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# ACCELERATED TESTING OF MECHANICAL AND CHEMICAL EFFECT OF THE ENVIRONMENT ON WEAR RESISTANCE OF PARTS OF TRIBOCOUPLES UNDER COMPLEX DYNAMIC LOADING

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*The wear of tribocouplings parts under complex dynamic loading conditions is considered. A methodology for accelerated testing of friction pairs under multi-component dynamic loading is offered. The designs stand for modeling the processes of contact interaction, and studies of the wear resistance of tribocouplings, which operate under complex dynamic loading conditions with various lubricating and cooling media, are presented. The results of the impact assessment of mechanic and chemical transformations in the contact zone of tribological interfaces for wear resistance according to the developed method are presented. The variable effectiveness evaluation of the degradation influence products of macromolecular compounds in the composition of cutting fluid on wear resistance of metals in the contact zone of tribocouplings are analysed. The use of the presented materials allows rationally selecting friction pair materials for given operating conditions, developing new wear-resistant materials and coatings, lubricant composition and cooling mediums.*

**Keywords***: wear, complex loading, friction, stand, polymer.*

## 1. Introduction

Metal deformation during friction with different loading schemes leads to structural rearrangements of the surface layer, changes in the energy relief of the surface, which is inextricably linked with the wear resistance of the tribocoupling. A promising direction for changing the loading conditions in the contact zone and controlling the wear resistance of the tribocoupling is the use of lubricating and cooling technological media of various characteristics.

From a physical point of view, the surface of metals is an atomic plane with an incomplete crystal lattice, which leads to a high sorption activity of the surface layer. This, in particular, leads to the Rebinder effect (external and internal), which consists in adsorption processes, primarily the plasticization of the metal in the contact zone with the transfer of plastic deformations to a thin surface layer and the wedging action of surfactants when they enter the cavity of surface cracks [1]. Various effects produced by the lubricating medium on rubbing surfaces can lead to both an increase in the resistance of the material to destruction and to the weakening of the material.

Multi-component loading initiates mechanic and chemical phenomena in the tribe-conjugation contact zone. Mechanic and chemical transformations differ from other chemical reactions initiated by physical methods in that they can develop at a relatively low average energy level per unit volume of matter. In alternating mechanical fields, the efficiency of the mechanic and chemical process sharply increases with increasing intensity of exposure and has the highest value under conditions of maximum concentration of mechanical energy per unit volume of a substance per unit time [2-4].

When studying processes in the zone of contact interaction of solids, one usually encounters difficulties associated with conflicting data on the wear resistance of tribocouplings and the impossibility of comparing different research methods. A number of authors to a greater extent carried out studies of the wear resistance of friction pairs using standard or modernized friction machines in the process of rolling or sliding samples. The research results obtained in this case do not allow creating a picture of the wear process that corresponds to the real process, since most of the tribocouplings operate under more complex loading conditions [5-7].

## 2. Research method and experimental technique

Most of the tribocoupling parts of various machines and mechanisms are under three-component dynamic loading during operation (shock and slip in two mutually perpendicular directions), due to functional mutual movements in different directions, the presence of vibrations or their combinations. Their wear resistance is significantly different from that which occurs under unidirectional or two-component loading [8, 9].

Given the complexity of the phenomena occurring in the contact zone of tribocouplings, methods of accelerated testing of friction pairs are of great importance, in which the necessary amount of information on wear resistance is obtained in a shorter time. The most acceptable is the test method based on the simulation of natural conditions on a special dynamic stand. In this case, the tests are carried out with a cyclically changing amplitude of displacements, contact pressure, and temperature. This makes it possible to reproduce test conditions for samples and full-scale parts close to operational ones, as well as to carry out programs of accelerated wear resistance tests, conducting them, for example, in the most severe modes, or in modes corresponding to the greatest accumulation of damage in the surface layer of rubbing parts [10 - 12].

A device for the study of friction with increased research productivity was developed. It allows testing simultaneously two contact pairs of specimens under three-component loading conditions with the possibility of providing the same contact load conditions, slipping in two mutually perpendicular directions and supplying a liquid or gas lubricating-cooling technological medium to the contact zone. The device has one holder with a fixed sample and two spring-loaded counter samples. The holder has the ability to move relative to the ball bearing in two mutually perpendicular directions under the action of the units for setting the transverse displacement, longitudinal displacement and impact energy. Variable loading conditions and longitudinal displacement parameters are set using a conical eccentric (Fig. 1).

In this case, the three-component loading of samples (impact and slip in two mutually perpendicular directions) is provided by the corresponding nodes. The energy (impulse) of impacts, as well as the amplitude and frequency of slips in the plane of impact, is controlled by means of a conical eccentric, by changing the rotational speed of the motor shaft, as well as by the springs of counter samples and the size of the gaps between the sample and counter samples.

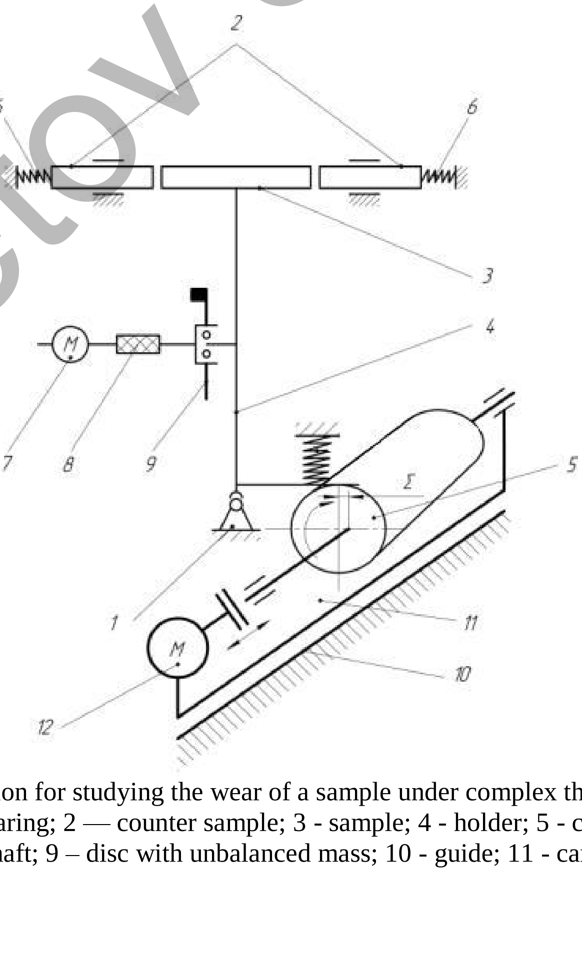


**Fig.1.** Scheme of the installation for studying the wear of a sample under complex three-component loading with two contact pairs: 1 - ball bearing; 2 — counter sample; 3 - sample; 4 - holder; 5 - conical eccentric; 6 - spring; 7 - electric motor; 8 - flexible shaft; 9 – disc with unbalanced mass; 10 - guide; 11 - carriage; 12 - electric motor

The relative motion of the sample and the counter-sample in two mutually perpendicular directions is provided by one holder, which simplifies the design of the device and increases the constancy of contact conditions. The use of two counter samples makes it possible to simultaneously study the wear of two contact pairs from the same or different materials. Preliminarily, in the neutral position of the eccentric, its conical surface is set, and in the process of wear studies, an equal gap is maintained between the sample and the counter-sample to ensure the same contact conditions. The amplitude of slips in the direction perpendicular to the plane of impacts is controlled by changing the position of the unbalanced mass relative to the axis of its rotation, the frequency (speed) of slips is controlled by changing the speed of the motor shaft.

The installation works as follows. In the neutral position of the eccentric 5, its conical surface sets an equal gap between the sample 3 and the counter samples 2 to ensure the same contact conditions. The conical eccentric 5 receives rotational motion from the electric motor 10 and carries out kinematic excitation of the holder 4 with the sample 3, which leads to the collision of the sample 3 and the counter-samples 2 and their slipping in the perpendicular direction to the collision plane due to the compression of the springs 6. The disk with an unbalanced mass 9 has an adjustable unbalanced mass to the axis of its rotation and receives a rotational movement from the electric motor 7, which leads to the movement of the holder 4 relative to the ball supports 1 and slippage of samples in the direction opposite to the collision plane.

If it is necessary to evaluate the effect of shock loading separately on the wear resistance of tribocouplings, a special setup was developed that allows testing two contact pairs of specimens simultaneously under shock loading conditions while ensuring the same contact conditions. This is achieved due to the fact that counter samples are installed with a gap relative to the sample in the device, the load creation mechanism has a conical eccentric, and the variable loading conditions are set using the loading creation mechanism and the registration and control system (Fig. 2).

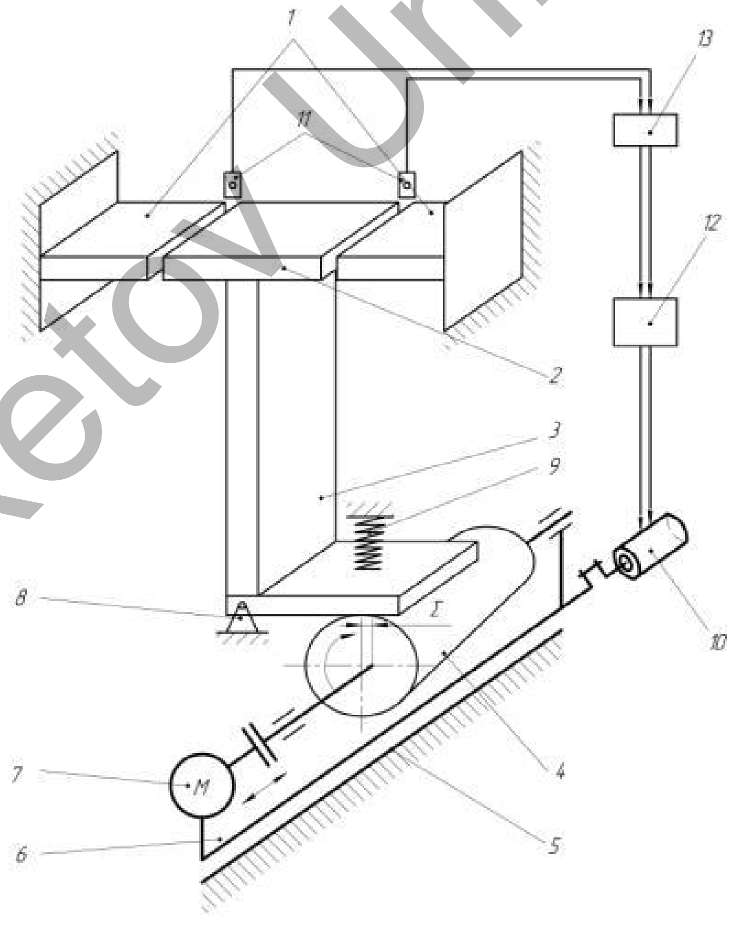


**Fig**.**2**. Scheme of installation for studying the wear of a sample under shock loading with two contact pairs:
1 — counter sample; 2 - sample; 3 - holder; 4 - conical eccentric; 5 - guide; 6 - carriage; 7 - electric motor; 8 - hinged support; 9 - spring; 10 - stepper motor; 11 - sensor; 12 - computer; 13 - analog-to-digital converter.

Impact loading is provided by the mechanism for creating loading in the process of swinging the sample holder relative to the hinged support due to the presence of gaps between the sample and the counter-sample. The energy (impulse) of impacts, the amplitude and frequency of impacts are controlled by means of a conical eccentric and by changing the rotational speed of the motor shaft, as well as by the size of the gaps between the sample and counter samples. Preliminarily, in the neutral position of the eccentric, its conical surface is set, and in the process of wear studies, an equal gap is maintained between the sample and the counter-sample to ensure the same contact conditions.

The use of two counter samples makes it possible to simultaneously study the wear of two contact pairs from the same or different materials. At the same time, in order to ensure the same contact conditions in the process of research, the possible uneven wear of the contact pairs is compensated by maintaining the same gap in the contact pairs. The same gap in the contact pairs is maintained by the registration and control system, which includes two sensors for measuring the gaps. The signal from the sensors using an analog-to-digital converter is recorded by a computer.

In the case of obtaining data on the difference in the size of the gaps, they are automatically corrected by the stepper motor of the conical eccentric according to the program from the computer. The installation works as follows. In the neutral position of the eccentric 4, its conical surface sets an equal gap between the sample 2 and the counter-samples 1 to ensure the same impact contact conditions. The conical eccentric 4 receives a rotational movement from the electric motor 7 and performs kinematic excitation of the holder 3 with the sample 2, which leads to the collision of the sample 2 and counter samples 1. In the process of research, two sensors 11 measure the gaps. The signal from the sensors using an analog-to-digital converter 13 is recorded by the computer 12. If differences in the gaps are determined, they are corrected by the stepper motor 10 of the conical eccentric.

## 3. Results and discussion

To check the degree of influence of mechanic and chemical transformations on wear resistance, according to the considered research method, a comparative assessment of the change in the intensity of wear of the samples was carried out when the polymer was introduced into the contact zone [13].

The wear intensity of 40Kh steel samples was studied under three-component loading conditions (impact and slip in two mutually perpendicular directions) with poly-methyl methacrylate (PMMA) being fed into the contact zone. The tests were carried out in the mode of boundary and semi-liquid friction with the supply of acetone and a solution of PMMA in acetone (1 g of PMMA powder per 200 ml of acetone) to the contact zone of the studied samples. At the same time, preliminary grinding of the polymer to a powder state contributed to the additional initiation of mechanical destruction and an increased content of free macro radicals in the solution.

Testing conditions: transverse slip amplitude 0.25 mm; longitudinal slips 0.15 mm; cross slip frequency 30 Hz; longitudinal slip frequency 66 Hz; normal load 20 N, test time 4 hours. The test results are shown in Figure 3. As follows from the results obtained, the introduction of PMMA into the contact zone leads to a significant increase in the wear rate of steel.

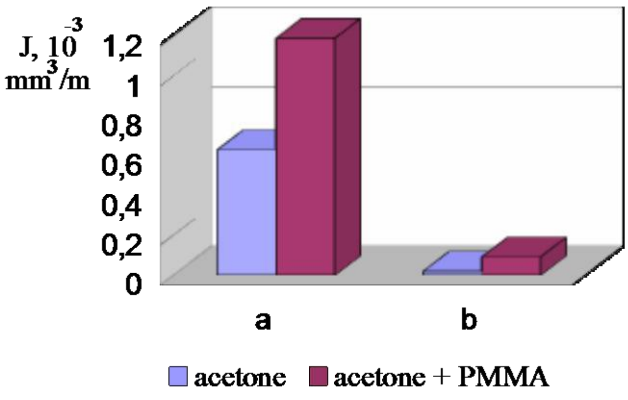


**Fig.3**. The intensity of wear of samples with the supply of acetone and acetone solution with PMMA to the contact zone: a – boundary friction; b - semi-fluid friction

Moreover, the more the solution is supplied, and, accordingly, the greater the amount of PMMA enters the contact zone, the greater the change in wear intensity is observed. The marked significant decrease in wear resistance is a positive factor for facilitating surface running-in and reducing cutting forces during processing.

Destructible polymers activate the destruction of iron particles similarly to low molecular weight surfactants [14-16]. When processing with the use of polymers, an increased destruction of metals is observed due to the formation of products of mechanical destruction of the molecular chains of polymers - free macro radicals. The lower the activation energy of polymer destruction, the higher metal destruction degree. Thus, phenol-formaldehyde resin has a three-dimensional structure, therefore, its destruction activation energy is higher than, for example, that of polyethylene, a polymer of a linear structure, and, moreover, of poly-methyl methacrylate. The activation energy of polyethylene is 60-70 kcal/mol, PMMA is 27 kcal/mol.

## 4. Conclusions

Varying the conditions for the occurrence of mechanic and chemical reactions in the contact zone of tribocoupling in the presence of polymer degradation products opens up great prospects for controlling the wear resistance of contacting parts. Optimization of these conditions, taking into account the dynamics of loading, makes it possible to expand the technological possibilities for ensuring the durability of tribocouplings both in the process of manufacturing parts of machines and mechanisms, and during their operation.

The presented stands can be used to assess the performance of friction materials in the nodes of real structures. When testing friction units on stands in a wide range, the main operating parameters are implemented, which ensure testing by the method of full-scale simulation and the method of accelerated tests for wear resistance of a large number of real tribocouples. It becomes possible to provide the necessary set of mechanical loading factors - a three-dimensional dynamic load, to separate the load factors, and also to combine them in different combinations, to regulate and control the loading parameters, including during the test cycle (this is impossible in natural conditions).

Test benches can be recommended for obtaining and studying the functional dependencies of the friction and wear characteristics of pair materials, comparative evaluation of friction pairs, physical modeling of real tribecouples, and assessment of the effect of mechanic and chemical phenomena in the contact zone on wear resistance. The proposed methods for accelerated testing of the wear resistance of tribocouplings will significantly reduce the cost of developing promising anti-friction materials and designs of new friction devices, selecting a lubricating-cooling technological medium and significantly reducing the time for their introduction into production. The test results will create prerequisites for a reasonable choice of materials for friction pairs for given operating conditions and can be used in the development of new wear-resistant materials and coatings.

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