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Experimental installation for wear tests of materials and coatings

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Abstract

On the basis of the analysis of existing tribological testing methodologies, which includes the selection of controlled wear parameters, the influence of the type of friction, contact geometry, surface roughness, the scheme of tribological research, the choice of a machine 2168UMT for friction testing of materials is substantiated. The friction machine allows you to install three samples at the same time, change the pressure in the contact zone in a wide range, control the moment of friction, the rotation frequency of the counterbody, the number of revolutions (friction path), change the rotation frequency, respectively, the sliding speed, automatically limit the distance traveled and other functions. The method of wear is adopted according to the finger-ring scheme, linear wear is monitored using an indicator rack with a value of divisions of the measuring device of 0.001 mm. To fix the samples on the machine caliper, holders were designed and manufactured, which ensure the self-fixation of the sample on the counterbody - a spherical joint made of the rolling body of the bearing. due to the fact that the samples were pressed against the counterbody with a force corresponding to the nominal contact pressure, they were self-aligned. After the sample was self-assembled, the whole structure was fixed by tightening the nuts. The counterbody is made of a rolling bearing ring, the material is steel SHX15, the hardness of the base is HRC 61. Three devices are mounted on the caliper for permanent lubrication of the running track immediately before the approaching sample. Thus, at certain values of pressure and speed, the mode of marginal friction can be reached, which was marked by a low coefficient of friction.

Key words: friction, installation, sample, wear, contact pressure, lubrication.

Introduction

It is desirable to evaluate the effectiveness of the surface modification of metal parts, tools, and equipment taking into account the conditions of further operation of the processing objects. Naturally, the rationale and choice of test methodology are of fundamental importance in forming conclusions regarding the effectiveness of the processing technology. At the same time, it is important, first of all, to ensure, to the extent that it is realistic, the adequacy of the test conditions to the modes of practical application of the processed parts. It is obvious that in this case, deviations not only in the type or method of testing, but also in the choice of limits for changing the main parameters of research can significantly affect the objectivity of the conclusions regarding the final results of the modification [1].

The main purpose of surface modification is, among other things (strengthening, increased corrosion resistance, fatigue resistance, etc.), increasing the wear resistance of friction pairs. Indeed, almost all processes of loss of performance of processing objects begin from the surface, among them wear is perhaps the most significant [2]. Therefore, it is important to choose a method of testing for wear resistance in such a way as to ensure adequacy to the conditions of future operation to the maximum extent possible, while the duration of the tests would be minimal, but this condition should not significantly affect the objectivity of the conclusions [3].

In general, most of the real operating schemes of general-purpose friction pairs refer to the model of frictional interaction, which is characterized by a system of parameters. These parameters precisely reflect the main processes of wear and strengthening of the surface as a result of frictional interaction, the mechanism of movement of fracture fragments, elastic and plastic phenomena on the surface that take place as a result of frictional interaction, up to adhesion (caking) of surfaces.

Literature review

Let's consider the existing designs of friction machines that implement tests according to the "pin-disk" scheme. In [4], pin-on-disc sliding wear tests for each experimental condition were performed with a commercial tungsten carbide (WC) pin on silicon carbide (SiC) discs to determine the variance of the wear and friction data. In [5], each case study included an explanation of the individual modifications required to set up the test, including hardware and software settings. These case studies represented several application areas generated annually by the CSM Instrumentation Test Laboratory. Paper [6] describes a new universal tribometer design that allows simulation of various contacts and test types, such as pin-on-disc, ball-on-disc, and linear reciprocating tests. The new equipment allows tribological testing of samples of piston rings and cylinder liners at low and high temperatures and extreme lubrication conditions of any typical gasoline or diesel engine. Some friction results were shown under boundary conditions of lubrication between piston ring and cylinder liner sliding pairs, describing how the Tribotest machine is driven by an AC servo motor, which is more accurate than a DC motor. In [7], a study of the rate of wear and friction for various materials under the influence of load according to the pin-on-disk scheme was carried out. The tests were carried out using a pin disc tribometer using SKD II and aluminum alloy A 5083 as the workpiece material. The test was tested using different types of grease with different loads. The article [8] presents the design of a "pin-on-disc" type tribometer designed for experimental characterization of static and dynamic friction behavior for various pairs of sliding samples. The normal force, sliding speed and temperature, as the main influencing parameters, are precisely controlled during the experiments by using vertical and rotational servo axes and an electric heater embedded in the rotating disk. A compact triaxial piezoelectric force sensor placed between the vertical-axis screw driver and the friction specimen provides direct measurement of normal and tangential forces used to calculate the coefficient of friction of the specimen. The document [9] exposes a machine built for testing the friction, lubrication and spoilage. Its test conditions have a large file of options to execute tribology tests checking the working conditions, like movement way (reciprocating or linear), parts in contact, movement speed, self-lubrication, part geometry, temperature range, humidity, materials. To perform this test, the tribometer uses the principle of the disc revolution, the load is applied directly over the arm and do the measure according to the standard obtaining the results with accuracy. In [10] pin on disc tribometer is a device to determine coefficient of friction and wear rate of the different materials. There is a need to design a tribometer as per standards for different applications. This study was about designing and developing a low-cost tribometer to study the wear of automotive engine materials under lubricants with nano additives. Pin on disc arrangement was designed as per ASTM standard G 99–17. The parameters that can be controlled in the test rig are load, sliding distance, sliding speed, wear track diameter, lubricant temperature, mixing time of nano additives in lubricants, mixing speed to the stirrer. A pin-on-disk tribometer for micro-scale applications is presented in paper [11]. The tribometer consists of a stationary mm-scale pin and a rotating disk. Friction and lubrication film thickness are measured by a laser position detector and a laser displacement sensor. Using this tribometer, hydrodynamic tests have been carried out with the specimens fully submerged in a lubricant. Results suggest that the sliding motion in the mm-scale operates with a direct contact at low speed, and in the hydrodynamic regime at a higher speed. When the sliding reaches the critical speed, the lubricant film is established, and the thickness of the film stabilizes and the friction increases with the sliding speed. The tribometer shows good repeatability in these tests. In [12] the design and fabrication of the apparatus are presented with initial test results conducted to investigate the power efficiency and wear performances of several polymer and metal samples. Our results show that for a fixed power transmission torque, there exists a critical pre-load between the drive components at which the wear and slip are maximum and the value of critical pre-load is independent of the material. Both wear and slip can be minimized to near-zero if an optimum pre-load, which is higher than the critical pre-load, is applied between the two components. Therefore, expanding the technological parameters of machines for friction and wear tests is an urgent task. hydrodynamic tests have been carried out with the specimens fully submerged in a lubricant. Results suggest that the sliding motion in the mm-scale operates with a direct contact at low speed, and in the hydrodynamic regime at a higher speed. When the sliding reaches the critical speed, the lubricant film is established, and the thickness of the film stabilizes and the friction increases with the sliding speed. The tribometer shows good repeatability in these tests. 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Selection and assessment of wear parameters

In setting up the test methodology, a special role belongs to the selection of wear parameters that need to be controlled. The nature of the friction process from the point of view of the lubrication regime is easiest to control by determining the friction coefficient [13]. In most experimental friction machines, this parameter is calculated by comparing the force of normal pressure in the contact zone with the circular force, to determine which it is necessary to control the moment of friction. In principle, linear and volumetric wear are interrelated, however, accurate determination of the volumetric parameter requires no less accurate knowledge of the actual contact area, and this parameter even in the theoretical aspect is somewhat complicated (taking into account the configuration of the microprofile).

The mass parameter of wear is determined in principle easily, but the main methodological problem when using it is that it is necessary to remove the samples from the stand every time, and re-installing them in the same position is practically impossible. For this reason, after each measurement, the reproduction of previous friction conditions in the sense of mutual abutment of surfaces, uniform pressure across the contact plane, etc. is unrealistic, and hence inevitable problems with the reliability of each subsequent measurement. True, in this sense, the method when the samples are installed in the head, modified together with it and tested in this form deserves attention. However, such a technique significantly increases the duration of tests.

Type of friction

The choice of the type of friction, as a rule, mainly depends on the design features of the real operating conditions of the friction pairs. It is obvious that most often in the conditions of most typical designs, sliding friction is observed, which, among other things, is the most productive in terms of wear rate. A special role is played by the choice of lubrication mode [13]. Dry friction, which would obviously ensure the maximum rate of wear and, accordingly, the minimum duration of the tests, nevertheless could slightly distort the wear process, since in this case the temperature in the contact zone and the parts of the friction pair as a whole would increase significantly [14]. In addition, it is problematic to find pure dry friction in real friction pairs. The liquid mode of friction requires special devices or test conditions that would guarantee this mode. In most real pairs of friction, there is a limit mode of friction, the provision of which is relatively easy to control through the coefficient of friction [15].

Contact geometry

The geometry of the contact is to some extent related to the type of mutual movement of the sample and the counterbody. In principle, the contact surface can be in the form of a plane, cone, cylinder or sphere. In addition to the plane, all other types theoretically provide contact geometry in the form of a line - straight or curved, including - spatial. It is obvious that depending on what the force characteristics of the contact will be, and, accordingly, its type - elastic or plastic, including intermediate forms, the real contact area will change significantly, which makes comparison of experimental results problematic. The contact in the form of a plane is most simply implemented, since in this case there are no issues with determining the nominal contact area. As for the type of mutual movement, with flat contact, the relative velocity vector should be directed tangential to the contact plane [14]. At the same time, in order to ensure equal wear conditions at all contact points, it would be desirable for the magnitude and direction of the relative velocity vector to be the same, since in this case, for example, a friction scheme similar to rotational friction or a variant of end friction, when the speed at different contact points is excluded is significantly different (a relatively large ratio of the width of the contact pad to the radius of rotation).

Surface roughness

Finally, a very important, if not decisive, role is played by the roughness of the contacting surfaces, both in particular and the established one, which is formed as a result of running-in. At the same time, the following is essential.During the run-in process, the surface of the sample is compacted due to the action of normal pressure and the interaction of the surface and the destruction fragments (depending on the type of movement mechanism of these fragments). In this way, the problem of choosing the value of the nominal pressure in the friction pair arises, since the test process will go differently if it is gradually increased during the experiment, while the surface microhardness will increase, or if a certain value of this pressure is immediately established. In the first case, the process is possible at certain, sometimes very large, values of the nominal pressure in the contact zone. An attempt to start the test immediately at this pressure value can usually lead to adhesion of the surfaces [14, 15].

Selection of the scheme and parameters of tribological studies

Thus, as a result of the above analysis, the following priorities emerge when choosing the scheme and parameters of experimental studies [13-15]:

1. The contact area should be as small as possible. In this case, both the distribution and magnitude of pressure stresses in the contact zone will be almost uniform over the entire area of the research object. True, then the ratio of the area of the zone near the edge to the total area increases, but this shortcoming can be compensated by more careful sample preparation. At the same time, chamfers or rounding of edges should be minimal and as stable as possible. In addition, minimization of the size of the contact surface will facilitate the installation of samples on the counterbody, in which case tight contact would immediately be ensured over the entire area.
2. The nature of the mutual movement of the sample and the counterbody, taking into account certain complexities of the design of their fixation, which must be self-installed on the counterbody, should be optimally chosen according to the scheme: the sample is stationary, the counterbody rotates. Then the sample slides over the counterbody along a track with a sufficiently large radius, which, compared to the size of the sample, ensures a minimal difference in speeds at all points of the contact area.
3. The optimal shape of the contact pad is a plane, and to minimize the impact of uneven pressure distribution around the edges, the shape of the contact pad of the sample is round. Among other things, in this case fixing and processing of samples with high accuracy is simplified. For the convenience of measurements, basing samples in, as well as minimizing the duration of tests, linear wear was chosen as a control parameter. In this case, there is no need to remove the samples from the stand and thus the problem of re-basing the samples disappears.

Presenting main material

The 2168UMT model friction testing machine was chosen as the test stand, which allows you to set three samples at the same time, change the pressure in the contact zone in a wide range, control the friction moment, the frequency of rotation of the counterbody, the number of revolutions (friction path), change the frequency in a wide range rotation, respectively - sliding speed, automatically limit the distance traveled and other functions. The method of wear is adopted according to the finger-ring scheme, linear wear is monitored using an indicator rack with a value of divisions of the measuring device of 0.001 mm. To fix the samples on the caliper of the machine, holders were designed and manufactured, the construction of which is shown in fig. 1.

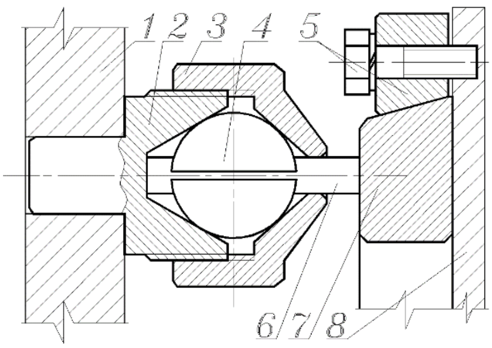
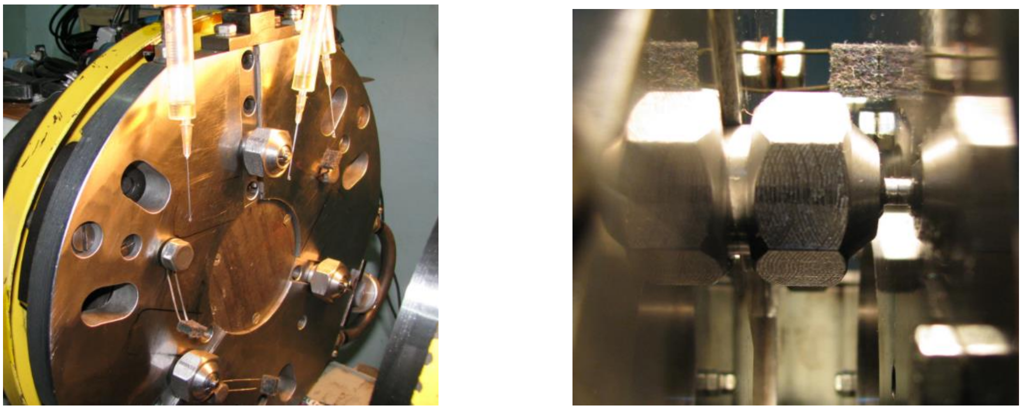


Fig. 1. Sample fastening scheme: 1 – caliper, 2 – saddle, 3 – nut, 4 – spherical joint, 5 – counterbody retainer, 6 – sample, 7 – counterbody, 8 – washer

The main element of the design, which ensures the self-fixation of the sample on the counterbody, is a spherical joint made of the rolling body of the bearing. Previously, the ball was released, a hole was drilled in a special centering device along the diameter of the sample, and then the ball was sprayed into two parts. To install the samples, the support with the holders is brought to the counter body and due to the fact that the samples were pressed against the counter body with a force corresponding to the nominal contact pressure, they were self-installed. After the sample was self-assembled, the whole structure was fixed by tightening the nuts. Visual control indicates a high quality of contact, since a stain is observed over the entire area of the sample already on the first segments of the friction path. The counterbody is made of a rolling bearing ring, the material is steel SHX15, the hardness of the base was HRC 61. The taper necessary for fixing the counterbody was formed by processing the ring using a mineral-ceramic cutter. The general appearance of the stand is shown in fig. 2 (a – a general view of the caliper in the retracted state, b – the holder in the working state). Three devices are mounted on the caliper for continuous lubrication of the running track immediately before the running sample. Thus, at certain values of pressure and speed, the mode of liquid friction can be achieved, which was marked by a low coefficient of friction. Samples of various steels were produced by fine turning (the tolerance was minus 0.05 to 0.01 mm). Within the limits of tolerance, samples were sorted into groups through selective selection, which made it possible to use samples of only one size group for a specific mode of modification in the following [15].



a) b)

Fig. 2. General view of the caliper of the friction machine

The latter makes it possible to achieve approximate equality of the contact area, simplifies modeling of the nominal pressure in the contact zone. Next, the samples were first ground in a special multi-position mandrel from one end (base), then to size along the length from the other. The design of the mandrel made it possible to ensure the perpendicularity of the ends of the cylindrical surfaces with high accuracy, but, as the practice of using samples in the friction machine showed, this accuracy is not enough for contact over the entire surface of the end from the very beginning of the wear resistance studies. This explains the need for the design of the holder described above. In the axial direction (the direction of the normal force), the samples are based on the bottom of the saddle 2 (Fig. 1), so the distance from the bottom plane to the base surface of the caliper must be maintained with high accuracy. The caliper disc itself is polished with high precision both on the plane of contact with the saddle and in the mounting holes for the shank of the saddles.

Conclusion

Thus, on the basis of the analysis of existing tribological testing methodologies, which includes the selection of controlled wear parameters, the influence of the type of friction, contact geometry, surface roughness, the scheme of tribological research, the choice of a machine 2168UMT for friction testing of materials with a device that ensures self-installation of samples on the counterbody is justified, namely, a spherical joint made of a rolling bearing body.

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Стечишин М.С., Диха О.В., Олександренко В.П., Цепенюк М.І., Курской В.С., Олександренко Є.Г.
Експериментальна установка для випробувань на знос матеріалів і покрить

На основі проведеного аналізу існуючих методологій трибологічних випробувань, що включає вибір контрольованих параметрів зношування, впливу виду тертя, геометрії контакту, шорсткість поверхні, схеми трибологічних досліджень обгрунтовано вибір машини для випробувань матеріалів на тертя. Машина тертя дозволяє одночасно встановлювати три зразки, в широкому діапазоні змінювати тиск в зоні контакту, контролювати момент тертя, частоту обертання контртіла, кількість обертів (шлях тертя), змінювати частоту обертання, відповідно, швидкість ковзання, автоматично обмежувати пройдений шлях та інші функції. Метод зношування прийнято по схемі палець-кільце, лінійне зношування контролюється за допомогою індикаторної стойки з ціною поділок вимірювального приладу 0,001 мм. Для закріплення взірців на супорті машини спроектовано та виготовлені державки, які забезпечують самовстановлюваність зразка на контртілі – сферичний шарнір, виготовлений з тіла кочення підшипника. за рахунок того, що зразки притискалися до контртіла з силою, котра відповідає номінальному тиску в контакті, вони самовстановлювалися. Після того, як взірець самовстановився, вся конструкція фіксувалась шляхом затягування гайок. Контртіло виготовлене з кільця підшипника кочення, матеріал – сталь ШХ15, твердість основи становила HRC 61. На супорті змонтовано три пристрої для постійного змащення бігової доріжки безпосередньо перед зразком, який набігає. Цим, при певних значеннях тиску та швидкості, може досягатись режим граничного тертя, що відмічалось низьким показником коефіцієнта тертя.

Ключові слова: тертя, самовстановлення, зразок, знос, контактний тиск, змащування