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A Review Paper On Fatigue Life Analysis And Its Improvement Of 4-Row Cylindrical Roller Bearing Used In Hot Rolling Mill

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Abstract
Cylindrical roller bearings with Deep end-cavity rollers are advantageous in applications where load and speed are major considerations in the operations of the bearings. An improvement in load distribution and thus load capacity may be realized, as well as contact stress is also reduced considerably by using a bearing with Deep end-cavity rollers. This bearing is basically used in rolling mill where heavy load is applied on bearing.
Deep end-cavity roller is proposed for rolling mill bearings with a view to reducing the contact stress distribution for life improvement. Deep end-cavity rollers are one of the advanced concept used to eliminate the sharp edge-stresses at the apexes of the roller. The main objective of this work is to enlighten the engineers to make use of deep end-cavity rollers to increase load carrying capacity and improvement of fatigue life.
Keywords: *Roll neck bearings, Cylindrical roller bearing, Deep end-cavity roller, Contact stress, Rolling contact fatigue (RCF), Fatigue life Etc.***.**

1. Introduction

Rolling is defined as a process in which metal is formed through a pair of revolving rolls with plain or grooved barrels. The metal changes its shape gradually during the period in which it is in contact with the two rolls. Rolling is a major and a most widely used mechanical working technique. A Rolling mill is a complex machine for deforming metal in rotary rolls and performing auxiliary operations such as transportation of stock to rolls, disposal after rolling, cutting, cooling, melting. Rolling mills are generally classified according to their product or their layout or temperature and are specified by the number of rolls in each stand. There are two types of rolling mill On The Basis of Temperature. 1) Hot Rolling: Rolling of metal is carried out at temperature above the recrystalization temperature. For example: Roughing, billet, merchant and tube rolling mills. 2) Cold Rolling: Rolling of metal is carried out at temperature below the recrystalization temperature. For example: Sheet and tube rolling mills.

1.1 Roll neck Bearings

In Rolling mills, Bearings are used depending upon the applications. Bearings used in Rolling mill are Spherical roller bearing, Cylindrical roller bearing, Thrust roller bearing and Tapered roller bearing. For Hot rolling mill, Now we are focusing on the Spherical roller bearing and Cylindrical roller bearing because of Special applications of rolling mill. In rolling mills, as shown in fig.1 (a) spherical roller bearings are mainly used for low-speed roll neck applications without special demands on axial guiding accuracy. As the mounting space is limited in radial direction, preference is usually given to spherical roller bearings. Spherical roller bearings are self-aligning; they can accommodate radial and axial loads. Since their axial clearance is four to six times their radial clearance, their axial guiding accuracy is moderate. Spherical roller bearings can be used for low and medium speeds.[8]

Fig. 1(a) 2-row Spherical roller bearing (b) 4-row Cylindrical roller bearing.[9]

Within a given mounting space cylindrical roller bearings offer the greatest load carrying capacity. Consequently, this bearing type is suitable for the highest radial loads and owing to its low friction coefficient for the highest speeds. Different types of cylindrical roller bearings are used for roll neck support. Cylindrical roller bearings as shown in above fig. 1(b) are used generally in fine -section and wire mills. They feature machined brass or steel cages. They are not only suitable for high speeds (up to 40 m/s), but they can also accommodate high loads. The finishing sections of such mills operating at rolling speeds of up to 100 m/s and more handle one single strand.[8]

2. Contact Mechanics for Roll neck Bearings

According to the contact area shape, there are point contact and line contact. It is obvious that after load applied line contact will become rectangle contact and point contact will be an ellipse contact area. Fig. 2 shows us the contact area type. For the bearing, initially the point contact happens between the ball and raceways under no external load. After the load displacement or force is applied, the point will become an area contact. In the numerical formulation, there are two groups of contact: point-surface contact and surface-surface contact. [6]

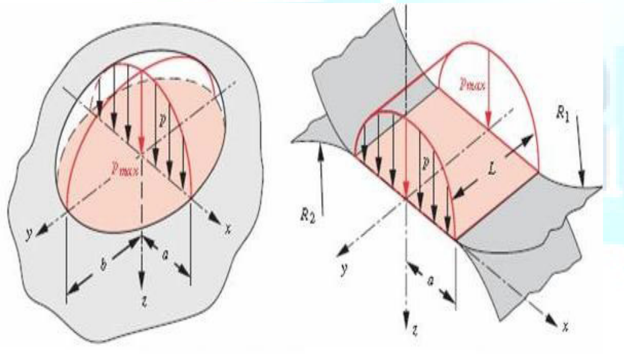

Fig. 2 Contact zones for Spherical, cylindrical and general Hertzian Contact.[6]

2.1 Equations used for Calculation of Hertz contact Stress for Line Contact

Following equation shows the calculation of the half width of the contact area. In the case of cylindrical contact we call this half with "b" instead of "a" as in the spherical equations. The extra length component allows for a larger contact area reducing the resultant stresses. Unlike the spherical contact equations the principle stresses do not always equal the normal stress components. There is a distance below the surface were the principle stresses reverse[1]. The equations for calculating all the principle and normal stress of the material a distance "z" away from the surface.[6]

Equation for the half width of the contact area of two cylinders.

$$b = [2F/\pi l*[\{\{(1-\mu_1^2)\}/E_1+ \{(1- \mu_2^2))\}/E_2\}/(1/d_1) + (1/d_2)]]^{1/2} \quad (1)$$

Maximum pressure within the contact area.

$$P_{(max.)} = 2F/\pi bl \quad (2)$$

Principle stresses along the Z axis.

$$\sigma_x= \sigma_1 = -2\mu[P_{(max.)}]*[1+z^2/b^2-|z/b|]^{1/2} \quad (3)$$

$$\sigma_y= \sigma_2 = - P_{(max.)} / [\{(1+2* z^2/b^2) / (1+ z^2/b^2)^{1/2}\}-2|z/b|] \quad (4)$$

$$\sigma_z= \sigma_3 = - P_{(max.)} / [(1+z^2/b^2)]^{1/2} \quad (5)$$

Maximum Shear Stress.

$$\tau_{max} = \sigma_1- \sigma_3/2 \qquad \text{For } 0\leq z \leq 0.436b \quad (6)$$

The equations[7] above lend themselves well to sanity checks of finite element analysis. With a full understanding of the contact stresses present in the system, an analysis must be made of the failure modes. The first thing to look at is the maximum compressive stress versus the compressive strength, of the materials. If the maximum compressive stress exceeds the compressive strength plastic deformation of the part will occur. The basic Hertzian equations focus mainly on compressive stress.

3. Contact-Stress Distributions for Roll neck Bearings:

A major objective has been to decrease the contact stresses at the roller–raceway interfaces, because these are the most heavily stressed areas in a bearing. It has been shown that bearing life is inversely proportional to the stress raised to the ninth power (even higher). For this reason significant efforts have been made to qualify contact stresses in the bearings. The reduction of the contact stresses has been achieved largely by designing the specific surface geometry of the roller–raceway contacts[2], because the contact-surface geometry has a direct effect on the distribution of contact stresses, and hence, it prescribes the load-carrying capacity of the bearing. Fig.3 shows different roller profiles[2] and the corresponding contact-stress distributions. As shown in the figure 3 the roller profile has a significant influence on the distribution of the contact stress and, hence, on the bearing load-carrying capacity and the life of the bearing.

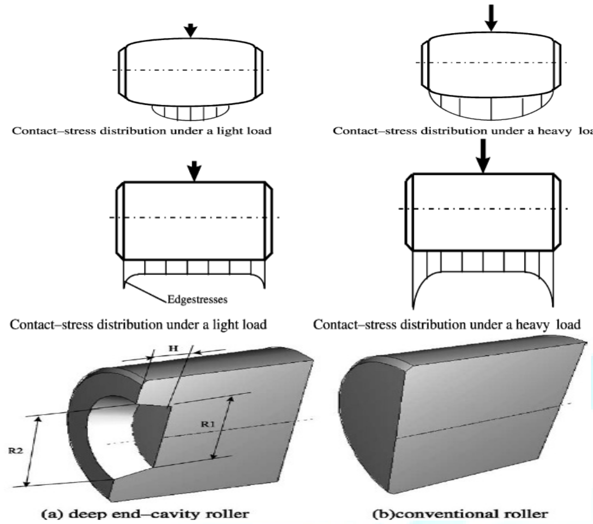

Fig.3 Typical roller profiles and corresponding contact-stress distributions.[2]

From fig. 3 we can conclude that stress distribution in Spherical roller bearing is less compared with Cylindrical roller bearing. But edge stresses are more in Cylindrical roller bearing. So we will modify the roller design from conventional roller to Deep end-cavity roller. By doing this we can reduce the edge stresses. Because of the contact stress distribution, load carrying capacity of the cylindrical roller bearing is high. Our main goal is to improve the load carrying capacity for Life improvement.

4. Rolling Contact Fatigue

The origin of RCF failure is understood to be stress concentrations, which initiate and propagate fatigue crack under cyclic loading. These stress concentrations occur due to surface or subsurface stress risers or to the geometry and kinematics of the contacting pair. Figure 4 summarizes a list of these stress risers, which have been the subject of numerous scientific investigations that have resulted in the improved life of rolling-element bearings. With the introduction of cleaner steels and greater precision in the manufacture of bearings, most of the surface and subsurface stress risers listed in Fig. 4 have been addressed. Nevertheless, the demand to operate rolling-element bearings in harsh tribolgical environments of lubrication, load, contamination, and temperature push for higher fatigue limits, and thus call for improved understanding of the RCF failure modes. Four distinct failure modes have been established in rolling-contact bearings[3]. These classifications include wear-type failures, plastic flow, contact fatigue, and bulk failures.

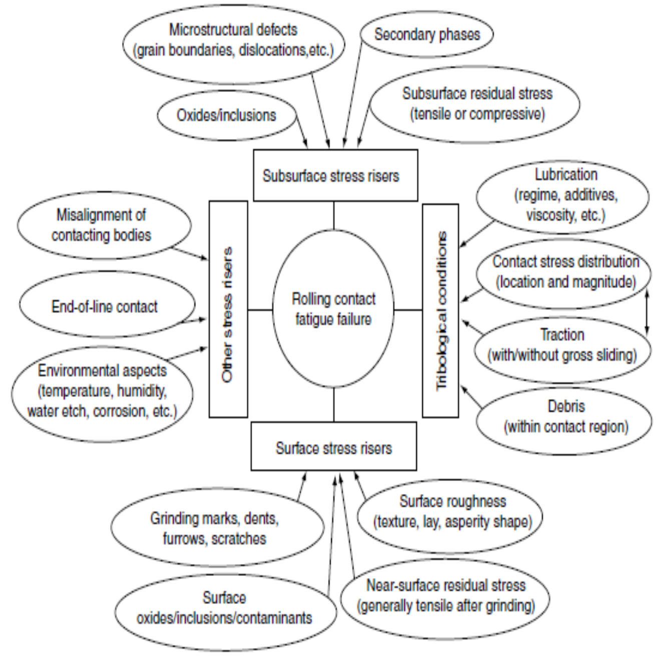

Fig. 4 Stress risers initiating rolling contact fatigue failure.[3]

5. Rolling Bearing Life

Life prediction of a roller or ball bearing is based on the statistical treatment of full-scale bearing tests conducted under controlled environments, for example, full-film lubrication regime, dust-free environment, and so on. Although these controlled environments are useful indicators of the RCF performance of rolling-element bearings, the actual life of a given bearing can significantly vary from the predicted life. It was reported that only 10% of all bearing replacements in the field can be attributed to classic RCF failure, whereas the remaining 90% are made for reasons and conditions not even closely related to RCF. Although this highlights the improvements achieved in designing and manufacturing better-quality bearings[9], it also indicates that other factors in addition to RCF need to be considered to predict the life of a bearing. Even under the controlled conditions of load, lubrication, and alignment in a dust-, corrosion-, and moisture- free environment, there is generally a large scatter in the RCF performance for a given bearing. Bearing manufacturers thus provide a statistical probability of the life of a bearing on the basis of experimental results conducted at a given load, speed, and lubrication regime. Weibull analysis can then be used to estimate the life expectancy of the bearing. Bearing life is generally referred to as L10, L50 or L90 and indicate the probability of failure (e.g., L10 indicates that 10% of the bearings in a given population will fail before a fixed number of stress cycles are reached).

Lundberg and Palmgren developed a theory that indicates the life of a roller or ball bearing at a given load (P) can be approximated using the relation[9]:

$$L_{10}=(C/P)^n \qquad (7)$$

where L is the fatigue life in a million revolutions, C is the load that gives an L10 life of 1 million revolutions, and n is a constant for a bearing type (e.g., n _ 3 for ball bearings and 10/3 for roller bearings). A detailed list of various values of n for different bearing types can be seen elsewhere. The use of a specific value of n is critical for a given bearing type, and the product law of probability is in effect (e.g., as the design changes from single-row to double row bearings). Hence, the life of a double-row bearing under similar conditions to that of a single- row bearing of identical design will be less than that of a single-row bearing.

6. Conclusions

On basis of this study it can be concluded that it is aimed at presenting the Cylindrical roller bearing with Deep end-cavity roller in various fields and the research and development conducted to improve technologies that will directly benefit the Rolling mill industries and other industries. Using of 4-row cylindrical roller bearing in place of 2-row spherical roller bearing is beneficial for us to reducing the contact stress distribution for improvement in load carrying capacity. Because of this improvement in life of the bearing.

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