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Study of Failure Modes of Rolling Bearings: A Review

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ABSTRACT :*In an industry, the failure of bearingis one of the main causes responsible for machiningbreakdowns.Rollingbearingsconsist of bearing rings, rollingelements and cages for the support of rollingelements. Bearing life refers to the total number of revolutions (or time period) a bearingperformssatisfactorilyunderstated conditions beforefailure. The typicalfailure modes are crack, improperlubrication and greasing, and improperloading of bearing on to the shaft. The work present here involves various modes of failures and diagnoses of damaged rolling bearings.*

Keywords:*Failure, Lubrication, Pitting, Rolling Bearing Temperature, Wearing.*

I. INTRODUCTION

This paper comprises of study of various modes of failure of rolling bearings along with their diagnosis. The bearing failure is one of the main reasons why the production is low in an industry. Rolling element bearings are widely used in an industry. Many problems associated with machineries are attributed due to the bearing failures. In order to reduce down time and to maintain product quality in a highly automated factory, it is essential to detect bearing status. Bearing damage is generally accompanied by a gradual deterioration in the operating behavior. Typical causes are material flaking of the contact surfaces in cases of fatigue damage. In order to prevent major damage it is generally sufficient for the operating personnel to detect uneven running or unusual noise in the bearing system.
Investigation of rolling bearing damages has been discussed below. It will help to understand about various behaviors of bearing.

II. INVESTIGATION OF ROLLING BEARING DAMAGE

Bearing damage can be analyzed by studying:

- The operating behavior of bearing arrangement and machine
- The condition of the dismounted bearing.

Symptoms	Source of Trouble	Examples
Uneven running	• Damaged rings or rolling elements • Contamination • Excessive clearance	Motor vehicles: increased wheel wobble and vibration of steering system Fans: increasing vibration Sawmills: increasing knocking in connecting rods.
Reduced working accuracy	• Wear due to contaminants or insufficient lubrication • Damaged rings or rolling elements • Changed adjustments(clearance or preload)	Lathe: Gradual development of chatter marks on work piece Grinders: Waviness of ground surface Cold rolling mill: periodic surface detects on rolled material such as stretcher strains, ghost lines, etc.
Uncommon running noise: Whining or high pitched noise	Insufficient operating clearance	Electric motors, gears; with gearboxes, the bearing noise is hard to identify since it is generally drowned in the running noise of the gears.
Low pitched rumbling or irregular noise	• Excessive operating clearance • Damaged running surfaces	

	• Contamination • Inadequate lubricant	
Gradual change in running noise	• Changes in operating clearance caused by temperature • Damaged raceway (from contamination or fatigue)	

III. UNUSUAL OPERATING BEHAVIOR

The surest way to detect sudden bearing damage is to monitor the baring temperature. Sudden damage is for example a consequence of lubrication breakdown.

3.1 Normal temperature behavior:

After commencement of bearing operation, the temperature which is generally measured at the outer ring gradually approaches a constant value (steady state temperature).

3.2 Disturbed behavior:

Temperature surge (interrupted lubricant supply, severe bearing damage, impeded running and danger of overheating). Increase of steady state temperature (deterioration of lubrication).

IV. EXAMINATION OF DISMOUNTED ROLLING BEARINGS

4.1 Determination of operating data:

- 4.1.1 application
- 4.1.2 bearing arrangement
- 4.1.3 speed
- 4.1.4 load
- 4.1.5 surrounding parts
- 4.1.6 environmental conditions
- 4.1.7 lubrication
- 4.1.8 sealing

4.2 Examination of the bearing environment

- 4.2.1 cleanliness inside and outside of seals
- 4.2.2 forces required to remove the securing components

4.3 Taking of lubricant samples

- 4.3.1 grease lubrication
- 4.3.2 oil lubrication

4.4 Marking of the bearings

- 4.4.1 mark position of rings relative to shaft and housing
- 4.4.2 mark or tie together parts of separable bearings
- 4.4.3 indicate on tags, mounting location of bearing

4.5 Examination of the seats

- 4.5.1 dismounting forces
- 4.5.2 dimensional tolerances of shaft and housing
- 4.5.3 form tolerances of seats (oval deformation)
- 4.5.4 roughness of seats (reduction of interference)
- 4.5.5 fretting corrosion

4.6 Assessment of the complete bearing:

Inspect:

- 4.6.1 general condition i.e. mounting marks, fretting corrosion, ring fractures, dimensional accuracy
- 4.6.2 condition of seals and dust shields
- 4.6.3 condition of cage
- 4.6.4 manual rotation
- 4.6.5 measuring of bearing clearance

4.7 Inspection of bearing components.

V. TYPICAL ROLLING BEARING DAMAGE

Rolling bearing damage may result in a complete failure of the rolling bearing at least, however, in a reduction in operating efficiency of the bearing arrangement. Bearing damage does not always originate from the bearing alone. Damage due to bearing defects in material or workmanship is exceptional.

Typical reasons for rolling bearing damage:

1. **Inexpert mounting:**
   a. Incorrect mounting method, wrong tools
   b. Contamination
   c. too tight fit
   d. too loose fit
   e. misalignment
2. **Abnormal conditions during operation:**
   a. overloads, absence of load
   b. vibrations
   c. excessive speeds
3. **Unfavorable environmental influences:**
   a. external heat
   b. dust, dirt
   c. passage of electric current
   d. humidity
   e. aggressive media
4. **Inadequate lubrication:**
   a. unsuitable lubricant
   b. lack of lubricant
   c. over lubrication

5.1 Rolling Element Indentations, Score Marks

5.1.1 Rolling element indentations:

Symptoms:

Indentations at rolling element pitch in the raceways of non-separable bearings.

Cause:

Mounting forces were applied through the rolling elements (wrong mounting sequence, inadequate tools).

Remedy:

Mount the tight fitted ring first. In the case of tight fits for both rings mount them simultaneously with the aid of a suitable disc.

5.1.2 Score marks:

Symptoms:

Score marks at rolling element pitch parallel to the axis in raceways of separable bearings.

Cause:

The ring was forced out-of-square into the rolling element set.

Remedy:

Prevent misalignment during mounting of separable bearings. Assemble parts at the save time turning them relative to each other. Use mounting sleeve, if necessary.

5.2 Foreign Particle Indentations:

Symptoms:

i. shallow indentations with very low raised edges caused by soft particles
ii. Deep indentations with higher raised edges caused by hard particles; significant danger of premature fatigue
iii. Many small indentations with high raised edges caused by brittle particles.

Causes:

i. Dirty mounting conditions
ii. Penetration of contaminants (defective sealing)
iii. Contaminated lubricant

Remedy:

i. Cleanliness during mounting and maintenance of the rolling bearings
ii. Use of suitable seals, replacement of defective seals
iii. Periodic exchange of lubricant (washing-out of the bearings).

5.3 Corrosion Damage:

5.3.1 Corrosion due to Humidity (Rust):

Symptoms:

Brownish discoloration of the complete bearing surface, consequential wear and premature fatigue, originating from the rust pits.

Causes:

i. Unsuitable storage (more than 60% relative air humidity in the warehouse)
ii. Extreme temperature vibrations (condensation moisture)
iii. Seal failure (accelerated by the abrasive action of dirt)
iv. Unsuitable lubricant

Remedy:

i. Storage conditions to comply with the specifications of the rolling bearing manufacturer
ii. Improvement of the seal
iii. Lubricant with corrosion inhibitors

5.3.2 Corrosion due to Aggressive Media:

Symptoms:

Generally black etching pits

Causes:

i. Unsuitable storage (aggressive chemicals stored in the same room)
ii. Seal failure
iii. Unsuitable lubricant

Remedy:

i. Storage conditions to comply with the specification of rolling bearing manufacturer
ii. Lubricant with corrosion inhibitors.

5.4 Vibrating with Bearing Stationary:

Symptoms:

Marks in the raceway surface at rolling element pitch. Compared with the marks caused by the incorrect mounting they have no raised edges.

Cause:

Vibrations (minute movements) of stationary machines in the areas of the components in rolling contact causing wear.

Remedy:

Operate endangered machines continuously at low speeds; use safety devices during transport which unload or preload the bearings.

5.5 Fretting Corrosion:

Symptoms:

Wear at the fitting surface (bore, outside diameter), possible consequences might be (a). Fatigue fracture of rotating components (generally shafts). (b). Impended floating bearing function of the stationary components (generally housings).

Causes:

i. Relative movements between components with too loose a fit
ii. Shaft bending, housing deformation.

Remedy:

i. Tight fits
ii. Rigid shaft (housing)
iii. Bearing seat coating.

5.6 Craters and Fluting due to Passage of Electric Current:

5.6.1 Craters:

Symptoms:

Craters in the raceway due to local melting at the contact area of the parts in rolling contact, sometimes several craters are generated in a row.

Cause:

Arcing, e.g. during welding or in case of earth failure.

Remedy:

During electro welding, do not direct current through the bearing (earthing).

5.6.2 Fluting:

Symptoms:

Brownish marks over the entire raceway circumference parallel to the axis

Cause:

Prolonged passage of alternating or direct current, even low currents cause marking.

Remedy:

Prevent current flow through the bearing (earthing, isolation).

5.7 Cage Damage:

5.7.1 Cage Damage due to Vibrations:

Symptoms:

i. Loosening of the rivets, rivet fracture.
ii. Fracture of the cage pockets

Cause:

Vibrations or impacts in addition to the normal cage loads, e.g. in vibration machinery or vehicles

Remedy:

During electro welding, do not direct current through the bearing (earthing).

5.7.2 Damage due to Misalignment:

Symptoms:

Heavy wear at the crosspieces between the cage pockets, deformation or fracture may occur.

Causes:

Inclination of the rings relative to each other, e.g. in the case of ball bearings under combined load resulting in different circumferential speeds of the rolling elements.High cage load in the circumferential direction, especially in case of insufficient lubrication.

Remedy:

Prevent misalignment by employing self-aligning bearings, or use bearings with polyamide cages.

5.8 Wear Damage:

Symptoms:

Roughening of the contact areas between rolling elements and raceways, abrasion of metal, increased bearing clearance or reduced preload.

Causes:

Insufficient load carrying lubricant film (inadequate, aged or contaminated lubricant); wear is promoted by foreign particles and abrasion.

Remedy:

Sufficient load carrying lubricant film (higher viscosity, EP additives), shorter lubricating intervals, improved sealing.

5.9 Seizure under High Load:

Symptoms:

Localized welding of the components in rolling contact (metal particles are torn away and applied to the opposite surface); bearings with a high proportion of sliding contact friction (tapered roller bearings, spherical roller thrust bearings) are particularly susceptible.

Causes:

i. Starved lubrication under high load and speed (operating viscosity too low)
ii. Starved lubrication under high load and low speed due to insufficient hydrodynamic lubricating film between roller face and lip
iii. Too high preload of the bearing arrangement
iv. Detrimental preload due to heat expansion
v. Skewing of rollers, e.g. in case of raceway wears.

Remedy:

i. Improvement of the lubrication (lubricant, EP additives, lubricant quantity, lubricant supply)
ii. Reduction of the preload or increase of the axial clearance.

5.10Skidding Damage:

Symptoms:

Roughening of raceways and rolling elements, wear resulting from seizure.

Causes:

Rolling element sliding on the raceway in the case of low bearing loads and in the case of starved lubrication.

Remedy:

i. Preloading of the bearings, e.g. with springs
ii. Sufficiently high load during test run
iii. Improvement of the lubrication.

5.11 Fatigue Damage:

5.11.1 Classical Fatigue:

Symptoms:

Subsurface cracks of raceway and rolling elements, material flaking (relatively deep pitting), undamaged areas of the raceway indicate good lubrication in the early stage of the damage.

Cause:

Fatigue life of a dynamically stressed bearing being reached.

Remedy:

Bearing must be replaced.

5.11.2 Fatigue due to Insufficient Lubrication:

Symptoms:

Large-area, superficial pitting, originating from the surface. Undamaged areas of the raceway are grey.

Cause:

Insufficient lubrication, resulting in an increase in friction and material stressing at the raceway surface.

Remedy:

Provision of load carrying lubricant film (EP additives, if necessary), increase in lubricant quantity.

5.11.3 Fatigue due to the Surface Distress:

Symptoms:

Material flaking, widening in the direction of cycling.

Cause:

Damage to the raceway, hard particle indentations is particularly hazardous.

Remedy:

i. Cleanliness and care during mounting
ii. Improvement in the sealing
iii. Clean lubricant.

5.11.4 Fatigue to Local Overhead:

Symptoms:

Contact ellipse "cut off" by the raceway boundary of a ball bearing. Fatigue damage at the edges of rolling element and track of roller bearings.

Cause:

i. Mainly moment load
ii. Misalignment of the bearing rings in misaligned housing bores or at out-of-square abutment surfaces
iii. Shaft deflection.

5.11.5 Fatigue due to Wear:

Symptoms:

Localized flaking, e.g. of rolling elements.

Cause:

Alteration in the geometry of components in rolling contact due to wear: e.g. in the case of contaminated lubricant or ingress of foreign particles through defective seals; consequence: local overhead.

Remedy:

i. Frequent change of lubricant
ii. Filtering of contaminated oil
iii. Improved sealing
iv. Early replacement of worn seals.

5.12Damage due to Overheating:

The cause of damage is difficult to determine from the damage pattern of an overheated bearing.

Symptoms:

Temperature surge leading to catastrophic failure due to bearing seizure.

Causes:

In addition to impeded running due to cage fracture there are the following causes:

i. Insufficient clearance under operating conditions, especially of high speed bearings
ii. Over lubrication
iii. Starved lubrication (inadequate viscosity, interrupted supply).

Remedy:

i. Increase bearing clearance or reduce preload until steady state temperature is reached
ii. Avoid lubricant retention within the bearing (provide outlets)
iii. Use adequate lubricant, check lubricating unit.

VI. CONCLUSION

The main aim of this review paper is to have a proper understanding of different bearing failures, their symptoms, causes and remedies over them. The first indication of rolling bearing damage is an unusual operating behavior of the bearing system. The above discussion of damaged bearings reveals a wide and varied range of phenomena. The inspection of bearing itself is frequently insufficient to pinpoint the cause of damage, it is also necessary to consider the surrounding components, the lubrication and sealing as well as the operating and environmental conditions.

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