

- 1- container for the tested substance
- 2- thermostat with a circulating pump
- 3- faucet, connected to atmosphere
- 4- faucet, connected to water manometer
- 5- capillary tube
- 6- water manometer

An original solution to keep the tests at a certain temperature is suggested. It is realized with the construction and shape of the container in which the tested probe is poured. It is heated with a serpentine, located in the container, through which a circulating

pump moves water with temperature, determined in advance and kept the same by a thermostat.

The methodology of defining surface tension is using the method of blowing a bubble in the capillary^[8, 9]. The formula for calculation surface tension is expressed by the following relation^{1/}:

$$\sigma = \sigma_0 \frac{H-h}{H_0-h} \quad (1),$$

Where σ - surface tension of the tested solution, N/m

σ_0 -surface tension of the solvent, N/m

H- manometric tension/pressure in water manometer of the test, mm

H_0 - manometric tension/ pressure of the solvent, mm

h- depth of capillary diving, mm

Distillated water is used as a solvent of disinfectants. Temperature relation to surface tension is studied at the intervals from 10 to 40 Degrees C with concentration of 3 to 10%.

Experimental results and their consideration:

1/ Research results of the influence of temperature upon surface tension value at different constant concentrations.

The Charts of Fig. 2 and Fig. 3 show how surface tension depends on temperature respectively BTC- 50E and Clorhexidine gluconate.

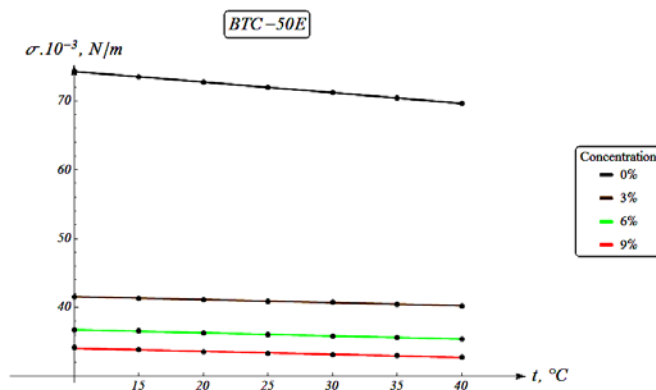


Fig. 2 BTC- 50E and its surface tension dependence on temperature.

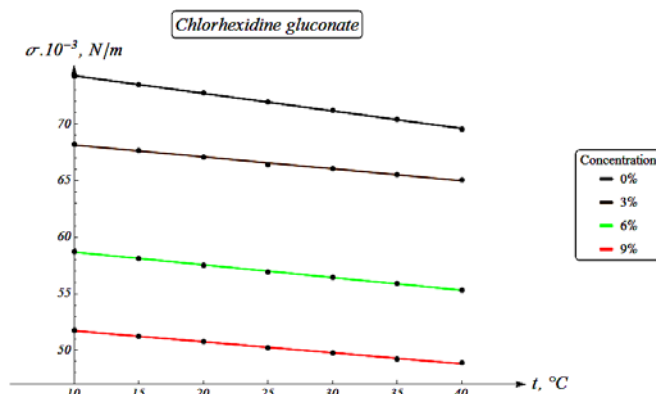


Fig. 3 Clorhexidine gluconate and its surface tension dependence on temperature.

Research results of the influence of concentration on surface tension value at different constant temperature.

The Charts of Fig. 4 and Fig. 5 show the relation between surface tension and concentration respectively BTC- 50 E and Clorhexidine gluconate.

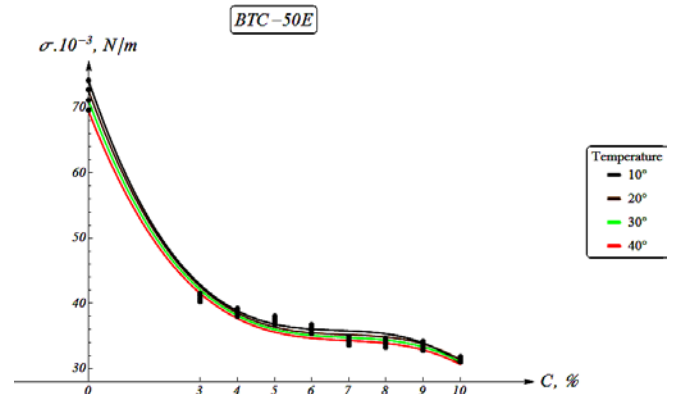


Fig. 4 Dependence of surface tension (σ) on concentration(C) in BTC-50E.

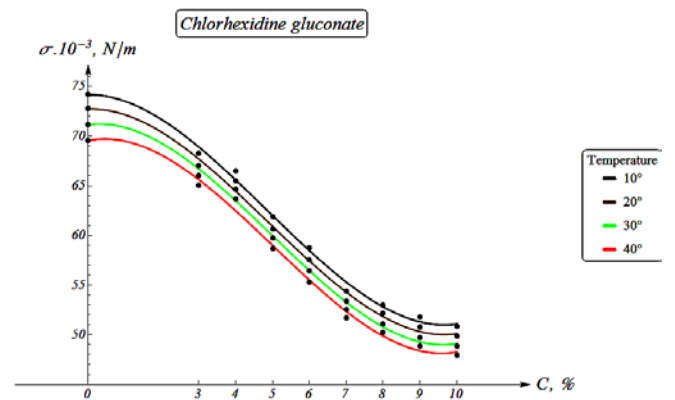


Fig. 5 Dependence of surface tension (σ) on concentration(C) in Clorhexidine gluconate.

After some statistics data processing of the results, represented in Fig. from 3 to 10 dependence on temperature – concentration the following regression equations are presented:

Table 3. Dependence on temperature – concentration 0% (Clorhexidine gluconate)

$\sigma = a - bt$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	75.823214	0.038609	1963.851751	<0.001
b	0.155500	0.001434	-108.444094	<0.001

Table 4. Dependence on temperature – concentration 3% (Clorhexidine gluconate)

$\sigma = a - bt$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	69.20642	0.085649	808.020191	<0.001
b	0.105286	0.003181	-33.098951	<0.001

Table 5. Dependence on temperature – concentration 6% (Clorhexidine gluconate)

$\sigma = a - bt$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	59.805004	0.049109	1217.790913	<0.001
b	0.112428	0.001824	-61.642597	<0.001

Table 6. Dependence on temperature – concentration 9% (Clorhexidine gluconate)

$\sigma = a - bt$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	52.702504	0.053845	978.785709	<0.001
b	0.097357	0.001999	-48.684782	<0.001

Table 7. Dependence on temperature – concentration 0% (BTC-50E)

$\sigma = a - bt$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	75.81500	0.032955	2300.573676	< 0.001
b	0.154428	0.001224	-126.176264	< 0.001

Table 8. Dependence on temperature – concentration 3% (BTC-50E)

$\sigma = a - bt$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	41.99	0.017008	2468.993	< 0.001
b	0.043	0.000632	-68.8674	< 0.001

Table 9. Dependence on temperature – concentration 6% (BTC-50E)

$\sigma = a - bt$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	37.20	0.020768	1791.252	< 0.001
b	0.044	0.000771	-57.8802	< 0.001

Table 10. Dependence on temperature – concentration 9% (BTC-50E)

$\sigma = a - bt$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	34.52	0.055309	624.1780	< 0.001
b	0.045	0.002054	-21.9420	< 0.001

After some statistics data processing of the results, represented in Figures from 11 to 18 dependence on concentration – temperature the following regression equations are presented:

Table 11. Dependence on concentration – temperature 10°C (Clorhexidine gluconate)

$\sigma = a + bC + cC^2 + dC^3$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	74.17171	0.7183	103.2472	< 0.001
b	0.041077	0.6174	0.066528	0.945
c	-0.75493	0.1533	-4.92277	0.004
d	0.052007	0.0101	5.125198	0.004

Table 12. Dependence on concentration – temperature 20°C (Clorhexidine gluconate)

$\sigma = a + bC + cC^2 + dC^3$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	72.715677	0.739386	98.345973	< 0.001
b	0.142418	0.635488	0.224109	0.831
c	-0.760631	0.157838	-4.819063	0.005
d	0.052050	0.010444	4.983751	0.004

Table 13. Dependence on concentration – temperature 30°C (Clorhexidine gluconate)

$\sigma = a + bC + cC^2 + dC^3$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	71.14906	0.7442	95.59918	< 0.001
b	0.468448	0.6396	0.732336	0.497
c	-0.81409	0.1588	-5.12410	0.004
d	0.054686	0.0105	5.201988	0.003

Table 14. Dependence on concentration – temperature 40°C (Clorhexidine gluconate)

$\sigma = a + bC + cC^2 + dC^3$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	69.54985	0.7360	94.49295	< 0.001
b	0.738862	0.6326	1.167967	0.293
c	-0.85292	0.1571	-5.42839	0.003
d	0.056638	0.0103	5.447759	0.003

Table 15. Dependence on concentration – temperature 10°C (BTC-50E)

$\sigma = a + bC + cC^2 + dC^3$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	74.02734	1.0091	73.35783	< 0.001
b	-16.6408	0.8673	-19.1863	< 0.001
c	2.447992	0.2154	11.36381	< 0.001
d	-0.12159	0.0142	-8.53030	< 0.001

Table 16. Dependence on concentration – temperature 20°C (BTC-50E)

$\sigma = a + bC + cC^2 + dC^3$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	72.51868	1.0333	70.17618	< 0.001
b	-15.7569	0.8881	-17.7409	< 0.001
c	2.246856	0.2205	10.18532	< 0.001
d	-0.10827	0.0145	-7.41788	0.001

Table 17. Dependence on concentration – temperature 30°C (BTC-50E)

$\sigma = a + bC + cC^2 + dC^3$				
parameter	estimate	standard error	t(5)- statistics	p- value
a	70.97618	1.0022	70.81453	< 0.001
b	-15.1400	0.8614	-17.5752	< 0.001
c	2.144242	0.2139	10.02175	< 0.001
d	-0.10299	0.0141	-7.27498	0.001

Table 18. Dependence on concentration – temperature 40°C (BTC-50E)

$\sigma = a + bC + cC^2 + dC^3$				
a	69.38927	0.9563	72.55758	< 0.0
b	-14.5553	0.8219	-17.7083	< 0.0
c	2.050705	0.2041	10.04508	< 0.0
d	-0.09826	0.0135	-7.27450	0.001

The values of specific constants and crucial temperatures are obtained in accordance with the help of the reached regression coefficients of from 3 to 10 on the base of experimental data for each of the solutions and given in advance constant concentration.

Regression correlations from 11 to 18 give the opportunity for acquiring information about temperature dependence of surface tension with other concentrations indirectly.

Figures 4 and 5 give data in accordance to surface active substances whose increasing is not advisable because of its economic effect.

Conclusion:

1. A new formulation of experimental research study is developed dealing with temperature and its relation to disinfecting solutions.
2. Regression correlations, reporting the influence of temperature and concentration on surface tension of water solutions of BTC- 50 E and Chlorhexidine gluconate, are obtained and they are applicable to producing disinfectants as well as to assessing their operating qualities.

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EMBEDDED SYSTEMS – PERFORMANCE EVALUATION, EMBEDDED MULTIPROCESSORS

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Abstract: All embedded systems need high performance and high energy efficiency for their faster real-time task execution. These can be achieved only with the implementation of new innovative technology on higher level than the processor, power battery and standardized test by the EDN Embedded Microprocessor Benchmark Consortium. The big.LITTLE technology is the reason so many users to enjoy the big performance and high power efficiency in their pockets nowadays.

Keywords: REAL-TIME EXECUTION, GLOBAL TASK SCHEDULING, GLOBAL INTERRUPT CONTROL,

1. Introduction

The trends in development of smartphones as an architecture class often make the real-time requirements very important. The real-time importance is even the reason of maximum execution time constraints for significant part of the application.

For example each frame rendering time is constrained by the processor time needed to receive and execute the frame before the next one arrives. This is characteristic of the so-called hard real-time systems. Some applications have even more sophisticated requirements. The average time for concrete task can be constrained by the limits in score when some maximum time is exceeded – typically named soft real-time. According to these approaches some incident miss are accepted only if the misses are not so frequent events.

It is common for the real-time performance to be very application dependable. Thus it can be measured by specific or application based program kernels or standardized benchmarks. The hard-real time system realization can be organized by tree variables. First of all it is the frequency each task uses.

Tightly connected to this are the particular hardware and software means to realize the frequency without any problem. Often it can be very difficult the new improvements for desktop products to be evaluated by real-time execution analyses. For example the speculative branch execution, cache memory and other technologies can put some indetermination in the classical code creating.

2. Preconditions and means for resolving the problem

Specific part of the code can be executed very efficiently or very inefficiently in strong dependence to the ability of hardware branch predicting techniques and cache memory performance expected. Designers have to analyze the code precisely, accepting the worst-case execution time – WCET. The traditional microprocessor approach can be very pessimistic if there is assumption that all the branches are mistaken and all cash searches end with cache misses. Hence in system creation period achievement of concrete WCET have to be proved, even if not so high-end system can be satisfied. [1]

In order to answer the new challenges in hard real-time systems in combination with common branch control architecture technologies and access locality it is possible entire processor design to be reconstructed. Even if the branch predicting technique perform very well the system reaction is more predictable by usage of static “hint bits” or flags attached to the instructions. By other point of view, although the cache use is better than the software managed memories on the chip, the last ones always have the latencies predicted.

In some embedded processors the cache can be turned very well to software managed memory on the chip by line locking. In that

way some cache line can be locked in place and replaced only if it is unlocked.

Performance evaluation

For those embedded systems which can be characterized by kernel performance for their applications, one of the best benchmarking is that of the EDN Embedded Microprocessor Benchmark Consortium (EEMBC). EEMBC is divided to six subclasses: games, telecommunication, network devices, automotive/industrial, office and customer. Although many applications for embedded systems are sensitive to small core’s performance, often the performance of the entire application (it may consist few thousand lines of code) is also critical. Hence many benchmarks for embedded systems are used only for parts from overall application performance.

The cost and power in the embedded market very often are more important than the performance. Besides the processor cost with all the interface circuits needed, next to it in price tag usually is the memory of the embedded system. In contrast to desktop or servers, common embedded systems do not use secondary memory. The variant full application to be in flash or DRAM is chosen.

The mere fact that most of the systems of this class, like PDAs and mobile phones are constrained by cost and form factor, causes the memory capacity needed for each application to be critical. Because of that power consumption more frequently is the main factor in processor choice, especially for battery powered systems. EEMBC EnergyBench is a product, making possible the energy consumption profile during EEMBC benchmarking process. Other application in that range is Energymark score for developer’s ability to test and indicate their processors with standardized and certified performance and power energy efficiency results. For general purpose testing and customer popularization EEMBC standardize the National Instruments product LabVIEW with proper GUI and toolboxes. [2]

3. Results and discussion

Embedded multiprocessors

The Multi processors are commonly used in server and some desktop configurations like the multiprocessors of vendors like Sun, Compaq and Apple. In embedded systems space, many special-purpose models use specific multiprocessor configurations like Sony PlayStation in games for example. Many specialized embedded designs use programmable general purpose processor or special-purpose DSP, finite-state units for stream-oriented Input/Output. From computer graphic and media to telecommunication products the use of such multiprocessors is traditional.

In those systems the internal processor interactions are perfectly organized and comparatively simple, mainly because the use of a simple communication channel (placed on silicon), but the base and heavy task is the communication protocols cooperation of the IO

communication units, built on few general-purpose processors. This type of multiprocessing is intelligible oriented in telecommunication and network field, where the scalability is critical.

Design of that type is the MXP processor of empowerTel Networks for use in VOIP systems. It has four base components: serial voice stream interface, full Ethernet interface with MAC layer, fast packet distribution support and channel look up and four MIPS 32 class R4000 processors with 12 KB cache each. MIPS processors are used for code execution of the VOIP channels, in this case with quality control echo correction, simple compression and packet encryption. If the goal is running of more independent voice streams, the multiprocessor is the perfect solution. [2]

Comparatively small size of the MIPS core means not so much transistors on the chip and the future opportunity for more channels realization, next to more sophisticated echo correction, voice activity detection and compression. Multiprocessors are widely spread because of two reasons.

The first one is that the problems with binary software compatibility, typical for desktop and servers are not so significant in embedded systems. Commonly the software for embedded application is written especially for the individual application or is well modified. Hence the VLIW is more suitable than the superscalar in high-end embedded instruction level parallelism.

Second place is for the fact that the applications often has natural parallelism, typical for game consoles, network switches and sell phones. The small constraints in thread level parallelism, complemented with more efficient usage of silicone field lead to widespread use of the multiprocessors in embedded systems in response to the more performance demanded.

The performance growing speed for the tablets and smartphones is far higher than the improvement rate in battery capacity or in semiconductor space. In the same time the customers expect much longer battery life in time of small technology improvements. These conflicting facts make the door for new ideas and approaches wide open for the mobile systems on a chip (SoC), approaches different from whatever improvements in processor technology and the power management.

Big.LITTLE is one of the technologies for power management used to save energy in mobile SoC. In combination with Dynamic Voltage and Frequency Scaling (DVFS), clock gating, temperature control, core power gating, retention nodes etc. it provides full set of power control tools in SoC.

Big.LITTLE works well on the fact that the usage profile of tablets and smartphones is very dynamic. Hard task periods such as web page initial loading and game graphic processing alternate with comparatively long time with low activity on tasks like text reading, user response waiting in game processing or common operations like text, e-mail or audio running.

The multiprocessor ARM big.LITTLE system has heterogeneous architecture based on two processor types - "LITTLE" processor, designed for maximum power efficiency and "big" processor capable to achieve best computing performance. The big performance cores tend to be used in burst working mode with small duration to act on peak frequency while more than 80 % of the working time the job is handled by the smaller cores on moderate frequency. The first widespread big.LITTLE realization is used in one system of the ARM Cortex – A5 and the ARM Cortex-A7 processors (fig.1) [3, 4]

Multiprocessors and accelerating systems in their work together need to share information. The additional processing cores improve the system performance and produce better efficiency, but to achieve that goal the shared data need to be perfectly managed to be the correct one where it have to be used. High-performance and high-efficiency clusters are connected with cache coherent interconnection like ARM CoreLink CCI-400 Cache Coherent Interconnect. That high-performance, energy efficient cache coherent system, is developed to be connection interface for all the processors and the dynamic memory access controller like

CoreLink DMC-400. The technology finally provides the virtual memory management and hardware coherence, vital for the software simplicity and scalability.

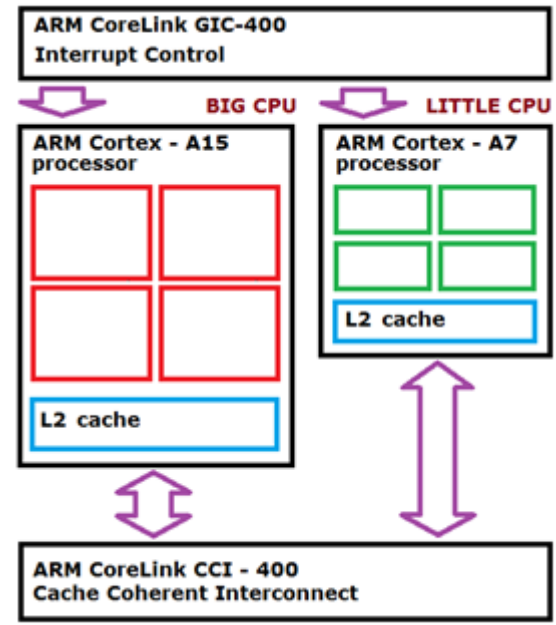


Fig. 1 Big.LITTLE system using ARM Cortex-A15 and ARM Cortex-A7

The operational system uses all processors like if it is one in their place. The user software in big.LITTLE SoC environment is identical to standard SMP processor. The main task here is correct forwarding of every task to the right processor, answer provided by the ARM CoreLink GIC-400 Interrupt Control and shown on figure 2. That system provides OS awareness for the big and the LITTLE processor status with the ability to navigate each execution thread to the best chosen processor based on dynamic attendance to each core. [3]

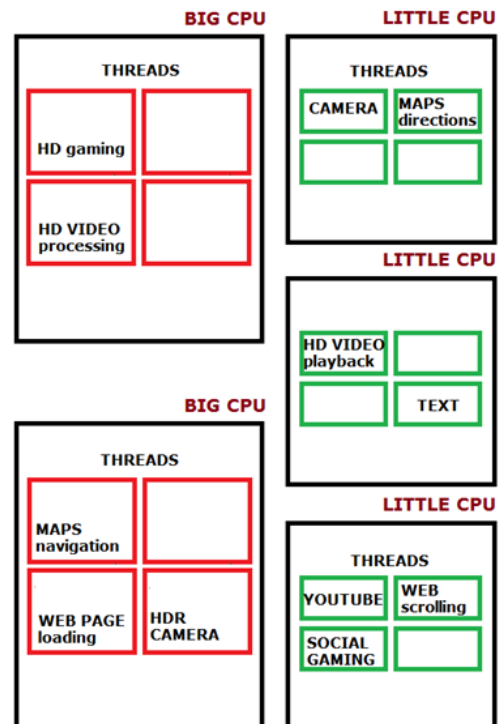


Fig. 2 ARM Global task scheduling

The software keeps every loaded thread activation history in order to be aware of the next execution requirements. The Global Task Scheduling enables task distribution between all processor

cores with 75% less power consumption for the same or higher performance.

To be the big.LITTLE processor invisible for the software, the processor subsystems should use fully coherent cache, the big and the LITTLE processors must be completely architecturally compatible. It means to use the same instruction set, as well as to be able to use the same extensions like virtualization, long physical addressing etc. The ARM Cortex-A series are designed to meet these requirements in recommended combination like the examples on Figure 3.

	1 st generation ARMv7 – 32-bit, 40 bit physical address	2 nd generation ARMv8 – 32-bit/64 bit
High-performance CPU	Cortex-A15	Cortex-A57
High-efficiency CPU	Cortex-A7	Cortex-A53

Fig. 3 ARM Cortex-A series big.LITTLE recommended combination

In each combination mentioned above high-performance and high-efficient cluster consists of no more than four cores. Smartphone applications mostly use one or two high-performance cores to handle performance expectation. The high-end smartphones and tablets on the other hand use the advantages of four big and four little cores together for their software. By Global Task Scheduling software all processors can be active in working, in order to provide hard load acceleration ability in combination with power efficiency. System with these features can be designed with cache coherent interconnect, Global Interrupt control and other components in addition like on the figure 4. [3]

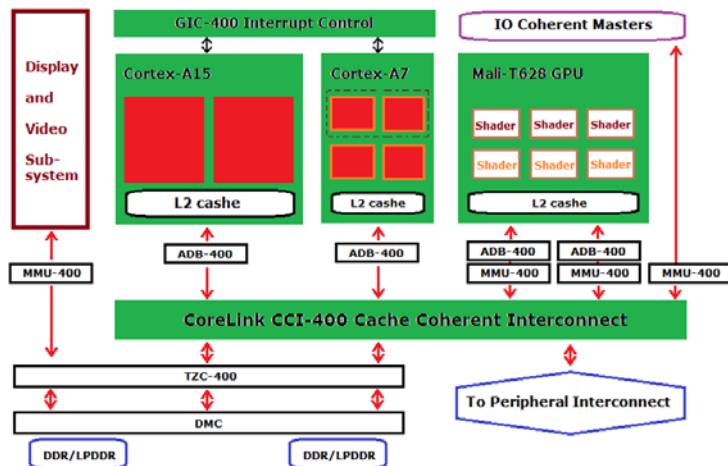


Fig. 4 Big.LITTLE hardware requirements

4. Conclusion

Basic characteristics of the big.LITTLE architecture are two.

The first one is high performance with some significant advantages: The big cores lead to extremely little respond time and very fast processing of more complex web content. The usage of big.LITTLE reduces processor power consumption, supports faster and more detailed graphics in the same SoC cost; The big.LITTLE technology makes possible high-end tablet performance to fit in a pocket size devices.

Second is the longer battery life. Big.LITTLE technology uses the most appropriate cores for the processor power demand. The power efficient LITTLE cores cannot be underrated too – they handle the common simple tasks like text and e-mail but take the workload about 95% of the time and in that way the power profile looks like such on the low power devices. Significant advantage is more than 40% energy safe than in standard SoC loads like web browsing. It is possible for the cores in the same time to achieve effective task distribution, allowing overall performance to be 40% higher for big multithread load in contrast to ARM Cortex A15 processor alone. [5]

The next in a row ARMv8 processor architectures like Cortex-A53 and ARM cortex-A57 fully support the big.LITTLE technology.

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THE MULTIPLE TRAVELLING SALESMAN PROBLEM AND VEHICLE ROUTING PROBLEM FOR DIFFERENT DOMESTIC DRINKS

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Abstract: The MTSP is a generalization of the traveling salesman problem where there are multiple vehicles and a single depot. In this problem, instead of determining a route for a single vehicle, we wish to construct tours for all M vehicles. The characteristics of the tours are that they begin and end at the depot node. Solution procedures begin by “copying” the depot node M times. The problem is thus reduced to M single-vehicle TSPs, and it can be solved using either the nearest neighbor or Clark and Wright heuristics. The classic VRP (Vehicle Routing Problem) expands the multiple traveling salesman problem to include different service requirements at each node and different capacities for vehicles in the fleet. The objective of these problems is to minimize total cost or distance across all routes. Examples of services that show the characteristics of vehicle routing problems include different Services deliveries, public transportation “pickups” for the handicapped, and the newspaper delivery problem etc.

In this paper will be present using of the principles of MTSP and VRP for optimal solution of vehicle routing for domestic energetic drinks and sparkling water in PET bottles in the different parts of the Republic of Macedonia

Keywords: MTSP, VRP, VEHICLE ROUTING

1. Introduction

The extension of this case is designated as Multiple Traveling Salesman Problem (MTSP), or a problem of multiple Traveling Salesman, and appears when the vehicle speed must be specified in the individual line or warehouse. The goal is to create a set of routes, one set for each vehicle with its speed. Features for this problem are that one node can be designated only for one vehicle, but the vehicle has more than one node. There are no restrictions on the size of the load that the vehicle can carry. The solution to this problem will give the order in which each vehicle must visit nodes that are marked. As in the single-vehicle case, the goal is to develop a set of routes with minimal expenses, where the cost can be presented in amount of euro or dollar, distance or driving time. If we limit the capacity of multiple vehicles and merge with the possibility of having variable needs of each node, the problem is classified and called Vehicle Routing Problem (VRP), or the problem of vehicle routing.

Alternatively, if needs of services happen to be in arches, rather than in the nodes, or if the demand is so great that the individual demand nodes become more numerous to specify, then we start to use the Chinese Postman Problem (CPP). This is a very difficult problem to solve and it is necessary to pay attention to it because it is in the context of research.

In [6], [7] and [8] vehicle routing problem is solved using different optimization methods as dynamic optimization, linear optimization, graph theory, game theory. For optimization criterion in these studies is chosen minimum fuel consumption.

2. Vehicle Routing Problem (VRP)

Vehicle Routing Problem (VRP) or the problem of vehicle routing and is consonant MTSP problem expands to include service requirements for each node in various capacities for vehicles. Purpose of these problems is to minimize the total cost or distance across all routes.

Table 1. Distance between cities in Eastern Macedonia

	1	2	3	4	5	6	7
1		39	99	50	91	168	154
2	39		60	55	66	145	131
3	99	60		116	52	151	156
4	50	55	116		40	109	113
5	91	66	52	40		83	66
6	168	145	151	109	83		85
7	154	131	156	113	66	85	

The amount of new units of product L-Carnitine which is transported in some cities in Eastern Macedonia, while the vehicle capacity (K) is 5000 units.

Table 2. Coalitions of units required

i	(2) Kumanovo	(3) Kr. Palanka	(4) Veles	(5) Stip	(6) Delc evo	(7) Strumica
di	14 000	900	1 400	2 000	900	1 800

Savings S_{ij} are calculated and displayed symmetrically with the following values in the table3.

Table 3. The estimated savings S_{ij}

	2	3	4	5	6	7
2		78	34	64	62	62
3	78		33	138	116	97
4	34	33		101	109	91
5	64	138	101		176	179
6	62	116	109	176		237
7	62	97	91	179	237	

Sorted savings [7.6], [7.5], [5.6], [5.3], [6.3], [4.6], [4.5], [7.3] [4.7], [3.2], [5.2], [6.2], [7.2], [4.2], [4.3]. First we consider the case of transport of the product from (7) Strumica to (6) Delcevo. They can be represented in the same route with the need of 2700 units in a vehicle with a capacity of 5000 units. It makes about $7 \rightarrow 6$, and 7 and 6 nodes will be neighbors of the route to the final solution.

In addition at the route from (7) Strumica to (5) Stip. If they are neighbors in the route it would be desirable to link $6 \rightarrow 7 \rightarrow 5$ and $5 \rightarrow 7 \rightarrow 6$. The total amount of 4700 units in this route does not exceed the capacity of the vehicle (5000). Because so far about 4700 units are transported it reaches the capacity of the vehicle, so the route of the first vehicle ends here. We will look at the route of the second vehicle in the nodes (3) Kriva Palanka and (2) Kumanovo. They can be represented in the same route as the requisite units for delivery of 1400 and 900, or 2300 units which meet the capacity of 5000 units.

The next route is (4) Veles and (3) Kriva Palanka, which may be related to previous route $3 \rightarrow 2$ to produce the desired route $4 \rightarrow 2 \rightarrow 3$ or $3 \rightarrow 2 \rightarrow 4$ of transported 3 700 units. The delivery of the entire quantity of (8400) units for Eastern Macedonia is running by two routes and two vehicles, and they are the following $1 \rightarrow 5 \rightarrow 7 \rightarrow 6 \rightarrow 1$ and $1 \rightarrow 4 \rightarrow 2 \rightarrow 3 \rightarrow 1$ routes. The total

distance that the first vehicle passes is 408 km, while the second vehicle is passing 246 km distance.

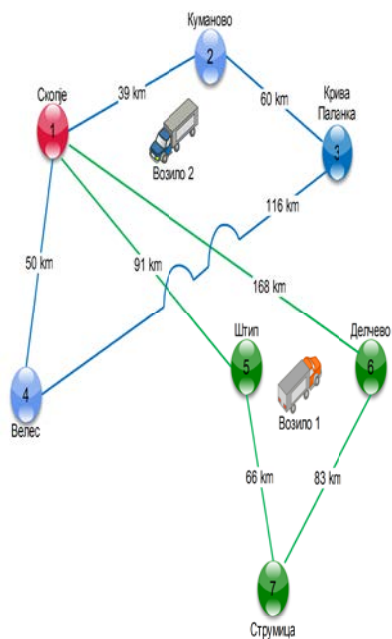


Figure 1. Vehicle routing problem for Eastern Macedonia

Savings and quantity of delivered units of a new product L-Carnitine with amount of 10,800 units in Western Macedonia, the display of routes and number of vehicles are given in the following tables and calculations.

Table 4. Distance between cities in Western Macedonia

	1	8	9	10	11	12	13	14
1		131	176	174	159	67	44	112
8	131		47	106	32	108	132	62
9	176	47		66	52	124	146	78
10	174	106	66		138	107	132	61
11	159	32	52	138		140	164	62
12	67	108	124	107	140		24	46
13	44	132	146	132	164	24		70
14	112	62	78	61	62	46	70	

The amount of units of a new product L-Carnitine which is transported in certain cities in western Macedonia, while the capacity of a vehicle (K1) is 7000 units and second (K2) is 4000 units.

Table 5. Coalitions of units required

	(8) Prilep	(9) Bitola	(10) Ohrid	(11) Krusevo	(12) Gostivar	(13) Tetovo	(14) Kicevo
di	1 600	2 000	2 000	1 200	1 200	1 600	1 20

Savings S_{ij} are calculated and displayed symmetrically with the following values in the Table6.

Table 6. The estimated savings S_{ij}

S_{ij}	8	9	10	11	12	13	14
8		260	199	258	90	43	181
9	260		284	283	119	146	210
10	199	284		205	134	86	225
11	258	283	205		86	39	209
12	90	119	134	86		87	133
13	43	146	86	39	87		86
14	181	210	225	209	133	86	

Sorted savings [9,10], [9,11], [8,9], [8,11], [10,14], [9,14], [11,14], [10,11] [8,10] [9,13] [10,12] [12,14] [9,12] [8,12] [12,13] [11,12] [13,14] [10,13] [8,13] [11,13].

First we will consider the case of transport of the product from (9) Bitola to (10) Ohrid. They can be represented in the same route for the transport of 4000 units in a vehicle with a capacity of

7000 units. It makes about $9 \rightarrow 10$ and 9 and 10 nodes will be neighbors of the route to the final solution.

In addition, we will consider the route from (9) Bitola to Krusevo (11) town. If they are neighbors in the route it would be desirable to link the $9 \rightarrow 10 \rightarrow 11$ or $11 \rightarrow 9 \rightarrow 10$ nodes. The total amount of transported 5 200 units in the route does not exceed the capacity of the vehicle (7000) units.

Next route with the greatest saving is the distance from (8) Prilep to (9) Bitola, if they are neighbors in the route it would be desirable to link $10 \rightarrow 9 \rightarrow 8 \rightarrow 11$ or $11 \rightarrow 8 \rightarrow 9 \rightarrow 10$ nodes. Because so far transported 6800 units are approaching the first vehicle capacity (7,000 units), and completes the route of the first vehicle.

Next will consider the route of the second vehicle in the nodes from (12) Gostivar to (13) Tetovo. They can be represented in the same route as the requisite units for delivery in 1200 and 1600, or 2800 units. The next following route is from (12) Gostivar to (14) Kicevo, which can be connected to the previous route $12 \rightarrow 13$ thus obtain the desired route $13 \rightarrow 12 \rightarrow 14 \rightarrow 12$ and $14 \rightarrow 13$ to 4000 units.

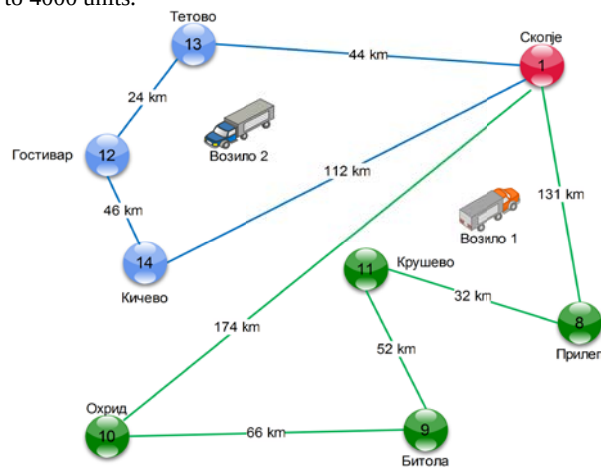


Figure 2. Vehicle routing problem for Western Macedonia

Conclusion

The delivery of the entire quantity of units (10,800) for Western Macedonia is performed with two routes and two vehicles, and those are $1 \rightarrow 10 \rightarrow 8 \rightarrow 9 \rightarrow 11 \rightarrow 1$ or $1 \rightarrow 11 \rightarrow 8 \rightarrow 9 \rightarrow 10 \rightarrow 1$ and $1 \rightarrow 14 \rightarrow 12 \rightarrow 13 \rightarrow 1$ or $1 \rightarrow 13 \rightarrow 12 \rightarrow 14 \rightarrow 1$. The total distance that the vehicle passes are, the first is passing 455 km, and the second vehicle of 226 km.

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ON THE MAIN APPLICATION PROPERTIES OF THE QUANTUM CONFINED STARK EFFECT

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Abstract: The present work is motivated by the tremendous interest in the semiconductor nanostructures. The study of the quantum confined Stark effect (QCSE) in semiconductor superlattices and semiconductor quantum wells has attracted a lot of attention, as it is important both for fundamental physics and in devices for optoelectronic applications. The present paper is a brief review of the main electronic properties, which are the basis for the QCSE device applications of semiconductor superlattices and semiconductor quantum wells.

Keywords: QUANTUM CONFINED STARK EFFECT (QCSE), ELECTRONIC STATES, SEMICONDUCTOR QUANTUM WELLS, SEMICONDUCTOR SUPERLATTICES, DEVICE APPLICATIONS OF QCSE, SEMICONDUCTOR NANOSTRUCTURES, ELECTRIC FIELD EFFECT, OPTICAL PROPERTIES

1. Introduction

Semiconductor nanostructures and particularly, double heterostructures, including superlattices, quantum wells, quantum wires, and quantum dots, are today the subject of research of two-thirds of the semiconductor physics community [1]. In modern age, the low-dimensional semiconductor nanostructures find practical applications in all important fields of industry and in our daily life. Some of the references include [1-16]. Modern electronic and optoelectronic devices are approaching nanometric dimensions and employ semiconductor nanostructures. As example, electronic devices based on quantum wells (QWs), such as the high electron mobility transistor, have shown outstanding performances, pushing the cut-off frequencies up to several hundred of GHz. Long-wavelength lasers for modern telecommunications have active regions with a sequence of QWs obtained from the heterojunction of two or more semiconductors.

Today, investigation of the electric field dependence of electronic and optical properties in semiconductor nanostructures, namely, semiconductor superlattices (SLs) and semiconductor quantum wells (QWs), is of great interest. This is mainly due to their actual and potential applications in various electro-optical devices, and thus the possibility to optimize nanostructure-based devices. Atomistic approaches become necessary for modeling structural, electronic and optical properties of such nanostructures and nanostructured devices [2].

In this paper we will make a brief survey of the most distinguished electronic and excitonic properties, which are the basis for the QCSE device applications of the quantum well (QW) structures (SLs and QWs).

2. The Stark effect – definition and description

The effect of an external constant electric field F on the energy electron states of quasi two dimensional electron gases or QW structures is one of the most common definitions of the QCSE (or Stark effect) [3,4].

Under application of a static electric field perpendicular to the QW layers, the energy levels are shifted (Stark shifts) from their zero-field positions (see Fig. 1) which is the QCSE (see Fig. 2).

There are two kinds of QCSE in QWs, depending on direction of applied electric field F :

- (a) - longitudinal QCSE. F is parallel to the growth axis / perpendicular to QW layers;
- (b) - transverse QCSE. F is perpendicular to the growth axis.

The transverse field problem is similar to the bulk problem and excitonic transition disappears at low field (< 10 kV/cm). The

absorption edge shifts to lower energy as in the bulk problem. Therefore here we will pay attention only to the longitudinal QCSE.

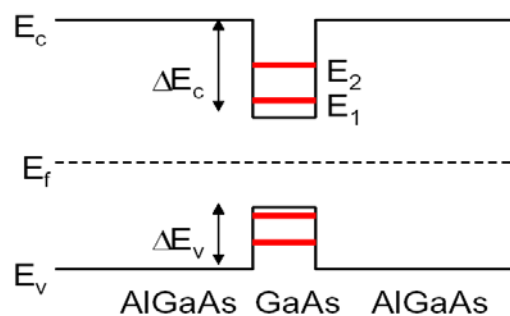


Fig. 1 Energy levels in $\text{Al}_x\text{Ga}_{1-x}\text{As}/\text{GaAs}/\text{Al}_x\text{Ga}_{1-x}\text{As}$ QW without application of F .

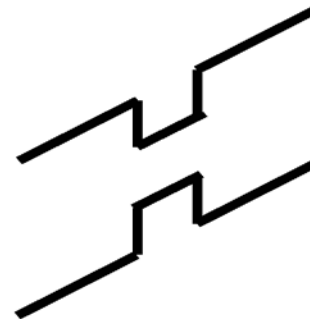


Fig. 2 QCSE in a QW. The distortion of the QW potential with applied electric field F .

The study of the QCSE when a constant longitudinal electric field F is applied to the QWs has attracted much attention both experimentally and theoretically [1-16], as it is important both for fundamental physics and in devices for optoelectronic applications. The detailed knowledge of the electronic and consequently optical spectra in QWs is quite essential to understand their device applications, for understanding the operating principles of the devices, based on the QCSE application. The theoretical and experimental methods and techniques for investigation of QCSE in QW materials are presented in many papers in the contemporary literature on the subject.

Some of the experimental techniques employed in measurements of QCSE and energy level Stark shifts in QWs are: picosecond luminescence, absorption current spectroscopy, electroabsorption, photoluminescence spectroscopy, electroreflectance and time-resolved photoluminescence [5-11].

The QCSE is an entirely quantum mechanical effect and it can not be explained classically.

The QCSE can be understood on the basis of the same formalism as the one discussed for the exciton and band to band transitions in absence of the electric field as long as one can assume that the QW subband levels are reasonably confined states. In principle, the QW states are quasi-bound states in the presence of the field with the wavefunction primarily peaked in the QW region. In the addressing exciton problem one assumes that the subband states are localized in the well and the exciton can be made up of only the confined states. There are several effects that occur in the presence of the longitudinal electric field:

1. The intersubband separations change. The field pushes the electron and hole functions to opposite sides (towards each band edge) making the ground state intersubband separation smaller. This effect is the dominant term in changing the exciton resonance energy.

2. Due to the separation of the electron and hole wavefunction, the binding energy of the exciton decreases (ground-state exciton peak energy decreases without severe line broadening of the exciton resonance).

When near bandgap light is shone on the QW structure, excitons are formed between the QW valence and conduction subbands. We shall be above all concerned with the lowest lying heavy hole ($E1-HH1$) and light hole ($E1-LH1$) excitons. The electric field polarizes $E1$ and $H1$ ($LH1$) along apposite directions and thus weakens the excitonic binding. However, the exciton association is considerably hindered by the conduction and valence potential barriers. In other words, the optical absorption near the bandgap energy can be shifted to lower photon energies (red shift) without destroying the strong excitonic features.

The electric fields as large as 500 kV/cm can be applied to QW structures without destroying the excitonic binding. In semiconductor QWs and SLs, sharp excitonic absorption peaks are clearly observed even at room temperature. When an electric field is applied perpendicular to the QW layers, the energy of the fundamental absorption edge shifts by a large amount without severe broadening of the exciton resonance. These properties enable one to utilize QWs for high-performance room temperature optoelectronic devices. This improved excitonic stability, which leads to peaked structures in the absorption coefficient, is accompanied by a tunability of the excitonic resonance energy.

It is interesting to note that some peculiarities occur when one applies electric field on the absorption spectra of the QW structures [12]. In that case not only the $H1$ and $LH1$ exciton shift to lower energy, but some of the forbidden transitions become observable. At the same time, electric field makes some of the allowed transitions stronger or weaker.

The attempts to increase the exciton energy shift for a given applied field have involved more complex structures, particularly graded gap QWs, double QWs, delta-doped QWs, etc.

Moreover, to improve the performance of these optical devices, band structure modifications in QWs have also been investigated. The electric field effects on the graded-gap QW structures, where the band gap of the well is inclined along the growth direction, are one of the most promising among the modifications for applications of making various fast optoelectronic devices [1,12-15]. The modification of the well potential shape can create different optical properties and thus optimize nanostructure-based devices.

The graded gap QWs were proposed in order to improve the Stark effect characteristics of the conventional rectangular QWs. The goal was to obtain a wider electric field region where the oscillator strengths are significantly large without any significant decrease of the Stark shifts. In the other words: from device point of view, it is desirable to have QW structures with a high absorption coefficient and a large Stark shift under low driving bias. The most

investigated with varying composition graded gap QWs are of the systems $Al_xGa_{1-x}As/GaAs$. When we consider compositional graded gap QWs of the system $Al_xGa_{1-x}As$, the employed Al-concentration profiles are linear or parabolic. Besides Al - concentration profiles, i.e. composition, the other structural parameters of the QWs also play a significant role on the QCSE in the QW. For example: the widths of the QWs and the type of the barriers.

The theoretical description of semiconductor nanostructures is of crucial importance since it allows us both to investigate fundamental physics and to optimize nanostructure-based devices. The capability of theoretical techniques to investigate and to predict physical phenomena concerning nanostructures is essentially related to the possibility of applying these techniques to treat the nanostructures which are usually composed by a large number of atoms. Theoretical calculations of the QW electronic structure in the presence of an electric field may include or may not include excitonic and temperature effects. The reason for these simplifications is that the main source of the red-shift of the exciton resonance is the field dependence of $E1(F) + HH1(F)$. These results play an essential role in searching and developing of new ideas for QW device applications.

Traditionally, nanostructures are studied via k,p approaches in the context of the envelope function approximation (EFA) [2]. In this case, only the envelope of the nanostructure wave function is described, regardless of atomic details. Modern applications, however, push nanostructures to dimensions and geometries where EFA may not be as accurate as required. Nowadays, advanced ab initio density functional approaches can be applied to describe systems with thousands of atoms. Such high-level description, however, requires large parallel supercomputer facilities which may not be suitable for routine structure and device simulations. Thus, the use of an intermediate level approach which improves the description of the system, i.e. leading to ab initio results (a complete quantum mechanical description based on a full band approach), but with a complexity similar to the k,p EFA, is highly required. Moreover, the charge rearrangement induced by the presence of electric fields should be considered for a realistic description of nanostructures and nanostructured devices.

Two basic methods have been proposed for atomistic nanostructured description, namely the tight-binding (TB) approach and the empirical pseudopotential method (EPM).

Of particular interest for device applications are the magnitude of the electric field induced changes in the energy levels (Stark shifts energy levels) and localization of the wave function inside the QWs.

In the paper [15] we present a realistic tight-binding (TB) numerical calculation of the energy values for the main bound electronic and hole states as well as their spatial distributions of single $Al_xGa_{1-x}As$ rectangular and graded gap parabolic concentration profile quantum wells QWs under and without application of a constant electric field applied perpendicular to the interfaces. We have used for numerical calculations the algorithm described and applied in [13,14] for detailed calculations of different graded composition QWs. This algorithm makes possible the application of the SGFM method for matching a final nonhomogeneous region with semi-infinite homogeneous regions. This allows realistic tight TB calculations for electronic states in rectangular and graded composition QWs in the presence of a constant electric field. We describe the presence of an external constant electric field F perpendicular to the interfaces with shifting of the diagonal terms of the empirical TB Hamiltonian matrix by the corresponding potential drop (in meV) across one monolayer. The width of both QWs is 12,43 nm or $N=44$ ML. The growth direction is [100]. The Al concentration x in the barriers is $x=0.36$. In the rectangular QW (RQW) x is $x=0$. In the parabolic QW (PQW) x varies parabolically from 0.02 at the barriers to 0.12 in the middle of the well. The calculated energies include excitonic and temperature effects in comparison with the experimental data.

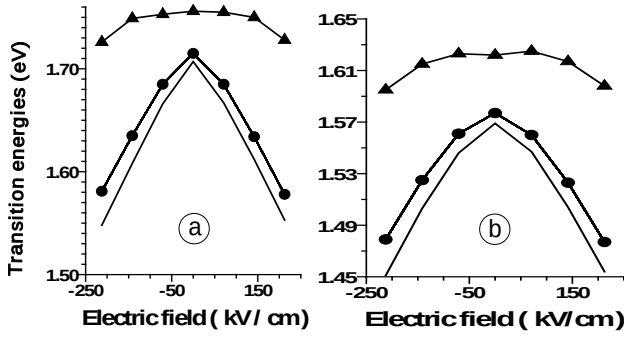


Fig. 1 Transition energies as a function of applied electric field for a) PQW and b) RQW. $E(C1-HH1)$ - solid line; $E(C1-LH1)$ - closed circles; $E(C2-HH2)$ - triangles.

Figure 1 shows the calculated main optical transition energies $E(C1-HH1)$, $E(C1-LH1)$, $E(C2-HH2)$ without and in the presence of a constant electric field for parabolic(a) and rectangular(b) QWs. For both QWs the transition energies decrease with increasing applied electric field. The transition energies are larger in the parabolic than in the rectangular QWs under application of the same electric field.

Figure 2 and Figure 3 show the total spectral strength spatial distributions for the conduction $EC1$ and the valence band $HH1$ bound states without (a) and in the presence (b) of a constant electric field. The field in Figures 2(b) and 3(b) is $F = 70.8$ kV/cm. For both QWs there is a complete overlapping of the spatial distributions at $F=0$. Both distributions of $EC1$ and $HH1$ have the amplitudes displaced in the same direction in the presence of the electric field, but the displacement for the parabolic QW (PQW) is larger than for the rectangular QW (RQW), which is a result of the concentration profile. At the critical value of the electric field the intensity of the optical transition tends to zero due to the absence of spatial overlap between the states. The critical value of the electric field is a very important characteristic for device application of the QW structure. This is the maximal value of the field, which can be applied to the device. The available experimental data are in a satisfactory agreement with these calculations.

The results obtained here demonstrate that the energy levels in the PQWs are more strongly affected by the electric field than in the RQWs. In this case the PQW has better Stark effect characteristics than the RQW.

The QCSE offers tunable optical response. Modern crystal growth techniques allow the doping of semiconductors down to atomic resolution (δ -doping). Impurity atoms give rise to strong confinement (localisation in two-dimensional system) by space charge potential, hence forming a quasi-two dimensional electron gas. The Stark effects in the single and multiple δ -doped systems are being intensively investigated in order to study their subband spectra and intersubband transitions of electrons. The results demonstrate that the TB method can be used to investigate the Stark effect in a double asymmetric QW system, which is interesting for coherent intraband radiation applications.

The first TB calculations of the QCSE in Si δ -doped GaAs QWs is presented in [15]. We have studied in detail the Stark shifts of the electronic states and their spatial distributions, as well as the subband spectra and intersubband transitions of electrons. The results obtained help to better understand the properties of δ -doped QWs with different impurity densities subjected to an electric field with different magnitudes. Such investigations are very promising in looking for δ -doped structures that provide good Stark effect characteristics for potential device applications, such as FETs and infrared devices, based on the electron intersubband transitions. The results demonstrate that the TB method can be used to investigate the Stark effect in a double asymmetric QW system, which is interesting for coherent intraband radiation applications.

We conduct realistic numerical TB calculations of the electron bound states, the hole bound states and their spatial distributions without and with applying a various values of the constant

longitudinal electric field F for four types of RQWs with different depth. We can say that the results from the TB calculations, such as in this work, help to study the physics of the nanostructures in the presence of applied electric field intensities. Such investigations that make possible to study in details the Stark shifts of the electronic and hole states and their spatial distributions, the subband spectra and intersubband transitions of electrons, are very promising in looking for quantum well structures that provides good Stark effect characteristics for potential device applications. Such investigation will help us to find a QW potential profile with better Stark effect characteristics. The investigation of the electric field effects on the optical properties of the QW structures with graded gap potential profiles (not conventional RQWs) is essential for the optimization of QW-based devices. The work is in progress in this direction.

Such investigations will help to find a QW potential profile with better Stark effect characteristics. The investigation of the electric field effects on the optical properties of the QW structures with graded-gap potential profiles is essential for the optimization of QW-based devices.

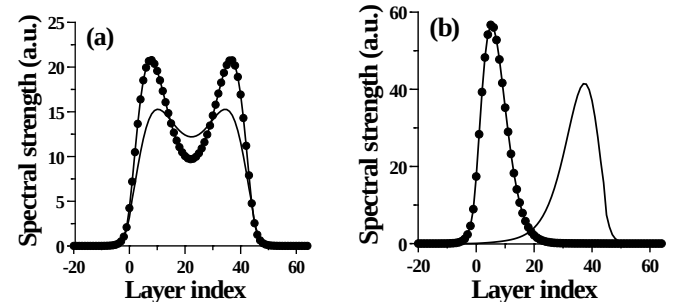


Fig. 2 Spectral strength for PQW, (a) with $F=0$, (b) with $F=70.8$ kV/cm, $EC1$ (solid line), $HH1$ (circles).

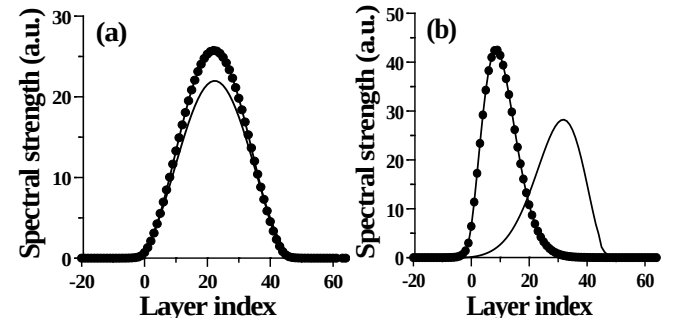


Fig. 3 Spectral strength for RQW, (a) with $eF=0$, (b) with $F = 70.8$ kV/cm, $EC1$ (solid line), $HH1$ (circles).

In the paper [11] were performed electro-absorption experiments on multiple GaAs-Ga_{0.68}Al_{0.32}As QWs at room temperature. By applying a longitudinal electric field (along the QW growth axes) of approximately 50 kV/cm, the photon energy becomes coincident with the $E1-HH1$ exciton resonance and the light beam is significantly absorbed. Thus, by switching the field on and off, the beam intensity can be controlled. One advantage of this on-off control is that it can be very fast.

3. FINAL REMARKS AND FUTURE WORK

Despite the fact that the QCSE was discovered almost 30 years ago, it still has attracted a lot of attention, due to its diverse actual and potential optoelectronic applications. Nowadays, the QCSE is qualitatively well understood, but there is no complete quantitative solution for the problem so far.

The QCSE operates in the linear absorption regime and uses an applied electric field to modulate the electronic, excitonic and optical properties. It is one of the most promising approaches for optoelectronic intelligent devices. It gives us the opportunity to do the best of optics and electronics.

Both experimental and theoretical studies of the QCSE when a longitudinal electric field is applied to the semiconductor QW structures are quite important for development of device applications. They could facilitate the search for new materials possessing unique electron and optical properties. This review will also help and tremendously facilitate the work of the experimenters and QW crystal growers.

Last but not at least, the Stark shifts of the electronic states and their spatial distributions need to be studied in order to seek unknown and possible QW properties and QW structures for the design of new potential QCSE device applications.

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COMPARISON OF THE FRICTION COEFFICIENT FOR SELECTED CAR SUSPENSIONS ELEMENTS

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Abstract: This paper presents values comparison of friction coefficient inside ball joints depending course given by the vehicle, period of exploitation and the vehicle brand. Friction coefficient were defined on the contact surface between steel ball joint pin and the ball joint seat made from plastic covered by PTFE. For the selected working pair of the elements comparison of friction coefficient in load function are done. The preform of the measurements methodology and the test bench are additional show in the paper.

Keywords: BALL JOINT, FRICTION COEFFICIENT, PIVOTING FRICTION, STRING.

1. Introduction

The set of phenomenon's in the contact area between two bodies in the rest, or moving towards oneself friction is called. As a result of these phenomena's resistance of motion are arises. A lot of kinds of the friction are distinguish. It is possible to distinguish diversity of friction conditions types inside the working pairs (figure 1).

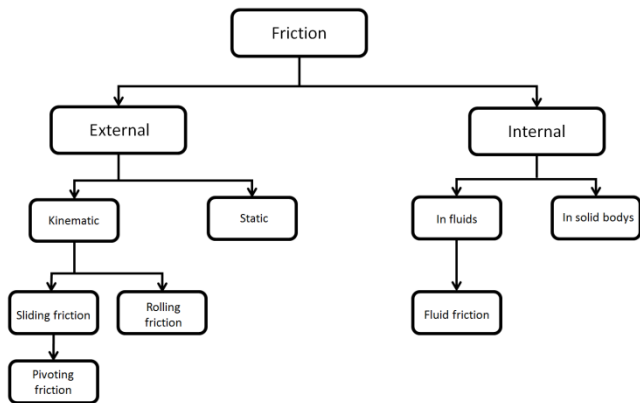


Fig. 1 Types of friction.

The machines constructors try to eliminate friction dry, replacing it more advantageous fluid friction. Because co-operating surfaces are not ideally smooth, on the top of irregularity of surface could be condition of dry or boundary friction and cavities are fill by lubricant. In such conditions the friction in the rough contact surfaces is the mixed friction.

2. The pivoting friction

One with special cases kinetic sliding friction is pivoting friction.

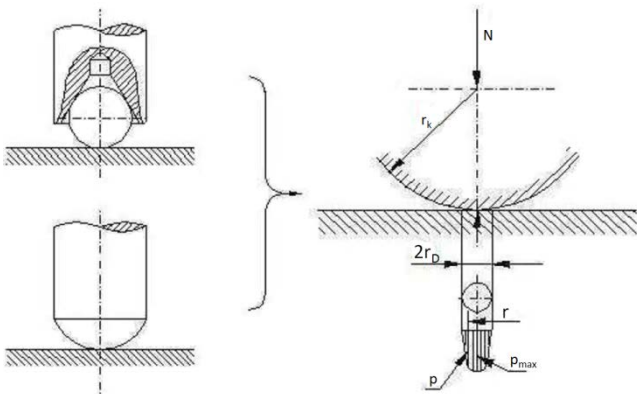


Fig. 2 Model of the bearing type spherical cap on plate; p - Hertz pressure, p_{max} - Hertz pressure max.

$$p_m = \frac{1}{\pi^2} \sqrt{\frac{6 \cdot N \cdot \frac{1}{r_k^2}}{\left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right)^2}} \quad (1)$$

where: ν - Poisson ratio, E - Young's modulus, N - axial force, r_o - contact radius, r_k - sphere radius.

Pivoting friction is created by continuous rotary motion or gyroscopic motion around normal in the point of contact between two co-operating surfaces. In the paper try analyzed pivoting friction conditions for flat surface – spherical cap model type (figure 2).

3. Research object

Moveable connection (kinematic pair) enabling the rotatory oscillate movement of the one connected component in relation to the second element are ball joint named. The axis pass through the ball joint, round which takes the place the turn of wheel in moment of turn the steering gear of vehicle by driver. Additionally the ball joint enable the angle deflection and transmit the shearing and longitudinal forces (along the ball joint axis). Because in the time of work ball joints performs swing-rotational movement, they are lubricated by solid oil by grease nipple or by graphite grease when the ball joint construction are knead by machinery in housing. Build and description of main components of ball joint shows figure 3.

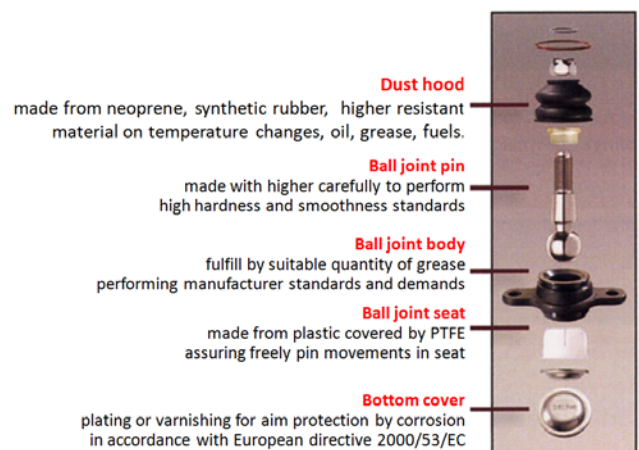


Fig. 3 Build and description of the of ball joint elements [1].

The ball joints construction approach to minimize friction by polishing the pin of ball joints. The grease used inside and pin additionally covered by teflon are also contributed to smooth working and for fast reaction time. Dust hood are mainly made from neoprene (CR), which characterize protection to temperature changes, oil and fuel conditions and protection to variable weather conditions. Nylon insertion inside nut prevents forming among pin

and nut corrosion inside, as well as makes impossible coming unscrewed nut. The most often ball joints defects are: get inside water, sand and other foreign matter are result of faster wear mates elements in ball joints are effect of splitting rubber cover [2].

4. Test bench for determination friction coefficient

Figure 4 shows the test bench for determination friction coefficient by the string twist angle measurement.

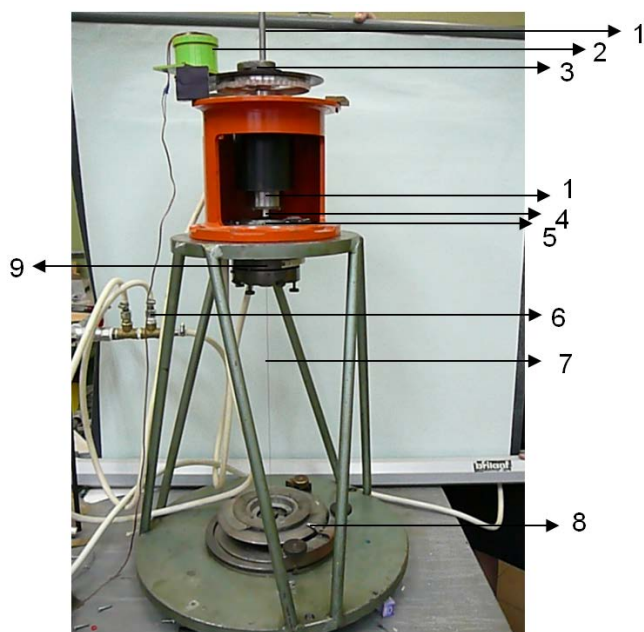


Fig. 4 Test bench for the friction moment and friction coefficient for the frictional pair ball joint – spherical cap; 1 – shaft, 2 – electric motor, 3 – weights, 4 – ball joint, 5 – tested ball joint, 6 – compressed air supply, 7 – string, 8 – disc to read the angle of torsion, 9 – aerostatic table [3].

The test bench are built from two cylindrical radial bearing and axial bearing. Drive from electric motor (2) are transferred between belt transmission on the shaft (1) which ended by the ball joint. The load of the researched friction pair is change by add weights (3) on the shaft (1). The tested ball joint (5) is placed on the aerostatic table (9) which is connected with string measurement (7). The second end of string is mounted to the table (8) which is used to twist string angle compensation. The angle of compensation is read from the scale plotted on the table (8).

5. Calibration of the strings

String patterns on a special measuring instrument bearings aerostatic (figure 5,6), placed on a table to eliminate external vibrations from the environment. Aerostatic fed bearing pressure of 10 bars. In order to obtain the actual value of the angle of torsion measurements made over ten series of successively burdening string weights G (figure 5) with a mass of about 2 g, 4 g, 6 g and 8 g (accurate mass values are given in the tables of measurement data). The arm weights of force was 50 mm. In this way data to calculate the torque and removal characteristics of the studied strings. The calculation results are presented graphically in charts 5 and 6 respectively for the strings 1 and 2. Constant strings calculated from the following equation.

$$k = \frac{P \cdot r}{\varphi} \quad (2)$$

Where k – constant of string, P – loading force, r – arm of a force, φ – torsional angle.

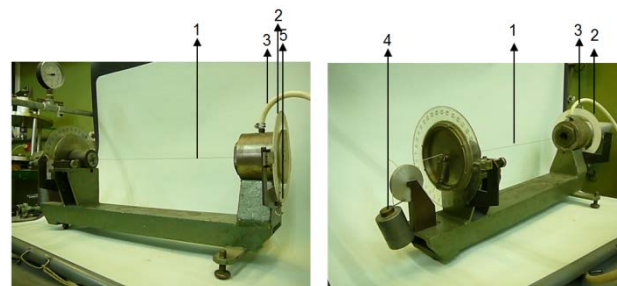


Fig. 5 The scheme of test bench for string calibration: 1 – string, 2 – disk for read torsional string angle, 3 – aerostatic bearing, 4 – weight for string load, 5 – the place for weights position.

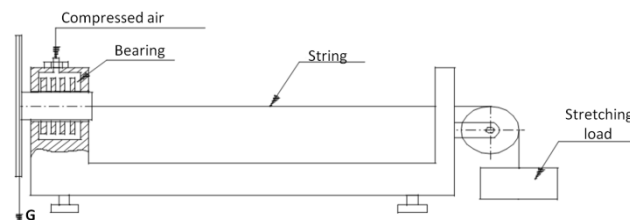


Fig. 6 The scheme of test bench for string calibration, where G is a load making string turns.

Analyzing the figures 7 and 8 can be seen that the real courses differ somewhat from the trend line, a line obtained by least mean squares defining characteristic. Differences may result from inaccuracies in reading the angle from the measuring instruments and an end to the phenomenon of coincidence measurement on the scale. A more accurate readings could be obtain by using the digital measuring instruments.

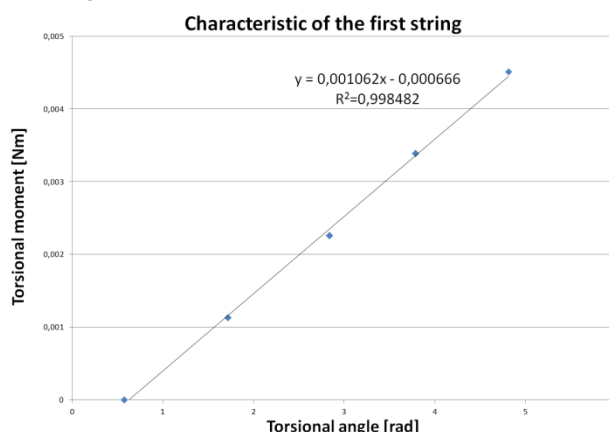


Fig. 7 Characteristic of the first string.

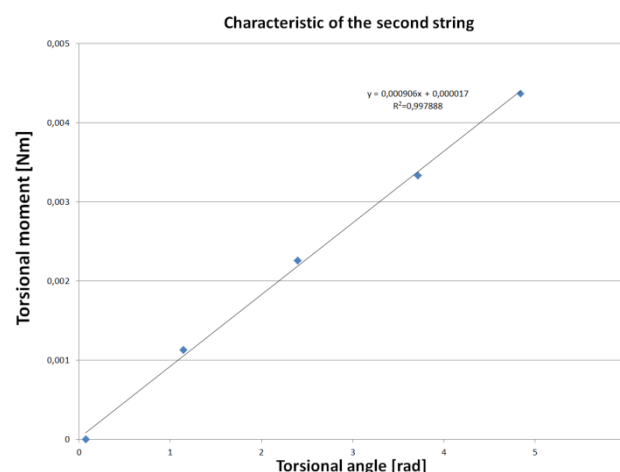


Fig. 8 Characteristic of the second string.

6. Comparison of friction coefficient for the test bench measurements and theoretical calculation

Bearing ball made from steel 100Cr6 with diameter 8mm and ball joint pin from steel were selected to researches. The ball joints selected to researches came from cars: Nissan Maxima (year of production 2008, mileage 185000km), Peugeot 206 (year of production 2007, mileage 95000km), Mercedes Sprinter (year of production 2005, mileage 230000km). All of the ball joints are mounted originally in mentioned cars. Described cars didn't pass the inspection on the diagnostic station for ball joints on the control arm reason.

Test bench researches lead by measure the torsional angle of the string in the loading function. The electric motor was started after mounted the ball joint and measure ball on the test bench. The measurement shaft with ball rotated with constant speed – 36 rpm. Then the test bench was step loaded by 2 N in the range 7,09÷16,9N. After that the test bench was lightened in inversely sequence. Weights were added for 500 cycles. Figure 9 shows the curves of the friction coefficient with approximation equations for the listed cars. Table 1 shows values of the friction coefficient.

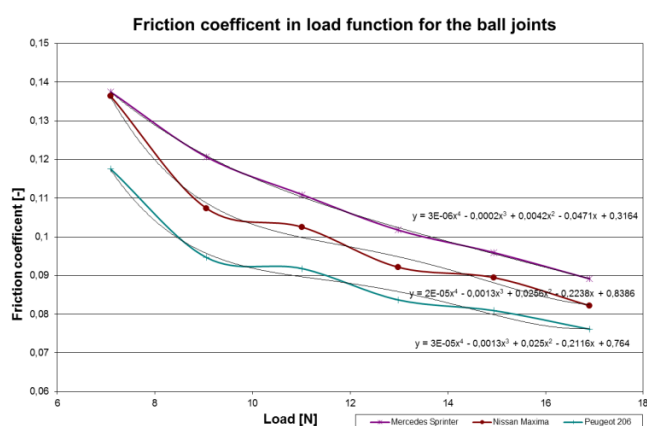


Fig. 9 Friction coefficient in load function for Nissan Maxima (green), Peugeot 206 (red) and Mercedes Sprinter (purple)

Tab.1 Values of friction coefficient and P_{max} for selected cars.

Load [N]	P_{max} [Pa]	μ - Friction coefficient [-]		
		Mercedes Sprinter	Nissan Maxima	Peugeot 206
7,09	1,04E+09	0,13748	0,13638	0,11754
9,05	1,13E+09	0,12067	0,10739	0,09465
11,01	1,20E+09	0,11091	0,10251	0,09178
12,97	1,27E+09	0,10176	0,09216	0,08371
14,94	1,33E+09	0,09593	0,08946	0,08092
16,91	1,39E+09	0,08914	0,08218	0,07609

7. Conclusions

1. Values of the friction coefficient decrease directly proportional with load increase.
2. The character of friction coefficient course in load function for analytic determinate is near to experimental course assigned.
3. Values of the friction coefficient read from the scale plotted on the table allow plastic strain.
4. Differences of friction coefficient for analytic calculations and from experimental don't cross 0,0025 in whole load range.

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PROACTIVE MAINTENANCE OF MOTOR VEHICLES

ПРОАКТИВНОЕ ОБСЛУЖИВАНИЕ АВТОТРАНСПОРТНЫХ СРЕДСТВ

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Abstract:

In this article the author describes particular maintenance systems used in the past, some of which are used also at present. The basic maintenance systems include maintenance after use, preventive maintenance with predetermined intervals, and conditioned-based preventive maintenance - predictive maintenance. The current trend in the field of vehicle maintenance tend to continuous monitoring of their actual status. By the help of a vehicle monitoring in use, it is possible based on current operating parameters to determinate the technical condition of the vehicle parts. Ideally to prevent the failure or damage of groups of vehicle. Tracking of vehicles in use can be effected through the telemetry. Telemetry is a technology that allows remote measurement and reporting of information.

KEY WORDS: PREVENTIVE MAINTENANCE, PROACTIVE MAINTENANCE, PREDICTIVE MAINTENANCE, TELEMaintenance, ON-BOARD DIAGNOSTICS.

1. Introduction

Quality and reliability control and the choice of optimal maintenance methods cannot be realised at present without properly functioning technical diagnostics. Thanks to the use of technical diagnostics, the maintenance itself has reached a new level which in a sense may be labelled as a completely new, generation different maintenance system.

Technical literature provides a number of definitions of "maintenance", more or less influenced by their authors or by the A vehicle is either in usable or unusable condition. Our aim is to maintain the vehicle in usable condition, which means to prevent its failures and limiting condition. This aim shall be achieved upon the lowest vehicle life cycle costs possible while keeping inherent reliability of the vehicle for the whole operating time. This is manifested in particular maintenance systems since the 1930's until the present, which is shown in Figure 1. In general, maintenance system approaches may be divided as follows:

force of a norm upon which they are based. For the purpose of this article, the following definition according to [1] is used: "Maintenance is a combination of all technical, administrative, and managerial activities during a life cycle of an item aimed at maintaining the item in condition, or returning it to condition, in which it can perform a required function."

2. Development of maintenance approaches

1. Corrective maintenance system.
2. Preventive maintenance system – schedule based.
3. Preventive maintenance system – condition based:
 - a) Predictive maintenance system.
 - b) Proactive maintenance system.

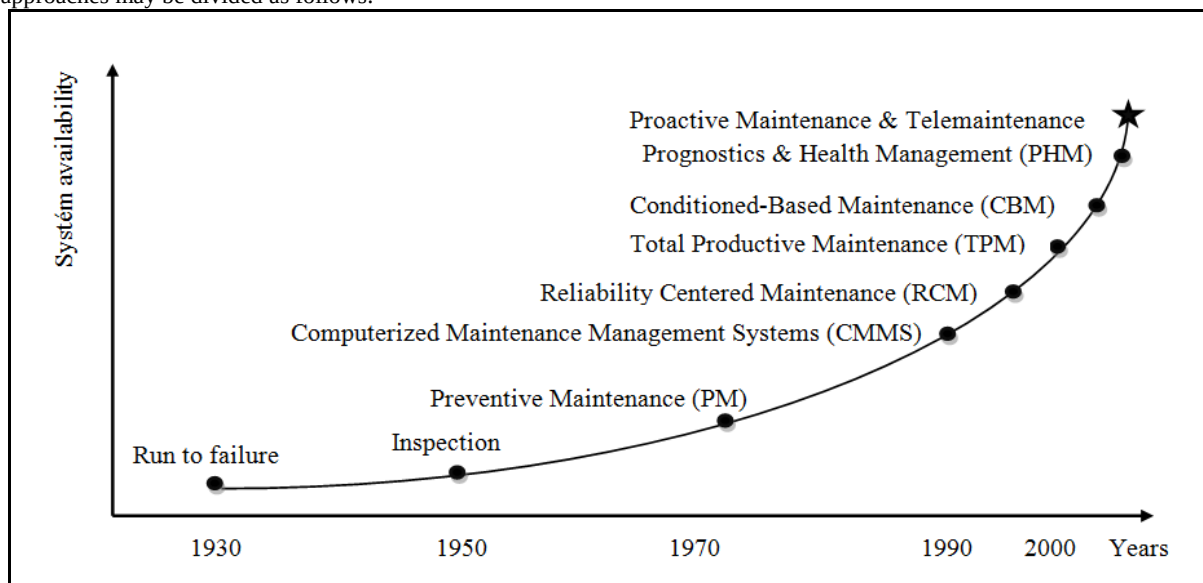


Fig. 1. Development of maintenance approaches since the 1930's [3]

2.1 Corrective maintenance system

This maintenance system represents the lowest level of the maintenance approach. It is maintenance performed after failure condition has been detected and aimed at bringing the item to condition in which it can perform required functions of the given equipment. In practice this means that the equipment is operated without supervision for its whole durability and maintenance is performed only when a failure occurs. In this case repair costs are high, including loss due to the vehicle being out of operation.

Corrective maintenance (1st generation maintenance) may be applied to simple and cheap machinery in which 100% backup and

prompt repair or replacement may be provided. This type of maintenance is obviously suitable only in these cases:

- The broken part may not be repaired or is not worth repairing.
- The machinery is cheap compared to maintenance costs.
- The part replacement is very fast, technically feasible and economically acceptable.
- No other maintenance method is possible to be performed.

In later years, corrective maintenance started to be completed with so called **Inspection**, the aim of which is to verify the compliance by measuring, monitoring, checking or comparing significant characteristics of the vehicle performed during the primary failure removal.

2.2 Preventive maintenance system with predetermined interval

This system is still frequently used since in principle it comes from the theory of reliability. Upon theoretical reliability and practical experience from a similar technique fixed time intervals are set for performing the “service maintenance”, it is so called “schedule-based maintenance”. Preventive maintenance is maintenance performed in predetermined intervals or according to specified criteria, and aimed at reducing the probability of failure or degradation of the item operation. [1].

An advantage of this system is the prevention of failure and thus reduction of corrective maintenance costs. However, preventive maintenance costs will increase. The aim is to keep the maintenance costs as low as possible. In practice the total maintenance costs are relatively high, but in the overwhelming majority of cases lower than for “corrective maintenance”. Another advantage is even distribution of costs in time, and the fact that costs incurred by a vehicle dropout are lower and mostly planned in advance.

A fundamental drawback of scheduled maintenance is the fact that the period (maintenance interval) is often shortened due to the reduction of failure risks and the action is performed on a vehicle which does not exhibit wear signs. Therefore maintenance costs increase and actions performed reduce planned durability of the vehicle. It is true that every useless dismounting and mounting of a part or assembly, or disassembling and assembling the whole vehicle, changes distribution of clearances and brings further unknown static and dynamic loads to the run-in vehicle. This leads to its increased wear and fatigue damage occurrence.

This maintenance system was gradually developed and completed in order to achieve maintenance costs reduction and keep inherent reliability of the vehicle. Higher efficiency was achieved by introducing so called “**Computerized maintenance management system - CMMS**” which leads to significant improvement of the maintenance efficiency by making information on performing individual types of maintenance more available [2].

The schedule-based preventive maintenance system was further completed with so called “**Reliability centred maintenance – RCM**”. This method is based on a systematic approach for the identification of purposeful and effective tasks of preventive maintenance which are performed in compliance with a specific set of procedures for determining intervals between the maintenance tasks. The aim is to improve overall safety, availability, and efficiency of the operation. It is also based on monitoring the total vehicle life cycle costs.

Further improvement of the schedule-based preventive maintenance system brings so called “**Total productive maintenance – TPM**”. The performance of each organisation depends especially on work organisation, utilisation of basic equipment, and qualification level of its employees. To achieve maximal performance the organisation must utilize optimally the vehicle productivity. In terms of losses, the vehicle maintenance represents a significant area where productivity should be increased and resources for cost reduction

sought. TPM utilizes abilities and skills of all employees with the aim to significantly reduce downtimes of vehicles and individual losses in their usage. On this account, organisations are strongly advised to use this progressive approach [3].

2.3 Preventive maintenance system – condition based

Technical condition based maintenance was gaining importance in past decades with the expansion of technical diagnostics. It is preventive maintenance comprising of monitoring performance or parameters and of consequent measures. Its main benefit resides in consistent removal of failures. Particular worn parts and parts or whole assemblies in the risk of failure are repaired or replaced optimally in advance. Thus failure occurrence is prevented. This technical condition-based maintenance system may be divided to:

- a) Predictive maintenance
- b) Proactive maintenance.

ad a) Predictive maintenance

This is condition-based maintenance performed upon a prediction derived from an analysis and evaluation of significant parameters of the item degradation. An action is performed on the item only when it is technically and organisationally justified sufficiently enough to maximally exhaust technical durability of the critical part, and at the same time unexpected accident was prevented. In other words, this is maintenance residing in a statement that only that is necessary to be repaired on the item and only then if it is indispensable. The maintenance itself is based on periodical evaluation of technical condition. Maintenance mechanisms applied to the vehicle allow yielding information on the change of technical condition of monitored parts. Such information is processed with the aim to estimate remaining durability, and thus to commence the process of a technical action (remedy). For monitoring signs of developing damages “Condition Monitoring”, usage of specialised instruments is required, designed for collecting and evaluating information. These instruments utilize so called technical diagnosis. The equipment is to be monitored and evaluated constantly, or at least periodically.

Costs of the maintenance itself are several times lower than in the previous alternatives. The vehicle downtime for the time required for preventive maintenance is usually negligible in comparison with corrective maintenance. However, initial costs of purchasing the diagnostic systems are relatively high. Therefore it is necessary to consider whether these costs of purchasing the technical diagnostics instruments together with maintenance costs will/will not be higher than maintenance costs without using technical diagnostics [8].

ad b) Proactive maintenance

Proactive maintenance is considered another higher level of maintenance. It is completely based on the previous predictive maintenance which it further improves so that its basis is the utilization of more complex technical diagnostics. Basically it is the top current version of predictive maintenance based upon actual condition of the item operated. It is analysed in detail in the following chapter.

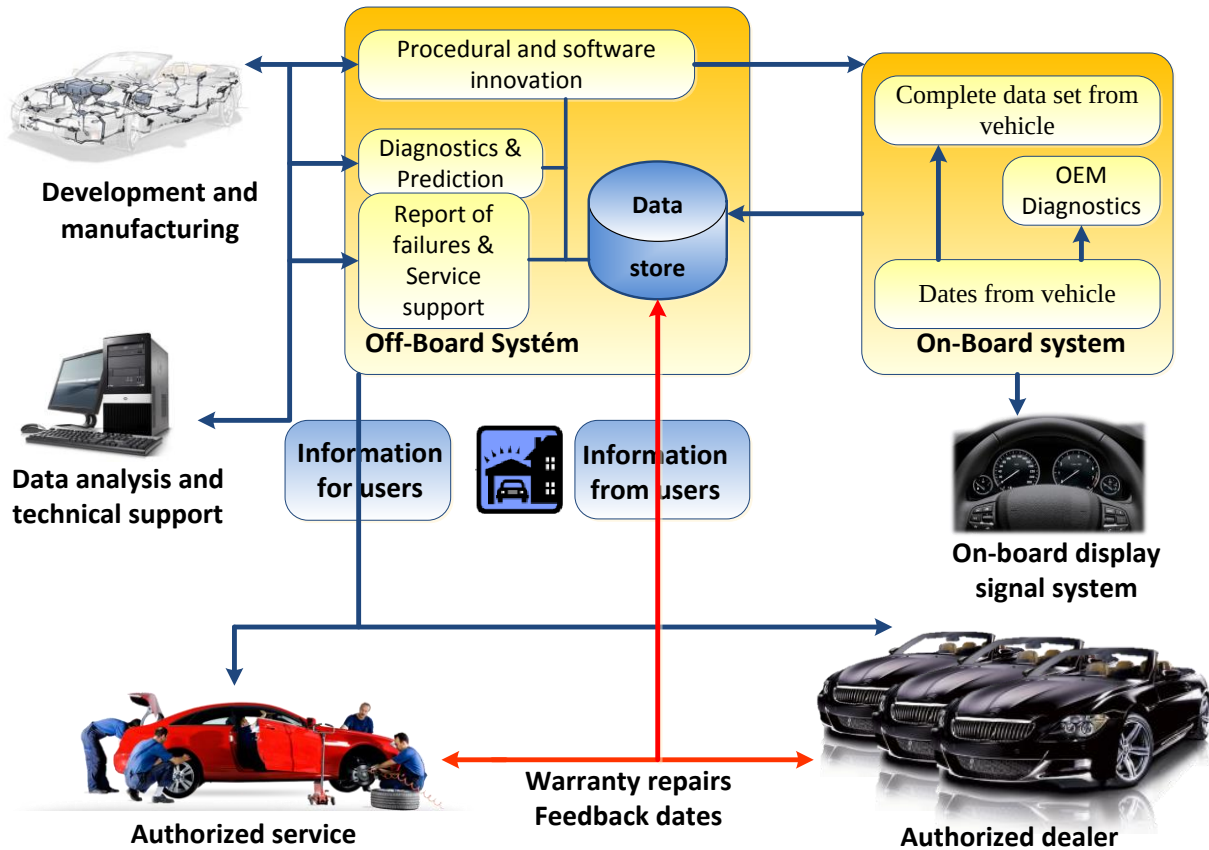


Fig. 2. Design of predictive maintenance

3. Results and discussion - Proactive maintenance system

One of the latest trends in maintenance systems is proactive maintenance completed with so called “telemaintenance”. The proactivity is manifested also in the fact that new vehicles are designed with respect to an easy access to their integral diagnostics. Possible connection of diagnostic systems, location of sensors and measuring spots for monitoring vibrations, temperatures, lubricant sampling and detection of other selected parameters should be considered during the vehicle design.

Proactive maintenance arose from the predictive maintenance type as a reaction especially to long-term findings that a certain group of failures repeats periodically upon clear causes. Known causes include mainly the following:

- Incorrectly organised maintenance work.

- Incorrectly performed maintenance (technical operation in the vehicle).
- Unqualified operators and maintenance personnel [3].

The proactive maintenance type is aimed at keeping inherent reliability of the vehicle on an acceptable level. As a source of information technical diagnostics is utilized. The main objective of proactive maintenance is:

- Further reduction of maintenance and operational costs.
- Prevention of failure occurrence and thus extension of an interval to preventive maintenance, meaning extension of the vehicle durability.
- Statistic control of accidental and systematic influences affecting the vehicle operability [3].

Proactive approach means not only monitoring and evaluating the vehicle condition, but especially performing such actions that prevent or at least postpone damage occurrence.

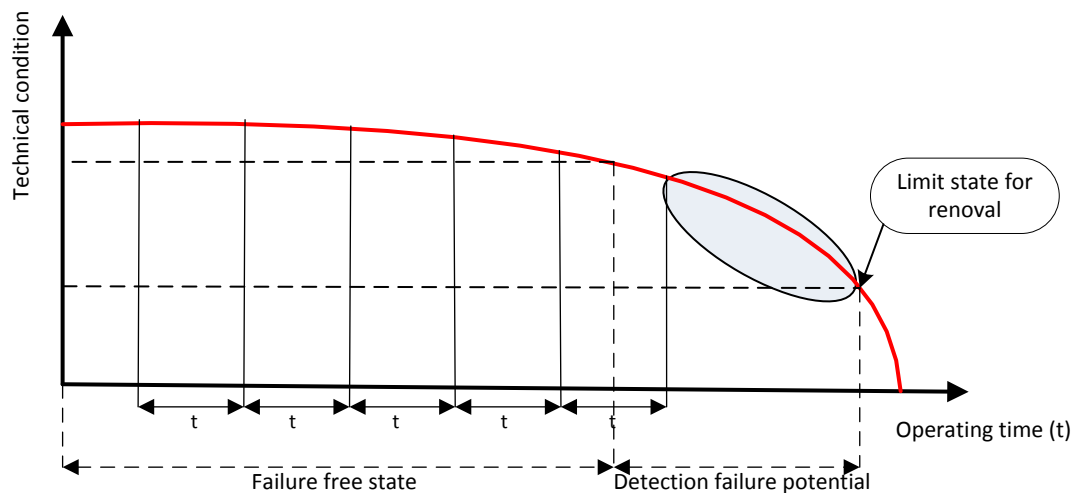


Fig. 3. Machine components technical condition of dependence on operating time

On-board diagnostics OBD is a label for diagnostic system installed in the vehicle system to ensure the control of exhaust emissions, which must be able to indicate failure and probable causes using the fault codes stored in the control unit memory. The aim is to ensure OBD standards throughout the life of your vehicle minimal amount of exhaust emissions [7].

The OBD II is characterized by monitoring these parameters to emissions:

- a) monitoring the lambda sensors,
- b) monitoring the fuel system and the air supply,
 - fuel injection pressure,
 - ignition advance,
 - intake air temperature,
 - intake air quantity,
 - absolute pressure in the intake pipe,
- c) monitoring the effectiveness of the catalyst,
- d) monitoring the exhaust gas recirculation,

Other parameters monitored:

- e) standardized output operational data,
 - vehicle speed,
 - engine speed,
 - coolant temperature and oil etc.,
 - engine oil pressure,
- f) monitoring of braking systems (ABS, ASR, ESP, etc.),
- g) monitoring of safety systems - airbags and anti-theft,
- h) monitoring of transmission (mostly automatic),
- i) condition of brake pads,

- j) condition of brake fluid,
- k) condition of the spark plugs,
- l) monitoring of active chassis - control wheels, suspension settings etc.,
- m) condition of accumulator battery and wiring,
- n) monitoring of engine oil quality.

The OBD system must be equipped with control lamp errors - MIL (Malfunction Indicator Light).

Detecting the state and quality of the engine oil is one of the newest ways using internal sensors. These are mounted directly on the engine. The measured data are transmitted using the CAN bus of the vehicle and then evaluated using the OBD II [9].

Sensors detect oil quality:

- amount of oil,
- temperature of oil,
- index TBN (Total Base Number) - measuring ability to neutralize acids - affects the oxidation and corrosion, oiliness and viscosity,
- dynamic viscosity of oil - η ,
- specific density of oil - ρ ,
- for diesel engines soot content in oil,
- water content in the oil,
- electrolytic conductivity - G , measures the concentration of salts and acids,
- permittivity - ϵ_r .

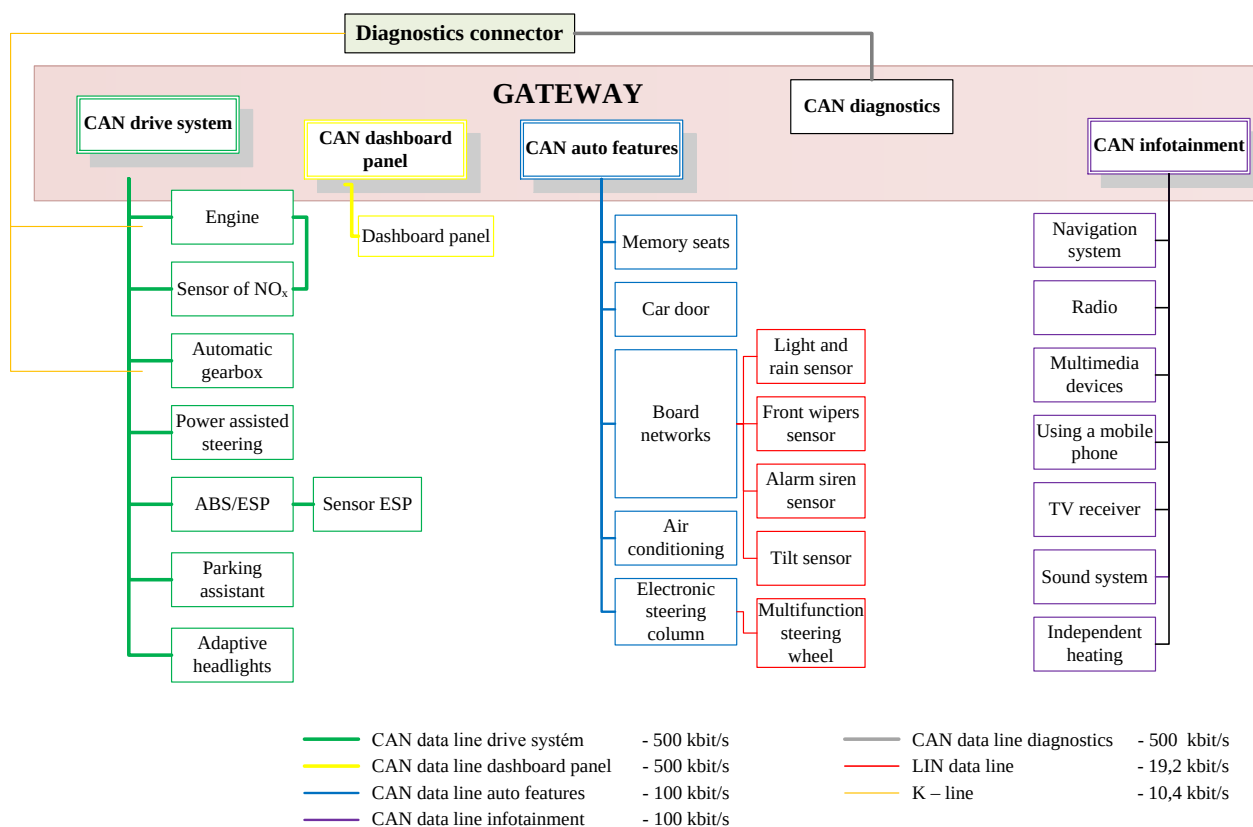


Fig. 4. Electric scheme for OBD vehicle

Predictive and proactive maintenance systems are based on information obtained from vehicle sensoric networks, which are inherently installed in vehicle. Therefore emphasis is put on installation of sensors in vehicles subsystems and also on their connection in backbone network with the intention to obtain efficiency of whole electronical vehicle diagnostics. CAN, LIN and other buses are already used for these purposes. One of the biggest requirement on OBD (on board diagnostics) is the creation of Gateway with single output diagnostics connector (Fig. 4).

The latest trend in the maintenance area is so called "telemaintenance", which may be explained as remote-controlled

maintenance employing the proactive maintenance principle. In some publications, the term "Remote Diagnostics & Maintenance (RD&M)" is used [5]. It is based on wireless transmission of technical data about the vehicle. The main field of its utilization is in companies specializing in long-distance transportation and also in military environment. This method enables on-line monitoring of parameters upon sensors integrated in the vehicle and wireless transmission of the information to a remote computer. This is utilized especially for securing missions in a foreign territory.

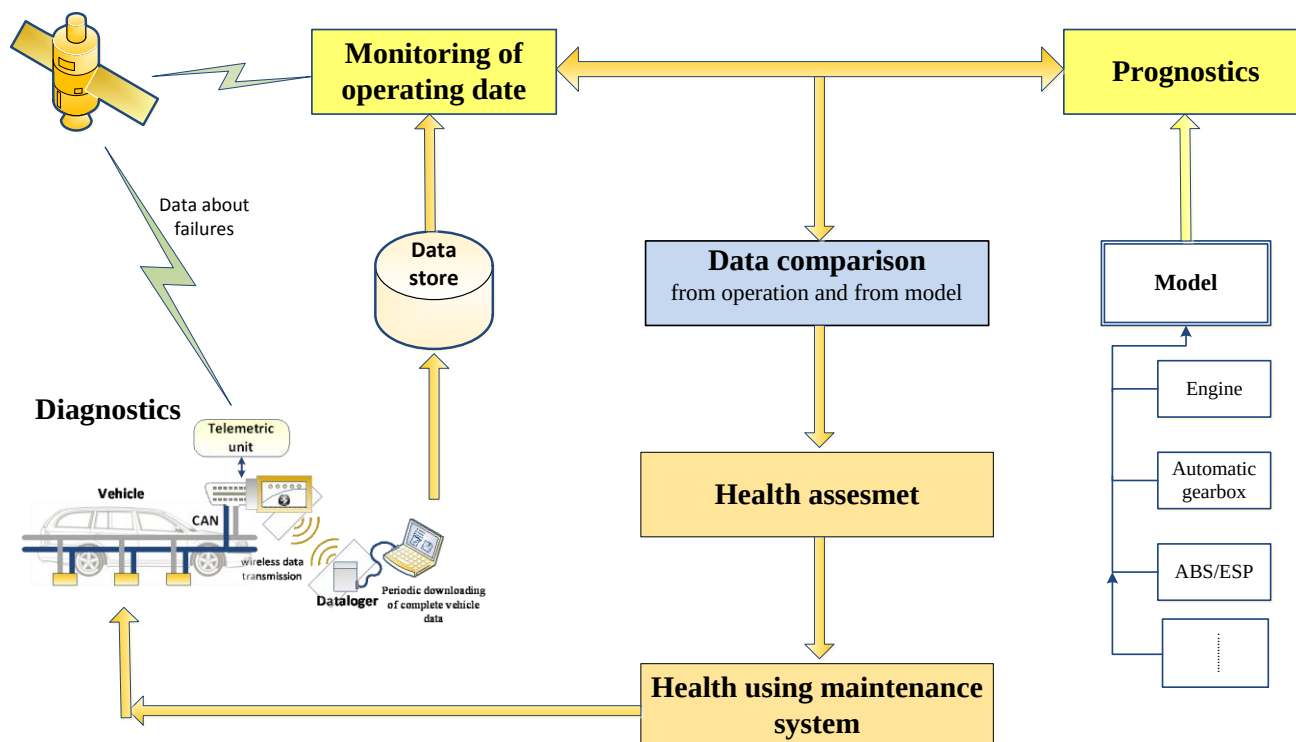


Fig. 5. Design of proactive maintenance with telemetry

Complete output data obtained from vehicle bus can not be transmitted using wireless monitoring. This is caused mainly by limited capacity of wireless connection on long distances. Therefore it is recommended to transmit just selected important data, mainly failure reports. Another data obtained from vehicle bus should be recorded from vehicle datalogger into computer memory and subsequently used to create analysis and prediction modeling.

Telemaintenance may be divided to the four following levels:

1. Diagnosed vehicle with a driver.
2. Support logistics centre where a computer processing the diagnostic information is located.
3. Experts performing the maintenance on the vehicle.
4. Vehicle manufacturer who supplies a technical database including drawings and technological procedures for maintenance [3].

Proactive systems are characterised by complete OBD and also by subsequent vehicle data transmission. Transmission of data can be executed by loading complete datalist in periodic intervals or by on-line data transmission. One of the most modern way is the usage of long distance transmission of selected data. These systems are applied in big transport companies and also in army conditions. Except of these requirements there is also an effort to create individual prediction models of single machine parts. Possible proposal could be seen in figure 5. These models are based on monitored data obtained from vehicle buses. Data are taken during vehicle operation. Afterwards there is a possibility to compare obtained data with true values and define real TS (technical state) of vehicle subsystems subsequently. Apart from defining the real TS, we should be capable to predict time period to service control, TTL (total technical life of vehicle) part alternatively. This could cause reduction of maintenance costs, operation and costs caused by vehicle temporary shutdown. The costs for acquisition are higher contrarily. Decisive criterion should be total LCC (life cycle costs).

4. Conclusion

The purpose of this article is to introduce to the reader the development of particular maintenance approaches since the beginning of the 20th century to the present. It includes advantages and disadvantages of performing maintenance after use, preventive maintenance with predetermined interval, predictive maintenance and proactive maintenance. The final part brings a new approach to maintenance based on on-board diagnostics, which is on-line testing

of diagnostic signals and their wireless transmission to the telemaintenance logistics centre.

The unified diagnostic systems for reasonable application of telemetry have to be introduced. It is also necessary to use unified CAN BUS. These issues should be already solved in acquisition phase. With regard to previous experiences, I would consider to unify all those components and systems into common control unit including single OBD connector for data transmission for subsequent analysis.

Using telemetry, which can be described as the wireless data transmission into logistic centres, with which is possible to analyse obtained data about technical state of vehicles in real time. The vehicle maintenance can be executed on the basis of comparison of obtained data and data recommended. These workshops should have possibility to contact crew of vehicle in order to give them advice about solution of the problem

Implementation of maintenance system based on telemetry enables cost reduction of proper realization of maintenance, on the other hand their purchase cause higher acquisition costs of vehicles and related portable wireless devices. Except the lower maintenance expenses, this access bring also the complete overview of general operation of all in this way equipped vehicles.

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DIAGNOSTICS AND MODELING OF COMBUSTION ENGINES WEAR AND DEGRADATION PROCESSES

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Abstract: The paper deals with ways of applying mathematical methods to evaluate the result of tribodiagnostics related to vehicle combustion engines. The idea is based on a discriminative analysis that makes possible to describe one qualitative parameter (complex technical state) by means of several quantitative parameters (i.e. quantity of diagnostic parameters). The results have been verified by means of considerable statistical data of T-3-930 engines made in the Czech Republic which are used in ground vehicles.

Keywords: WEAR, TRIBODIAGNOSTICS, QUALITATIVE AND QUANTITATIVE PARAMETER, COMPLEX TECHNICAL STATE

1. Introduction

Generally, wear depends not only on the friction character (rolling or sliding) but also on a complex physical-chemical process occurring on the sliding surfaces of a tribological unit. An external undesirable product of the friction system action is a very wide range of wear particles. From the diagnostic point of view, it is important that these particles carry nearly comprehensive information about the mutual connection among individual elements of such a system, that is, what the conditions for production of the particles in individual friction couples are. A combustion engine is characterized by simultaneous contacts of many friction couples and, thus, also by simultaneous production of wear particles at all of these points. The problem is, on the basis of number, shape, size, or coloration of the particles, to determine what tribological processes are in progress in the engine. Wearing dynamics can be evaluated according to:

- material composition of particles,
- intensity of particles production,
- distribution of particles' size groups,
- morphology and shape of particles' surface features, etc.

Generally, the wear products can be categorized as follows:

Adhesive particles (rubbing wear particles)

These are "one-dimensional" particles, whose length and width are approximately equal, at 5-15 μm , but are only 0,25-0,75 μm thick. These particles are characteristic for wear of steel components therefore they have very good magnetic characteristics. During the ferromagnetic analysis, these characteristics can practically always be recorded. Their genetic origin is in the Beilby layer, from which they gradually spell and are washed off by the lubricant. Their number and especially their size characterize the adhesive wear intensity.

Abrasive particles (cutting wear particles)

They always characterize an improper mode of engine operation. From the tribo-technical point of view two origins of abrasive particles may be indicated:

- a) – Action of a heterogeneous particle between friction surfaces results in strong surface scratching, tribological mode changes, and rapid wearing of the friction surfaces. The abrasive wearing has its origin in, for example, siliceous powdery particles that leak into the engine through insufficiently tight of air filters.
- b) – Penetration of a harder material of the friction couple into a softer one. The probability of forming particles in this way increases when friction couples with a considerable difference in their surface hardness are contacting.

In any case, abrasive particles are of a characteristic of a "micro-cut" or of a coiled "thin wire" shape. The shape considerably differs for those abrasive particles that infiltrate into

the engine after a partial or complete disassembly, that is, during running-in mode (cutting wear). They are shaped into crescents or swords with sharp protrusions on their ends. Generally, the size of abrasive particles ranges in the interval of 50-300 μm with a very short thickness of 0.25 μm , Fig. 1.

Spherical particles (spherical debris)

They belong to the main types of particles originating in fatigue wear of a rolling kind. Generally, they originate in consequence of Beilby layer fatigue on internal or external surfaces of bearings. The spheroids' dimensions are relatively short $\varnothing$ 2 – 5 μm . In the Ferro scope lens, they appear like little black points; with better magnification, a polished surface with light reflection in the center is evident. The presence of these particles on a ferrogram signalizes an ongoing failure of anti-friction bearings. It has been verified by experiments that one rolling element is able to produce 6 – 7 million of spheroids before a failure occurs.

Laminar particles

Most often originate as a consequence of redistribution processes in lubricating systems. Repeated flow of oil and, therefore, also flow of particles through the system results in particles' plastic deformation (for instance, between a rolling element and a ring path). Rolling out the spheroids and other tri-dimensional particles results in thin flat laminas of minute thickness. Their length ranges from interval 40 to 250 μm and their width from 10 to 50 μm . Particles are characterized by a plain surface and irregular edges. As a rule, the presence of these particles is attended by the presence of spheroids; in these cases, the process of a gradual failure of the anti-friction bearing has begun.

Fatigue particles

They characterize the most common failure of tooth wheels. These are tri-dimensional particles with a comparable length, width, and thickness. The particles' surface is irregular, scratched with irregular sectioned edges. Dimensions of these particles fluctuate from 10 to 150 μm . Fatigue particles can further be divided into two groups:

- a) The "chunky" (micro-prism) type has an irregularly rugged surface and a size of 10-80 μm ; on the surface, they usually have secondary originated inclusions.
- b) The "scuffing" (high-temperature abrasion) type comes up on the teeth sides of tooth wheels during high pressure and temperature, Fig. 2. The particles' material is usually thermally affected, which is indicated by particles' coloration of distemper tints.

Abnormal particles (severe wear particles)

The extreme and breakdown wear particles that originate with seizing or a strong abrasion. They arise from mechanical deterioration of the Beilby layer under the action of an excessive load. In the touch-point of friction surfaces, this layer does not have

the necessary loading capacity and is scratched off. The abrasion rate is so high that the Beilby layer's restoration is impossible. During the diagnostic analysis, it is then impossible to register any adhesive abrasion particles that are replaced by tri-dimensional particles, always with a characteristic sharp edge and dimensions of 30-70 μm .

Non-ferrous particles

Their appearance may be similar to abnormal particles (severe wear particles), especially because of their shape and size. They always differ in their coloration and magnetic features. They originate as a result of contacting steel and nonferrous metals alloys during the adhesive mode of abrasion.

Iron oxides – magnetite Fe_3O_4 originates under high temperatures and pressures, mainly owing to insufficient lubrication of the friction surfaces. The surface of these particles is black, plain, and of a shingle character; the size of these particles fluctuates around 5 μm . The high-temperature oxides presence relates to abrasion of the materials made of a high-strength steel or a bearing steel. Alpha-hematite Fe_2O_3 signals corrosion of the machine function surfaces by action of water. Pink or red hematite particles can be recorded by analyses of samples taken during the running-in mode of engine operation.

Corrosive and other particles

During tribodiagnostic analyses, the presence of secondary originated non-metallic particles can also be recorded, except for metallic abrasion. Dust particles – small spherical or prismatic particles – silicates with a size of up to 30 μm . They are translucent and clear. Tribopolymers – are shaped into spherical particles or tiny cylinders in the amorphous form. The tribopolymers core is always composed of submicronic steel particles. Organic substance of the particle can be dissolved with an appropriate solvent or by heating it at more than 300°C. Fibers mainly originate from filtration materials. Cotton fibres are ribbon-like in shape; synthetic fibres are straight, with conspicuous luminous refraction on their edges.

Stated characteristics of the most important categories of particles signal the fact that there are two origins for particles indicated:

1 – Primary particles – generated directly by the friction couples. They characterize directly the abrasion mode according to generally known findings.

2 – Secondary particles – originate from a transformation of primary particles after repeated passage through the system. The relative rate of presence of primary and secondary particles depends on several factors, for instance, on the lubricating medium's volume, number and efficiency of oil filters in the system, efficiency of other processes of particles separation from the system, real thermal and mechanical load of the engine, number of tribological units, the type of lubricating oil used, etc.

The difference in effect of factors mentioned during evaluation of individual engines requires separate monitoring of each type and design type of the combustion engine.

For evaluation of the wear mode of machine groups (engines, gearboxes, etc.), in practice, two basic strategic approaches are used:

- 1 – trend evaluation of the wear mode using time series.
- 2 – multidimensional statistic monitoring and its evaluation.

Specific features characterize both of these approaches, and it is impossible to consider one as absolute and exclude the other one.



Fig. 4 Strong cutting wear steel particle, so-called two-point abrasion. Harder member of the friction pair penetrates into softer member of friction pair and separates chips from it. Magnified 1000 x.



Fig. 5 Ferrogram from oil diesel engine. Spheroid always indicates the development of fatigue crack. Magnified 1000 x.

2. Trend evaluation of the wear mode

During normal engine operation, a balanced concentration of the wear products develops in the lubricating medium. This means that the concentration speed of various origin wear products equalizes with the speed of mechanisms removing the wear products from the lubricating medium. Removal of these wear products is carried out mainly by filtration and sedimentation, followed by loss of oil from the system and chemical reactions. Owing to the complexity of the problems related to reactive kinematics of organic ingredients contained in the lubricant and generated here as a consequence of chemical reactions for the duration of lubricant exploitation, it is impossible to obtain the data needed for reactive kinematics calculation. The balance equation expressing the substances balance between inflow of wear products from the friction points of the system into the lubricant and their decrease owing to the action of individual decreasing mechanisms can be derived from a deterministic model Fig. 3 and Fig. 4. The basic differential equation expressing the dynamic balance in the model under consideration is:

$$V \cdot c + m \cdot dt - c \cdot f \cdot p \cdot dt - c \cdot Q \cdot dt = (c + dc)(V - Q \cdot dt) \quad (1)$$

where

V ... oil volume in the lubricating system (dm^3),

c ... concentration of wear products in lubricant medium at the time t (mg/dm^3),

f ... total coefficient of wear products decrease (mg/s)

p ... oil quantity delivered to the engine friction points (dm^3/s),

Q ... oil loss volume (dm^3/s).

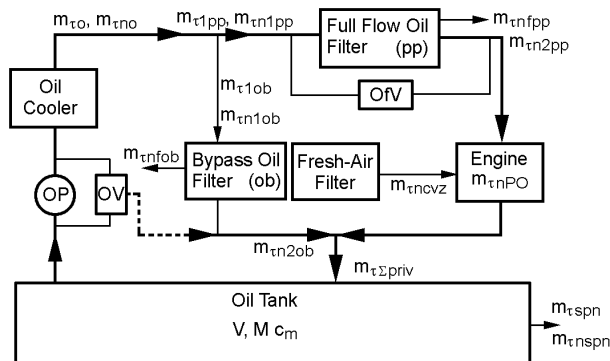


Fig. 9 Lubricating oil system of combustion engine.

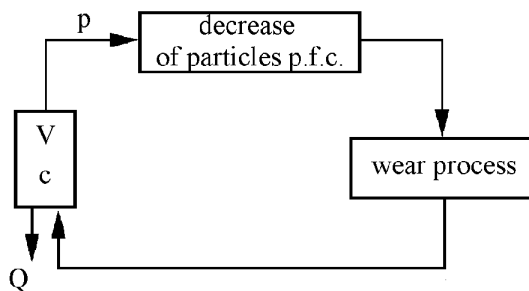


Fig. 10 Diagram showing the process of production and decrease of wear products in the lubricating system of a combustion engine.

The instantaneous volume of lubricant V varies during the time as a result of loss of lubricant in the system (caused by leakages, burning, etc.) according to the relationship:

$$V = V_0 - Q \cdot t \quad (2)$$

where

V_0 ... initial lubricant volume at the beginning of the given time period.

The loss coefficient f represents generally all the loss mechanisms acting inside of the considered system (that is, filtration, sedimentation, chemical reactions, etc.).

Wear products' generation speed m represents dynamics of the wear process (degradation), which varies in time. The general expression for this change is usually stated in linear dependence on the time t :

$$m = m_0 - a \cdot t \quad (3)$$

where

m_0 ... initial speed at the beginning of the time period,

a ... acceleration.

To enable the solution of the equation and to determine the resulting relationship for calculation of the speed of wear products generation, the following simplifications are recommended:

- in the given time period between two sequential sampling values, the m and Q are considered to be constant,

- the value of the coefficient f is estimated on the basis of oil filters' pervious action and the speed of wear products' sedimentation.

In the case of products of oil degradation reactions, the loss coefficient is not considered because as K matter is to determine the concentration of relevant substances dissolved in the lubricant.

After substitution for V according to the relationship (2), modification and dereliction of the expression of the second order (i.e. $Q \cdot dc \cdot dt$), the equation transforms to the form:

$$(m - c \cdot f \cdot p) \cdot dt = (V_0 - Q \cdot t) \cdot dc \quad (4)$$

which can be further modified as

$$\frac{dt}{V_0 - Q \cdot t} = \frac{dc}{m - c \cdot f \cdot p} \quad (5)$$

After integration in the limits c_1 to c_2 for c , t_1 to t_2 for t and after the final modification, we will get the final relationship for the mean speed of wear products generation:

$$m = \frac{(c_2 - c_1 \cdot e^A)}{1 - e^A} \cdot f \cdot p \quad (6)$$

$$A = \frac{f \cdot p}{Q} \cdot \ln \frac{(V_0 - Q \cdot t_2)}{(V_0 - Q \cdot t_1)} \quad (7)$$

However, during operation of real combustion engine vehicles, the lubricating medium is continuously refilled, and thus the calculation of m is correspondingly more complicated. After each oil refilling by the volume V' to the original volume V_0 , the original concentration of wear products c changes to c' :

$$c' = \frac{c \cdot V}{V + V'} \quad (8)$$

During the number of n constant time cycles and the number of a refilling with a constant volume of oil to the V_0 and on all of the premises mentioned above, the main speed of wear products generation can be calculated according to the relationship:

$$m = \frac{(c_n - c_1 \cdot B^{2n-1} \cdot e^A)^n \cdot (1 - B \cdot e^A) \cdot f \cdot p}{(1 - e^A)(1 - B^2 \cdot e^A)} \quad (9)$$

where

$$B = \frac{V_0 - V'}{V_0} = \frac{V_0 - Q \cdot t}{V_0} \quad (10)$$

However, the stated theoretic calculations must be applied to conditions of factual operation of vehicles with combustion engines. To deduce appropriate conclusions and to describe long-term trends of monitored indices developments, it is necessary to determine their trend, that is, to replace the progression of empirical values with a progression of values without a random fluctuation and, thus, to equalize interval time series using a suitable method. For equalizing time series, an analytic equalizing is frequently used in technical routines. This equalizing consists of describing the course of given time series by a simple theoretic and analytic function of the type $y = f(t, b)$ where t is a time variable and b represents a vector of unknown parameters. In principle, this is a simple regression where the time series index features a dependent variable and time (time variable) an independent variable. To determine the “best” values of parameters, the minimum of sum of deviations (residua) squares of the measured and calculated magnitudes of a dependent variable is used as a regress criterion in technical routines most often.

$$U = \sum (y_i - Y_i)^2 = \min \quad (11)$$

Where the function U is called the objective function, which is minimized during the calculation of parameters.

As the whole progression of nonlinear dependences can be transformed using an appropriate transformation to a linear dependence, the linear regression method is used most often

$$y = (b_1 \pm s_{b1}) + (b_2 \pm s_{b2})t \quad (12)$$

Coefficients of the regression linear equation will be determined providing that partial derivations of the objective function U must be zero; then, by solving them, the estimations will be obtained

$$b_1 = \frac{(\sum y_i - b_2 \cdot \sum t_i)}{n} \quad (13)$$

$$b_2 = \frac{\sum t_i \cdot \sum y_i - n \cdot \sum t_i \cdot y_i}{(\sum t_i)^2 - n \cdot \sum t_i^2} \quad (14)$$

The trend value, as a criterion for serviceable condition of the engine and its lubricant medium, respectively the upper or lower limit of the interval of gradient of regression line reliability can be then considered.

$$L = b_2 \pm s_{b2} \cdot t_\alpha \quad (15)$$

and parameters of the line

$$s_{b2} = \frac{S_{y,t} \cdot n}{\sum t_i^2 - (\sum t_i)^2} \quad (16)$$

$$S_{y,t} = \sqrt{\frac{U}{n-2}} \quad (17)$$

where

s_{b2} ... standard deviation of the coefficient b_2 ,

t_α ... critical value of the “Student division” for selected level of importance,

$s_{y,t}$... standard deviation characterizing scattering of outcomes along the given regression line.

3. Multidimensional statistical evaluation

Modelling of stochastic magnitudes characterizing a real condition of equipment is an important element in tribotechnical diagnostics application. Besides the trend approach, the probability model can also be used. Such a model enables us to define one qualitative variable u by means of several quantifiable parameters $X_1, X_2, X_i \dots X_p$. The primary set, as well as the informative selection which represent the primary set, are subsequently resolved into several groups (generally “ k ”). Individual groups have to correspond to variants of the variable “ u ”. A priori probability of belonging to groups is

$$\pi_h \approx P(A_h), h = 1, 2, \dots, k, \quad (18)$$

where

π_h ... probability of belonging to the group of number h

$P(A_h)$... probability of the event A_h and it can be estimated according to the informative selection structure.

$$\pi_h = \frac{n_h}{n}, \quad (19)$$

where

n_h ... the number of elements in the group h ,

n ... the number of selection elements.

After carrying out multidimensional observations “ x ” a-posteriori probability can be determined using the Bayes formula:

$$P(A_h / x) = \frac{\pi_h \cdot f_h(x)}{\sum_{h=1}^k \pi_h \cdot f_h(x)}, \quad (20)$$

where

$P(A_h/x)$... conditional probability of the phenomenon A_h/x ,

$f_h(x)$... conditional density of probability of the complex of “ p ” considered variables for $h = 1, 2, \dots, m$.

f_h ... vector of coefficients in the h^{th} group,

x_i ... vector of measured values.

To categorize unknown elements, it is necessary to provide for a decision-making rule for their classification within individual groups. The selection area is divided into “ k ” not-overlapping classification areas. Each element is categorized into such a group where the a-posteriori probability will be maximal, and, simultaneously, the incorrect classification probability will be minimized. The total probability of incorrect classification can be described by the equation

$$\omega = \sum_{h=1}^k \pi_h \sum_{h' \neq h}^k P\left(\frac{x \in \varphi_{h'}}{A_h}\right) = \sum_{h=1}^k \pi_h \sum_{h' \neq h_{\text{opt}}}^k \int f_{h'}(x) dx \quad (21)$$

where

ω ... total probability of incorrect classification

$\varphi_{h'}$... area into which the object is incorrectly classified

For objects classification, it is sufficient to search for the group where the numerator in the Bayes formula (20) is maximal, because the denominator is common for all groups.

$$\psi_h = \pi_h \cdot h_h(x) \quad (22)$$

By expressing the probability of multidimensional normal classification by logarithmic calculation and omission of the addends, which are common for all of the groups, we obtain a quadratic discriminative score

$$\psi_h^{(Q)} = x' \cdot \varphi_h \cdot x + v_h \cdot x + \rho_h \quad (23)$$

with a matrix of quadratic form

$$\varphi_h = \frac{1}{2} \cdot \sum_h^{-1} \quad (24)$$

a vector of linear coefficients

$$v_h = \mu_h \cdot \sum_h \quad (25)$$

and a constant

$$\rho_h = 1n\pi_h - \frac{1}{2}1n \left| \sum_h \right| - \frac{1}{2} \mu_h \cdot \sum_h^{-1} \cdot \mu_h \quad (26)$$

where

$\Psi_h^{(Q)}$... quadratic discriminative score,

x' ... line vector of values,

x ... column vector of values,

φ_h ... quadratic form matrix in group h ,

$\sum_h^{-1}$... inverse matrix to covariant matrix in group h ,

v_h ... vector of linear coefficients in group h ,

μ_h ... vector of mean values in group h ,

ρ_h ... quadratic discriminative constant of the group h ,

π_h ... a posteriori probability of belonging to the group h ,

$|\sum_h|$... determinant of covariant matrix of the group h .

If another condition of covariant matrices correspondence is observed, discrimination can be performed by means of a linear discriminative score.

$$\psi_h^{(L)} = \alpha_h \cdot x + k_h \quad (27)$$

with a vector of coefficients

$$\alpha_h = \mu_h \cdot \sum_h^{-1} \quad (28)$$

and a constant

$$K_h = 1n\pi_h - \frac{1}{2} \alpha_h \cdot \mu_h \quad (29)$$

where

$\psi_h^{(L)}$... linear discriminative score in the h^{th} group,

α_h ... vector of coefficients in group h ,

K_h ... linear discriminative constant (constant of the h^{th} group).

$\wedge$... over π_h it indicates the choice probability of belonging to the h^{th} group.

$\bar{\mu}_h$... vector of mean values in the h^{th} group.

The discrimination efficiency can be verified by means of substitution that is application of discriminative classification on a selective set and percentual expression of incorrectly classified objects.

4. Results and discussion

The above methodology of evaluating multidimensional diagnostic signals has been applied to objective evaluation of results obtained by means of ferrographic analysis. Four basic groups of engines were indicated, as follows:

1. Current wear - this group involves all the states characterized by absence of increased quantity of inadmissible particles.

2. Limit wear - this group is characterized by the presence of particles of an inadmissible type. Such an engine needs intensive examination.

3. Critical wear - this group involves an engine threatened by a serious defect of some part within the engine. Further operation of such an engine should not be allowed with respect to technical and/or economical viewpoints.

4. Running - in mode - this group is characterized by the phase presence of particles typical for this and inadmissible in other phases of the engine operation.

All the modes of wear are modelled, according to the number of types of particles present in oil samples. It is known in advance what kind of engine they come from. The results are compared by considering the number of particle types in a 1 ml oil sample, used for preparation of the ferrogram. During analysis of the ferrogram, nine particle types were detected:

1-Cutting wear particles, 2-Laminar particles, 3-Fatigue particles, 4-Spherical debris, 5-Severe wear particles, 6-Corrosive particles, 7-Oxide particles, 8-Non-ferrous metallic particles, 9- Others.

For every particular group, the mean values of the number of particle types were determined and numbered as shown in Table 1. Using these mean values in compliance with Eq.(27) a parameter can be formed called the complex ferrographic parameter F . The parameter makes possible to describe the dependence of a latent implicit parameter of the current state of the engine wear by means of vector of measured values, i.e., number of particular types of particles (29).

Based on results of the selective set, the complex parameter can be written in the form:

$$F_h = f'_h \cdot x_i - K_h \quad (30)$$

where

F_h ... values of the parameter F in the h^{th} group.

The vector of coefficients is an element, which involves internal coupling of selective statistical sampling. It is based on the relation:

$$f'_h = x_h \cdot V^{-1} \quad (31)$$

where

V^{-1} ... inverse of covariation matrix of the selective set.

The constant in Eq. (30) involves first of all the demands on vector ranging in accordance with a reselected criterion, i.e.:

$$K_h = 1n\pi_h - \frac{1}{2} f'_h - x_h \quad (32)$$

In the above procedure, Eqs. (30) - (32), a selective set of oil samples has been worked out. For predestinated groups there were particular parameters numbered as shown in Table 2. Any unknown vector of measured values can be assigned to one of the indicated groups. This means it will be placed in the group of maximum parametric value.

Applying the ranging criterion to the original selective set, the quality of the assigning method and the quality of the description of particular indicated groups of engines can be evaluated. From the total number of samples (106) involved in the selective set, 98 samples were evaluated correctly, i.e., full compliance with the actual state of the engine, known before. Standard deviation of determination of the technical state of the engine is about 7,6 %. The standard deviation of each particular group is given in Table 3. Higher values of the relative standard deviation in the IVth group (running-in mode) are closely connected with poor knowledge of

the course of tribological phenomena during running in of engine T3-930. To decrease this value it is necessary to consider a larger statistical set formed to describe all the indicated groups with the same validity. The above method of evaluating ferrographic analysis is suitable for a large number of ferrography users. It is rather difficult to count particular types of particles, but the counting is defined precisely and the results obtained are unambiguous. Once the ferrosopic evaluation of the ferrogram has been mastered, there is no other difficulty in using the above method. The group characteristics specified is valid for the T3 - 930 engines. When dealing with an engine of another type, it is necessary to verify the validity by further research. An important factor to note is that the decisive feature for assigning an element to a certain group is not the value of the parameter F, but the maximum value of the parameter. This is the difference in application of discriminative analysis in comparison with applications published in the open literature.

Table 1: Vectors of mean values in particular groups.

Type of Particle Code	MEAN VALUES OF NUMBER OF PARTICLES IN GROUPS			
	CURRENT [pcs/ml]	LIMIT [pcs/ml]	CRITICAL [pcs/ml]	RUNNING-IN [pcs/ml]
1	1.560	4.539	6.979	5.426
2	1.501	3.934	6.548	0.917
3	0.737	3.207	6.827	1.170
4	1.208	3.238	5.110	0.629
5	0.486	2.543	5.117	1.046
6	0.971	2.508	4.102	2.510
7	0.489	2.533	5.681	0.719
8	1.809	4.005	5.636	0.464
9	0.789	2.649	5.100	1.874

Table 2: Ferrographic Characteristic of Groups.

Group Parameter	Vectors of Coefficients f_{ih} and Constants of Groups K_h			
	Current	Limit	Critical	Running-In
1	0.718	1.350	0.632	2.067
2	0.609	0.771	0.600	0.031
3	-0.839	1.236	-0.206	-1.175
4	0.703	1.179	0.644	-0.172
5	-0.787	-0.489	-0.501	-0.416
6	0.405	0.352	0.598	1.395
7	-1.175	-1.703	-0.553	-1.738
8	1.171	1.715	0.900	0.370
9	0.029	-0.135	0.459	0.876
K_h	1.921	5.425	7.195	6.696

Table 3: Standard Deviation of Groups.

GROUPS	I	II	III	IV
S_d (%)	6.35	8.33	8.33	14.30

5. Conclusion

The considerably simplified model presented here enables applications of multidimensional classification of particular ferrographic (or other) oil analyses and shows the utilization possibilities of this method for interpretation of tribodiagnostic check-up results. However, the practical exploitation depends on particular tasks to be solved. The trend evaluation performs a methodical function during evaluation of tribodiagnostic measuring results. But interpretation of results still depends on the qualifications of the expert who can judge individual changes, their size, and deviations from normal state. These facts somewhat complicate putting tribodiagnostics into practice, because reliable results depend on the qualifications and experience of the expert.

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THE HEAT BALANCE OF ENGINE FED BY DIESEL OIL AND BMD BIOFUEL

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Abstract: In the present paper the issue of external heat balance in the diesel engine is presented. The methodology of heat balance estimation, as well as the comparison of the researches results concerning engine with the common rail injection system, which is fed by mineral diesel oil and BMD biofuel has been presented. The impact of biofuel on the nature of changes in the heat balance has been estimated. The researches were performed on the measurement station based on the 13 points ESC test. It has been stated that the use of fuel assigned in the ESC test in the engine fed by biofuel (BDM) slightly increases in comparison to the engine fed by mineral diesel oil (ON). However, there can be noticed the change of the flow of energy input in the heat balance of the engine fed by both types of fuel.

KEY WORDS: HEAT BALANCE, DIESEL OIL, BIOFUEL, ESC

1. Introduction and theoretical basics of the heat balance

The heat balance in the internal combustion engine is an equation thanks to which the energetic changes of the circuit can be estimated. Making use of the balance makes it possible to indicate the value of energy carried to the engine, the value of energy carried from the circuit as usable work, and the value of energy that is lost as emitted heat. On the basis on the measurement results of the mechanical engine work and thermal energy emitted by engine, the external heat balance can be determined. For the purpose of that determination the law of energy conduct that provides the heat balance equation is used. This equation goes as following:

$$Q_0 = L_e + Q_{ch} + Q_w + Q_{ns} + Q_{dys} + Q_r, \quad (1.1)$$

Where :

Q_0 – total amount of heat carried to engine, L_e – usable work, Q_{ch} – heat carried to cooling factor, Q_w – heat loss of fumes exhaust, Q_{ns} – amount of heat lost due to imperfect and incomplete fuel combustion, Q_{dys} – dissociation heat loss, Q_r – the rest of balance which includes elusive heat losses carried to ambient

The basics for assigning the heat loss in the internal combustion engine is the calculation of energy carried to it in fuel.

The heat flow carried to the engine is determined from the dependence: in order to assign the heat flow carried to engine Q_0 it is necessary to know its value and G_e .

$$Q_0 = G_e W \quad (1.2)$$

Where:

G_e – weigh of fuel carried in a time unit . kg, W – the fuel value of fuel kJ/kg

The next heat balance component is the heat flow carried from the circuit into the cooling system Q_{ch} .

Another important component of heat balance is the heat flow of engine fumes Q_w .

Other significant components of heat balance are heat losses coming from imperfect and incomplete fuel combustion Q_{ns} as well as dissociation losses Q_{dys} .

$$Q_{ns} + Q_{dys} = (1 - \xi) G_e W, \quad (1.3)$$

Where:

ξ – heat release rate

Heat losses coming from engine radiation are called the balance rest Q_r

Calculations algorithm will be presented due to the use of data from point 2 of engine work according to ESC test. During measurement, the 2nd engine was working with rotational speed of 2412.5 rotations/minute and the load of 35.9 Nm.

In the presented calculations the fuel value W of diesel oil has been assumed as constant and equal of 42700 kJ/kg.

$$Q_0 = G_e W = 0,79 \cdot 42700 = 33,733, kW \quad (1.4)$$

The usable engine power was assigned from the dependence:

$$N_e = \frac{M \cdot \pi \cdot n}{30} = \frac{0,0359 \cdot \pi \cdot 2412,5}{30} = 9,065 [kW] \quad (1.5)$$

While:

$$M = \frac{N_e}{\omega} = \frac{60 \cdot N_e}{2 \cdot \pi \cdot n} = \frac{30 \cdot N_e}{\pi \cdot n} [kNm] \quad (1.6)$$

The next heat balance component is the heat carried to cooling factor Q_{ch} . To compute it, one needs to know the input and output temperature of the cooling system and take into account their differences in the calculations. During measurement, it is essential to measure the speed of water flow (m) flowing through water meter. According to the fact that studied engine is cooled by the water solution, in the calculations the specific cooling factor heat has been assumed as the specific heat of water $c_w = 4,18$, kJ/kg·K.

Thus

$$Q_{ch} = c_w \cdot m \cdot \Delta T \left[\frac{kJ}{kg \cdot K} \cdot \frac{kg}{h} \cdot K \right] = \left[\frac{kJ}{h} \right] = \left[\frac{kJ}{s} \cdot \frac{1}{3600} \right] \quad (1.7)$$

$$Q_{ch} = \frac{4,18 \cdot 246 \cdot 10,9}{3600} = 3,1[kW] \quad (1.8)$$

The heat loss of fumes exhaust Q_w has been assigned from the dependence:

$$n_p = \frac{p_{ot}}{T_{ot}} \cdot \frac{V_s}{MR} \cdot \eta_v = \frac{1009000}{296} \cdot \frac{0,001248}{8314,3} \cdot 0,658 = 0,000336[kmol] \quad (1.9)$$

- The amount of kilo moles of fumes and air (n_s , n_p) in time unit
- Average specific heat for constant pressure Mc_p
- Fumes and air temperature

The filling factor for four-stroke engine is calculated in the following way:

$$\eta_v = \frac{V_p}{30niV_s} \quad (1.10)$$

$$n_s = n_p \cdot 1,04 = 0,000336 \cdot 1,04 = 0,000350[kmol] \quad (1.11)$$

After calculating the amount of kilo moles of fumes and air, it is necessary to calculate how many of them fall on the time unit. The calculations are to be made with the use of the following equation:

$$n_p = \frac{i \cdot n}{120} \cdot n_s = \frac{4 \cdot 2412,5}{120} \cdot 0,000350 = 0,000469 \left[\frac{kmol}{s} \right] \quad (1.12)$$

$$n_s = 1,04 \cdot n_p = 0,000488 \left[\frac{kmol}{s} \right] \quad (1.13)$$

The assigning of specific air and fumes heat requires the analysis of their components in the determined conditions during the time when engine is working. It is necessary to determine the percentage performance of each component and then, according to temperatures, match the proper specific heat of each of them.

$$(Mc_p)_s = (Mc_v)_{N_2} \int_t^0 z''_{N_2} + (Mc_v)_{O_2} \int_t^0 z''_{O_2} + (Mc_v)_{CO_2} \int_t^0 z''_{CO_2} + (Mc_v)_{H_2O} \int_t^0 z''_{H_2O} \quad (1.14)$$

$$(Mc_p)_s = 28,016 \cdot 0,7553 \cdot 0,742 + 32 \cdot 0,703 \cdot 15,45 + 44,01 \cdot 0,8039 \cdot 0,1545 + 18,02 \cdot 1,4792 \cdot 0,053 = 30,68 \left[\frac{kJ}{kmol \cdot K} \right] \quad (1.15)$$

$(Mc_p)_p$ is assigned analogically to $(Mc_p)_s$.

After substituting all already calculated values Q_w totals :

$$Q_w = n_s (Mc_p)_s T_s - n_p (Mc_p)_p T_p = (0,000488 \cdot 30,68 \cdot 509) - (0,000469 \cdot 21,35 \cdot 296) = 4,66[kW] \quad (1.16)$$

Dissociation losses Q_{dys} and losses resulting from incomplete fuel combustion Q_{ns} are assigned together. They are included in the combustion losses similarly to the previously mentioned component Q_w .

$$Q_{ns} + Q_{dys} = (1 - \zeta) G_e W \quad (1.17)$$

Supercharged diesel engine has been studied. The heat release rate ζ for the engine is placed in limits of 0.6-0.8. It has been determined that $\zeta=0,8$.

$$Q_s = Q_w + Q_{ns} + Q_{dys} \quad (1.18)$$

thus

$$Q_s = 4,66 + 6,74 = 11,41[kW] \quad (1.19)$$

Whereas Q_r has been assigned in test point 2 as :

$$Q_r = Q_0 - N_e - Q_{ch} - Q_w - Q_{ns} - Q_{dys} = 33,73 - 9,065 - 3,1 - 4,66 - 6,74 = 10,1[kW] \quad (1.20)$$

2. Measurement methodology and research location.

For the purpose of the study there have been used diesel oil and BMD fuels. They were compared in the area of made-up heat balance concerning , above all, reached power.

In the present studies there were used commonly available diesel oil and fuel with BMD (Bio Mix Diesel) addition which were tested in the diesel engine of Fiat 1.3 JTD. BMD fuel is a mixture of three components. In the first production phase rapeseed oil is mixed with butanol. Butyl alcohol is alcohol of high density and it is used as rapeseed oil solvent. Such an order of mixing both components results as mixture of similar density to diesel oil. This mixture is called BM (Bio Mix) [1] [2] [3] [6].

The studies which make use of two different types of fuel were made on 1.3 JTD Miltijet engine which is the second generation of turbocharged engine with CommonRail system.

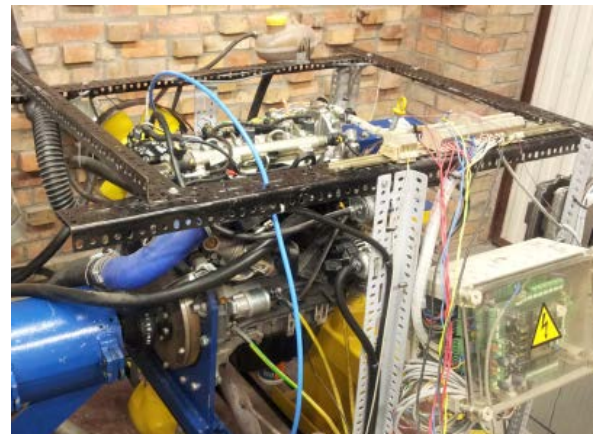


Fig. 2.1. 1.3 JTD 16V engine on the test bed.

The researches were made in properly equipped engine roller performance tester in Department of Vehicle Engineering, Faculty of Mechanical Engineering, Wrocław University of Technology.

3. Measurements results.

Engine working points have been matched according to ESC test proper procedures. They also have taken into account the external characteristics of the engine.

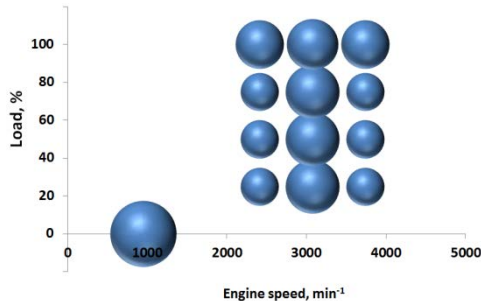


Fig. 3.1. ESC test points

Figures 3.2 and 3.3 present total heat balance of engine fed by BMD fuel and diesel oil.

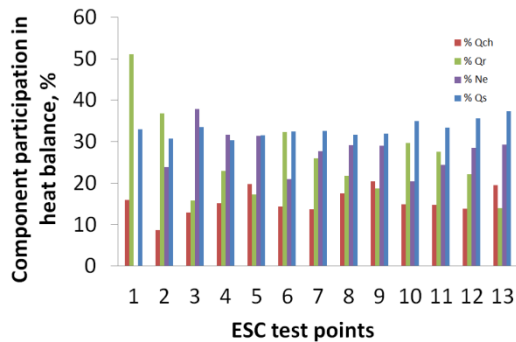


Fig. 3.2. Engine power and heat balance formulated in kW of 1.3 JTD 70CV engine fed by BMD fuel, assigned in ESC test points

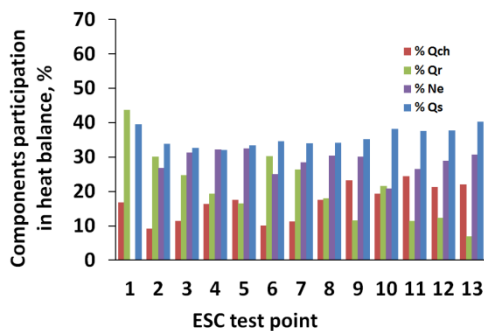


Fig. 3.3. Engine power and heat balance formulated in kW of 1.3 JTD 70CV engine fed by diesel oil, assigned in ESC test points

Taking units use of fuel of the studied engine in ESC test into consideration, the results are as follow:

Table 3.1 Comparison of units use of fuel in the ESC test concerning engine fed by BMD and Diesel oil (ON).

ON	BMD
[g/kWh]	
304,26	320,52

From what has been presented it follows that the difference in units use of fuel in engine fed by both types of fuel is not significant. From the calculated data it follows that the result is 5.53%. However, the changes in distribution of heat proportions seem to be interesting. It is clearly visible in the following diagram.

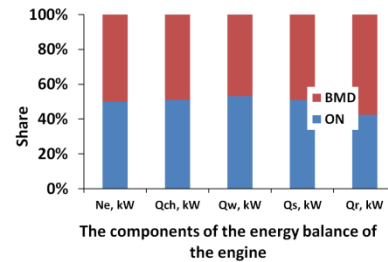


Fig. 3.4. Participation of heat flow assigned in the ESC test of studied engine fed by diesel oil (ON) and BMD.

4. Results analysis and conclusions

From the analysis of the performed studies it is necessary to conclude that fuel additions such as butanol and rapeseed oil mixed with diesel oil in the proper proportions give the desired energy effects.

Assigning of heat balance allows to carry out the analysis concerning the amount of thermal energy which is produced during combustion process in various conditions of working engine fed by both types of fuel and it allows to compare the proper balance ingredients.

The consumption of BMD fuel is slightly higher (due to its lower fuel value). In the performed studies under conditions of ESC test this consumption grows of 5%.

It has to be explained why particular heat flow participations are changing according to different types of fuel used in the engine, especially because of the fact that the combustion heat of both types does not significantly differ.

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USING OF WASTE HEAT OF INTERNAL COMBUSTION ENGINES

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Abstract: Article discusses about the use of heat exchangers for stationary combustion engines and cogeneration units. The paper is dedicated to the problem of unused thermal energy in stationary engines. It analyzes possibilities of accumulation of heat energy and its possible application in various fields. The paper deals with the classification of heat exchangers and with the subsequent description of design solutions of heat exchangers types used in given field.

Keywords: HEAT EXCHANGERS, COGENERATION UNITS, WASTE HEAT, COMBUSTION ENGINES, UNUSED ENERGY

1. Introduction

Nowadays if we omit alternating economic crisis. We can talk about ecological time. Political thinking towards just environmental but also economical, gives new insight into the lifestyle and comfort of man. A great impact just on these aspects has energetic. It is due to the increasing energy demands of human society, on which depends in no small measure the environmental burden and efficiency of energy use.

Possibility how to reduce energy consumption, is the way of savings. Reduction in fuel consumption can be utilized in a direction, which deals with the production of several types of energy, and possibly also of the products from the primary source at the same time. To this category can include cogeneration, trigeneration and polygeneration. Find a use for the heat is not as easy as in the case of electrical energy. But nevertheless is being offered several options, such as use of heat for hot water or direct water heating and its subsequent use for houses or large objects, depending on the performance of the cogeneration unit itself. Another option would be to use the absorption unit to transform heat to cold, making it possible to extend services to the production of cold water, for example for supply of air conditioners.

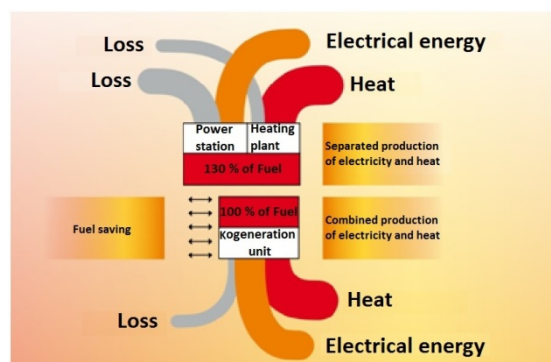


Fig. 1 Cogeneration principle

For all these systems the energy transformation is decisive the method how to submit it. For this intention in case of heat is used inseparable part of most of the systems which is called the thermal coupling node. Thereby may be various types of heat exchangers, coolers, condensers etc. The most common devices nowadays belong heat exchangers. In this case, for the generation of thermal energy from the exhaust gas and its subsequent use in other applications.

2. Use of heat exchangers in cogeneration units and stationary internal combustion engines.

For use of stationary internal combustion engine to generate electricity, or in other applications, arises a waste heat [1]. In most cases, this heat is not used in any way, but today's time more and more forcing producers and consumers to invest in technology that

can leverage the potential of unused energy and contribute to cost saving. To this end has started to use exhaust gas heat exchangers. An exhaust heat exchanger is positioned on the exhaust pipe, removing heat flue gases, which could then be used for various applications.

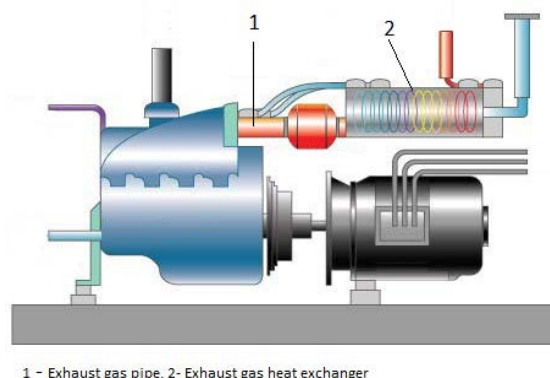


Fig. 2 Position of exhaust gas exchanger in stationary combustion engine

Exhaust gas temperature at the start of the exhaust pipe is in the range 500-700 °C. This means that the exhaust gases offer a great potential for utilization of waste heat. The exhaust gases in the most of cases heat up liquid, which can subsequently be used in several ways.

3. Use of thermal energy from stationary engines

Possibilities of using waste heat are several. The most common include heating domestic hot water and heating. Smaller stationary engines can cover claims of houses alternatively smaller buildings. Using the largest units with up to 2 MW, or combining multiple units into a single source of energy can cover demands for heating and DHW for larger building or complex of several buildings.

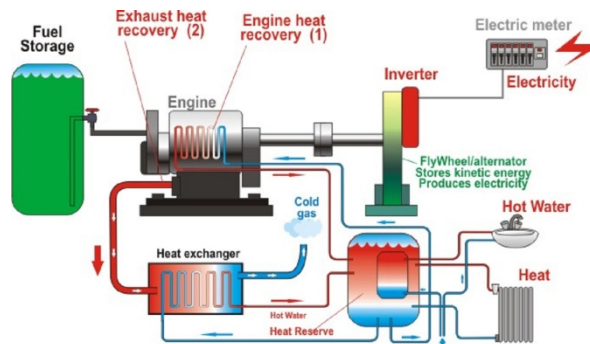


Fig. 3 Cogeneration unit with supply of heating water and hot domestic water

A further possibility is the use of waste heat to accumulate in the storage tanks, and its subsequent use, if needs. In the Nordic countries, the use of waste heat necessary to ensure of the right engine function. Heat is used for heating of intake air and in a case of engine shutdown for maintaining the operating temperature for the purpose to avoid cold starts. With the similar principle is already dealing automakers like BMW with their technology Efficient Dynamics. Automakers already knows for a long time, that the heating of combustion engine in winter requires more fuel and the engine also produces larger amounts of emissions. Thus the engine is warmer, thus there is less friction and decreases consumption and CO₂ emissions [2]. BMW engineers have calculated that the warmed engine after start in the winter consumes about 10% less fuel than a cold engine.

The heat exchanger which heats the fluids and shortens warm-up phase of the engine is already commonly used in gasoline engines. The faster the heated oil in the gearbox and the engine is at operating temperature, the lower the energy losses by friction and fuel consumption. For diesel engines, BMW sees the potential saving in heating the interior. Modern units are already so efficient that the waste heat from them is unable to heat cabin. Therefore, in vehicles with diesel engines is started mounted auxiliary electric heater with 1000 W power, which in winter increases fuel consumption by an average of 1 l per 100 km. In this regard can help heated interior by heat exchanger. Attachments electric heaters will thus become superfluous. The heat exchanger, like in gasoline engines may also participate in faster heating of diesel engine to operating temperature.

4. Heat exchanger

Device used for targeted transfer heat energy from the one heat medium to another one, according to the second law of thermodynamics, is called a heat exchanger [3]. These facilities include a large group and can be found in many sorts of systems without us realizing it. According to the purpose and primarily according to the action, which takes place in the heat exchanger can be divided into the condensers, evaporators, coolers, regenerative heat exchangers etc. Another division is quite normal according to the method of heat transfer, ie whether there is contact between the media etc.

Heat exchangers are divided into:

- Recuperative - media are separated by a solid impermeable wall and not coming into contact
- Regenerative - occurs periodically substituted flow heating and cooling media in the defined area.
- Contact - media come together for some time in contact without chemical reaction, and then are separated.
- Mixing - media are in a certain place mixed and continuing as a mixture.

The most commonly used type of heat exchanger is recuperative. This group primarily include tubular and plate heat exchanger. From the point of view flow is the most common counter-flow design, which results in better heat distribution than in parallel flow design.

• Tube heat exchanger

In this type of exchanger, heat exchange takes place between the tube and the tubular-space. Tubular space normally consists of pipes or tubes of circular cross section, but we can meet with cross-sections of other shapes such as oval, square etc. To

reduce the dimensional parameters of tubular exchangers can use all sorts of ways to increase the area of the pipe from the side of the pipe as well as the tubular space. For this purpose are used, for example ribs.

Tube heat exchangers can be divided according to the construction on:

- With shaped tubes
- With straight pipes
 - Tube in tube
 - Tube in the shell

Design with shaped tubes represent different tube axis arranged in the shape of a helix, spiral etc., located in the shell.

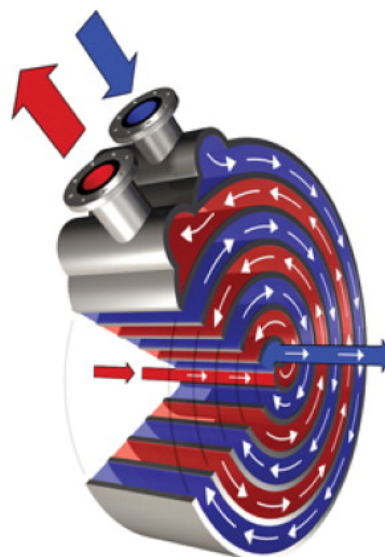


Fig. 4 Spiral tube heat exchanger

Exchangers in design tube in tube are among the simplest device in the above category. It's occurred like dismountable and non-dismountable which are exclusively for pure thermal media.



Fig. 5 Shell & tube heat exchanger

In general the tube exchanger with jacket is the most commonly used heat exchanger, where the main structure consists of a tube bundle placed in the shell of a cylindrical shape. These exchangers are manufactured at many different versions, depending on the configuration of inlet and outlet orifices, pipes, construction attachment of different thermal dilatation of tubes and plastics etc. This type of heat exchanger typically includes partitions that perform two basic functions. Aretation of tubes resulting in a reduction of bending and vibration and also primarily direct the flow of media that is purposely altered to the cross-flow that increase the intensity of heat transfer. The system also has the disadvantage that, with the inclusion of partitions create higher pressure drop.

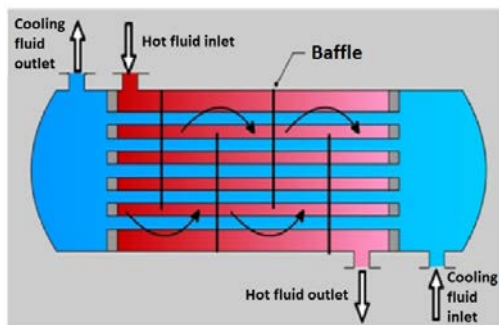


Fig. 6 Tube heat exchanger with baffles

Tube heat exchangers are characterized by good heat resistance and affordable price. However, their disadvantages are small compactness and high weight. The case of the pipes with small diameter, in which is the aqueous medium dirty it's expected gradual decrease of the cross-section pipe up to its complete clogging.



Fig. 7 Real construction of tube heat exchanger with baffles

• Plate heat exchanger

Plate heat exchangers are based on a patent that has already been registered in 1878 by German inventor Albrecht Dracke. This principle, when one liquid cooling another liquid and liquids are flowing on both sides of group thin metal plates, became the basis for the construction of the heat exchanger - commercial plate pasteurizer Alfa Laval.

For more than 130 years was plate heat exchangers developed and structurally modified to devices that are used in thousands of different applications in all industries. Plate heat exchanger was previously designed for heating and cooling of the milk, but now is commonly used for heating and cooling in industrial processes and it is the basis of air-conditioning in buildings or it provides heating of hot water for hundreds of millions of people.

This type of heat exchanger is characterized with a row lying plates which bear shaped reinforcements create turbulence of heat transfer medium and enlarge the heat-conveying surface. The heat transfer medium, as shown in the figure flows between the slabs of small thickness, whereby the heat is transmitted between substances mainly convective. Plate heat exchangers can be sorted into dismountable and non-dismountable. Non-dismountable exchangers are usually occur in the brazing or welding design, which can also be used in case of the aggressive heat transfer medium. For plate heat exchangers is a clear advantage of their higher performance per unit area, therefore low weight and small size which is for the same performance about 5 times smaller than in tubular heat exchangers. However, the benefits are offset by higher prices and demanding production technology.

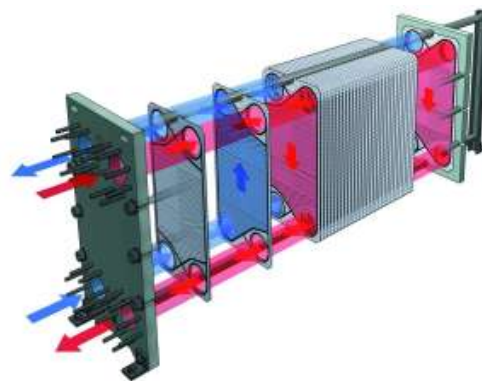


Fig. 8 Plate heat exchanger

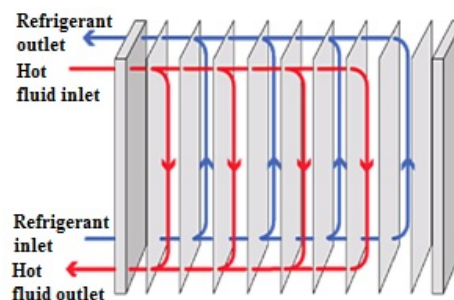


Fig. 9 Fluid flow in plate heat exchanger

5. Conclusion

Nowadays, everyone looking for ways to save the largest amount of funds. Hence arise technology with which we can use energy from waste heat for other applications. Exhaust gas heat exchangers are increasingly appearing in conjunction with stationary combustion engines and automotive industries. Use of this technology to many manufacturers interesting solution as fuel economy and reduce emissions. The rate of fuel savings and overall efficiency of the plant will require yet another survey, which I will dedicate next steps in my work.

Acknowledgement:

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