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Experimental Investigation of Flaking Failure in Roller Bearings and it's Preventive Measures

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Abstract : **Bearing is a machine element having the main objective to reduce friction between moving parts. Loads acting on the bearing are from different directions such as radial and axial direction. If the operating loads and speeds are known then one can calculate bearing life expectancy based on material fatigue. Bearing failures have great impact on the industry and economy. The proper bearing must be selected to avoid failure and for its complete efficiency during application. Many other factors also come into play while the selection of a bearing such as speed, motion, temperature, rolling element, etc. However, even after proper selection, one cannot guarantee the faultless operation of bearing during it's predicted life span due to flaking, fretting, wear, false brinelling, creep, seizure, corrosion, and lubrication problems. A thorough inspection was carried out on a sample of around hundred damaged bearings, that were returned back to the manufacturing industry [1]. On close monitoring, it was found that the majority of bearings were damaged at a position of bearing clearance, inner/outer surface of rings and due to change in chemical properties of bearing material. Based on the inspection, it can be said that, flaking was found to be dominant in the set of damaged bearings. Flaking is the erosion of small pieces of bearing material due to many reasons. Different causes of flaking are minutely presented in this paper. Findings also include some effective measures of prevention essential to maintain bearing efficiency.**

Keywords — **Bearing efficiency, Bearing Clearances, Dynamic load, Flaking, Grease gun, Manufacturing**

I. Introduction

Bearings, today are one of the most important machine elements which are used in almost each and every engineering domain. The purpose of a bearing is to restrict the motion of the component on which it is mounted, thereby allowing movement of that component to the only desired direction. The problem of friction and thereby heat generation can also be easily overcome by mounting specific bearing at the precise location. As of today, there are many different types of bearing available based on many factors, each and everyone has its own usage importance and specific field for its implementation. Some of the factors that differentiate bearings are the type of loads acting, the structure of rolling element, motion, speed, application, etc.

Rolling element bearing is a type of bearing which is well known for its ability to carry the radial load as well as thrust load very efficiently. Rollers are used in the rolling bearing which are positioned between the two races, inner race and outer race in which they roll, thereby distributing load at the contact edges of rolling elements and races. Based on the rolling element, this bearing has it's own types such as ball bearing, cylindrical roller bearing, spherical roller bearing, tapered roller bearing, needle roller bearing, etc. Tapered roller bearings have a conical roller as it's rotating element which carries both radial as well as axial load of the component, making it the most efficient bearing. In tapered roller bearings, the contact area between roller and races is more as compared to different roller bearings, thereby this bearing can efficiently carry heavy loads at high speeds. This bearing has found it's application in gearboxes and engines of heavy automobiles, mining industries, lathe machines, rail industries, paper mills, etc.

The demand for any bearing is based on its capacity and reliability which can be expressed in terms of rating life. The service life of bearings is expressed in terms of time when a bearing is used for operation at a constant speed and, in terms of travelling distance (km) when a bearing is used in railway rolling stock or automobiles [2]. This rating life can be easily calculated based on loads and many other factors. However, in spite of much accuracy in calculating this rating life, most of the time bearing fails quite before its rating life prediction. Such a situation progressively damages the component on which it is mounted and the whole machine may get damaged resulting in catastrophic

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losses. There are many reasons for a bearing to break in earlier stages such as heavier loading than designed, careless lubrication, ineffective sealing, too tight fits, temperature, and many more. Each of the previously mentioned factors has their specific damage on bearings which results in different types of failures.

In almost every bearing, there is a chance of one or more failures resulting in successive errors and this may lead to massive damage. Looking at the failures, some of them are flaking, wear, fretting, creep, false brinelling, rust and corrosion, seizure, etc. Some causes of failure of a bearing in early stages may be due to carelessness in misalignment, mounting, loading, and lubrication.

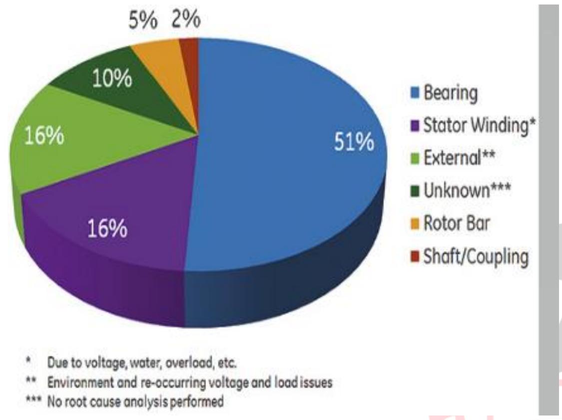

Fig 1: Failure distribution statistics of squirrel cage motors

As cited in the figure [3] of this paper, the author portraits bearing as one of the major factors responsible for the failure of the squirrel cage motor. In fact, not only in motor, but also in any machine, the bearing is one of the most sensitive element and must be checked and maintained properly. The point behind presenting this example is to portray the importance of bearing and need for prevention of its failures.

The industry where the experiment was carried out is the manufacturer of different types of ball and roller bearing. Normally, most of the bearings are returned back to industry from it's clients after early failure for possible replacement. A minute inspection was carried out on hundred of such bearings. It was observed that most of the bearings that went through inspection process had unparalleled rollers with respect to rolling raceways, reddish brown coloured area, presence of dents on rollers and rings. All these observation follows failure caused by flaking factors [4]. One can say that, out of all failures, flaking is the most dominant one which can be resulted from almost any small fault and is found in almost all types of bearing. Thus, the study of flaking becomes essential to understand it's factors completely and look out for its preventive measures

II. Industrial analysis of flaking

Flaking is the erosion of small pieces of bearing material due to many reasons. The common cause of flaking is normal fatigue which acts when the bearing has reached the end of its normal life span. Due to the removal of these fine particles from the raceway and rolling element of bearing, it's surface becomes rough, strength decreases, and further impact of ongoing fatigue causes initiation of a crack in raceways and rollers. This crack gradually progresses in the opposite direction of load and such condition results in complete failure of bearings, thereby vastly damaging the corresponding machine on which the bearing is mounted. Flaking can be said as the super set of all the factors causing premature failures. The main factors that cause flaking in bearing are as follows [5]:-

A. Preload
B. Excessive load
C. Misalignment during Mounting
D. Bending of the shaft
E. Lubrication problems

A. PRELOAD

In application such as machine tool spindles, electric motors, gearbox, precise rotary motion is required with a higher degree of stiffness and positional accuracy. To achieve this precision, a sustained load must be applied to the bearings during assembly and such load is known as preload. This process of preloading is done on bearing to ensure constant distance between rollers and raceways with proper radial clearance. This process adds sustained axial load onto bearing raceways while locking both raceways to the firm position. The amount of preload depends on load parameters, starting torque, running torque, stiffness factor, and life. Preload is given by moving each ring axially relative to other, to and fro from roller if axial preload is required.

The problems due to preload arise when fits are too tight, excessive driving up on a tapered seating, temperature differential being too high between inner and outer rings and excessive preloading conditions. This condition causes the formation of heavily marked path type pattern in raceways of both rings and eventually removal of material may take place at the heavily loaded zone.

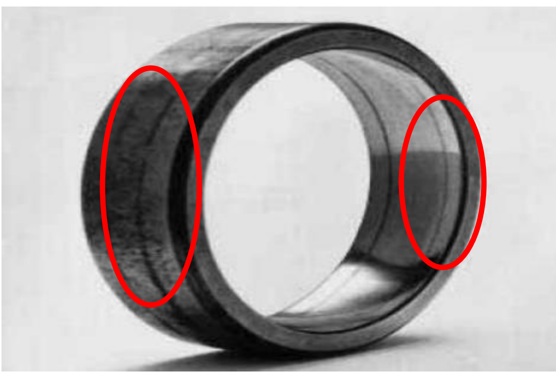

Fig 2: Outer ring of a ball bearing which has been driven too far up it's taper seating.
(Courtesy : Precision Bearings Pvt. Ltd.)

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The preventive measures that can be taken include selection of larger initial internal clearance, avoiding driving of bearing highly up it's tapered seating, and resetting the bearings to obtain lighter preload in excessive preload conditions.

B. EXCESSIVE LOADING

Even though the static and dynamic load of a bearing are pre-determined, load magnitude tends to fluctuate during operation along with high operating temperatures. The basic reason behind reduction of these capacities is the reduction of raceway and rolling element hardness at high temperatures [6]. If this load gets increased more than the specific load a bearing can handle, such condition is termed as excessive loading.

Suppose the dynamic equivalent load of a bearing is calculated as follows :-

P = XFr + YFa…..……[7]

Where,

P = dynamic equivalent load, N

Fr = radial load, N

Fa = axial load, N

X = radial load factor

Y = axial load factor

Here X and Y depend upon the geometry and construction of a specific bearing, whose value can be defined from the bearing catalog.

This dynamic equivalent load is the summation of the radial load and axial load. This sub loads(radial load and axial load) are the ratio of the applied force to the cross-sectional area of the bearing, where applied force is normally the weight supported by bearing in the specific direction. However during operation, if the radial load and axial load become more than the specific load, than such bearings are considered to be under excessive load conditions. Such bearings will become hot and eventually it's material will become softer and failure will take place consequently. Heavy wear paths will occur on rollers as well as on raceways.

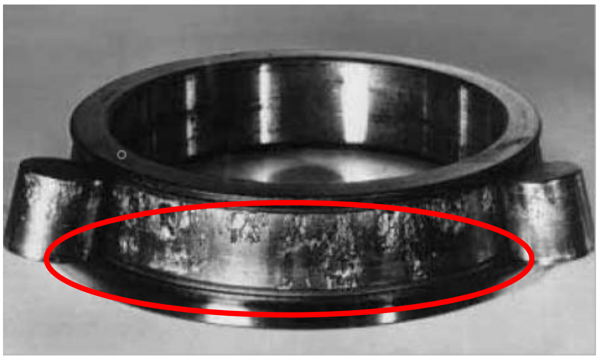

Fig 3: Cone and rollers of taper roller bearing under flaking failure. Heavy loading and inadequate lubrication is the cause. (Courtesy : Precision Bearings Pvt. Ltd.)

Reducing load, redesigning bearing to bear higher loads and proper lubrication is the key to avoid excessive load conditions.

C. MISALIGNMENT DURING MOUNTING

There are many methods for mounting of a bearing depending on fitting conditions and type of the bearing. Initially fits are applied to the rings of bearing which varies as follows:-

1. Condition in which shaft rotates

   Interference fit - Inner ring

   Clearance fit - Outer ring

2. Condition in which outer ring rotates

   Interference fit - Inner ring

   Interference fit - Outer ring

The main reason behind using interference fit in the outer ring is due to the rising of the creep on the ring seating under high radial load having clearance fit. When creep occurs, the fitted surfaces become abraded, causing wear and considerable damage to the shaft [8]. Due to such conditions, wearing of bearing material takes place. Under heavy loading conditions, both rings must have an interference fit. The heavy rotating load on bearing rings causes it's expansion, thereby causing ease of the fit on the seating. This condition again causes creeping of the bearing. Similarly, the nearing radial internal clearance is also reduced due to the expansion of the inner ring. Also, force is applied during mounting of the bearing on housing which must be done with extreme care. Any degree of misalignment may lead to high angular loading and distortion may occur.

The force applied during the fitting of the bearing must be accurate, whose value can be obtained as mentioned :-

Ka = 9.8fk • Δdeff • B ｛1-d2/Di2｝ x 103 ……(Solid Shaft)……………………………………..…[9]

Where,

Kav = Necessary force for fitting or removal of bearing, N

Δdeff = Effective Interference x 10-3, m

fk = Frictional coefficient

B = Nominal inner ring width x 10-3, m

d = Nominal bore diameter of inner ring x 10-3, m

Di = Average bore diameter of outer ring x 10-3, m

From the above equation, it can be said that the force required for fitting and removal of a bearing depends on interference allowance, the dimension of rings, and the finish of the shafts.

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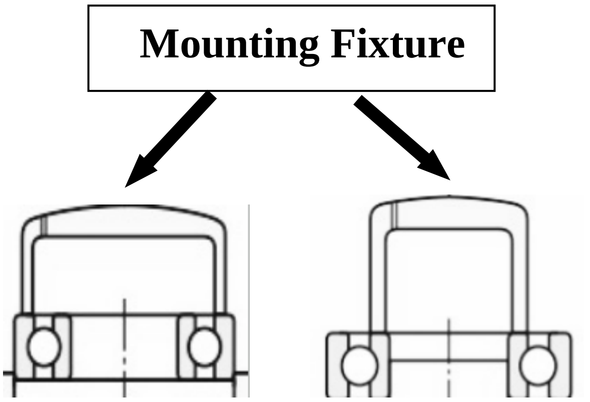

Outer Ring Fitting Inner Ring Fitting

Fig 4: Mounting Conditions of Ball bearing

As shown in fig 4, Mounting fixture must be properly mounted before pressing to prevent misalignment problems. This figure illustrates the application of mounting fixtures on the outer and inner ring of the ball bearing. After proper alignment of fixture onto rings, force must be applied perfectly in the direction of the axis. Any angular force during this process may cause deviation in desired clearance between ring and ball. Improper clearance further causes problems during the expansion of bearing and it's surface particles may split off during operation. Thus, It is essential to take proper precautions during mounting processes to avoid failure of bearing during operation.

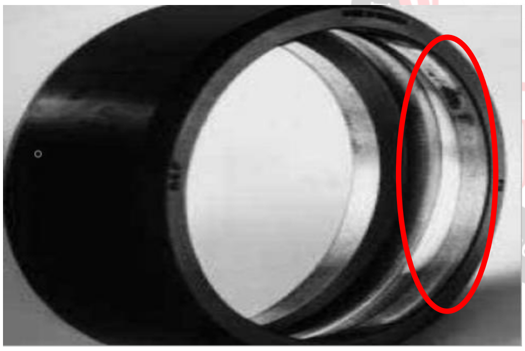

Fig 5: The outer ring of the deep groove ball bearing is out of alignment with the shaft which is caused due to the oval configuration of the ball on account of misalignment.

(Courtesy : Precision Bearings Pvt. Ltd.)

Applying force evenly on the surface, using mounting sleeve with parallel faces, providing proper initial oiling between fitting surfaces, less application of hammer, using smooth seating with its proper positioning are some of the preventive measures that must be taken to avoid bearing failure problems during mounting.

D. BENDING OF THE SHAFT

Bending of the shaft is one of the most frequently found shaft deviations and it comes from the machining process and heat treatment process. Most of the time these deviations on the surface of the shaft are randomly distributed. Sometimes, due to the oval housing or seating, the shaft gets bend in no time during operation and puts high tension onto the inner rings of the bearing. As a result, internal clearance decreases, friction increases, and flaking of bearing material take place. As internal clearance is low, during expansion inner ring does not get enough fit to expand and puts high force onto rollers. These rollers which are already having high temperature gets deformed easily under such conditions and flaking of material takes place due to striking of inner ring and rollers.

Fig 6: The Plummer Block

As shown in the fig 6 [10], the Plummer block provides support to the shaft with the help of bearings. The purpose of this block is to support larger loads along with providing efficient bearing life. However, if the bore of this block is mounted on an uneven base, it becomes Oval when the bolts of the base are tightened. Operation of shaft and bearing in such an oval bore results in bending of the shaft and thereby the failure of bearings. The same problems can be observed while using split housing or machine frames.

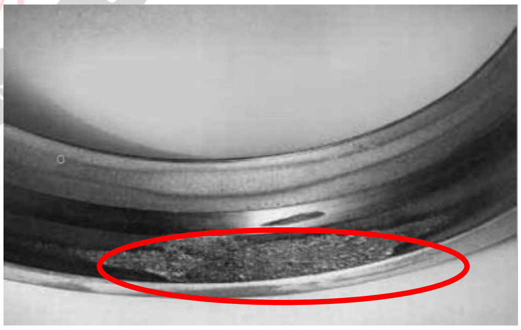

Fig 7: Flaking has occurred in the outer ring of the spherical roller bearing as it was mounted in a housing with oval bore.

(Courtesy : Precision Bearings Pvt. Ltd.)

As a precaution, one must adjust the base accurately to prevent its unevenness during operation. Once the shaft becomes oval or housing gets deviated, it is better to manufacture a new shaft or housing to remedy its effect onto bearings. However, it is also possible in some cases to grind the shaft if the bearing is mounted onto the sleeve.

E. LUBRICATION PROBLEMS

Lubricants help in reducing friction between components of bearing. The most essential function of a lubricant is to

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prevent direct metal to metal contact between raceways, rollers, and cages of bearings. It becomes a prominent duty to provide timely and proper lubrication to prevent problems arising in bearing. The problems faced by bearing in this sector are as follows:-

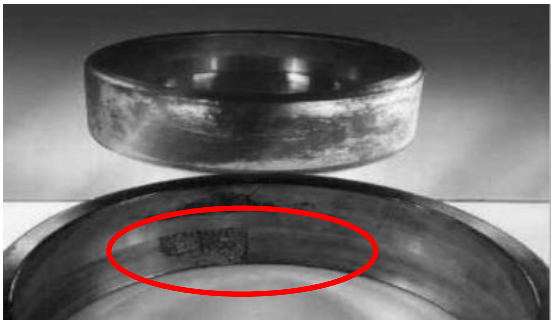

Fig 8: Flaking in the raceways of the outer ring of a spherical roller bearing caused due to corrosion
(Courtesy : Precision Bearings Pvt. Ltd.)

1. Contamination :-

Contamination occurs due to the entry of some foreign particles like dust or dirt into the lubricant. This factor doesn't take into account the quality and quantity of lubrication. There is very little space between raceways and rolling elements through which lubricant having unique viscosity passes. If a foreign particle takes entry in this space through lubricant, it may scratch the surface of active components of a bearing. Surface material may start splitting and gets washed away through the lubricant.

The main cause of lubrication failure, in this case, are dirty tools and hands used during lubrication. This problem can be prevented by the use of clean tools, location, and hands during working and also by providing proper filtration of the lubricants before applying them into the bearings.

2. Corrosion :-

Corrosion in bearings can be very costly as it completely weakens its component in no time. The main agent causing corrosion is the presence of water molecules in the lubricant. When these water molecules pass through the zone of higher load area in bearings, hydrogen ion gets detached from water and due to the amalgamation process, it passes into the small cracks of bearing. As it passes, the crack enlarges and as a series of event, it will result in premature failure. Red and brown colored areas are generated onto rolling elements and raceways. These areas are very weak and are easily noticeable. However being noticeable, the damage of this failure already reduces the lifespan of bearing to a great extent. The solution to corrosion is to try and keep water out or use chemical additives along with water.

3. Improper lubrication :-

Excessive or very little lubrication is another factor which causes a bearing failure. Excessive lubrication builds up the heat as there are no enough void areas for heat dissipation. This build-up heat changes the properties of lubricant and may restrict the flow of upcoming new lubricants. This situation of high temperature and choking of lubricant inside bearing will reduce the efficiency of operation which will lead to high operating cost.

Suppose Grease is being used as a lubricant. Grease gun having filled with grease is used and pumped into space with pre-calculated frequency. The amount of grease is provided by pumping with a specific frequency. The formula for deciding grease quantity is :-

Gq = 3.2319DB x 10-3, kg…..……….……[11]

Where, D = Bearing O.D x 25.4 x 10^{-3}, m

B = Total bearing width x 25.4 x 10^{-3}, m

However, this quantity also varies with certain factors which are shown in below-mentioned table :-

Factor	Variance	Greasing frequency requirement / Time
Temperature	Increases	Increases
Moisture	Increases	Increases
Contamination	Increases	Increases
Vibration	Increases	Increases
Start/Stop frequency	Increases	Increases

Table 1

As shown in above table, requirement of greasing during certain time increases with the increase in temperature, moisture, contamination, vibration and frequency of operation.

All above-mentioned factor must be considered along with the formula during the calculation of grease quantity requirement and it's frequency. It is essential to keep records of amount of grease provided to avoid excessive or too little stage of lubrication. One must measure the number of ounces of grease being released per pump with scale.

III. CONCLUSION

The flaking process in bearing contributes largely to the failure of a bearing. Despite many factor causes flaking in bearing, it can be prevented up to some extent with proper precautions and efficient methods. The cause of flaking failure in the bearing is the result of a fault in pre-loading and excessive loading conditions, misalignment during mounting, bending of the shaft, lubrication problems an many more, which can be prevented by providing larger initial internal clearance, reducing load and redesigning bearing to bear higher loads, using mounting sleeve with parallel faces and providing proper initial oiling, adjusting the base accurately and grinding if necessary, recording the amount of lubrication and applying pure and accurate quantity of lubrication respectively. Thus, flaking is a dominant cause of failure of bearings which must be given

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utmost attention. However, one can conclude that with proper prevention and utmost care as mentioned, failure of bearing which arises due to flaking can be reduced largely corresponding to an increase in efficiency of bearing and increment in its life span. All these small details must be implemented so as to avoid bearing failure during operation and avoid its impact not only on human life but also onto ongoing industrial development and the country's economy.

REFERENCES

[1] "Precision Bearings Pvt. Ltd." ZNL Bearings, Ahmedabad, India

http://znlbearings.com/index.html

[2] "Calculation of service life." KOYO Bearings, JTEKT Corporation,

https://koyo.jtekt.co.jp/en/support/bearing-knowledge/5-2000.html

[3] IEEE Petro-Chemical Paper PCIC-94-01

[4] "Bearing Damage and Measures." New Bearing Doctor, NSK Ltd.,

https://www.nsk.com/common/data/ctrgPdf/e7005c.pdf

[5] "Flaking(Spalling)." Causes of Bearing Failure and Condition Monitoring,

https://shodhganga.inflibnet.ac.in/bitstream/10603/175410/17/16_chapter%203.pdf

[6] "High temperature capacity." Bearing selection; Load & Life, American Roller Bearing Company,

https://www.amroll.com/bearing-selection-load-life.html

[7] "Dynamic equivalent load." KOYO Bearings, JTEKT Corporation,

https://koyo.jtekt.co.jp/en/support/bearing-knowledge/5-4000.html

[8] "Fits and Clearances." NSK Ltd.,

https://www.bearing.co.il/FITS06.pdf

[9] "Bearing Mounting." KOYO Bearings, JTEKT Corporation,

https://koyo.jtekt.co.jp/en/support/bearing-knowledge/15-3000.html

[10] "Split roller bearing with standard plummer block SPL series." HKT Bearings Ltd,

http://hktbearings.com/en/portfolio/sub01_2/?ckattempt=1

[11] "How to Calculate Grease Quantity and Frequency for Bearings." Machinery Lubrication,

https://www.machinerylubrication.com/Read/31524/calculate-grease-quantity

 DOI : 10.35291/2454-9150.2021.0063