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RESEARCH

Parameters of Internal Combustion Engine Efficiency While Introducing Additives in the Oil

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A B S T R A C T

The resource of modern internal combustion engines (ICE) ranges from 200 thousand up to 1 million km. This is due to significant design changes in the ICE systems, as well as the properties of working oils and additives to them. Parts of an internal combustion engine have reached the limit of accuracy. The topical direction of extending the service life of assemblies and ICE systems is the use of various nanoparticles added to the lubricant. Ten different nanoparticles were selected for the experiment. When conducting experimental studies a gasoline 4-cylinder injection ICE was used. "Vybeg" and "Razgon" testing were carried out using a device for complex and element-by-element diagnostics of ICE. The operational tests of the Wagner nanoparticle confirmed its effectiveness in reducing friction: the run-out time increased by an average of 0.4-0.5 s; a decrease in the time of acceleration of the internal combustion engine on one cylinder was 0.9-3.2 s; the difference between the steps of the idling regulator was 9-12 steps; at idle, a decrease in the concentration of CO (-0.01-0.03%) and CH (-10-60 mln^{-1}) was revealed.

1. INTRODUCTION

According to comprehensive studies of Russian and foreign researchers, the resources of modern internal combustion engines (ICE) range from 200 thousand to 1 million km [1-3]. According to some data, this figure has long crossed the line of 1 million km. This is largely due to significant structural changes in the ICE systems [4,5], in particular with the use of modern lubricants thickened with various additives [6,7]. It is beyond doubt that it is impossible to increase the resource parameters of the internal combustion engine only by constructive improvement of components and systems.

Superhigh engine conditions lead to the contamination of engine oil with its oxidation products [8, 9]. Dynamic acceleration modes, top speeds and torsional moments reduce the ICE service life. Wear products of friction pairs and impurities in a running engine further accelerate the dynamics of wear [4]. However, this process can be significantly slowed down by the use of anti-wear additives. Anti-wear additives are additives or their reaction products which form a thin strong film on high-loaded parts [10-13].

Manufacturers of most modern automotive oils select a balanced complex of additives that provide oil with good detergent and dispersing properties. According to some statistical data, the impurities accumulating in the oil (about 80 %) have a particle size not exceeding 2-5 microns [14]. The dynamics of changing the frequency of maintenance (replacement) of oil filters and engine oil (*L*, km) by year on cars in Europe is presented in Fig. 1.

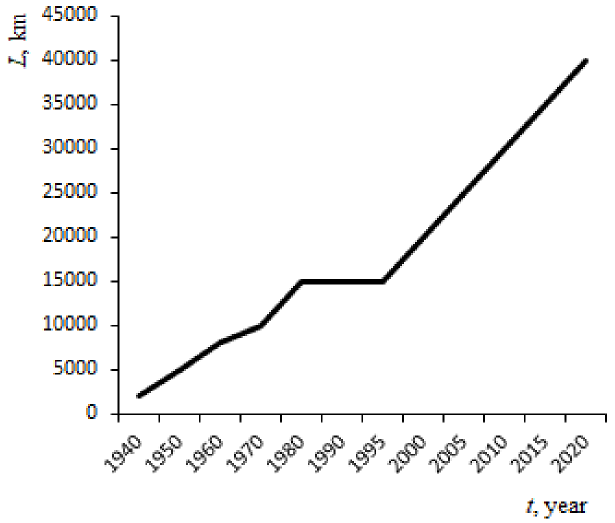

Fig. 1. Change in the frequency of maintenance (replacement) of oil filters and engine oil *L*, km on cars in Europe by year.

The presented data indicate a significant increase in mileage before changing the oil and filter element. The filter elements of modern cars are made from thinner synthetic fibers that provide better cleaning of engine oils. The most effective measures are: development and application of fundamentally new oils and additives to them, improvement of components and parts of the internal combustion engine, provision of a signify can't reserve of power and torque, improved operating conditions, etc. [15–18].

Currently, the technology of robotic assembly and manufacture of engine parts has reached the limit of accuracy. 10 years ago nominal clearances in CM bearings were 0.2–0.05 mm, for modern new ICE they are 0.1–0.01 mm and even less. Consequently, the gap in the friction nodes is significantly reduced. Particles with a diameter of 1–5 μm can be considered critical now, especially if their concentration is sufficiently high. As can be seen from Fig. 2, the strongest wear is observed when particles with a size of 20–30 μm are present in the oil [19].

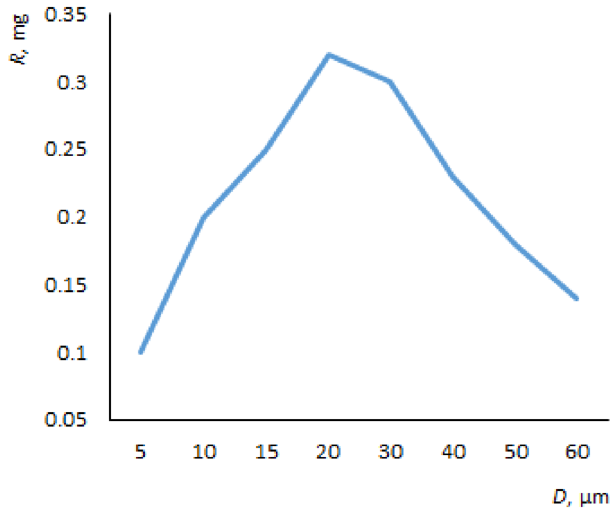

Fig. 2. Intensity distribution of wear *R*, mg depending on the particle size *D*, μm.

Another direction of extending the service life of components and systems of the internal combustion engine is the use of "wear free technologies", which consist in the use of various nanoparticles added to the lubricant [20–22]. The active nano-additives used in wearless technology belong to the category of particles that can instantly reduce friction and wear in the mates of assemblies and mechanisms. In addition, they can maintain the effect of reducing friction for a long time during operation, as well as to slow down the aging and wear of automotive engineering systems [23-26].

According to the principle and basic mechanism of functioning in operating conditions, nanopreparations can be divided into four classes [27,28]: friction modifiers, remetalizants, conditioners, revitalizants [29,30]. Friction modifiers include: ULTRA CARB COMMERCIAL, OLIKS Maximum, Prolong AFMT, Forum, Aspect, etc. They are added in an amount of 5-15 % of the oil volume. Their main advantage is a 3…4 times decrease in the friction coefficient. However, their application boundaries are small by the ICE wear, only up to 30 %. Their main mechanism of action is the formation of anti-friction and anti-wear films on the surfaces of conjugated parts. Their significant drawback is the influence on the change in the physical and chemical properties of fuels and oils [31,32].

Remetalizants include: Rimet, Resource, Supermet, etc. This additive provides a 1.5…2 times decrease in the friction coefficient. Its positive feature is a partial restoration of the dimensions of the parts of resource conjugations due to the formation of anti-friction films. They are recommended for use even when the conjugation wear is up to 40...50 %. At high concentrations, these additives can affect the physical and chemical properties of fuels and oils [33,34].

Metal conditioners also known in operation include: Fenom, RENOM, ER, ENER-GYRELEASE, WAGNER, etc. The friction is reduced by 5...7 times. Metal conditioners protect against scuffing and premature wear of resource conjugations. They are recommended for use when the wear is up to 40 %. They have no noticeable influence on the physical and chemical properties of fuels and oils [27,28].

Revitalizants include RVS (RVS), XADO, FORSAN, SUPROTEC, NIOD, OMKA, REA-GENT-2000, etc. They provide the formation of a protective metal-ceramics layer at the molecular level with the part surface [35,36]. The layer of up to 0.1...0.2 mm is characterized by a high hardness and wear resistance. The mutual diffusion of metal and metal carbides reaches the depth of 10–30 microns. They provide a 3…5 times decrease in friction. Practice shows that the protective coating is maintained even if the mileage is 100,000 km. It is proved that revitalizants allow to restore surfaces with the wear of up to 70 %. They do not change the properties of fuels and oils [37].

The results of analyzing well-known nanopreparations showed significant advantages of the nanopreparations belonging to the "metal conditioners" and "revitalizants" classes. The preparations which can be used at any ICE wear stage are predominantly applied in operational practices.

Thus, the purpose of the research is a comparative study of various additives added to the engine oil, as well as their further study on stand facilities and in operating conditions.

2. THEORETICAL PROVISIONS

The operation of automotive oils shows that mechanical and other impurities most intensively accumulate in the first 50...140 hours of engine oil operation. After that comes some stabilization of oil aging. Stabilization consists in establishing a balance between the rate of accumulation of contaminants in the oil and their removal by oil cleaners, which determines the equilibrium state (Fig. 3) [5,38-43].

The intensity of mechanical impurities accumulation depends on the load and climate conditions of the engines, as well as the quality of oil cleaners. By 70...160 hours of work, the content of mechanical impurities in the oil stabilizes [38, 39].

The law of accumulation of mechanical impurities content can be represented as [18]:

$$Q_t = \alpha\left(1 - e^{-kt}\right) + q \,. \tag{1}$$

where Q_t is content of mechanical impurities in the oil at the time of its operation t, h; α and k are analytical factors; q is content of mechanical impurities in fresh oil, g.

At the same time, oil viscosity intensively increases during the first 60...180 engine hours [19,28,38,39].

The analysis of using various oils showed a significant dynamics of the intensity of viscosity growth in the initial period of operation. This is due to the active heating and evaporation of low-boiling low-viscosity fractions and the accumulation of polarized fractions and oxidation products in it.

Under operating conditions, the viscosity change of oil from the operating time is subject to the following empirical dependence [19,29,38,39]:

$$U_t = \alpha\left(1 - e^{-kt}\right) + U_0 \,. \tag{2}$$

where α and k are coefficients depending on the operating conditions of the oil; U_0 is initial viscosity of the oil used, mm^2/s.

As is known, the alkaline number of the oil is the main indicator of additives aging [19].

The intensive reduction of the alkaline number in the first period of operation confirms the activity of oxidative processes of low-stable hydrocarbons in the entire volume of engine oil. The performance of engine oils of modern ICE was: in terms of pollution – 70...75 %; alkaline number – 40...45 %; on kinematic viscosity – 55...80 % [38,39].

The experimental research was divided into three consecutive stages. The task of the first stage was to determine the most effective preparation, which allows us to exclude the formation of scoring and jamming in a tribo-conjugation. At the second stage, we performed complex and element-by-element diagnosis of the ICE. At the same time, we evaluated the effectiveness of the additive selected at the first stage. At the final stage, we carried out experimental studies with the introduction of a pollutant. The influence of the selected additive was evaluated by measuring the rundown time and acceleration time.

3. EXPERIMENTAL RESEARCH METHODOLOGY FOR CHOOSING ADDITIVES (RESEARCH STAGE 1)

The task of the first stage of our research was to choose an effective nanoparticle for adding into the ICE oil.

The purpose of this experimental research was a relative evaluation of various nanopreparations and choosing the most effective ones for their subsequent use in the engine oil. The samples were produced from high-hardness alloyed steel, in particular, from the bearing roller and ring (ShH15 steel, hardness 72 HRC). During the tribotechnical experiments, the geometric characteristics of the samples remained unchanged. The durability limit of the material and its hardness were also unchanged. In this case, the samples acquire the ability to withstand significant deformations without destruction. It follows that when using the proposed samples, the main and only component of the wear rate according to the formulas of Kragelsky [44] will be the friction coefficient, which depends on the friction conditions, i.e. from the brand of the tribopreparation in the composition of the lubricant. Other components are unchanged.
It follows from the formula of Kragelsky [44] that the best friction condition is achieved when various anti-friction films applied on the surface of the parts have a low shear resistance of the formed welding bridges.

To compare the effectiveness of various nanopreparations, we developed a fecility (an analogue of the Timken friction machine), which allows us to determine the maximum load *M*, N·m in the tribo-conjugation, under which there occurs scoring (jamming) and the motor stops.

For the experiment ten different nanoparticles were considered: 1 – pure motor oil; 2 – Forum; 3 – ARRT (technology of antifriction and resource-reducing treatment of an ARR composition); 4 – RA (reducing agent); 5 – Forsan universal (FORSAN Nanoceramics); 6 – RVS; 7 – Reagent-2000; 8 – Suprotec universal; 9 – Ceramic "Wagner"; 10 – Oil Package "Wagner".

4. RESULTS OF THE EXPERIMENTAL RESEARCH FOR CHOOSING ADDITIVES (RESEARCH STAGE 1)

The results of tribological studies of various nanoparticles on burring specimens conducted by the above method are presented in Fig. 3.

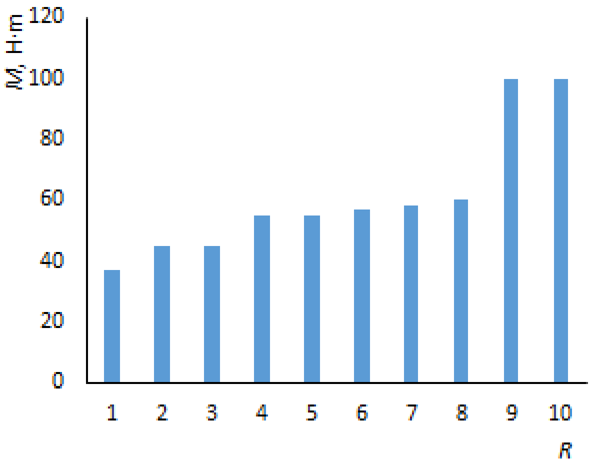

Fig. 3. Diagram of the relative change in the maximum load *M*, N·m in tribo-conjugation in which a seizure (jamming) and stopping of the motor on the type of nanoparticle R occurs: 1 - pure engine oil; 2 - Forum; 3 - ARRT; 4 - RVD; 5 - Forsan universal; 6 - RVS; 7 - Reagent-2000; 8 - Suprotec universal; 9 - Ceramic "Wagner"; 10 - Oil Package "Wagner".

The results showed that only two out of ten nanoparticles can guarantee the exclusion of scuffing formation and samples seizure in friction conjugation. These are particles of the Wagner company. It was found that these particles also have a unique wear resistance. It turned out that the amount of wear when using Wagner samples is an order of magnitude lower compared to other nanomaterials in the composition of engine oil. The relative coefficient of friction, in terms of the ammeter on the device, was also 5...7 times lower. The amount of current consumed by the motor did not exceed 0.5 A with Wagner particles. On all other particles, the current was 4...5 A. Thus, Wagner preparations were chosen for our further research.

5. EXPERIMENTAL RESEARCH METHODOLOGY FOR TESTING THE WAGNER ADDITIVE (RESEARCH STAGE 2)

The tasks of the second research stage were: to develop a research facility and a device for complex and element-by-element diagnosis of the ICE. To carry out experimental studies to establish the relationship between the parameters of the ICE rundown and the operating properties of the oil during its long-term use together with the Wagner additive. To this end, we used a research facility (Fig. 4), which is a gasoline 4-cylinder injection ICE mounted on a frame [9].

Fig. 4. Research facility.

In addition, we have developed a device for complex and element-by-element diagnosis of ICE (Fig. 5). This instrument allows us to determine the following parameters: 1) power of mechanical losses; 2) ICE acceleration time; 3) coasting time of ICE; 4) fuel consumption. The device allows us to determine the technical condition of the internal combustion engine systems by identifying the offset balance of the indicator power and the power of mechanical losses when creating test modes. One of such tests is measuring the rundown time in any frequency range of the engine crankshaft rotation [31]. The coasting time test can be carried out for all simultaneously working cylinders, and for individual cylinders of the engine. The second important test for the acceleration time is also carried out in any range of operating frequencies of the ICE crankshaft rotation.

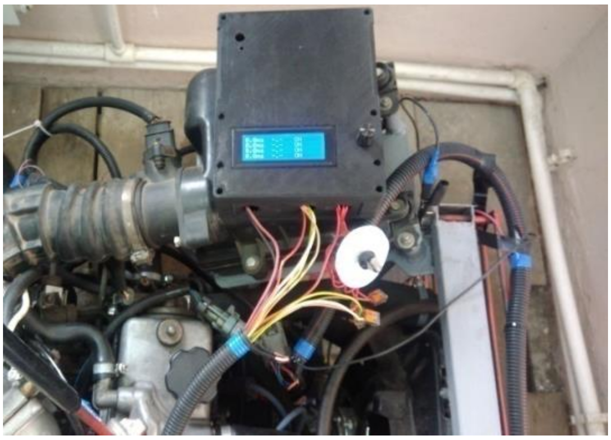

Fig. 5. A device for complex and element-by-element diagnosis of ICE.

We used Mobil SUPER 5W40 synthetic oil during all the experimental studies. The oil temperature was maintained stable at the level of 70-80 ^{0}C. The oil temperature was measured by a probe (thermocouple) of the ASKON-02.00 gas analyzer.

Measurements were carried out for two lubricant combinations: 1. The engine runs on 5W40 oil without a nanoparticle; 2. The engine runs on 5W40 oil with the addition of the Wagner nanoparticle.

The tests were carried out on two ZMZ-4062 engines. The first ICE had a mileage of 53,850 km before the test, the second ICE - 83,994 km. The mileage before changing the oil corresponded to 10,000 km. Only MobilSUPER 5W40 synthetic oil was poured during the entire operation period.

The experiment algorithm is as follows.

1. The measurement of all parameters was made on the oil without nanoparticle. A flushing was added in the oil. Within 10–15 minutes the machine was working on flushing oil. Then all the oil was drained. Fresh oil with Wagner nanoparticle was added. The machine worked for 30 minutes.
2. All parameters were measured on oil with a Wagner nanoparticle. The measurement results were recorded and later analyzed.

3. The coasting time was measured on four working cylinders. From 4500 min^{-1} to 1000 min^{-1}. The test was repeated three times in each measurement mode.
4. The acceleration time was measured on one working cylinder with three others completely shut off. The limits for ICE acceleration were 2000–3500 min^{-1}.
5. The measurement of the number of steps of the additional air regulator was carried out when the engine was idling at a rotational speed of the engine crankshaft frequency of 860 min^{-1}.
6. The measurement of the hourly fuel consumption was carried out at idle and at a frequency of rotation of the engine crankshaft – 3000 min^{-1}.
7. The measurement of toxicity was carried out by ASCON-02.00 gas analyzer: 1. The concentration of CO in the exhaust gases was measured, %; 2. The concentration of CH in the exhaust gases was measured, mln^{-1}.
8. The measurement of toxicity was made at idle and at the frequency of rotation of 3000 min^{-1}.

6. RESULTS OF ENGINE OPERATIONAL TESTS ON THE USE AND IMPLEMENTATION OF QUALITY CONTROL OF THE WAGNER NANOPARTICLES (RESEARCH STAGE 2)

The tests were carried out on multiple engines. One of them was with a mileage of 53,850 km on one meter.

According to the developed method, the coasting time was measured on the engine without a nanoparticle, which was 2.6 s. After pouring the nanoparticle, the coasting time increased to 3 s. This suggests friction reduction in the ICE systems.

The acceleration time was measured using a device for complex and element-by-element diagnostics of ICE systems. The measurement results are presented in Table 1.

Based on the results, we made an unambiguous conclusion about reducing friction: a decrease in the acceleration time of the internal combustion engine on one cylinder was 0.9–3.0 s.

Table 1. Acceleration time measurement.

	Cylinder number			
	1	2	3	4
Oil without nanoparticle	4.6	5.3	6.2	6.9
Oil with nanoparticle	3.7	4.3	4.3	3.9

The results of measuring the steps of the regulator idling: without nanoparticles – 96; with nanoparticles – 87. Reducing the steps of the idling regulator also indicates a reduction in friction.

The results of the measurement of toxicity are presented in Table 2.

Table 2. Toxicity measurement results.

	CO concentration			
	at idle, %	3000 min^{-1}, %	at idle, mln^{-1}	3000 min^{-1}, mln^{-1}
Oil without nanoparticle	0.09	0.18	160	80
Oil with nanoparticle	0.06	0.24	100	140

At idle, a decrease in CO (-0.03%) and CH concentration (-60 mln^{-1}) was found. However, at 3000 min^{-1} an increase in toxicity of CO (+0,06 %) and CH (+60 mln^{-1}) was observed. At this initial stage of burn-in of the internal combustion engine and additives, the increase in toxicity is explained by the ingress of washing into the cylinders and its burnout.

The fuel consumption at idle: oil without nanoparticles – 1.4 l/h; oil with nanoparticles – 1.2 l/h. The fuel consumption decreased by 0.2 l/h, which is consistent with the previously presented results, which characterize the reduction of friction.

The second engine had 83994 km mileage on the odometer. Measurement of the coasting time on the engine without nanoparticle, was 2.6 s. After pouring the nanoparticle – 3.1 s. The result of the coasting test indicates a reduction in friction.

The acceleration time was measured by the device and presented in Table 3.

The analysis of the results shows: the acceleration time of individual cylinders decreased on average by 1.8-3.2 s. That confirms the reduction of friction.

Table 3. Acceleration time measurement.

	Cylinder number			
	1	2	3	4
Oil without nanoparticle, s	12.5	10.3	7.9	6.9
Oil with nanoparticle, s	9.3	8.5	5.2	4.6

The results of measuring the steps of the idling regulator: without nanoparticles – 93; with nanoparticles – 81.

Reducing the steps of the idling regulator indicates a reduction in friction. The results of the measurement of toxicity were summarized in Table 4.

Table 4. Toxicity measurement results.

	CO concentration			
	at idle, %	3000 min^{-1}, %	at idle, mln^{-1}	3000 min^{-1}, mln^{-1}
Oil without nanoparticle	0.21	0.26	540	110
Oil with nanoparticle	0.20	0.38	530	120

At idle, a decrease in the concentration of CO (-0.01 %) and CH (-10 mln^{-1}) was observed. However at 3000 min^{-1} the increase in toxicity of CO (+0,12 %) and CH (+10 mln^{-1}) is revealed. At this initial stage of burn-in of ICE and nanoparticles, the increase in toxicity is explained by the ingress of washing into the cylinders and its burnout.

The fuel consumption at idle: oil without nanoparticles – 1.4 l/h; oil with nanoparticle – 1.2 l/h. The fuel consumption decreased by 0.2 l/h, which is consistent with the previously presented results, which characterize the reduction of friction.

7. EXPERIMENTAL RESEARCH METHODOLOGY WHEN INTRODUCING A POLLUTANT (RESEARCH STAGE 3)

The task of research stage 3 was to develop an experimental methodology for testing the additives and choose instrumentation to control the oil with the additive. To study the relationship between the degree of clogging of oil filter elements and the pressure drop on them with the introduction of a pollutant. To study the dependences of the pressure drop on the working fluid temperature.

We used the research facility (Fig 4). The studies were carried out according to the experimental procedure of GOST 25476-82.

Quartz dust with a specific surface 10500 cm^2/g was used as the input artificial pollutant according to GOST 8002-80 for filters with nominal filtration accuracy of not more than 25 microns and with a specific surface of 5600 cm^3/g according to GOST 14146-88 for filters with nominal filtration accuracy of 40 microns and more. The uniform distribution of the pollutant in the selected portion of the working fluid was provided using a laboratory stirrer. Contaminated portion of the working fluid was injected into the test bench tank for 2–3 minutes while the hydraulic system was running. The temperature of the working fluid was measured in the stand hydraulic system and the pressure drop across the filter 5–7 minutes after the introduction of the pollutant is completed, and then the measurements are repeated every 5 minutes until the value of two or three subsequent pressure drop measurements, in terms of the nominal temperature, coincide with accuracy equal to the accuracy of measuring instruments.

The procedure for the introduction of artificial pollutant is repeated until the concentration of the latter will not create the maximum differential pressure specified in the technical specifications for specific types of filters. The dependence of pressure on the mass of the external pollutant was constructed according to the test results.

The dirt capacity of the filter element was calculated by the formula [15]:

$$G = M \cdot s. \quad (3)$$

where M is mass of the introduced pollutant, mg; s is time elapsing before reaching the maximum pressure drop from the initial to the maximum specified in the specifications for specific types of filters.

The tests to determine the dirt holding capacity are carried out at least three times for the filter elements of one nano size.

The results are considered satisfactory with a coefficient of variation of not more than 10 %. With a larger deviation of the dirt capacity from the average value, the number of tested filter elements should be increased.

8. RESULTS OF THE EXPERIMENTAL RESEARCH WHEN INTRODUCING A POLLUTANT INTO THE OIL (RESEARCH STAGE 3)

Experimental studies were carried out in order to determine the boundaries of the efficiency of the oil together with the additive during the introduction of a pollutant. Before the main part of the experiment was carried out on the research bench, the pressure values before and after the filter element were measured with the oil temperature within 60–112 °C. According to the experimental data obtained, tables were drawn up and a graph was plotted as a function of the pressure drop versus temperature during heating and cooling of the oil (Fig. 6).

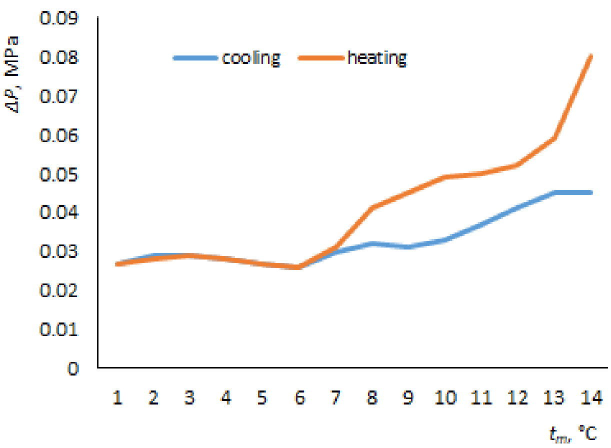

Fig. 6. Graph of pressure drop versus working fluid temperature.

At the final part of the experiment, the dependence of the pressure drop on the filter element on the amount of pollutant introduced was investigated. Guided by the method of testing (GOST 25476-82) quartz dust with a specific surface of 10500 cm²/g was injected into the oil and readings from manometers were taken. The measurement results are shown in Table 5. The experiments were carried out until the bypass valve on the filter was opened.

Table 5. The measurement results of experimental studies.

No.	*G*, mg	*t*, °C	P_1, MPa	P_2, MPa	*Q*, l/h	*ΔP*, MPa
1	300	95	0.071	0.041	46	0.030
2	600	88	0.072	0.041	47	0.031
3	900	92	0.076	0.042	46	0.034
4	1200	86	0.080	0.045	46	0.035
5	1500	90	0.080	0.043	46	0.037
6	1800	91	0.080	0.040	46	0.040

Note. *G* – amount of the introduced pollutant, mg; *Q* – meter reading, l/h.

The results of experimental studies are presented in Fig. 7.

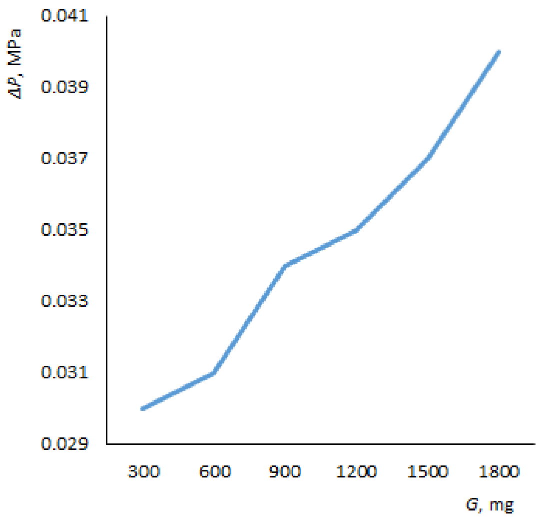

Fig. 7. Graph of pressure drop *ΔP*, MPa on the amount of pollutant *G*, mg.

The analysis of Fig. 7 shows that the introduction of a pollutant into the oil significantly accelerates the clogging of the filter. An increase of 300 mg gives an almost linear increase in the pressure drop on the filter element. With the introduction of 600 mg of the pollutant, all the positive results from the action of the Wagner additive were reduced to zero. This is due to the spread of the pollutant throughout the lubrication system and an increase in friction.

Further studies on the two treated internal combustion engines consisted in monitoring diagnostic parameters every 1000 km during a total mileage of 30,000 km. This study allowed us to determine the duration of the Wagner nanoparticle. The operational control of the parameters showed a steady retention of the properties of the Wagner additive after 15,000 km of run, after which the oil was changed and the next portion of the additive was introduced. In the subsequent period of 15,000 km, a repeat result was also observed, consisting in the stable maintenance of the run-on time by 0.4–0.5 s longer and a decrease in the acceleration time by 0.9–3.2 s relative to the base oil without an additive. However, this effect can significantly decrease in dusty operating conditions or in the absence of a planned replacement of consumables.

In addition, we also managed to control the complex output parameter that is the power of mechanical losses N_{ML}, kw Fig. 8.

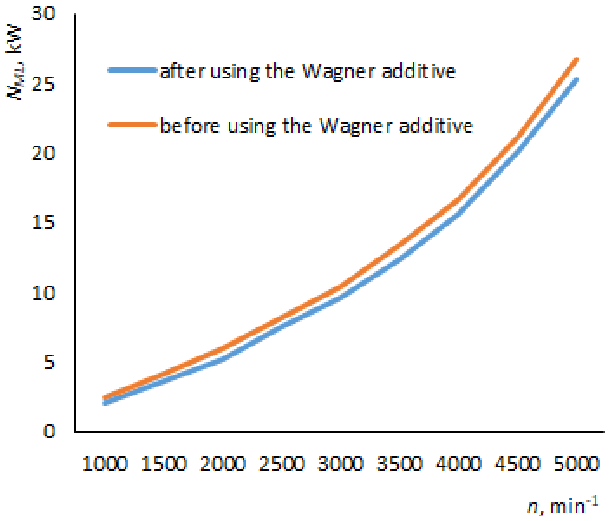

Fig. 8. Graph of dependence of the power of mechanical losses N_{ML}, kW on the rotational speed of the engine crankshaft n, min^{-1}.

The power control of mechanical losses after the addition of Wagner additive showed an instant friction reduction in the range of 0.1–0.5 %. Subsequently, after cleaning the spark plugs, the effect of the additive effect increased and amounted to 0.5–3 %.

The best effect of the application of the additive can be seen in Fig. 9.

Thus, Fig. 9 shows a trend in the displacement of the moment of resistance below the initial variation (without an additive). The balance of the indicator moment and the moment of mechanical losses is shifted to the right, providing a greater length of the working zone of one working cylinder.

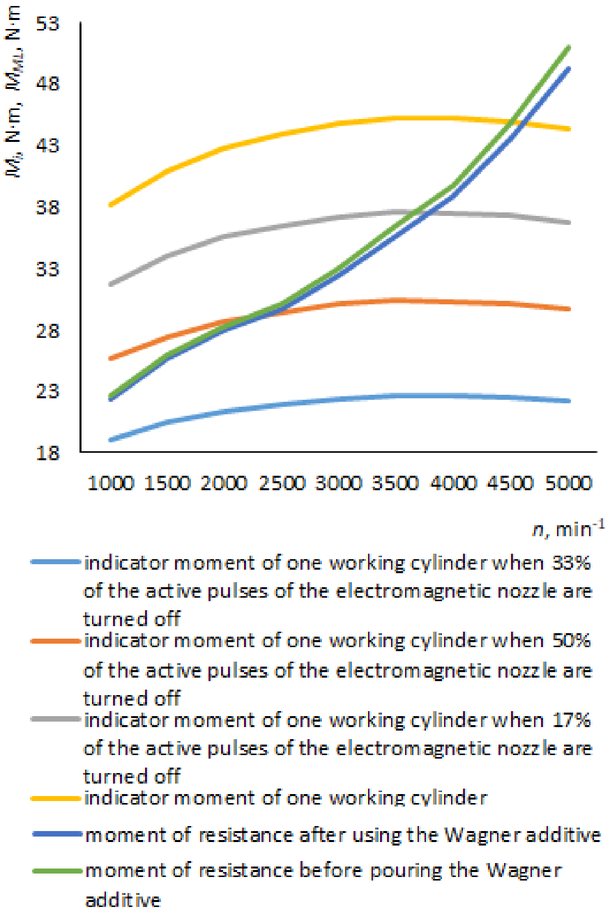

Fig. 9. Graph of the indicator power M_i, N·m, power of mechanical losses M_{ML}, N·m on the rotational speed of the engine crankshaft n, min^{-1} during the work of one cylinder.

9. CONCLUSION

1. The studies of trends in the frequency of maintenance (replacement) of oil filters and engine oil have shown that at the moment the norms are 20,000–30000 km. There are trends approaching 40,000 kilometers by 2020.
2. The analysis of engine oil performance showed that by 70...160 hours of work the content of mechanical impurities in the oil stabilizes. The strongest wear of engine bearings is observed when particles with a size of 20–30 microns are present in the oil. The viscosity of the oil intensively increases during the first 60...180 engine hours. The stock of the working capacity of engine oils of modern ICE was: in terms of pollution – 70...75 %; alkaline number – 40...45 %; on kinematic viscosity – 55...80 %.
3. The experimental studies using the Timken friction machine involved ten most well-

known tribological products and chose the most effective one – the Wagner nanoparticle. The amount of current consumed by the motor did not exceed 0.5 A with the Wagner particles. On all other particles, the current was 4...5 A.

4. We have developed a research facility on the basis of a gasoline 4-cylinder injection engine and an instrument for complex and element-by-element diagnosis of the engine. The effectiveness of the Wagner additive to reduce friction was experimentally established: the average run-on time increased by 0.4–0.5 s; a decrease in the time of acceleration of the internal combustion engine on one cylinder was 0.9–3.2 s; the difference between the steps of the idling regulator was 9–12 steps; at idle, a decrease in the concentration of CO (-0.01-0.03 %) and CH (-10-60 mln^{-1}) was observed.
5. We have developed an experimental technique for testing additives and have selected instruments for controlling oil with an additive. An increase of pollutant to 300 mg gives an almost linear increase in pressure drop across the filter element. With the introduction of 600 mg of the pollutant, all the positive results from the action of the Wagner additive were reduced to zero.
6. After 15,000 km, steady preservation of the initial results of the introduction of the Wagner additive was observed that is an increase in the run-on time by 0.4–0.5 s and a decrease in the acceleration time by 0.9–3.2 s relative to the base oil without the additive.

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