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STABILIZATION OF LUBRICATING MATERIALS OPERATIONAL PROPERTIES BY THE TREATMENT WITH ELECTROSTATIC FIELD

The influence of imposed external electromagnetic and electrostatic fields is investigated based on operational properties of lubricating environments. The device for the improvement of lubricating materials operational properties is developed and principles of its work are described. Based on the experimental results and analysis of publications the increase of lubricating materials and tribotechnical systems resource enhancement by the means of electrostatic field is grounded.

Досліджено вплив зовнішнього електромагнітного і електростатичного полів на експлуатаційні властивості мастильних середовищ. Розроблено прилад для підвищення експлуатаційних властивостей мастил. Описано принцип його дії. На підставі приведених експериментальних результатів, аналізу досліджень і публікацій обґрунтовано підвищення ресурсу мастил електростатичним полем.

electrostatic field, friction, lubricating material, operating properties, tribotechnical test, second structures, surface of friction, wear,wearproofness

Introduction

The complex of physical and chemical, operational and environmental properties of lubricating materials (LM) determines resource and reliability of heat engines. Modern LM must have low evaporability and high thermal stability. Apart from these important properties, LM must meet the high requirements to mode and properties of their work under various conditions, which determine the necessity of stabilization or tribo-engineering characteristics enhancement for existing materials, or necessity to search for new directions and methods of LM creation for the knots of friction of machines and mechanisms.

At this time in view of the dramatic rising in price of natural resources, the increase of operational properties of tribo-engineering systems and in particular LM becomes scientific and technical issue of the day. Therefore, the question of LM operational properties enhancement is an important component of choosing priority directions of providing reliability of motor technique and friction knots work.

Research and publication analysis

The analysis of works [1–5] shows that many researchers used various technological operations based on physical, physical and chemical and chemical processes for the renewal of waste LM in order to remove ageing products and contamination.

One of the methods of LM operational properties improvement is their electro-physical treatment, which involves application of magnetic field to fuel or LM with simultaneous imposition of high-frequency electromagnetic field with frequency equal to the frequency of precision protons in the given magnetic field. It is also shown in the given work that the process of oxidization of hydrocarbons with growth of temperature runs at different speed, which grows to the set limit border, whereupon it declines. Conducted research of diesel fuel flash showed that after electro-physical treatment there is an increase in cetane number of fuel by 2−3 units, that means that the period of flash delay decreases. It in turn contributes to the origin of active flame centers, that in future starts the chain reactions of the burning process, which results in reduction of pressure growth rate in the cylinder and to softer work of the engine, improvement of its efficiency and environmental features. In addition, electro-physical treatment of diesel fuel diminishes temporal and specific fuel consumption by 2–4 % at all rotation frequencies of the crankshaft, although the greatest effect was observed in the idling mode (temporal fuel consumption diminished by 8–12 %). It was defined by the research of anti-wearing properties of diesel fuels «ЛІ-0,2-40» and «ЛІ-0,5-40», that electro-physical treatment caused reduction of wear within the friction pair of steel "ШХ 15" at sliding friction by 40−45 % and 33−38 % accordingly.

These experimental results show the increase in surfactants content in the fuel. These substances are adsorbed on the friction surfaces, prevent contact of details, and consequently increase wear resistance of fuel equipment details.

It is known that fuels and lubricating materials, as well as other nonpolar liquids, are able to become tribo-electric as a result of motion [5]. Electrification (charging) of dielectric liquids is related to the appearance of double electric layers on the parting of two liquid environments, or on the parting „liquid – solid substance". At friction of liquids at metals in the processes of flow or splashing dielectric liquids are electrified due to the electrolytic division of charges on the border of metal with liquid. Electrification at friction of two liquid dielectrics is the result of double electric layers existence on the parting of liquids with different dielectric capacity, liquid from greater dielectric capacity gains positive charge, and one with lower gains negative (Cohen rule).

Due to low specific electric conductivity of hydrocarbon fuels and LM they actively become electrified, keep and accumulate electric charge. At certain charge density electrostatic field tension can attain critical values and there will be an electric discharge.

On the whole, the origin of electrostatic charges is conditioned by the following terms: presence of one of charges formation mechanisms – flow, dispersion, crushing etc.; presence of terms for their accumulation; formation of electrostatic field with maximal tension at one of the areas, which exceeds aggressive tension of environment at this area; presence of explosive vapor concentration in the place of hasp; formation of spark hasp with higher energy than the minimum value of energy of inflammation of the given environment. Simultaneous existence of all terms is the necessary condition.

Problem formulation

The work was aimed at development and substantiation of the method for LM operational properties stabilization under the influence of the external electrostatic field, and also at studying the possibility of changing LM friction index and wearing level of friction knots by their treatment with the indicated field. The process of electromagnetic and electrostatic fields forces interaction with hydrocarbon environment and process of LM operational properties enhancement were the objects of the research. The subject of the work is the investigation of the influence of electrostatic field on the formation of tribo-engineering characteristics of LM, their anti-wearing properties and wear resistance of contacting surfaces at maximum sliding friction.

Concept and methods

The output of our investigation was development of the device for the improvement of operational properties of fuels and lubricants [6; 7].

The device consists of (fig.1): flow chamber *1*, with the winding *2* placed over its external surface and not fixed metallic balls *3* inside.

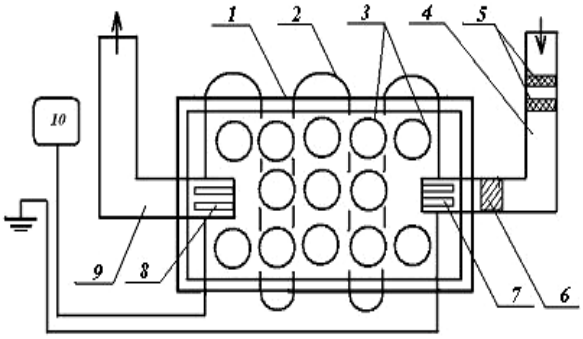

Fig. 1. The diagram of the device for fuels and lubricants operational properties improvement:
1 − a running chamber;
2 − a puttee;
3 − metallic marbles;
4 − the entrance union coupling;
5 − lauter metallic string-bags;
6 – striped electret;
7, 8 − longitudinal cuts;
9 − the initial union coupling;
10 − a high-voltage source of feed

The flow running chamber 1 is connected with the input *4* and output *9* pipelines, here their sections placed into the flow chamber *1* have longitudinal cuts *7* and *8* accordingly. Metallic filtrating nets *5* are placed inside each of input pipeline *4* and striped electret *6* is glued on the internal surface of pipeline *4* in the area nearer to the entrance into the flow chamber 1. The internal surface of input pipeline 9 contains isolating coverage. The power supply *10* is connected to the winding *2*. Flow chamber 1, metallic balls *2*, input *4* and output *9* pipelines are made of materials with identical polarization and with higher dielectric capacity, than that of fuels and lubricating materials [6].

The principles of the device work are as follows. Fuel or liquid dielectric LM are fed by the pump into the pipeline *4* to the flow chamber *1*. Having obtained electric charge as a result of tribo-electrification, fuel or LM increases this charge at passing though the filtering net *5* and striped electret *6* (considerable increase in charge value and its stabilization within all the flow volume takes place). Strongly electrified fuel or LM keeps the charge when it gets into the flow chamber *1* due to identical polarization orientation of materials of pipelines *4* and *9*, balls *3* and flow chamber 1 itself. Power supplied to the winding *2* from the source *10* forms the electromagnetic

field in chamber *1*, whose power lines cross already charged liquid environment distributed on the surfaces of balls *4* in the form of thin tape. Tension of the united electric field rises hereupon, that creates high electrification of fuel, conduces to high level of charge stabilization and its sufficient smoothing within the volume of LM regardless of its speed. Longitudinal cuts *7* and *8* on the proper areas of pipelines *4* and *9* contribute to the increase in the total contact area of phases «pipeline wall – liquid», which means that greater size of ions takes part in the electrolytic mechanism of electrostatic charge increase. In addition, the indicated longitudinal cuts *7* and *8* at corresponding sections of pipelines *4* and *9* cause the reduction of hydraulic resistance which increases the flow of fuel or LM, and consequently its best tribo-electrification. The isolating coverage on the internal surface of output pipeline *9* provides saving of the received charge as far as the combustion chamber or friction knot.

The combination of external electromagnetic field and tribo-electrification was the basis for a new structural decision. Thus, at motion via a pipeline fuel or LM is charged and after getting into the flow chamber filled with balls, this charge is multiplied under the influence of electromagnetic field formed by the winding. With the increase of phase division «wall of pipeline – liquid» a greater size of ions of one sign is adsorbed and they take part in the electrolytic mechanism of electrostatic charges formation. Therefore, longitudinal cuts on the edges of input and output pipelines diminish hydraulic resistance that positively affects the fuel flow rate and promotes more intensive tribo-electrification.

It is also possible to use the developed device not only for treatment of dielectric fuels before entering the combustion chamber but also for stabilization of operational properties of lubricating materials.

Measurings were conducted using the scheme DFLC (rp) «ring-plane», standards were made of «ШХ15 – ШХ15», T_{rot} = 185 rev/min, m=5 kg, taking into account the radial beating $\delta = 0 \pm 1,5$ mkm. Estimation of standards wearing was done based on profilograms of friction paths and computer calculation of experimental results.

In accordance with the task set the following materials and terms were chosen. Jet fuel TC-1 in as-received condition, in as-received condition treated with electrostatic field during 1 hour, in as-received condition treated with electrostatic field during 2 hours, in as-received condition treated with electrostatic field during 1 hour and settled for 15 days; diesel fuel in as-received condition, in as-received condition treated with electrostatic field during 1 hour; lubricating oil M-20 «Azmol»: in as-received condition, in as-received condition treated with electrostatic field during 1 hour.

The control of initial parameters of contacting surfaces roughness was executed on laser scanning profilograph-profilometer «LSPP-05" [8]. Wear of friction surfaces was measured using profilograph-profilometer «Kalibr M-201». We studied the wear of immobile flat standard. To reduce the error of measurements three profilograms (contour records) were taken to the depth of the worked material along the path of sliding and one - across. Based on the results of measuring friction path profile the mean arithmetic value of linear wear of material was determined.

The friction device was developed by the authors of work [6] and produced according to Thimen scheme (disk – plane), which provides the linear contact and simulates friction pair «shaft – hub». The friction knots are adjusted to model values of radial deviation within the limits of admittance for the chosen diameter of the opposite sample. Double action of friction device is very useful for comparison of anti-wearing and anti-frictional properties of two different constructional or lubricating materials under the identical test conditions. The drive is electric motor of direct current, that allows to regulate speed of sliding in the range 0...1 m/s. The device is equipped with the checking systems and automatic support of rotation frequency. Functional possibilities of device DFLC (rp) include testing wide spectrum of constructional and lubrication matirials under controlled sizes of radial deviations of contacting surfaces. In the given research, measurements were carried out in the mode of maximum friction.

Lubricating materials were tested by the four-stage method developed in the laboratory of the Newest tribotechnologies of National aviation university [10]. At each of the first three stages the opposite sample passes a 500 m way, intended for formation of the second structures typical for the explored environment. The fourth is of longer duration (3000 m) and is necessary for research of anti-wearing and anti-frictional properties in co-operation with the tribo-chemically changed environment under investigation. The fact of the secondary structures formation is proved by dark coloration of friction. However this method was developed for the research of LM on the laboratory friction devices with the linear contact DFLK(o), DFLK(p) and DFFLK and it doesn't take into account the influence of radial vibrations amplitude on anti-wearing property of lubricating environments, and the number of adjusted stages was defined for limited range of LM. Therefore, the applied method of research must determine:

− influence of radial vibrations amplitude of tribosystem on anti-wearing properties of LM;
− maximum values of radial deviations of opposite sample working surface, at which it is possible to determine anti-wearing properties of LM;
− number of stages of tests necessary to form stable second structures for every type of lubricating environments at the controlled sizes of radial deviations.

Working surface of the opposite sample, which executes relative rotation, 35 mm in diameter and 3 mm wide, is made of steel «ШХ15» and is adjusted using diamond pastes on cylinder generatrix to the roughness by R_a less than 0,02 μm (to minimize influence of roughness factor). Working surface of immobile flat standard, 40 mm in diameter and 4 mm wide, was also adjusted using diamond pastes to the roughness R_a less than 0,02 μm at front surface. The roughness of the surface was explored on «LSPP–05». Speed of rotation of the opposite sample during the test cycle was constant. Axial loading, depending on the type of lubricating environment was 0...2000 N.

Standard, opposite sample, bath and all fastening details were cleaned with acetone and dried before the beginning of the test to remove products of mechanical treatment and residuals of lubricating environments from the surface and defat them.

The criterion of wear was the depth of friction path on the immobile standard, which was measured on profilograph-profilometer «Kalibr M – 201».

Results of investigations

The results of basic experiments are represented in graphic dependences (fig. 2, 3, 4).

The presented graphs prove that the size of wear considerably went down (approximate by 4 times) at treatment of jet fuel TC-1 with electrostatic and electromagnetic fields and less considerable decline was received as a result of treatment of diesel fuel with the indicated fields (1.3 times) and oil M-20 «Azmol» (1.2 times). It must be noted that in the resulted experiments, time of LM treatment during one hour and during two hours gave almost identical results. Another positive result is that jet fuel TC-1 after settlement over 15 days in the closed vessel for 3000 m of the passed way gives wear at the level 4,5 mkm, which is considerably less in comparison with the size of wear defined for basic jet fuel. It is necessary to remind that the error of the given measurement method makes up 4–5 % and we can confidently state positive results of our experiments, and consequently the improvement of LM operational properties by treatment with imposed electrostatic and electromagnetic fields.

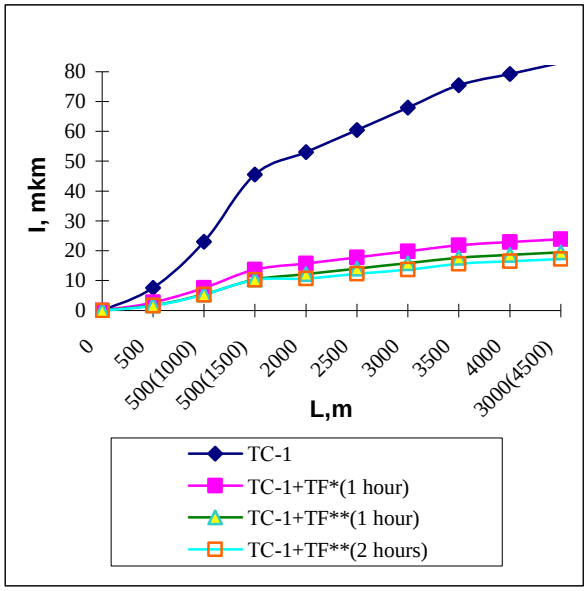

Fig. 2. Dependence of wear level on the friction path in the research of anti-wearing properties of jet fuel TC-1:
TC-1 – basic (in as-received condition);
TC-1+TF*(1 hour) – jet fuel TC-1 treated with the fields during 1 hour at tension U=500V;
1+TF**(1 hour) – jet fuel TC-1 treated with the fields during 1 hour at tension U=2000V;
TC-1+TF**(2 hours) – jet fuel TC-1 treated with the fields during 2 hours at tension U=2000V

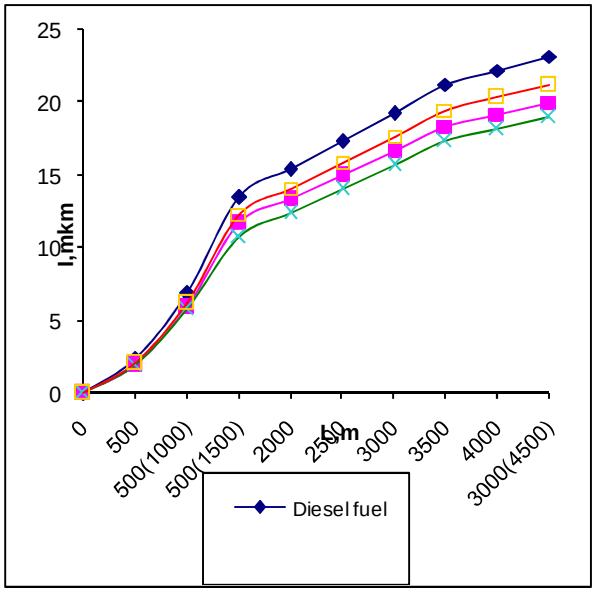

Fig. 3. Dependence of wear level on the friction path in the research of anti-wearing properties of diesel fuel:
diesel fuel – basic diesel fuel (in as-received condition);
diesel fuel + TF*(1 hour) − diesel fuel treated with the fields during 1 hour at tension U=500V;
diesel fuel + TF**(1 hour) − diesel fuel treated with the fields during 1 hour at tension U=2000V;
diesel fuel + TF**(2 hours) − diesel fuel treated with the fields during 2 hours at tension U=2000V

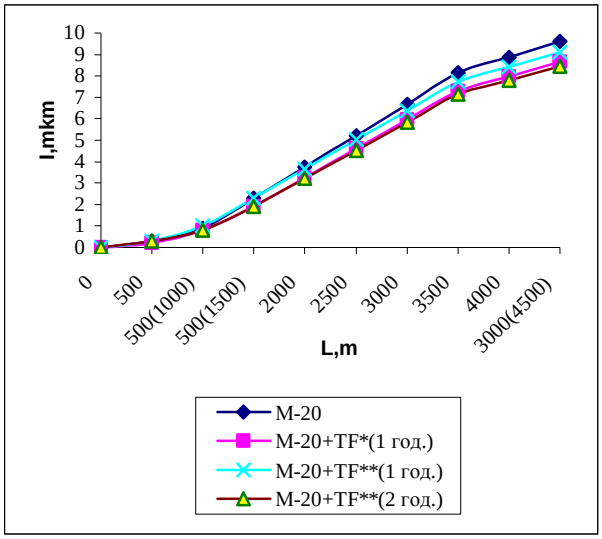

Fig. 4. Dependence of wear level on the friction path in the research of anti-wearing properties of lubricating oil M-20 «Azmol»:
M-20 – basic (in as-received condition);
M-20 + TF*(1 hour) – oil M-20 treated with the fields during 1 hour at tension U=500V;
M-20+TF**(1 hour) – oil M-20 treated with the fields during 1 hour at tension U=2000V;
M-20 + TF**(2 hours) – oil M-20 treated with the fields during 2 hours at tension U=2000V

Conclusion

The offered device can be applied for the improvement of LM operational properties on power installations of different types, but mainly in combustion engines in order to prepare fuel and improve operational properties of mineral lubricating environments for the knots of friction.

Experimental research of the influence of external electromagnetic and electrostatic fields on LM (jet fuel TC-1, diesel fuel, oil M-20 «Azmol») operational properties gave the following results:

− it was determinated that the size of wear of the explored standards in the environment of jet fuel TC-1 considerably went down (approximate by 4 times) and lower values were received for the environment of diesel fuel (1.3 times) and oil M-20 «Azmol» (1.2 times);

− the best results are received at application of electrostatic field;

− the tension of the field has considerable influence on reduction of wear intensity: the highest level of wear reduction was observed at external tension U = 2000V and intensity of the field E = $1{,}1 \cdot 10^6$ V/m, lower level of wear reduction was at tension U = 500V and intensity of the field E = $0{,}27 \cdot 10^6$ V/m;

− it was found out that time of treatment at identical intensity of the field has insignificant influence on wear reduction. In the presented experiments, influence of LM treatment time on the size of wear during one hour and during two hours gives similar results.

References

1. *Остриков В.В.* Современные технологии и оборудование для восстановления отработанных масел / В.В. Остриков, А.Н. Зозуля, И.Г.Голубев. – М.: ФГНУ «Росинформагротех», 2001. – 64 с.

2. *Повышение* ресурса технических систем путём использования электрических и магнитных полей : моногр. / Е.Е. Александров, И.А. Кравец, Е.П. Лысиков и др. – Х.: НТУ „ХПИ”, 2006. – 544 с.

3. *Кравец И.А.* Репаративная регенерация трибосистем / И.А. Кравец. – Тернополь: Изд. Бережанского агротехнического института, 2003. – 284 с.

4. *Влияние* электрофизического воздействия на эксплуатационные свойства дизельного топлива / В.И. Морозов, Я.Е. Белоконь, А.И. Окоча, С.Т. Усатенко // Исследования процессов подготовки, применения и контроля качества авиаГСМ и спецжидкостей. – К.: КИИГА, 1992. – С. 94–98.

5. *Сканави Г.И.* Физика диэлектриков (Область слабых полей) / Г.И. Сканави. − М.: Энергоатомиздат, 1991. – 253 с.

6. *Методологія* визначення протиспрацьовувальних властивостей мастил за критеріями трибохарактеристик утворюваних у них вторинних структур / О.Ф. Аксьонов, О.У. Стельмах, С.П. Шимчук та ін. // Вісник НАУ. – 2006. – № 2. − С. 62–64.

7. *Пат. 31878 Україна.* МПК (2006) F02M 27/00. Пристрій для обробки діелектричних паливно-мастильних матеріалів / І.Л. Трофімов, О.М. Зубченко, І.А. Кравець. – Опубл. 25.04.08. Бюл. № 8.

8. *Пат. 34918 Україна.* МПК (2006) F02M 27/00. Спосіб обробки діелектричних паливно-мастильних матеріалів / І.Л. Трофімов, В.В. Бурикін, П.П. Захарчук. – Опубл. 26.08.08. Бюл. № 16.

9. *Лазерний* скануючий профілограф-профілометр Дедал ЛСПП / С.М Кіяшко, Є.М. Смірнов, О.У. Стельмах та ін. // Наукові нотатки. – Луцьк, 2004. – Вип. 15. – С. 135–136.

10. *Стельмах А.У.* Методика идентификации ГСМ по противоизносным и антифрикционным свойствам с учетом реальных условий их работы / А.У. Стельмах, О.Ю. Сидоренко, Р.Е. Костюник // Технологические системы. – 2002. – №3. – С. 96–101.

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