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WEAR RESISTANCE OF NITRIDED STEEL IN DRY FRICTION

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Abstract: the wear resistance of nitrided steels in the dry mode of friction was studied. In contrast to experiments at the limit of friction, dry friction can be used for different steels at the same pressure value, which eliminates the problem of comparability of results and contributes to the objectivity of conclusions regarding the effectiveness of various modification processes.
Keywords: steel, nitriding, dry friction

1. INTRODUCTION.

The metal surface should be considered as a special variety of defects, since it destroys the periodicity of the solid body in one direction - perpendicular to the surface in the direction of the external environment. This thesis is confirmed by the fact that it is the boundary layer, the structure of which differs to a certain extent from the actual base of the solid body, that can interact more actively with external factors that stimulate surface modification. At the same time, it is the presence of a real surface, as a structure with a certain orderliness characteristic for each specific type of it, that is the stimulus that causes most of the physical or chemical processes of the interaction of a solid body with the environment [1], and its structure should be understood as a structure of a solid near the surface. This part of the solid body near the mathematical surface, or the near-surface layer, can be considered as a three-dimensional structure that differs from the solid body itself, since within several atomic layers it may include atomic nodes different from the atomic nodes of the main volume, while the distance between the layers in the direction normal to the surface not only differs slightly from the parameters of the lattice of the main volume, but also has a variable character, as a rule, in the direction of increasing as it approaches the mathematical surface. However, it should not be forgotten that the near-surface layer is a crystalline structure for which two-dimensional periodicity is preserved in planes parallel to the mathematical surface. Thus, from the above, the conclusion should logically follow that the violation of the specified natural periodicity of the near-surface layers inevitably affects in a certain way all the characteristics of the surface as a whole, and its ability to resist wear. This circumstance was noted to a greater or lesser extent in classical works on tribology [2, 3], however, proper coverage of research results, on the basis of which it would be possible to form practical methods of experiments to determine the characteristics of wear resistance of metal surfaces, neither in them nor in other works not marked

It is known that during the adsorption of gases, that is, the concentration of the components of the gaseous medium on the surface, a monomolecular adsorption layer is formed - a monolayer. The filling of the surface, i.e. the measure of monolayer integrity, at low pressure values is proportional to the pressure of the adsorbate in the gas medium. If gas molecules, due to the presence of a strong chemical or physical bond, do not have the opportunity to move on the surface, then this is localized adsorption with the formation of an adsorption complex. At the same time, the adsorbate and the near-surface layer can form their own two-dimensional structure. The speed of adsorption depends on the integrity of the monolayer, i.e. when approaching the state of continuous filling of the surface with an adsorption layer, it gradually decreases to zero and vice versa, the speed of desorption phenomena increases in the opposite direction. Chemisorbed and physically sorbed gas particles on the surface differ in the type of

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electronic bond between the adsorbate and the base. If the electronic state of the adsorbed molecule undergoes significant changes up to the formation of chemical bonds with the surface, then we are talking about chemisorption. If the molecule is held on the surface by Van der Waals forces caused by the polarization of the unexcited molecule, then this type of adsorption refers to physical adsorption.

It is obvious that the mechanical impact on the surface significantly changes the parameters of adsorption phenomena, which also cannot but affect the wear processes. A significant influence on the course of surface destruction is given by the value of work output, as well as the crystal structure of the surface. Indeed, the concept of output work is largely conditional considering the convention of the term "beyond the surface", since the potential energy depends on the distance to the surface as a mathematical category. In the presence of an absorption layer, an additional surface double layer appears, which also significantly affects the amount of output work.

From the above follows the conclusion regarding the importance of taking into account the parameters of the wear process and other conditions that characterize this process, on the objectivity of research results, especially in the formation of practical recommendations.

The work [4] analyzed the results of research on the wear resistance of steels, which were obtained under conditions of extreme friction. The main conclusions from the analysis were reduced to the fact that any wear process is a combination of successive compaction of near-surface layers and their removal. The results of the experiments also show that, under conditions of extreme friction, it is extremely difficult, and in some cases impossible, to use such values of the specific pressure on the friction surface, at which it would be realistic to compare the results obtained for different samples, made of different grades of materials and processed according to using various technological processes. Since the friction zone was constantly lubricated during the tests, a layer of lubricant was present on the friction surface up to a certain pressure value, which led to extremely low linear wear rates. However, depending on the characteristics of the modified surface, there was a critical value of pressure at which the layer of lubricant was squeezed out of the friction zone, which led to instantaneous adhesion of the surfaces. With a gradual increase in pressure, it was possible to reach relatively high critical pressure values. An attempt to immediately conduct tests on new samples at pressures close to these critical values inevitably caused seizure of the surfaces. This, together with the impossibility of objectively comparing test results obtained at different pressures, explains the need to switch to the scheme of experiments with dry friction.

2. **RESEARCH METHODOLOGY**.

Experimental studies were carried out on a universal machine for testing materials for friction, model 2168UMT with some modernization of the friction unit, which is detailed in the work [5, 6]. The testing of the experimental modes was carried out on samples, the method of preparation of which is given in the same place, and to check the possibility of further comparison of wear processes, objects with significantly different surface characteristics were selected: soft surfaces are represented by samples made of steel 20 without modification, modified - by steel 45 after their nitriding in a glow discharge. The latter before nitriding had a surface hardness of HV0.1 215, after modification HV0.1 700...730. The initial series of experiments was carried out on steel 20 samples without their modification. The hardness of the hardened steel counterbody was HRC 60. The speed and pressure were chosen within such limits that the surface temperature of the samples in the friction zone did not exceed 40˚C. At the speed of the relative movement of the sample in relation to the counterbody V=0.1 m/s and the pressure 10.16 MPa (this value turned out to be optimal, since more or less heavy wear is observed with it and there are no sticking phenomena), uniform wear is observed, the amount of linear wear is on average is 15.4 μm/km of path. The friction coefficient ranged from 0.05 to 0.11, which in the experimental conditions corresponded to a friction force of 29.4 to 64.7 N.

3. **RESULTS OF WORK AND THEIR DISCUSSION**

First of all, it can be seen from Figure 1 that the intensity of the wear process significantly increases in the dry friction mode, which leads to a significant increase in the productivity of experimental studies (in some cases, one experiment in the limit friction mode lasted for weeks, and in the dry mode it was possible to perform it in several shifts).

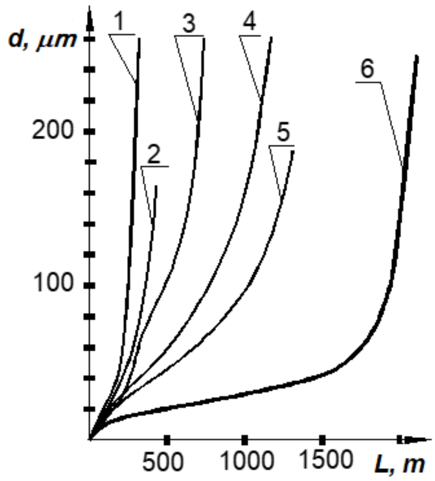

Figure 1 - Dependence of linear wear on the path of friction and pressure: 1 – steel 20, p=16 MPa; 2 – steel 45, p=16 MPa; 3 - steel 20, p=10 MPa; 4 – steel 40X, p= 16 MPa; 5 – steel 45, p= 10 MPa; 6 – steel 41CrMo4, p=16 MPa

In addition, the thesis regarding the decisiveness of the effect on the intensity of wear of pressure on the friction surface was confirmed, since the same indicators of linear wear d were achieved with an increase in pressure with a significantly smaller friction path L. The brand of material (initial values of physical and mechanical indicators) in combination with the existing modification surfaces also significantly influenced the intensity of wear. So, for example, for steel 41CrMo4, nitrided in the glow discharge, in some cases the intensity of wear is almost an order of magnitude lower compared to steel 20. In contrast to the methodology of experimental studies based on the principle of application of limit friction, in the dry friction mode it is possible to achieve results with the same pressure values for almost all steels, which excludes the question of comparability when analyzing the results of research. The importance of this provision is evidenced by the comparison of wear curves for the same steels at different pressure values (Fig. 1). Since the same value of linear wear for the same material, but at different pressures, is achieved with significantly different values of the friction path, establishing the relationship between the listed factors would pose a certain problem. Graphs in fig. 1 confirm the effect on the wear intensity of the physical and mechanical parameters of the surface and its modification, while stronger steels, as well as steels that have undergone a certain modification treatment, wear out under the same conditions (pressure and speed of relative movement, which for all experiments was 0.1 m/s) with a lower intensity, which in the graphs corresponds to the angle of their inclination.

The effect of structural transformations of the surface is confirmed by Figure 2, which shows the results of fixing linear wear with a small interval of the friction path. The wear schedule in this case is a stepped curve following periods of formation of strengthened structures on the surface, when wear is practically absent, and periods of destruction of these surface structures.

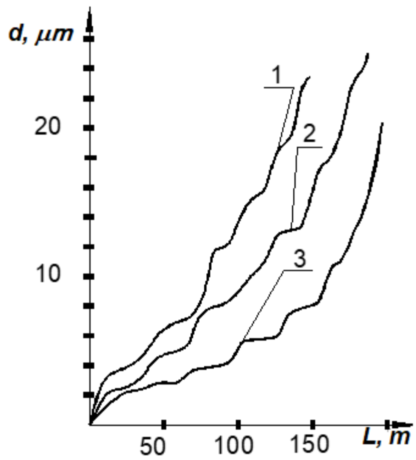

Figure 2 - Character of surface wear in the initial period of testing 1 - steel 20, 2 - steel 41Cr4, 3 - steel 41CrAlMo7

For modified surfaces, a similar phenomenon is especially characteristic in the initial period, when the zone of nitrides and internal nitriding wears out [7]. Another important phenomenon for the analysis of the influence of the modification results on the wear resistance parameters of the surface was established - the effect of relaxation processes in the near-surface layers, which have already acquired some structural transformations under the influence of pressure in the friction zone.

Black dots in Figure 3 show points 2, 4, 6, when wear resistance tests were suspended and resumed the next day. For all steels, a certain slowing down of the wear process is noted after a break with a gradual return to the intensity characteristic of a certain brand of steel (Fig. 3).

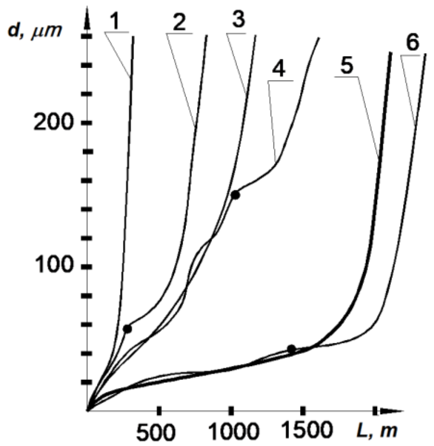

Figure 3 - Effect of relaxation structural transformations of the surface: 1, 2 – steel 20; 3, 4 – steel 41Cr4, 5, 6 – steel 41CrAlMo7, the test stop points are marked with dots

The reason for this phenomenon can only be relaxation of stresses, equalization of structure characteristics in near-surface layers, and the consequence of all this can be strengthening of the surface, which explains the decrease in the intensity of the wear process [8]. Over time, as the strengthened layer breaks down, the indicators of the surface condition become equal to those before the break and the intensity of wear is restored.

CONCLUSIONS:

1. The study of wear resistance in the dry mode of friction ensures a significantly higher productivity of experiments. Unlike the limit friction experiments, dry friction can be used for different steels at the same pressure value, which eliminates the problem of comparability of results and contributes to the objectivity of conclusions regarding the effectiveness of various modification processes.
2. According to the results of previous experiments, such a compromise pressure value can be 16 MPa.
3. The effect of relaxation transformations of surface structures has been established, on the basis of which it is recommended to carry out research on wear resistance during one continuous session.

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