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RATED AND EXPERIMENTAL MODELING OF TRIBOLOGICAL PROPERTIES OF CONSTRUCTIONAL AND LUBRICATING MATERIALS

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The theory of a test for depreciation scheme cone - three balls for two-factor model wear (contact pressure, sliding speed) determining the characteristics of the patterns of wear. Test method recommended for testing tribological properties of structural and lubricants.

Key words: experimental modeling, wear, contact pressure, sliding speed.

Introduction

Testing of tribological properties of the lubricants is one of the main stages to assess their suitability for use in friction units. The quality of the lubricant in this case can be evaluated basing on its operational properties, the most important of which are antifriction, antiwear and extreme pressure properties. The lubricating oil researches due to the new development are very important. The researches of lubricants on constructionaly simple machines with using the examples, which have simple geometric form, got the widest using. As examples can be used balls, cylinders, rectangular prisms, rolers. At the same time, the most widespread was the four-ball circuit testing [1]. Methods for fourballs friction machine are standardized and widely used in the whole world (GOST 9490-75, U.S. - ASTMD 2596, ASTMD 2783, in Germany - DIN 51350, Poland - PN - 76/C - 04147, in England - IP 300, Bulgaria - BDS 14150-77). According to GOST 9490-75 «Liquid and plastic lubricants. Method for determination of lubricant properties at fourroller machine defined by the following characteristics: wear indicator, the critical load, welding load, scoring index. In the modern conditions of machines exploitation, when the number of lubricants and additions to them increased greately, and also sphere of their using expanded the, previously mentioned indixes can not give a comprehensive description of lubricants tribological properties in all possible exploitation conditions. In particular, sliding speed factor becomes important, which is not taken into account during oil testing. Fourroller scheme has restrictions about constructive materials testings, because the balls are made of standard steel ball bearing. Production of ball samples for materials testing is practically unsuitable and difficultly implemented. In this work for testing of different constructional materials is proposed the scheme «cone - three balls», which makes it possible to use as subjects conic samples from various materials.

Basic material

Design model. Three balls 1, 2, 3 of equal radius (figure 1) R are located in the plane so that they are contacted by the scheme picture 1, at the same time their centers form an equilateral triangle $O_1O_2O_3$. Cone 4 with angle γ at the vertex is located on the three lower balls so that each contact with the points A_1, A_2, A_3. The upper cone applied force Q, which is transmitted to each of the three lower balls along the perpendicular from the cone generatrix at the points of contact of the balls, creating a level of force $Q_1 = Q_2 = Q_3$.

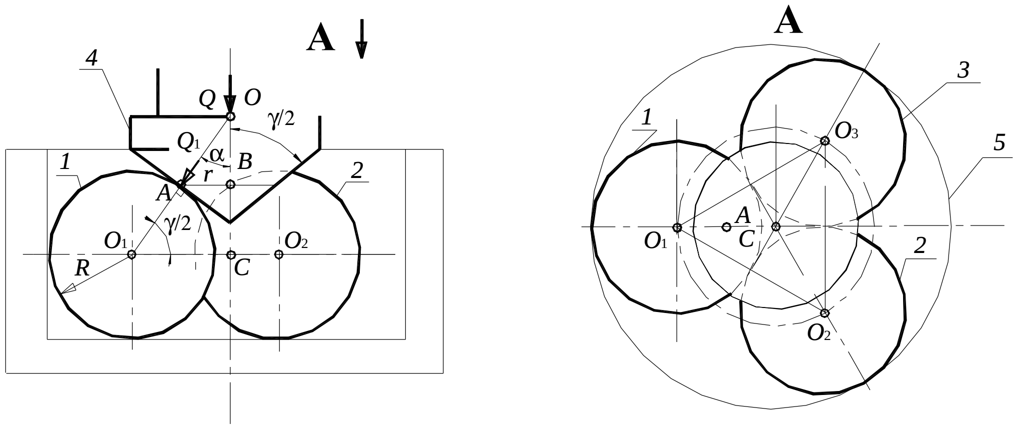

Fig. 1 - Diagram "cone - three balls"

Having holder 5 provides stable fixed position lower balls in vertical load force Q and the rotation point of the cone around a vertical axis.

Contact geometry and load

To determine the forces acting between the cones and balls, it is necessary to determine their direction and angle α (fig. 1):

$$\alpha = 90^{o} - \gamma / 2, \quad (1)$$

where γ – the angle at the vertex of the cone.

The forces acting along the normal to each ball, expressed in terms of the overall strength ratio:

$$Q_1 = \frac{Q}{3\cos\alpha} = \frac{Q}{3\cos(\gamma/2)}. \quad (2)$$

The value r that determines the distance from the axis of rotation of the cone to the point of contact with the balls, you determine the similarity of triangles OO_1C and OAB:

$$r = O_1C\frac{OA}{OO_1} = O_1C\left(1 - \frac{R}{OO_1}\right). \quad (3)$$

The value O_1C is the radius circle circumscribing the right triangle (fig. 1):

$$O_1C = \frac{2\sqrt{3}}{3}R.$$

From the right triangle OO_1C:

$$OO_1 = \frac{O_1C}{\cos\gamma/2} = \frac{2\sqrt{3}R}{3\cos\gamma/2}. \quad (4)$$

So after intermediate substitutions we obtain:

$$r = R\left(\frac{2\sqrt{3}}{3} - \cos(\gamma/2)\right). \quad (5)$$

Friction way

Assume that the size of the contact area balls small compared to the size of the contact area of the upper cone ($\bar{a} << r$). Calculation of friction path will carry for average radius.

Path of friction S for contact cone area:

$$S = 3(2\bar{a})nt. \quad (6)$$

where n – number of revolutions per unit time of the cone;
t – The duration of the test.
$\bar{a}$ – The average radius of the contact area of the cone and balls.

Wear model

To describe the process of wear, including the presence of a lubricant, it is used mathematical shapes patterns of wear. The pattern of wearing is established experimentally and approximated by some functions. The mostly widespread was disseminated presentation of experimental regularities as intensities wear of different parameters (contact pressure, sliding speed, temperature). To determine the parameters of the wear patterns the tests are made of samples with variable area contact during wear. During the tests on wear periodically or continuously sizes are measured of worn contact area according to the way of friction. According to test results is based approximating function. Based on the results of tests to determine the numerical values of model parameters wear wearcontact solved the inverse problem for the body contact appropriate configuration.

To assess the wear of the investigated sample scheme conical cone - three balls take as a model depending on the wear rate of the determining factors as:

$$\frac{du_W}{dS} = fK_W \left(\frac{\sigma}{HB}\right)^m \left(\frac{VR^*}{\nu}\right)^p, \tag{7}$$

where u_W - linear wear of the conical surface, m;

S - path to the friction cone, m;

f - coefficient of friction;

σ - contact pressure, MPa;

HB - hardness, MPa;

V - sliding speed, m/s;

R^* - кeduced radius of the contacting bodies, m;

ν - кinematic viscosity oils (at 100 °C), m2/s;

K_W, m, p - options patterns of wear.

We take the form of worn surface as a circular groove of radius profile $\bar{a}$. Assume that the contact pressure under tight ball on the worn surface of the groove cone distributed evenly. Then rightly value:

$$\sigma = \frac{Q_1}{\pi \bar{a}^2}. \tag{8}$$

Relationship of maximum wear u_W and size of contact $\bar{a}$ center platform area is defined be the geometry of crossing conjugate cone and balls. In this case, we consider the scope of radio R contact with the cylinder radius catfish r. With sufficient accuracy desired dependence can be represented as [2]:

$$u_W(S) = \frac{a(S)^2}{2R^*}, \tag{9}$$

where $R^* = \dfrac{Rr}{R+r}$ - given the radius of the cone and ball contact.

Let the experimental dependence of the radius of the circular groove wear the cone of friction path is represented as a power - law approximation:

$$\bar{a}(S) = cS^{\beta}, \tag{10}$$

where c, β – approximation parameters, which are determined based on the results of tests.

Integrating equation (7), we obtain the integral form of the model wearing the cone:

$$u_W(S) = fK_W \int_0^S \left(\frac{\sigma(S)}{HB}\right)^m \left(\frac{VR^*}{\nu}\right)^p dS. \tag{11}$$

Substituting the left side of an equation, expression (9) for wear due to the radius of the contact area and to the right – the expression (13) for the contact pressure, we obtain:

$$\frac{\bar{a}^2(S)}{2R^*} = fK_W \int_0^S \left[\left(\frac{Q_1}{\pi \bar{a}^2(S)}\right)\frac{1}{HB}\right]^m \left(\frac{VR^*}{\nu}\right)^p dS, \tag{12}$$

or, in view of (8), after integration by way of friction we get:

$$\frac{c^2 S^{2\beta}}{2R^*} = fK_W \left(\frac{Q_1}{c^2 \pi HB}\right)^m \left(\frac{VR^*}{\nu}\right)^p \frac{S^{1-2\beta m}}{1-2\beta m}. \tag{13}$$

From the feasibility conditions of (13) for any S follow:

$$2\beta = 1 - 2\beta m. \tag{14}$$

Where:

$$m = \frac{1-2\beta}{2\beta}. \tag{15}$$

To find the parameter p conduct testing at two values of the speed slipping V_1 and V_2, where we get data from two groups of parameters:

$$\bar{a}_1 = c_1 S^{\beta};$$
$$\bar{a}_2 = c_2 S^{\beta}. \quad (16)$$

Substituting (16) into (13) , we obtain two equations:

$$\left.\begin{aligned} \frac{c_1^{\,2}\beta}{R^*} &= fK_W \left(\frac{Q_1}{c_1^{\,2}\pi HB}\right)^m \left(\frac{V_1 R^*}{\nu}\right)^p; \\ \frac{c_2^{\,2}\beta}{R^*} &= fK_W \left(\frac{Q_1}{c_2^{\,2}\pi HB}\right)^m \left(\frac{V_2 R^*}{\nu}\right)^p. \end{aligned}\right\} \quad (17)$$

Dividing the first equation into the second, after transformations we obtain:

$$(c_1 / c_2)^{2m+2} = (V_1 / V_2)^p. \quad (18)$$

Where

$$p = (2m+2)\frac{\lg(c_1 / c_2)}{\lg(V_1 / V_2)}. \quad (19)$$

To find the coefficient K_W we use one of the equations (17):

$$K_W = \frac{\beta c_1^{\,2m+2}}{fR^*}\left(\frac{3\pi HB\cos\alpha}{Q}\right)^m \left(\frac{\nu}{V_1 R^*}\right)^p. \quad (20)$$

The geometric dimensions of the cones for testing may be taken with materials GOST 23.221-84 [3]. Specified Standard specifies a method for experimental determination of temperature -term stability of liquid and plastic lubricants in friction -based friction torque measurement and bulk temperature.

Conclusion

The theory of a test for depreciation scheme cone - three balls for two-factor model wear (contact pressure, sliding speed) determining the characteristics of the patterns of wear. Test method recommended for testing tribological properties of structural and lubricants.

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Диха О.В., Гедзюк Т.В. **Розрахунково - експериментальне моделювання трибологічних властивостей конструкційних і мастильних матеріалів**

Розроблена теорія методу випробувань на знос за схемою конус-три кульки для двохфакторної моделі зношування (контактний тиск, швидкість ковзання) з визначенням характеристик закономірності зношування. Метод випробувань рекомендований для випробувань трибологічних властивостей конструкційних і мастильних матеріалів.

Ключові слова: експериментальні моделі, знос, контактний тиск, швидкість ковзання