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EXPERIMENTAL MODEL FOR STUDYING THE TENSION IN CONTACT AREA OF CERAMIC BEARINGS

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Abstract: *This paper presents the qualitative and quantitative aspects of the phenomenon regarding the contact area by applying the concepts of the breaking mechanics in the case of the ceramic tribosystem contact which stimulates more precisely the ceramic bearings.*
Key words: *alumina, breaking mechanics, ceramic bearings*

1. INTRODUCTION

As a result of recent technological progress, the environments and conditions under which rolling bearings (hereafter referred to as bearings) are used and becoming severe and diverse (Takebayashi, 2001). As a result, many industrial customers want to get bearings that can be used in these special environments or under such severe conditions. The applicability of all types of ceramic materials for ceramic bearings for example of silicon nitride (Si_3N_4), zirconium oxide (ZrO_2), silicon carbide (SiC) and aluminium oxide (Al_2O_3) was discussed in international references (Fujiwara et al, 2001).

This paper well focuses an alumina, which shows characteristics of being the most superior bearings material amongst various ceramic materials, and will present its basic performance for application to bearings. Specifically, such subjects as static load carrying capacity, rolling contact fatigue life, influence affecting the life of surface scratches and flaking will be discussed.

2. ALUMINIUM OXIDE MATERIALS (Al_2O_3)

2.1 Characteristics

Table 1 shows a comparison of the characteristic of aluminum oxide and high carbon chromium bearing steel.

Alumina has approximately 35-40% of the density approximately 1.8 times the Young's modulus and approximately 17 % of the linear expansion coefficient of bearing steel. Moreover. it can be seen that the value of the fracture toughness of alumina is small in comparison in that of high carbon chromium bearing steel, this means alumina is a brittle material.

Test material / item	alumina	High carbon steel
density (g/cm^3)	3.9	7.87
Hardness HV	1470	740
Young's modulus MPa	38 x 10^4	20.5 x 10^4
Poisson's ratio	0.23	0.28
Bending strength MPa	379	540
Linear expansion coefficient. 1/^{0}C	7.1 x 10^{-6}	11.8 x 10^{-6}
Fracture toughness MPam$^{1/2}$	Aprox 4.8	Aprox 20

Tab. 1. Comparison of characteristics between alumina and high carbon chromium bearing steel

3. HERTZIAN CONTACT AREA – CURVE SURFACES

Two bodies, from isotropic and homogenous materials edged by curved surfaces, before the deformation, they meet in a point. Both bodies are pressed by conducted forces on the line that joins the curving centers of the surfaces in their tangential point.

The edging surfaces of the bodies could be approximately described through second degree polynomials in x' and y'.(Popinceanu, 1985)

$$z_i = A_i x'^2 + B_i y'^2 + C_i x' y' \quad (1)$$

with i = 1,2 for body 1 and 2; also we have:

$$z_1 = \frac{1}{2R_1^*} x_1^2 + \frac{1}{2R_1^{**}} y_1^2; \quad z_2 = -\left(\frac{1}{2R_2^*} x_2^2 + \frac{1}{2R_2^{**}} y_2^2 \right) \quad (2)$$

$R_i^*, R_i^{**}, i = 1,2$ are the main curved radiuses of the bodies in the origin point

The distance $h = z_1 - z_2$. From (1) and $h = z_1 - z_2$ we have:

$$h = Ax^2 + By^2 = \frac{1}{2R^*} x^2 + \frac{1}{2R^{**}} y^2 \quad (3)$$

h being a positive measure, A and B are positive (Popinceanu, 1985)

Equation (3) represents the geometrical place of the surfacing points being in contact at the h distance one from another.The profile of the contact surface is an ellipse. Adding and deducting terms with terms we obtain:

$$(A + B) = \frac{1}{2}\left(\frac{1}{R^*} + \frac{1}{R^{**}} \right) = \frac{1}{2}\left(\frac{1}{R_1^*} + \frac{1}{R_1^{**}} + \frac{1}{R_2^*} + \frac{1}{R_2^{**}} \right) \quad (4)$$

$$|B - A| = \frac{1}{2}\left[\left(\frac{1}{R_1^*} - \frac{1}{R_1^{**}} \right)^2 + \left(\frac{1}{R_2^*} - \frac{1}{R_2^{**}} \right)^2 + 2\left(\frac{1}{R_1^*} - \frac{1}{R_1^{**}} \right)\left(\frac{1}{R_2^*} - \frac{1}{R_2^{**}} \right)\cos 2\alpha \right]^{\frac{1}{2}}$$

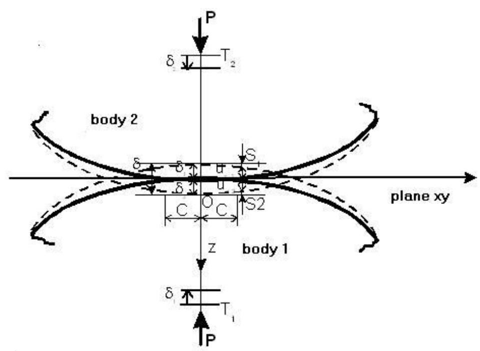

Fig. 1.Geometry of Hertzian contact area

$$u_{z1} + u_{z2} + h = \delta_1 + \delta_2 \quad (5)$$

The relation (5) between the bodies, the elastically deformations $u_{z1,2}$ of two points from the surfaces which are in contact and the distance h, represent the equation of the movement in the contact problem considered above.

From the relation (3) and $\delta_1 + \delta_2 = \delta$ results:

$$u_{z1} + u_{z2} = \delta - (Ax^2 + By^2) \quad (6)$$

If S_1 and S_2 (fig. 1) are two points outside the contact area, then the following relation stands (Richerson, 2004):

$$u_{z1} + u_{z2} < \delta - Ax^2 By^2 \quad (7)$$

In this paper we will always take into consideration a contact between bodies from identical material, such as alumina 99,8%. The elasto-theorethical problem is defined thereby: we search the normal strength distribution P(x,y), acting on the contact area, which inside the contact area satisfies the relation (6), and outside, relation (7).

4. THE EXPERIMENTAL MODEL FOR CERAMIC CONTACT BALL/RING

For the experimental determination of the loading capacity of the ceramic bearings it is statically applied the ring/ball coupling. The rolling rings are cut from ceramic bushings with 46 mm diameter, in which the rolling ways R_k were processed. The R_k value it is chosen so it assures an adaptability coefficient S between 1,02-1,06.(Rich, 2004)

To determine the contacts' strengths which appear in the elliptical contact area we took into consideration the fact that they depend on the adaptability coefficient S between R_k and R_B. We follow to determine the way S influence the strengths from the hertzian contact area.

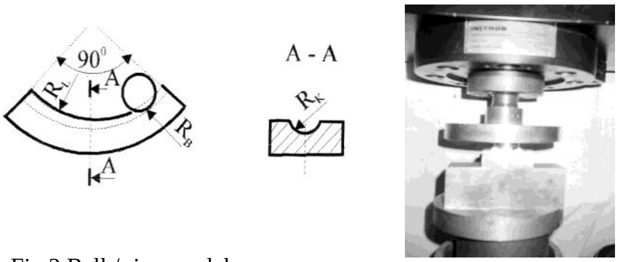

Fig.2 Ball / ring model

5. RESULTS

In this model the ceramic rings are applied in more points with a force P. After each testing the possible cracks are verified with the optical microscope. The force P increases with dP=500 N. At a big value of the force, the cracks appear at the edge of the contact ellipse as it is shown in fig.3. The cracks don't appear around the contact area.

A large number of experimental tests were carried out in order to establish the probability of forming cracks depending on the force that is applied for a ball radius of 3 mm. The medium crack force for which 50% of tests cracked was determined around the value of 7800 N (for model R_B=3 mm and S=1,06).

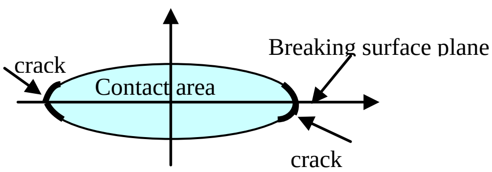

Fig. 3. Cracking initialization

Depending on the force applied, the probability of forming cracks is presented in fig. 4.

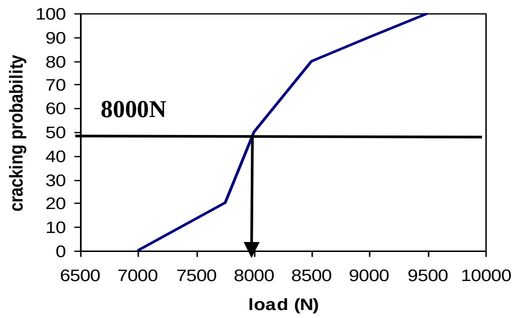

Fig.4. Cracking probability

To determine the contact pressures and the tensions in the contact area we used the following data: ball radius R_B = 3mm; rolling ways radius R_K = 3,18 and 3,06 mm; ring radius R_L = 23mm and adaptability coefficient S = 1,06 respectively 1,02. We can observe the increase of pressure together with the increase of S; also in fig.5 we can observe the maximum values of the tensions in points A and B.

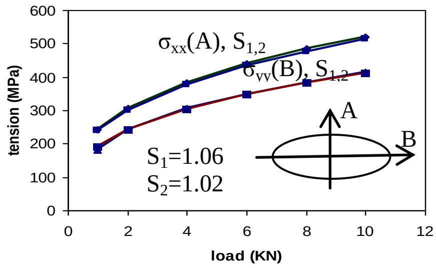

Fig 5. Tension value

6. CONCLUSION

Achieving the experimental model ring/ceramic ball comes closer to the ceramic radial bearings. With this model it was determined the carrying capacity of the ceramic bearing model. In order to determine the contact tensions which appear in the elliptical contact area we took into the consideration the fact that they depend on the adaptability coefficient S determining therewith the way in which S influences the contact tensions from the hertzian contact area.

The results obtained create the premises of the breaking mechanics involment in the case of the ceramic materials study inside the pressure contact study. Also, we will follow the contact phenomenon in applications concerning geometrical and complex tension stages, by implementing inside the mechanical structures intelligent systems, which can assure in every moment informations regarding the stage of tensions and also the degree of fatigue.

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