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EVALUATION OF DEFORMATION OF CONTACTS BETWEEN ROLLING BODIES AND THE WAYS OF ROLLING BEARINGS

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Abstract: *The paper presents aspects of the relative movement of the cinematic ways of rolling bearings and rolling bodies, how to generate waves of global deformation response during contact between them. The paper presents the destructive effects of the wave of global deformation response over the quality of the surfaces of these components.*
Key words: *bearings, surface contact, deformation, degradation*

1. General

Indisputable ball bearing advantages compared with sliding bearings currently makes, by some estimates, about 90% of buildings to be with rolling bearings. If the processing technology can achieve outstanding performance of accuracy and surface quality execution, we can observe large differences in their behavior in service. Experimental studies of failures show that validaty of theoretical determinations depends very much on how to exploit them from transporting, storing them reaching problems tenice specific guidance on handling and mounting their compliance with the conditions on site, using technologies and suitable devices and recommended the Enforce-recommendations on the types and qualities of lubricants used and how lubrication and sealing, etc .. the sensitivity of these machine parts according to usage is illustrated by the multitude of conditions that must be followed in choosing the best solution depending on size and direction tasks, type bearing of the speed and temperature, the accuracy of rotation and noise conditions imposed by misalignment of the camp, the role of the overall (fixed bearing or bearing free) solution for securing and axial adjustment and the method of compensation of thermal expansions of the parts to be joined with them.

The paper tries to explain some of these features related to behavior in exploitation by assessing the state of deformation of the rolling element and raceway contact area mechanic.

2. The state of deformation of the rolling elements and driveway in area of mechanic contact.

In Figure 1, it is considered the case of a radial ball bearing having a fixed inner ring and the outer ring rotates with the angular velocity ωe, and the balls with ωball. Due to specific characteristics of the materials of which the bearings are made, very high hardness and reduced elasticity, results that the surfaces of the rolling elements and driveway made on the rings surfaces suffer elastic deformations or in case of overloads even plastic deformations. These deformations are in the form of waves of deformation.

In the case of ball bearings used for static loads, (with relative motion of small scale (n <10 rpm) and very low frequency, or when during rotation they must absorb large shocks for short time) is considered as the limit of the maximun force on the ball, [CRB] called basic static load noted by C_{or} indicated in catalogs for ball bearings for each bearing size, the value of force causing a deformation as a permanent deformation on the rolling ways of 0.0001 of rolling body diameter. This force will be purely radial, for radial ball bearings and pure axial thrust ball bearings. Basic static force is calculated according to ISO 76. In this case the safety of operation is determined by the size of the deformations of the rolling way of the ball bearing.

Due to this, this work tackles the aspects connected to deformation in the contact zone, even if by value the dimensions of these waves of deformation are very small compared to the dimensions of bodies which are in contact.

Because of the ball's elasticity, under the influence of the radial force F, the object in question suffers an ovallization. In accordance with fig.1, in the direction of the force action the ball radially compresses up and down with Δr, respectively a radial dilation with Δr in the plane perpendiuclar to the direction of the force through the center of the ball. These deformations can be considered of comparable dimensions. In the direction of the F force, a supplementary deformation can be observed following the real equillibrium profile between the ball's surfaces and the two rolling paths with Δr_i, of the inner ring, respectively with Δr_e of the outer ring. Due to these deformations, considering the supplementary deformation of the ball to be negligible, that wave of deformation is generated in the time of movement in the contact state of smaller dimensions than the wave relaxing one, that follows the contact of the two bodies. Because the inner ring is fixated, the point of maximum load is also fixated, having maximum wear. The second contact, between the rolling bodies and the outer ring is a stable contact. At

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the same time, the value of the contact force rises from 0, at the maximum value described in fig 2, and then decreases to 0 on the opposite side. The state of tension throughout the contact is given following the findings made by the author, during the Resistance Laboratory from ANMB through photoelasticity, using the polariscope (fig.2)
It is obvious that these loads and deformations of the bearings, in the case of a stationary working regime (e.g. bearings from a diesel generator of a ship when the current consumption is constant) generates a stress on the superficial coating of the surfaces which are in contact periodically, due to the high number of cicles and respectively to the long periods of work time.
In accordance to fig.1, the wave of deformation on the outer ring obviously produces a radial dilation in space of the two surfaces of the ring as well as the of the balls to the very same surfaces in the time in which they are not in contact. The same observation is valid for the contact between the fixated inner ring and the ball bearing.

Conclusions

The above analysis proves that during the time of contact between the rolling bodies and their roll paths deformations appear, which in some cases can only be in the elastical domain. In the case of flawed evaluation or due to the temporary appearance of overloads, the continuous or periodic deformations can be in the plastic domain.
After the deformation of the superficial layer through dilation, within the layer normal tensions on the surfaces in contact are generated, which due to very high durity of bearing materials, will generate micro-fissures of nanometric dimensions. These wil represent the primers for future degradation of the respective surfaces. So, after compressing the surfaces following contact, during the forming of the deformation wave, when the superficial layer dilates (fig.1) in these micro-fissures lubricant from the lubrifying film which covers the surfaces of direct contact will seep in. Afterward, during the contact between the ball and the roll path, the formed micro-fissures absorb oil due to the dilation of the superficial layer of the surfaces which will come into contact. During the contact, micro-fissures from the two surfaces close eachother up. This way, during the compressing of the superficial layer of surfaces in contact, the lubricants inside the micro-fissures, being incompressible, will be subjected to very high instantaneous pressures. The lubricants will penetrate the base material's structure after the principle of minmal resistance, on different directions in space.
The micro-fissures are going to grow in size inside the duperficial layer as well as in the bodies mass. Obviously as the relative speed of contact is higher the duration of eliminating the lubricant decreases and the advancement phenomenon of the micro-fissures grows. In time, due to the high number of cicles that the surfaces are subjected to, the micro-fissures expand. During this expansion, a part of them can fuse in a way in which the very small particles dettach form the superficial layer of the respective surfaces. As an effect, the deterioration of the surface quality takes place, the phenomenon being called pitting.
The phenomenon advances in time,being visible to the naked eye through the disappearance of the metallic luster specific to the finished surfaces of bearings. Another defect is the amplification of the noise made by these bearigs while working.
Furthermore, the particles having an increased hardness, due to hardening following elasto-plastic deformations, if they are not filtered, an increase of surface destruction by abrasive wear will be generated. Overlapping of the two destructive phenomena can lead to an accelerated degradation of the bearing, fact confirmed by experimental research.
At the same time, during contact, a spatial state of tensions and deformations within the mass of the two bodies in contact is generated. Due to deformation by compression with different gradients throughout the depth of the material in the contact zone(fig.2), these gradients with different values in space, can generate shear tensions τ, which will produce micro-fissures between layers. In time these will develope under the aspect of surfaces of approximately plane form, parallel to the body surface. Adding the effect of lubricant film seeping, separations of very thin layers will be generated. The phenomenon that appears in practice is called exfoliation. With respect to the material's properties of the two bodies in contact as well as the exploitation regime the effect will be categorised depending on:

- The magnitude and the time variation manner of the net load;
- The existance of stress shocks;
- The surface dimensions and shapes in contact;
- The relative velocities of the bodies;
- The level and manner of lubrication;
- The running period of fatigue conditions;
- Termic conditions,etc.

This evaluation example of contact between the rolling pieces of bearings and the role paths is very useful for analysing the causesforwhich the reliability of these machine elements can be different from one case to another. This imposes the detailed knowledge of the conservation, transport, storage, the technology and

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aparatus used, lubricating condition, lubricant quality, termic regime and load dynamics particularities. Further we have a few examples.

Uses

In fig.3[URB] we have a case of a ball bearing’s inner ring, the surface of which has been initially degraded by pitting and continued through equally assigned exfoliations with the pitch between the roles. The trapezoidal shape is the maximal dimension of the local ring surface degradation. The rest of the damaged surfaces of approximate isosceles triangle shape have regressed heights. These show that while running the ring’s deviation from perpendicularity off its theoretical axis was sufficiently large. The periodicity of these defects may be specific to the regular vibration aplications which resonate with the roll’s rotation frequency, or by installing shock loads which through their influences following a lasting contact, represent the primers for future defects. In the case analysis the dimensional and placement asymmetries indicate the cause to be faulty mounting, or the deformation of the axis or construction, combined with a periodic variable load. In absence of the variable load the degradation would have been uniform on the entire length of the circle arch. So, due to the deviation from perpendicularity, with the rolls passing through this area an overload appears because of the distance reduction between the roll paths. Due to the oscillating loads, having a certain frequency, at the passing of each roll through the degraded points, a supplementary load appears which generates a deformation wave which, because of the fatigue phenomenon, initiates at the rolling path border beginning the pitting phenomenon followed by the exfoliation. An argument which confirms the variable load as being the main cause is the fact that with the removal of „excess” material the surface damage advances towards the interior of the ring and not radially inward.

Fig.3

Another example fig.4 [URB] is that of the cylindrical rolls of a radial bearing (different from the one in fig.3). The exterior cylindrical surface has suffered a degradation by pitting. A very homogenous degradation can be observed on the roll’s circumference. This shows an exploitation regime with a stress that is constant and uniform in time. Instead, along the rolls height a much more pronounced degradation can be seen on the upper part, which tends to zero on the lower region. We can conclude that at the base of this phenomenon sits a deviation from perpendicularity during the run time that is larger than the standard,or the constant deformation of the shaft subjected to a uniform load due to it’s flexibility. The manner of disperion of the surface erosion described above proves that the overload had values just above normal, the deformation wave had values close to normal. If the distribution of erosion on height was uniform we could talk about normal wear. Obviously this deviation reduced the life span of the bearing in question.

Fig.4

An eloquent example referring to the deforming wave model used for interpreting the erosion contact surfaces belonging to bearing components is showed in fig. 5. An erosion through plastic deformation of the roll paths surfaces of an oscillating cylinder roll bearing, with two rows of rolls can be spotted.

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Fig.5

The resulting deformation shows that the bearing was highly undersized. The bearing was used with a bearing housing with a alternating rotational movement having a small and constant rotation angle. It is possible that the bearing housing once belonged to a large mass production machine in which the bearing housing had a single movement. The change in color of the ring’s material can indicate a high working termic regime which made the superficial layers erosion impossible as in the case described earlier. The surface’s erosion shape clearly shows the forming of the deformation wave, which has been accentuated at every turn. The unquestionable quality of the eroded surfaces, the absence of any erosion in the superficial layer proves that the movement was also very slow. This in turn has allowed a plastic deformation devoid of structural damage and avoiding hardening of the superficial layer. It is possible that the working termic regime assures the elasticity and most of all the plasticity of the respective layer.

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