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THE IMPACT OF THE ENERGY STATE OF THE SURFACE OF FRICTION PAIRS ON THE FRICTION AND WEAR IN INTERNAL COMBUSTION ENGINES

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Abstract

The elements creating a friction pairs are described to be very difficult in terms of defining all optimal parameters in an unequivocal way. The research on stability of friction pairs is focused on the surface and the top layer of surface in the parts concerned. The main goal is to find new design solutions and materials, thereby achieving one million kilometers of mileage to main repair in the case of internal combustion engines. The biggest structural difficulties are noticeable in friction pairs where it can be observed sliding and returning motion, which is also connected with sealing function. A typical example of such pair is piston ring – cylinder sleeve in piston – rings - cylinder unit in an internal combustion engine. Engineers are currently seeking an additional factor, which would enable gaining the reduction of tangential force by reducing the friction coefficient in elements of friction pair during operations. The surface free energy may be such factor - it results from molecular structure and nature of the bonds between the molecules present in the material. Components of surface free energy determine the tribological properties of the material, which is reflected in the stability of the units. Energy state of the surface, which is connected with chemistry and characteristics in the material, is the first step to consider about the impact on wearing in internal combustion engine. This is the main topic of this article.

Keywords: *friction pairs, top layer of surface, sealing function, piston ring, cylinder sleeve, combustion engine, tangential force, friction coefficient, molecular structure, bond, tribology*

1. Introduction

Friction pairs are designed from elements, where is very difficult to define in unequivocal way all optimal parameters.

Research on stability of friction pairs is focused on the surface and the top layer of surface in the parts. The main goal is find new solutions to design and material, thereby achieving one million kilometres of mileage to main repair in the case of internal combustion engines.

The biggest structural difficulties are noticeable in friction pairs where we can observe sliding and returning motion, which is also connected with sealing function. A typical example of such a pair is piston ring – cylinder sleeve in piston – rings - cylinder unit in combustion engine.

Engineers are currently seeking an additional factor, which would be enable to gain the reduction of tangential force by reducing the friction coefficient in elements of friction pair during operations.

Such a factor may be the surface free energy that results from molecular structure and nature of the bonds between the molecules present in the material. Components of surface free energy determine the tribological properties of the material, which is reflected in the stability of the units. This is the main topic of this article.

The properties depend on the part of the material construction, which consists of atoms. According to the theory of Rutherford's atomic nucleus is positively charged and composed of neutral nucleons. In addition, they revolve around him very light and negatively charged electrons

and balance of the whole system is ensured by the forces of electrostatic attraction.

Bohr said in turn that around each atom the electrons move along the track, which resembles the shape of a circle or ellipse and its energy state which is determined. Therefore, if electron could create a bond with another atom and change orbit, emission or absorption of energy is needed [1, 3].

2. Interatomic interactions

Interatomic interactions are the ability of the formation of these atoms, depending on the type of covalent bonds, ionic metallic coordination or hydrogen. The covalent bond is formed by one, two or three common pairs of the bonding electrons. Energy difference between joined atomic orbitals is small.

Ionic bond is a bond without code, and is characterized by the transition of electrons an atom less electronegative atom with higher capacities, which can bind electrons. Then one atom becomes positive and the other negative. Elements of the outer shell electrons which are not strongly bonded, and closer to another metal element to create a metallic bonding matrix which forms the foundations constructed with nuclear and electron gas, which is comprised of free electrons and the resulting properties such as high conductivity thermal and electrical.

Coordinating bond is formed between a donor atom that provides electrons from the free electron pair and the acceptor atom, which accepts electrons to the unsatisfied electron orbit. Hydrogen bonding appears in organic compounds (less in the inorganic) and is the result of electrostatic binding interactions. It is based on hydrogen atom, in other words, it is a proton and has a directional character [1, 3].

3. Intermolecular interactions

Atoms join in molecules, which affect among themselves and form complicated structures more and more. Intermolecular interactions are called Van der Waals forces. We can distinguish four types of intermolecular forces.

The first are dispersion forces of London, which can take place only next to close proximity of molecules. They arise from difference of electric charges distribution, which are generating a quick – changing dipole moment in neighbouring molecules, what is the reason of attraction.

The second type is force, which we call a conformation of molecules and it is connected with electrostatic interaction of atom's group. It comes into being because of instantaneous changes of atom's orientation in molecules three – dimensional system. What is the most interesting they can change position without ripping of chemical bond.

The third sort of interactions is Keesom electrostatic forces, which occur between permanent dipoles. They are molecules with asymmetric packing of positive and negative electric charges. Inductive forces are the fourth kind of interactions between non-polar molecules, which do not have a permanent dipole moment if they found themselves under electrostatic field action.

Attempt on the understanding of atom's interactions is the best way to comprehend all matter properties, because each bond determinates a solid body form.

There is existing a dependable boundary, where molecules can join and create a finite structure of solid bodies and liquids. Each one object we can consider like a phases with different properties and with own surface layer, which is a border between two continuous mediums. In addition, it has different characteristics than core of material and it comes from physical, chemical and thermal interactions [1, 3].

4. Surface layer

We can say that surface layer owns two states. The first condition is called as natural state and this is the effect of object forming like a result of interactions with unlike mediums. Example of

this thought can be represented by oxides generating. The second state refers to intentional modifications in order to obtain specific properties. To exemplify it we can consider processes of plastic forming or application of coatings.

The top layer has a paramount importance in the exploitation process, which is highlighted by the fact that any irregularities in the structure are starting from the surface, or in close proximity. The surface layer and the core have different energy states, which results in differences in their structure and properties.

This is the results of increased energy state on the surface, which also entails an increase in the sorption processes. Of course, during surface treatment, we can observe impact of factors such as mechanical, thermal and chemical stresses, but also the one that is comes from changes in surface area during operation. The top layer is also an element of tribological processes and determines element wearing. Whether the item is no longer fit for recycling determines wearing that results from the friction and is inducing thermal, chemical and mechanical processes.

During the object processing, its surface acquires new properties, which can be design machine design for long life. The top layer is very diverse in terms of physicochemical properties and thickness of each zone, this is the result of kind of treatment, chemical composition, treatment strength and heat, which is excreted during all operations, chemical reaction, and chemical components exchange with the environment.

For example, if the surface resistance parameter will increase also under the influence of plastic deformation it is called strengthening. The effect of changes in physical, chemical and mechanical properties include increase of hardness, fatigue strength, yield strength, but also reduction of the impact strength or elongation.

Together with increase of depth we can observe another areas that pass very into another one very smoothly, which is often very difficult to determine a surface basic parameter, which is the thickness. The presence of long-range intermolecular interactions causes the zone formation as an effect of sorption processes. The state of residual stress affects the heterogeneity of structure, which are caused by the interaction of differently deformed zones. Machine elements usually cooperate with each other in the presence of an additional lubricating agent, which is adsorbed to them, and therefore in the following we will focus on the phenomena occurring within the boundaries of the phase in elements of friction pairs [2].

5. Energy state in friction pairs

Between friction pair, which is cooperating in rotational motion and plane – translational motion are present intermolecular interactions, which cause rise of interfacial forces on the surfaces. Atoms of one phase are attracting by atoms of second stage and are migrating to the moment of equilibrium achieving.

Different forces in interfacial range can cause effects like adsorption, wetting or adhesion. Phase boundary condition can be described by thermodynamic functions like internal energy, free energy, free enthalpy (Gibbs function). Total internal energy of each phase after differentiating can define us superficial tension of solid and depends on parameters as temperature, entropy, pressure, volume, interfacial tension, interfacial surface, chemical potential and number of molecules in substance.

We assume that all surface processes proceed in constant temperature and under constant volume while interfacial tension it is nothing else than free interfacial energy. If one of phases is air or vacuum, we can talk about free surface energy, especially for solid body. Surface free energy can be assigned on the basis of:

- Surface tension of molten solid body,
- Young's modulus and other parameters,
- Constituents.

It noticed that exists a clear linear dependence between melting point and surface tension in metallic elements. The higher temperature is the bigger surface tension is in given temperature. Obviously also alloying agent show the influence here, for example from non-metallic elements as oxygen, nitrogen or sulphur.

It assumed that we have intermolecular interactions, which are consequence of Young's modulus and it depends on distance between middles of molecules, which are staying in equilibrium of forces like attraction and repulsion. In consequence of it, we can define surface free energy of solid body, but only on condition that we know Young's modulus value and intermolecular distance in time when proceeds equilibrium of this interactions.

Calculation of surface free energy makes sense if crystal lattice is free from defects and we know something about number and kind of bonding in solid body. Hardness and surface free energy are a result of material structure and we can observe a dependence, which is connected through rigidity modulus and Poisson's fraction, but in this case obtained value of surface free energy seems to be overvalued a little bit.

According to Fowkes theory, the surface free energy is composed of dispersion's constituent, which comes from London forces as an effect of electron's motion around the nucleus and has universal character. Energy of these interactions has a big importance in wetting phenomenon and adhesion. In slight degree depends on temperature. We can estimate it if we know an average atomic number and density of solid body.

The next constituent derives from metallic bonds and appears only if these bonds exist. It comes from solid's free electrons. The third element of surface free energy originates from hydrogen bonds, which create a very permanent bond that we can recognize it like chemical compound.

The last constituent comes from polar interactions, also is connected with ionic or covalent bonds and energy which is descending from is very big. In short, surface free energy consists of dispersion's constituent and of rest which is called like polar part generally and here is not included any characteristic constituent for metals or of other solids.

Liquid in measuring vessel is curving in the vicinity of walls and creates concave or crowned meniscus. This is the result of cohesion forces action and membrane tension. We can distinguish distribution surface between solid, gas, solid and liquid or liquid, and gas. Between them is existing surface tension. Meniscus form with vessel a wetting angle, which is dependent on:

- Attraction force between liquid molecules,
- Attraction force of liquid molecules by body surface in contact place,
- Attraction force of molecules in scope of intermolecular interaction,
- Gravitation.

This angle has a big meaning for lubrication processes and that is why we are talking about tribology. Wetting angle we can evaluate with help of methods as:

- Method of liquid rising in capillary tube,
- Stalagmometer method,
- Bubble method,
- Wilhelmy method,
- Extensometer method,
- Method of drop weighted,
- Method of movable board,
- Method of drop measurement.

Wetting is a spreading of liquid drops on the solid surface fully or partly. It's described by Young's equation which depends on surface free energy of solid, interfacial surface free energy of solid and liquid, surface free energy of liquid and angle which is created between liquid – solid. It refers to perfect system, where there is not any contamination. This is the reason that we use measuring liquid with known surface tension to be able to make calculation of solid surface free energy.

Wetting and interfacial surface free energy is connected with adhesion working, where the drop will be able to spread. In this case it is required that we need to introduce a specific energy conditions of interfacial borders. It is a very important ratio of cohesion working to adhesion working; we can determine cohesion working for lube oil on the basis of oil surface tension, which is the amount, needed to disrupt interactions. In this case we establish that surface free energy has only two constituents which are dispersion and polar and it is a geometrical average of dispersion and polar interactions [1, 3].

6. Summary

For summary, we can admit that surface free energy is dependent on Young's modulus, rigidity modulus and hardness. Dispersion constituent of surface free energy can give us wetting measure, which is wetting angle and depends on value of this constituent. It appears in case if the dampening substance is non-polar liquid (lubricating grease). This quantities can be used as an indicator how to select material for elements of wearing pairs that ensure the biggest resistance to theirs attrition. Also if will be guaranteed certain wettability of lube oil energy loss on friction will be smallest what was the topic of this article.

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