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Consideration of service life extension of lubricants

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Abstract
Article is devoted to the questions of cleaning of lubricatins from mechanical impurities. Questions of application of electrostatic cleaners for removal of solid insoluble particles from dielectric liquids are considered. Questions of influence of non-uniform electric fields on structure of lubricatins and on processes of formation of self-generated organic films were estimated.
The researches concerning influence of electric field on change of concentration of the main components of mineral lubricatins are conducted. Investigations were fulfilled on the friction machine SMTs-2, which was equipped with system of measurement of thickness of a lubricant layer in the mode of friction rolling with slipping [1], in the conditions close to toothed gearings operating conditions: total rolling rate is 1.8 m/s, contact tension - 500 MPa, relative slip - 20% ÷ 80%, temperature of a working medium is 363K.
Key words**:** LUBRICANT FILM THICKNESS, MECHANICAL POLLUTION, ELECTRICAL FIELD

Purpose

Researches on the influence of the electrical field on the change in concentration of the main components of the mineral lubricants.

Methodology

The researches were conducted by friction machine SMC-2, which was equipped with measuring system of lubricant film thickness in the mode of rolling friction with slipping [1]. The experiments were conducted under conditions similar to the conditions of gears operation: total rolling velocity - 1.8 m/s, contact pressure - 500 MPa, the relative slip - 20% ÷ 80%, media temperature - 363K.

Results

The paper is devoted to lubricants purification from mechanical impurities. The problems of electrostatic cleaners use for removing of nonsoluble solid particles from dielectric fluids were considered. The impact of non-uniform electrical fields on the structure of lubricants and on the formation of self-generating organic films was evaluated.

Scientific novelty

Scientific novelty of the research is confirmation of assumptions about the decrease in lubricating ability of lubricants with increasing in content of mechanical impurities and in the abrasive wear of tribosystems elements.

Practical value

It was established experimentally that electrostatic cleaners allow reducing of the contamination level of used oils to a level suitable for use in machinery.

Problem statement Reliability and durability of machines and equipment depends substantially on lubricants quality.

According to researches of the company General Electric, the slide-type valves with servo-control are the most contamination-sensitive elements of mechanisms. The analysis of represented data shows that shearing force of the valve decreases from 19.5 N to 6.3 N in case of change of impurity level of operating fluid from 12th to 3rd purity level according to the NAS-1638 standard (that corresponds to increase of purity level from 16th to 7th class according to the standard GOST 17216: 2004).

Unsolved problem determination

The use of mechanical filters is one of the weak points of modern lubricants purification technology. These filters are characterized by low contaminant capacity, low value of pressure difference, low regenerative capability.

Methods, where the force fields including electrostatic one are used, are perspective for removal of mechanical pollution. They can be applied for recovery of operational properties of dielectric fluids with value σ = 10-12 ÷ 10-9 cm/m [1].

Analysis of the latest researches

The comparison of chemical bonds breaking energy [2] with the energy of external electrical field

of electrostatic separator in dielectric fluids [3] allows for the conclusion of possibility of chemical bonds breaking of organic acids and alcohols molecules, lateral C-C – bonds in highly-molecular alkanoic isohydrocarbons and naphthenic hydrocarbons of mineral oils with subsequent formation of nonsaturated hydrocarbons and active groups such as CO, COOH, CH. At that, breaking of the main hydrocarbonic chains are unlikely, it is also known that reactions of molecular dissociation are possible only in close proximity to electrodes, that is in areas with the maximum value of field voltage.

Determination of unsolved part of general problem

Operating efficiency of electrostatic cleaners is rather high, but this brings up the questions of effect of electrical fields on ultimate composition of the purified fluids. It is related to the fact that when oils purification from mechanical pollution by means of electrostatic cleaners they are under the influence of external electrical field of high voltage (3 ÷ 9 kV). According to Frenkel-Pool theory, in case of interaction of external electrical field with components of complex hydrocarbons, the reactions of molecules dissociation can take place; that in turn can affect the lubricating capacity of oils, which pass through electrocleaners.

Work objective formulation

Reliability of hydraulic system depends substantially on oil properties and reliability of each element (pump, servomotor, valves, etc.) undergoing high pressures, friction and other mechanical effects. In order to guarantee the best operational conditions of hydraulic system, the hydraulic oil should be purified by special filters. During hydromechanical systems operation, oil filters not always provide high-quality purification of oil from mechanical impurities; as a result, the lubricant is polluted intensively. In this paper, the possibility of oils service life extension due to purification by the method of electroseparation is investigated.

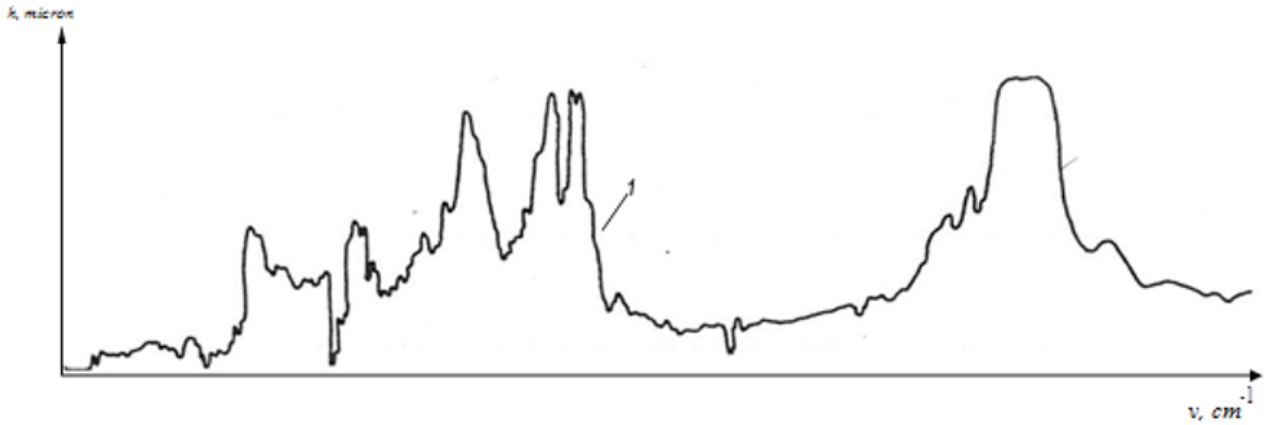
Statement of basic material

The operating fluid of aviation hydraulic systems AMG-10 was used under supply condition and after processing by electrical field of voltage $1.5 \cdot 10^3$ kV/mm in order to investigate the impact of electrical field on ultimate composition of mineral oil. The ana- lysis of samples structure was carried out by means of infrared spectrophotometer. In this experiment, the qualitative comparative analysis of fluids spectrograms under supply condition and after processing by electrical field was carried out (Fig. 1). From the obtained spectrograms, it is seen that concentration of the main fluid components is unchanged.

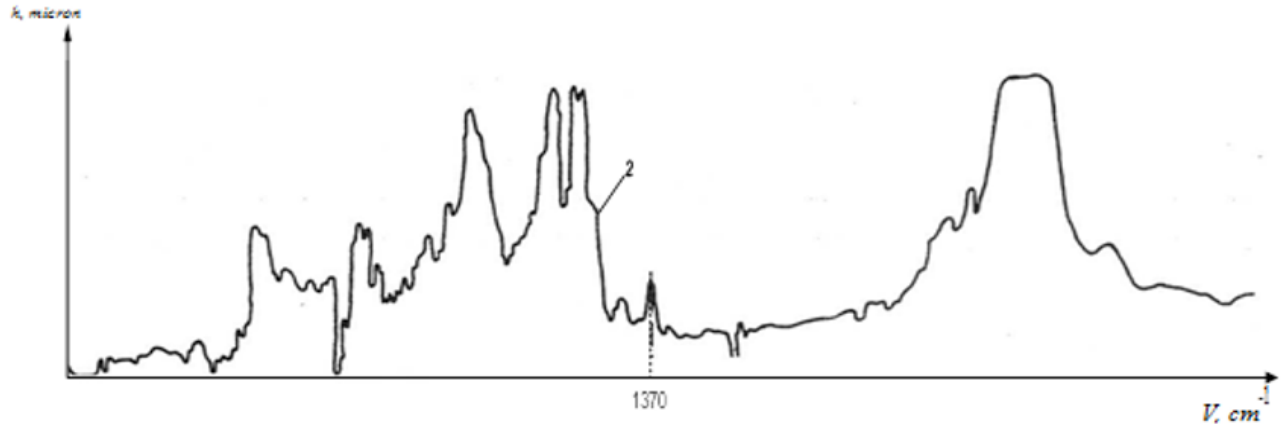
At the same time, change of range (increase in peak height) in the field of stretch vibration of esters ($\nu = 1370$ cm^{-1}) in fluid, which was processed by electrical field, is observed. Experience has proven that the majority of used lubricants (by the assigned resource) possess quite good tribotechnical characteristics.

In the conditions of high cost and severe deficiencies in oil products, the application period of these materials can be extended, or the opportunity of application in mechanisms with lower quality requirements can be provided.

The change of molecular structure of the medium, reduction of operational additives concentration and the raise of impurities content (mechanical substances and water) are the main criteria of lubricants nonconformity to the specifications.



(a)



(b)

Figure 1. Infrared spectrograms of fluid AMG-10: a) under supply condition; b) after processing by electrical field

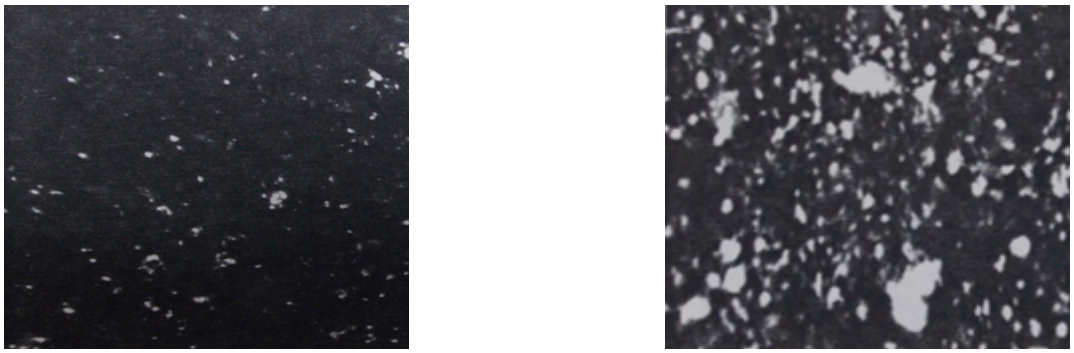
The researches show that concentration of basic components of mineral lubricants and technical fluids in operation remains almost invariable except for the materials functioning at very high temperatures. Thus, from the standpoint of extension of lubricants shelf life, the main problem is removal of excess mechanical impurities and recovery of additives concentration.

The oils and technical fluids are polluted at all the production and operation stages. The most frequently, firm insoluble pollution comes in the following ways: from the atmosphere (dust) as a result of metals corrosion and destruction of nonmetallic products of transportation and storage means; when using of cleaned reservoirs and pipelines of poor quality during production and repair of units; as wear products of tribosystem elements. The components wear products, metals corrosion products, nonmetallic elements destruction products and water are the major part of mechanical pollution in operation. Impurity of technical fluids is standardized by GOST 17216: 2004 "Grades of liquids purity".

In Table 1, granulometric composition of liquid pollution for aviation hydraulic systems AMG-10 under supply condition and after operation is shown, and in Fig. 2, the microphoto of this liquid samples is presented.

Table 1. Granulometric composition of liquid pollution for AMG-10 under supply condition and after operation

Quantity of pollution particles in volume 100 cm^3 pce.						Purity level (GOST 17216: 2004)
5÷10 micron	10 ÷ 25 micron	25 ÷ 50 micron	50 ÷ 75 micron	75 ÷ 100 micron	> 100 micron	
5115	135	52	–	–	–	9
682270	619960	42480	860	550	290	17



(a) (b)

Figure 2. Microphotos of liquid samples for aviation hydraulic systems AMG-10: a) under supply condition; b) after operation

Table 2. Dependence of wear of separate surfaces of the pump axis on purity level of operating fluid

Purity level	Wear (cm^3/s) at the maximum particles size					
	10 micron	15 micron	20 micron	25 micron	30 micron	35 micron
10	$1.8 \cdot 10^{-15}$	$3.1 \cdot 10^{-14}$	$1.5 \cdot 10^{-13}$	$3.7 \cdot 10^{-13}$	$5.6 \cdot 10^{-13}$	$5.7 \cdot 10^{-13}$
12	$2.2 \cdot 10^{-15}$	$1.8 \cdot 10^{-13}$	$6.0 \cdot 10^{-13}$	$1.4 \cdot 10^{-12}$	$2.1 \cdot 10^{-12}$	$2.2 \cdot 10^{-12}$
14	$2.3 \cdot 10^{-14}$	$4.6 \cdot 10^{-13}$	$2.3 \cdot 10^{-12}$	$7.6 \cdot 10^{-12}$	$1.2 \cdot 10^{-11}$	$1.4 \cdot 10^{-11}$
17	$2.2 \cdot 10^{-13}$	$5.3 \cdot 10^{-12}$	$3.7 \cdot 10^{-11}$	$1.2 \cdot 10^{-10}$	$2.2 \cdot 10^{-10}$	$2.4 \cdot 10^{-10}$

Data on wear of pump elements of hydraulic system depending on purity level of operating fluid are introduced in Table 2.

Currently, there are many ways of mechanical impurity removal from operating fluids. All of them can be conventionally divided into three groups: filtration; purification using the force fields (gravitational, electrical, magnetic cleaners); purification using various physical and chemical properties of pollution and operating fluids.

Filtration is the main method of providing of high requirements to purity. Modern filters with metallic or capillary-porous filter elements provide a filtering degree up to 5 ÷ 10 microns when liquid pumping to 300 l/min.

But such methods of cleaning for used lubricants and technical fluids are too expensive. Therefore, combined cleaning methods are applied in such cases. At the first stage, it is reasonably to use gravitational cleaners (defecation technique). At the next stage, fluids purification is carried out by means of rough and fine purification (for example, according to the diagram presented in Fig. 3). There is background for free radicals and unsaturared molecules formation in case of interaction of mineral lubricants with force fields of electrocleaners. Therefore, we can suggest that the use of electroclearing devices in filtration systems can positively affect the processes of formation of self-generating organic films (SGOF) on friction surfaces [4].

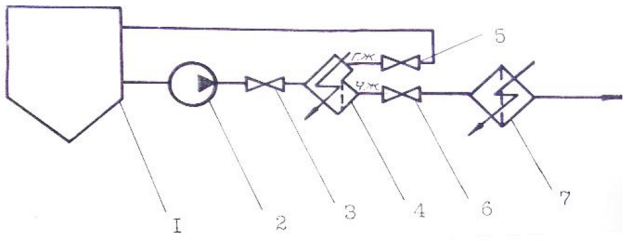


Figure 3. The diagram of purification by the used operating fluid using the electric separator and electrocleaner: 1 – container for purified fluid; 2 – pump; 3, 5, 6 –crane; 4 – electric separator; 7 – electrocleaner

As the investigated medium, the oil I-20A, which forms SGOF poorly according to preliminary data, was used. The oil under supply condition and purified from mechanical pollution to the fifth purity level by the mechanical filter FG-44/2, and also purified by an electric separator with electrode voltage of 5 kV was used for experiments. The granulometric composition of pollution is presented in Table 3.

Table 3. Granulometric composition of pollution of oil I-20A

Oil condition	Granulometric composition of pollution, pcs/cm^3					Level (GOST 17216: 2004)
	5÷10 micron	10 ÷ 25 micron	25 ÷ 50 micron	50 ÷ 100 micron	> 100 micron	
Under supply condition	6358	756	58	3	–	9
After filtration	367	132	–	–	–	5
After electrical cleaning	295	150	–	–	–	5

Whether there is SGOF on surfaces of friction was determined by measurement of lubricant layer thickness at breaks before experiment (*h1*) and after experiment (*h2*). If there is no SGOF on the friction surfaces, $h_1 = h_2$. Results of experiments are presented in Table 4 and in Fig. 4.

Table 4. Results of experiments on formation of SGOF by oil I-20A

Oil condition	20%		40%		60%		80%	
	h_1, micron	h_2, micron	h_1, micron	h_2, micron	h_1, micron	h_2, micron	h_1, micron	h_2, micron

After filtration	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
After electrical cleaning	0,1	1,63	0,1	1,91	0,1	1,74	0,1	1,16

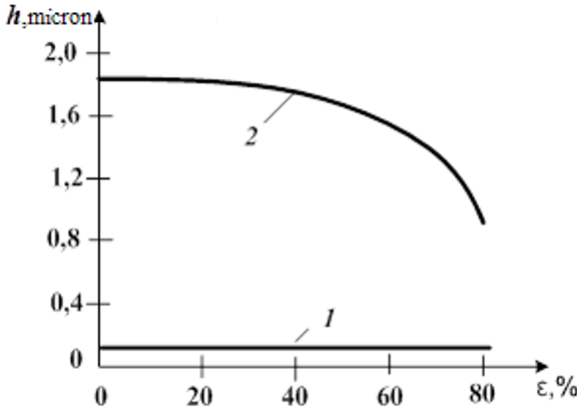


Figure 4. Dependence of SGOF thickness for oil I-20A on slip coefficient

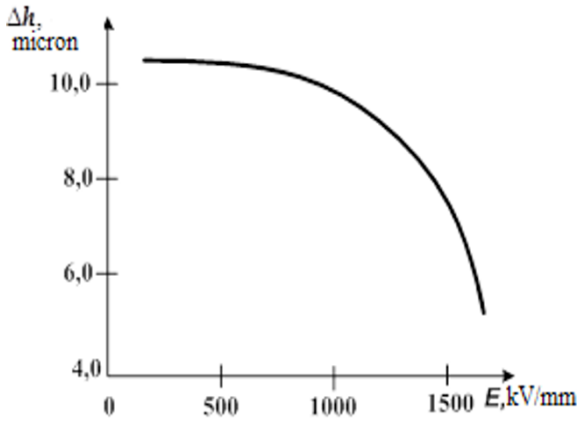


Figure 5. Dependence of linear wear of the samples with BrO10010 operating together with steel ShH15 on voltage of electrical field when processing of fluid AMG-10

Proceeding from the fact that due to interaction of electrical field with hydrocarbon fluids, the reactionary-active molecules and radicals are formed in the latter, we can suggest that formed molecules and radicals will be actively adsorbed on all the solid surfaces, including firm abrasive particles of mechanical pollution. Consequently, the isolating oil layer, which will protect friction surface from direct contact with abrasive particles, is formed on solid particles. The protective film on particles of 5 microns in size is less conductive to decrease in specific loads in the tribocoupling inasmuch as such particles fill hollows of microroughnesses of friction couples, level surfaces and bring the tribosystem to a steady state.

For the purpose of evaluation of electrical field effect on abrasive activity of particles of firm disperse phase, the experiments according to the pattern disk-plane were conducted in the medium of operating fluid AMG-10 by experimental friction machine.

The investigated fluid was brought to the first purity level by means of membrane filters; then the artificial pollutant - electrocorundum (9 points of hardness according to Mohs scale) of known granulometric composition and of the quantity corresponding to the fifteenth purity level (0.016% of mas.) was added. After that, the fluid underwent processing by electrical field of voltage up to 1.5·103 kV/mm in the near-electrode zone. Elements of tribocouples were made of bronze BrO10010 and steel ShH15; the test modes are the following: the slid speed is 0.3 m/s, axial load is 12.5 kg. The researches results are presented in Fig 5, 6.

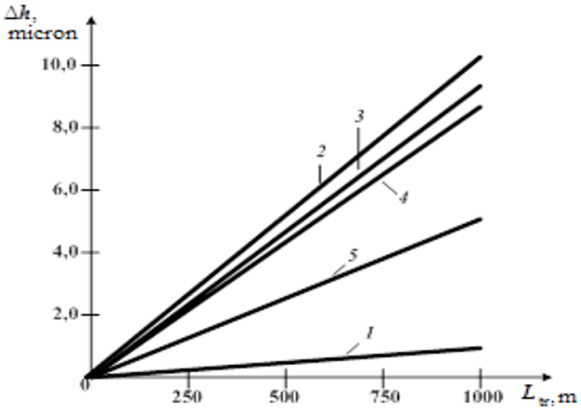


Figure 6. Linear wear of the samples with BrO10010 operating together with steel ShH15: 1. - fluid AMG-10 purified to the first purity level; 2. - fluid AMG-10, which is artificially polluted by electrocorundum (0,016% of mas.); 3. – fluid AMG-10 under supply condition after processing by electrical field (U = 3000 V); 4. - fluid AMG-10 under supply condition after processing by electrical field (U = 6000 V); 5 - fluid AMG-10 under supply condition after processing by electrical field (U = 9 000 V)

Conclusions and prospects of development

Thus, in course of work, it was established that purification of mineral lubricants with electric cleaners along with other ways of purification is conductive to extension of the oils life.

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A Calculation Method of Soil Water Resources Based on SCS-CN Model

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Abstract

Soil water resources are the most important water resources for agricultural production and ecological environment. However, currently, there has been yet no consensus on the concept and calculation method of soil water resources. According to water balance theory and recharge of soil water resources, this paper firstly defined soil water resources in terms of agriculture and then proposed a calculation method of soil water resources based on soil conservation service curve number model (SCS-CN model). Besides, the annual dynamic variation of soil water resources in hydrological years with different frequency and the soil water resources of main crops in their growth periods were calculated by taking the example of Baoding Plain, Hebei, China. Studying the variation of soil water storage in years with different frequency is of vital significance for addressing annual regulation of soil water. Additionally, defining soil water resources of crop in growth period can effectively guide irrigation, save irrigation water, and scientifically, rationally balance water demand and supply of crop in growth period. Confronting the increasing shortage of water resources, scientifically, reasonably evaluating soil water resources in a region and efficiently utilizing these