A MICRO-ABRASIVE WEAR TEST FOR TWO LAYERS COATED SYSTEMS

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ABSTRACT: *We have prepared a new method for determination next 3 coefficients: K_1 (substrate), K_2 and K_3 for two layer coatings by using Calo-test method. This method is important because of: 1° first coating has good adhesion and second one has extreme hardness. This combination has very small abrasive coefficients K_2, K_3, and tools with two coating can work effectively for a long period. 2° Calo-test is a very simple and not expensive and the test determine coating thickness. In this determination of thickness, tool is damaged very little and it can be used after test. At the end, presented method gives opportunity for further generalization – determination of mechanical properties (micro-abrasive wear coefficients K_1, K_2, K_3, K_4,...) for substrate with more than two coatings.*

Keywords: abrasion/wear coefficients/substrate/two coatings

1. INTRODUCTION:

During the cutting operation, the HSS tools are exposed to extremely large mechanical and temperature stresses. The theoretical and practical importance analised the HSS tools with protective coatings is great becouse: 1) selection of suitable material and the geometry of the tools. 2) selection of the type of hard coating and its distrbution aiming to improve mechanical characteristics of the main adge. 3) selection of the cutting speed and the type of cooler. Special tools intended for the harder working condition coldn't work for succesfully with hard layers, and in this case the solution mast be found in appllaying the superhard coatings. The main quality of this layers are hardness about 3000 HV (and more). Diamond coatings have the highest hardness, but this surface layers are convenient only for coating the materials without Fe. For creation the tools with a good wear resitance (maybe) the soulution must by found in appllaying two layers coated systems. An investigation of hard coating micro-abrasive wear resistance by using Calo-test method is presented by two authors K.L. Rutherford, I.M. Hutchings, Surface and Coating Technology 79 (1996) 231-239. In that work authors have presented a new method for analyze and determination of two abrasive wear coefficients: K_C (coating) and K_S (substrate). The method can not be used for substrate with two coatings.

2. EXPERIMENTAL:

Mechanical properties for 3 materials: K_1 (substrate) and K_2, K_3 (two coatings) can be determined by virtue of 3 sinple Calo-tests (3 small calottes a ≈ (2 ÷ 3) mm diameter and h = 0,04mm height). Calo-test uses WC ball, with diameter 2R = 25mm and diamond paste (1 μm).

On the fig 1. we see calo-test experiment with a diamond paste (1 μm) was applied as the abrasive medium. The diameter of rotating ball (WC) D=2R=25mm. with a constant tangential velocity of up tu 0.5 m/s = Rω.

3. RESULTS AND DISCUSSION:

Calo-test method was usually used for thichkness measurement as a simple, easy and not expensive technique. In this investigation calo-test method was used as abrasive wear test. This method was successfully appllied for determining wear coefficients: K_s (substrate) and K_c (coating) [1]. In our paper we are propose theoretical model for determining the wear coefficients for substrate and two coatings with thickness about (2÷5) μm.

If the ball wearing only coating 3°, then is according to paper [1]

$$F S_3(\delta_3) = V_3^C(\delta_3) / k_3 \qquad A \qquad (1)$$

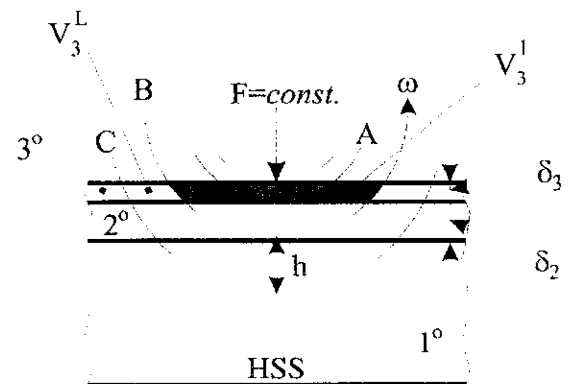

Fig. 1. The Calo test with WC ball

where are: F-normal force, $S_3(\delta_3)$-wearing way of coating 3°, $V_3^C(\delta_3)$-wear volume of calotte 3° thickness δ_3, k_3-wear coefficient of coating 3°.

If the wearing process are continue then must be satisfy a conditions: $F = F_2^{'} + F_3^{'} = const.$, $S_2(\delta_2) = S_2(\delta_3)$

$$F_2^{'} S_2(\delta_2) = V_2^C(\delta_2) / k_2 \qquad \text{B} \qquad (2)$$

$$F_3^{'} S_2(\delta_2) = [V_3^l(\delta_3) - V_3^C(\delta_3)] / k_3 \qquad \text{B} \qquad (3)$$

where are: $V_2^C(\delta_2)$ wearing volume of calotte 2° thickness δ_2 B, $V_3^l(\delta_3)$ wearing volume of layer 3° thickness δ_3 – B.
With addition (2) and (3) we obtain

$$F\cdot S(\delta_2 \,\&\, \delta_3) = V_2^C(\delta_2) / k_2 + V_3^l(\delta_3) / k_3 \qquad (4)$$

In the paper [1] we may see a similar expression. Authors K.L. Rutherford and I.M. Hutchings was using equation (4) for determining wear coefficients k_1 and k_2. However its method is not possibly using for two layers. Because that, we are going on a second way. We are continue the process wearing as C. Then must be satisfy a conditions: $F = F_1 + F_2 + F_3 = const.$, $S_1(h) + S_2(\delta_2) + S_3(\delta_3) = S(h \,\&\, \delta_2 \,\&\, \delta_3)$. $S_1(h) = S_1(\delta_2) = S_1(\delta_3) = S_1$.

$$F_1 S_1(h) = V_1^C(h) / k_1 \qquad 1° \qquad \text{C} \qquad (5)$$

$$F_2 S_1(h) = [V_2^L(\delta_2) - V_2^C(\delta_2)] / k_2 \qquad 2° \qquad \text{C} \qquad (6)$$

$$F_3 S_1(h) = [V_3^L(\delta_3) - V_3^l(\delta_3)] / k_3 \qquad 3° \qquad \text{C} \qquad (7)$$

Addition (5), (6) and (7) we obtain:

$$F\cdot S(h \,\&\, \delta_2 \,\&\, \delta_3) = \frac{V_1^C(h)}{k_1} + \frac{V_2^L(\delta_2)}{k_2} + \frac{V_3^L(\delta_3)}{k_3} \qquad (8)$$

$$x = V_1 / FS, \quad y = V_2 / FS, \quad z = V_3 / FS$$

$$\frac{x}{k_1} + \frac{y}{k_2} + \frac{z}{k_3} = 1 \qquad (9)$$

Now there is a necessary 3 experiments (minimum) for obtaing $M_1(x_1, y_1, z_1)$, $M_2(x_2, y_2, z_2)$, $M_3(x_3, y_3, z_3)$.
On the fig.2. we see a plain with three coefficients k_1, k_2, k_3.

$$\begin{vmatrix} x_1 & y_1 & z_1 & 1 \\ x_2 & y_2 & z_2 & 1 \\ x_3 & y_3 & z_3 & 1 \\ x & y & z & 1 \end{vmatrix} = Ax + By + Cz + D = 0 \qquad (10)$$

$$k_1 = -D / A, \qquad k_2 = -D / B, \qquad k_3 = -D / C, \qquad (11)$$

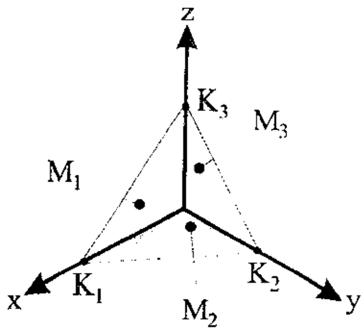

Fig. 2. The plain $\Pi \ni [M_1, M_2, M_3]$ with the three coefficients k_1, k_2, k_3

4. CONCLUSION

For determining 3 wear coefficients k_1(substrate 1°), k_2(coating 2°), k_3(coating 3°) we may using calo-test method. The main equations are (8), (9), (10) and (11), where F = const., S - a total wear way, and V_1, V_2, V_3 are a wearing volume substrate 1°, coating 2°, and coating 3°. Equations (8), (9), (10) and (11) are using with minimum 3 experiments (or more). Then we obtain 3 points (or more) $M_i(x_i, y_i, z_i)$, i=1, 2, 3. $[M_1, M_2, M_3] \in \pi$ - fig.2. The plain π have a tree segments: k_1 on the axis x, k_2 on the axis y and k_3 on the axis z. This segments are determining with equations (10) and (11). At the end, presented method gives opportunity for further generalization determination of mechanical properties (micro-abrasive wear coefficients k_1, k_2, ... , k_n) for substrate with more than two coatings.

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