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Tribological interaction of the ferromagnetic surface and its existence conditions in a pulsed magnetic field.

> *Planet Earth is a living organism with its internal and external base of life - the Sun. Magnetic field is a system of orientation in the World Space and on Earth, due to the location of directional magnetic field lines from south to north. So We live in a magnetic field (MF)*

<u>Analysis of the problem</u> (the problem). The state of studying the influence of MF on tribological parameters is very scanty. A few works in comparison with other directions are broadly covered. One of the works of Chinese scientists drew attention to the fact that tribological research was carried out in a protective volume from the MF of the Earth. (tensile strength of the Earth is average of 0.0005 Tesla). It was founded that the wear of the friction pair increased in comparison with open conditions by almost 20%.

Weak magnetic fields (0.0005 ... 0.01 Tl) effectively carry out structural rearrangements in materials and systems, causing changes in internal order and appearance. However, the physical nature and mechanisms of the influence of such magnetic fields on nonmagnetic materials are still largely unclear. Non-metal polymeric materials, wood, and others, react to the action of the MF, especially if they are in an unstable state, under the influence of external deformation loads, from which the interatomic connections are destroyed (twisted trees in the forest or swamp).

<u>Actuality.</u> Unstable conditions, which are formed due to the relative displacement of the surface layers, undergo instantly and destroy the structure at the point of the contact. This way of research provides accelerated conditions for studying the influence of MF on the change in the state of materials, that under the stationary conditions requered the years of studying.

Changes in the energy state of the outer surface of the friction can not be imagined without interference of the surrounding MF, which influences on the electronic structure of the material surface layers, especially when these surfaces are in an unstable state.

An unlimited number of tribological mechanisms consists of details made from different classes of materials. Their relation to the action of MF to a greater extent (ferromagnets) or smaller (paramagnets), or which counteract its orientation (diamagnetics or antiferromagnets), at the time of friction, affect the structure and the creation of an intermediate structural component between the surfaces.

Ideally, it is desirable to find the mechanism by which the transformation of the conditions of antiwear can be transformed, that is, the influence of the MF on the counteraction to the internal tribological parameters of the system. Hypothetically, it is possible to imagine if the MF is directed towards the surface, which, during the friction, wears out faster (by displacing a positive gradient), then the conditions for moving the products of wear (ferromagnetic origin) will be directed by MF to an energy-instable friction plane which, due to its structural imbalance "settle" on the surface layers by forming new structural components.

Support and explanation of any scientific hypothesis is an experiment. In our laboratory there are tribological researches of various pairs in the oil under the influence of MF with a tensity from 0.1 to 0.5 Tl in the conditions of reverse-headway motion and friction of sliding at change in speed and load.

The purpose of the study is to determine the conditions under which the parameters of external friction change from the influence of MF, and to confirm the mechanism of transformation by a metallographic analysis of the surface. The aim of this investigation is to determine tribological parameters ШХ-15 steel hardened by martensite on the glass with different direction of MF in the oil environment. The methodology of the research is based on monitoring, changing the state of the surface of the steel under the influence of MF in the process of friction. The flow of magnetic lines perpendicularly intersects the actual contact area (ACA) and changes in the processes of structural transformation during deformation of the surface. Given that, the ferromagnetic material origin most responsive to the impact of the MF, the main focus of tribological study in MF is a pair of friction of ferromagnetic structure.

Experiment conditions:

- in space: the sample is placed on the top, the lines of the MF goes through it , the direction may be changed;

-the sample is on the bottom, it lies in the bath with M10G2k oil and moves progressively in the rotational-reverse movement;

-MF is closed through the sample and counterfilm along the magnetic circuit.

So the flow of magnetic lines concentrated in the contact pattern on the glass with magnetic induction (for example) 0.3 Tl in the way of 60 km with velocity of 0.2 m/s in the middle of contr sample 40mm in length, with a normal load of 0.6 kg on the sphere surface with a diameter of 6.72 mm. Magnetization induces conditions of regulation by moving the products of wear in the environment of the oil in the contact area (Fig. 2). Given that the magnetization is inversely proportional to the amount of magnetization, the smaller particles magnetized faster and better to the friction surface, remaining in the contact area.

The object of scientific research is the processes occurring in the surface layers of the sample with the formation of surface protective films, changes in their parameters and properties.

The subject of scientific research is the establishment of regularities of processes occurring between physical objects, friction surfaces of the sample and counter samples.

Analyzing the results of tests of the model tribological pair, we see a significant difference in the wear of the surface of a sample of steel SH-15 in the process of tribological testing. On Fig. 1, the displacement of the energy flow of the MF is investigated in the direction of the sample.

The justification of the physical model relies on the directed action of the MF to the products of deterioration relative to the actual contact area, and the zone adjacent to it. It is known that the flow unevenly (with varying density) crosses the contact surface, depending on the roughness of the surface, with the greatest concentration on the tops. [1] At the end of the tops the products of wear will be kept and simultaneously smeared on the surface of the friction, their main mass will remain on a specimen that will have less hardness and will be more easily deformed. It is proved in static conditions that the influence of MF facilitates the deformation of the electronic structure in the volume of the material, which is caused by the magnetic-plastic effect, the material is easier to "float" and change its form. [2]

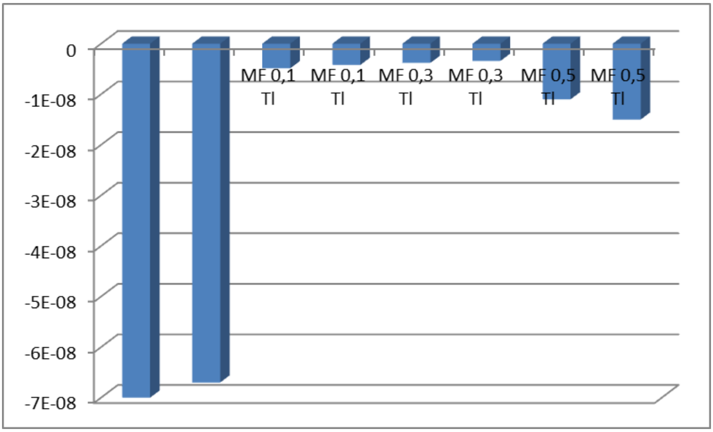
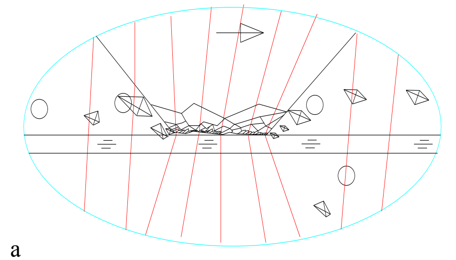


Fig. 1. Relative volumetric wear of steel SH-15 in M10G2k, mm3 / km, on a glass with an rotate- progressive motion.

Under the influence of MF, the strength decreases, volume volatility of ferromagnetic material increases. Thus, the bulk of the wear products involuntarily "precipitates", that is, it is magnetized to the metal surface, while changing its internal energy. In the process of friction with the instantaneous displacement of the contact, the influence of the MF for the obtained period of time does not reduce its impact on the data points of the ACA. Figure 2 shows the surface of the friction with the direction of the MF in the direction of the sample. In this case, the wear products will find a place on the path of the largest cluster of magnetic lines (ML) (Fig. 2) and will be pressed against the metal surface. A significant accumulation of small wear products will cause the effect of magnetic oils, in addition, the impact of MF softens the metal due to which it is well rolling on the surface and is characterized by a brown color (in the photo), similar to wear products.



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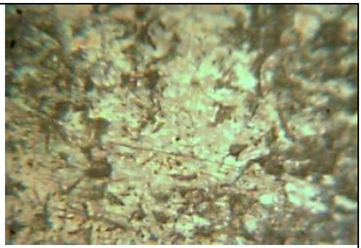

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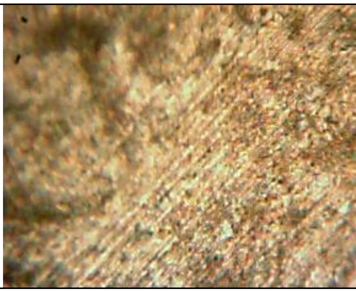
Fig.2. Friction conditions with the direction of the magnetic field in the direction of the sample (ferromagnet) a) contact pattern, b) the contact of steel ШХ-15 on the glass.

With increased plasticity of the material, its deformation processes are applied in the surface layers of the material by creating films ~ 0.5 ... 1 μm. Wear of steel SH-15 (from 0,3 to 0,4 * 10-8) in the directed MF more than 10 times less than without MF (6,5 * 10-8 mm3 / km, fig.1). The surface of friction is divided into light areas that characterize open areas. Thin surface films formed in the process of MF and friction, acquired a brown color, occupy almost 75% of the area. Dark fields - products of wear are collected in conglomerates from metal particles, occupy a position around the contact and drift in oil under the control of ML in the MF space.

Thus, with the direction of the MF on the sample with the increasing the magnetization due to an increase in the induction of MF from 0.1Tl to 0.5 Tl, in our opinion, all the wear particles are involved in the friction mechanism.



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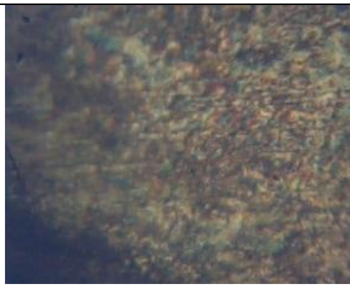

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Fig. 3 Foto of friction surface ШХ-15 on glass in М10Г2к. For the experiment, oil was used after 500 hours in MF. The small particles of wear products in the form of conglomerates are on the surface.

Indicators of wear in the MF have ambiguous parameters:
-the least wear is observed at 0,3 T, which is stipulated (in our opinion) by the selection of the wear products of steel particles with the size from 0 to 5 microns;

- in the case of induction of MF 0.1 T, the particles of the wear products are driven in an oil environment, and due to insufficient magnetization, it is easily carried out from the contact zone;

-extended wear at 0.5 T, is due to greater magnetization of wear products, different fractions even abrasive.

Taking into account that the wear products have different fractions, and about 67% are from 0.5 to 1.5 microns, the rest are larger, then their distribution at the different values of the MF induction will vary in their volume between the areas of friction in the oil [3].

Analyzing the topography of the steel SHK-15 friction surface without the participation of the MF in the oil M10G2k, which worked 500 hours in MF, is characterized by the thickness of the tribological film 5 ... 10μm, which have the appearance of roughly smeared on the surface of conglomerate volumes, (Fig. 3) with sharp edges and cracks that break from the surface of friction and transferred to the oil. Due to this, the sample has a significant deterioration (Fig. 4, from 6 to 7 * 10-8 mm3 / km). The area of protective films on the surface of the friction reaches approximately 2500 ... 3000 μm2.

Discussion of research results. The efficiency of different sized parts in the friction units, is mainly characterized by the area of friction and wear of the material in the contact area. Loss of mass of part site in comparison with its general dimensions will be negligible, therefore preservation of working surface in working condition is an actual problem for maintenance of operational parameters of the whole mechanism. In the 50 years of the last century, Professor Selivanov O.I. [4] promoted non-lethal parameters of friction nodes. Scientific and technological progress has made a step in determining of the recovery mechanism in the process of wear, such a mechanism as a selective transfer.

The use of MF energy, also aimed at increasing the wear resistance of the cutting tool, by changing the shape of the crystal lattice, the position and location of dislocations in solid alloys, and the formation of carbide compounds. In conditions of stretching of iron in MF there are no boundaries of domains in which dislocation is collected [5], while the processes of plastic deformation proceed at significantly lower efforts. Deformation of the material in the surface layers facilitates the formation of wear-resistant films considerably with a thin structure, similar to wear-free.

There are three parameters associated with the deformation in the tribo volume of the ACA: the first is the mechanical deformation of the friction surfaces, the second one - from the influence of the MF on the material of the tribo pairs. The third parameter under the action of the MF softens the products of wear that are in the zone of action of the MF. All of these parameters reduce the strength of the surface and facilitate the deformation of ferromagnetic materials, this is reflected in the formation of surface protective films, which increases the wear resistance, creating a positive gradient of the deformation component on the surface of the friction.

A significant influential parameter of magnetic origin for steel is the Curie point that characterizes the transition of the material from the ferromagnetic properties in the paramagnetic ($Fe_{Curium} = 770^0C$), resulting in a significant reduction of their magnetic properties (decreasing by almost 5000 times). At the same time, at the points of the ACA, which exist in microseconds, the steel is rebuilt from a bulk-centered crystal lattice in the center-center and vice versa, which increases the formation of the carbide phase.

When changing its magnetic properties, the deformation parameters of the material, which take part in the formation of a positive gradient of deformation, are changed, that is, the surface in the contact zone becomes softer (Fig. 4). According to the statements of Kragelsky B.I. the choice of a good friction pair requires the minimum introduction of the second plane into the corresponding area of friction. It has been experimentally established that if the size of the abrasive particles contained in the oil or other liquid does not exceed 5 μm, they adsorb the oil oxidation products, which can reduce the intensity of wear of the parts. Particles of larger sizes begin to cause damage. If there is less than 5 μm of particles in the lubricant, wear rate is 0.3 mg / hr, and with particles of 10 μm - 0.92 mg / hr. The firm "Vikers" (Great Britain) provides for the hydrosystems the following particle size distribution: 0 ... 5 μm -39%, 5 ... 10 μm - 18%, 10 ... 20 μm - 16%, 20 ... 40 μm - 18 %, 40 ... 80μm - 9%. [6].

The coefficient of friction is distributed with the increase of magnetization in rice 1 SH-15 in the glass is equal to 0,05..0,08, with the passage of MF as a sample goes to 0,09 ... 0,1. The largest is within 0.1 ... 0.12 with friction without MF.

The additional gradient of the friction pair between SH-15 and glass in the environment of oil is created due to the presence of oil and an increase in the deformation component on the surface of SH-15 from the influence of MF. In addition, the appropriate pair is a glass with a characteristic of a rigid body and a stainless surface on roughness. Thus, the collection of factors provoked a reduction in wear and a justification of the structural components of the surface of the friction.

In our opinion, based on the increase of the deformation component of the material of ferrite origin, during the friction, separation of the products of wear occurs due to different magnetization strength of the particles and their displacement with the oil from the contact zone. The oil washed away large particles of wear products at a distance from the contact and the zone of operation of the MF. It is known that the force of the MF decreases in the cube to the distance of action. The magnetization of small wear particles passes faster and their elasticity increases in the MF, helping them to roll over the area of friction.

The scientific novelty is obtained by introducing into a friction technology the auxiliary energy in the direction of the MF, and taking into account the physical changes of the material from the action of the MF.

Practical significance. Possibility to create friction conditions in which the processes of surface build-up are carried out by material of wear (matrix). The proposed restoration technology in the process of operation is recommended for use in nodes of friction and wear.

General conclusions:

- the basis of the mechanism of wear in the MF is saturation of the surface of the friction by those ferromagnetic products of wear that receives the lubricant from the operation of the details.
- with the direction of the MF in the direction of the sample surface in the friction, all products of wear create both the lines and thin films;
- with the increase of the induction of MF in the friction zone, the number of particles that participate in the restoration of the surface of friction changes, but much of the large particles begin to work as abrasive, which increases wear;
- the friction surface without impact of MF has a rough topography of formed protective films up to 10 μm in thickness which is characterized by a porous structure;
-with repeated use of oil in the MF on the friction surface of the sample, were not found thick protective films, and instead of them the fine patches of protective films were spread, indicating the use of thin fraction wear products.

References

1. Vonsovsky S.V. Magnetism. Magnetic Properties of Dia, Pair, Ferro, Antiferro, and Ferrimagnetics. M .: Nauka, ch. Ed. Phys. by Lit 1971. - 1032 pp.

2. Особенности пластической деформации металлов и сплавов в магнитном поле. Обзор М. А. Васильев Институт металлофизики им. Г. В. Курдюмова НАН Украины,Успехи физ. мет. / Usp. Fiz. Met. 2007, т. 8, сс. 65—105 Оттиски доступны непосредственно от издателя Фотокопирование разрешено только в соответствии с лицензией 2007 ИМФ (Институт металлофизики им. Г. В. Курдюмова НАН Украины)

3. Закалов, О.В. Основи тертя і зношування в машинах: Навчальний посібник / О.В. Закалов, І.О. Закалов. – Тернопіль: Видавництво ТНТУ ім. І.Пулюя, 2011. – 322 с.

4. Боярских Г. А., Боярских И. Г. ТЕОРИЯ СТАРЕНИЯ МАШИН Учебно-методическое пособие к практиче-ским занятиям и самостоятельной работе студентов Технология транспортных процес-сов», 4-е изд, испр. и дополненное. Екатеринбург: Изд-во УГГУ, 2015. 47с.

5. Закалов, О.В. Основи тертя і зношування в машинах: Навчальний посібник / О.В. Закалов, І.О. Закалов. – Тернопіль: Видавництво ТНТУ ім. І.Пулюя, 2011. – 322 с.234 pg

6. Д. С. Каменецкая, И. Б. Пилецкая, В. И. Ширяев, ФХММ, **35**, № 2: 318 (1973)