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from specialty «Mechanical Engineering»

Discipline RT 4319 «Repair technology»

Module AP 9 «Production automation»

LECTURE NOTES

Topic 10. Bearings: Types, Operation, Maintenance and Failure Analysis

1. Introduction to Bearings

Bearings are essential mechanical components designed to support rotating or moving machine elements while reducing friction between contacting surfaces. They are widely used in industrial equipment, including electric motors, pumps, compressors, gearboxes, conveyors, turbines, and machine tools.

The primary function of a bearing is to support radial and axial loads while allowing controlled movement between mechanical components.

Bearings play a critical role in equipment reliability because their condition directly affects the performance of rotating machinery. Bearing failures can cause increased vibration, overheating, noise, shaft damage, and unexpected equipment shutdowns.

Therefore, proper bearing selection, installation, lubrication, inspection, and maintenance are essential for ensuring reliable machine operation.

2. Main Functions of Bearings

The main functions of bearings include:

- Supporting rotating shafts and other moving components.
- Reducing friction and energy losses.
- Maintaining the correct position of rotating elements.
- Transmitting radial and axial loads to the machine housing.
- Ensuring smooth and stable machine operation.
- Reducing wear between moving mechanical surfaces.

The selection of a suitable bearing depends on the magnitude and direction of loads, rotational speed, operating temperature, environmental conditions, lubrication requirements, and expected service life.

3. Main Types of Bearings

Bearings can be divided into two major categories: rolling-element bearings and sliding (plain) bearings.

3.1. Rolling-Element Bearings

Rolling-element bearings use balls or rollers positioned between inner and outer rings. These rolling elements reduce friction by replacing sliding contact with rolling contact.

The main types include:

– Ball bearings: Use spherical rolling elements and are suitable for relatively high rotational speeds and moderate radial and axial loads.

– Cylindrical roller bearings: Designed primarily for high radial loads and commonly used in industrial motors and gearboxes.

– Spherical roller bearings: Can accommodate heavy radial loads and some misalignment between the shaft and housing.

– Tapered roller bearings: Designed to support combined radial and axial loads.

– Needle roller bearings: Use long, thin rollers and are suitable for applications with limited installation space.

Each bearing type has specific operating characteristics and load-carrying capabilities.

3.2. Sliding (Plain) Bearings

Sliding bearings support moving components through direct sliding contact between surfaces, usually separated by a lubricant film.

They are commonly used in large industrial machines, turbines, compressors, and other equipment operating under heavy loads.

The main advantage of sliding bearings is their ability to support significant loads and provide stable operation at high rotational speeds when properly lubricated.

Unlike rolling-element bearings, sliding bearings do not contain balls or rollers. Their performance depends heavily on lubrication conditions, surface quality, operating temperature, and load distribution.

4. Bearing Loads and Operating Conditions

Bearings are designed to support different types of mechanical loads.

Radial loads act perpendicular to the shaft axis. These loads are common in electric motors, pumps, fans, and other rotating equipment.

Axial loads act parallel to the shaft axis. They are frequently generated by helical gears, pumps, and other machines with thrust forces.

Combined loads occur when radial and axial forces act simultaneously. In these cases, bearings must be selected according to their combined load-carrying capacity.

Other important operating factors include rotational speed, temperature, contamination, vibration, and lubrication conditions.

Selecting a bearing without considering these factors can significantly reduce its service life.

5. Bearing Lubrication

Lubrication is one of the most important factors affecting bearing performance and reliability.

The primary purpose of lubrication is to reduce friction between moving surfaces, prevent excessive wear, remove heat, protect against corrosion, and minimize contamination-related damage.

The most common lubricants are grease and oil.

Grease lubrication is widely used in electric motors and many industrial machines. Grease provides relatively simple application, remains in the bearing housing, and offers protection against moisture and contaminants.

Oil lubrication is commonly used in high-speed machinery, gearboxes, turbines, and heavily loaded equipment. Oil can provide effective heat removal and continuous lubrication when properly circulated.

The selection of lubricant depends on bearing type, rotational speed, operating temperature, load, and environmental conditions.

Incorrect lubrication can cause overheating, increased friction, premature wear, and bearing failure. Both insufficient lubrication and excessive greasing can negatively affect bearing performance.

6. Common Causes of Bearing Failure

Bearing failures can occur for several reasons. Understanding these causes is important for developing effective maintenance strategies.

The most common causes include:

– Insufficient lubrication: An inadequate lubricant film increases friction and wear between bearing surfaces.

– Incorrect lubrication: Using unsuitable grease or oil can reduce bearing performance and accelerate degradation.

– Contamination: Dust, water, metal particles, and other foreign materials can damage rolling surfaces.

– Improper installation: Incorrect mounting procedures, excessive force, or unsuitable tools can damage bearings.

– Misalignment: Shaft misalignment creates additional loads and uneven stress distribution.

– Overloading: Excessive radial or axial loads can cause premature fatigue and deformation.

– Overheating: Excessive temperatures can degrade lubricants and change the mechanical properties of bearing materials.

– Corrosion: Moisture and aggressive environmental conditions can damage bearing surfaces.

– Fatigue: Repeated mechanical loading can eventually cause surface cracking, pitting, and material separation.

In many cases, bearing failure is not caused by a single factor but by a combination of operating and maintenance problems.

7. Bearing Inspection and Condition Monitoring

Regular inspection and condition monitoring help identify bearing defects before they result in equipment failure.

Several methods are commonly used.

Visual inspection: Technicians examine bearing housings, seals, lubricant condition, and visible signs of damage or leakage.

Vibration analysis: Vibration measurements help identify defects in rolling elements, inner and outer rings, and other rotating components.

Temperature monitoring: Increased bearing temperature may indicate insufficient lubrication, excessive loading, contamination, or mechanical problems.

Lubricant analysis: Oil or grease samples can be examined to identify contamination, degradation, and the presence of metallic wear particles.

Acoustic monitoring: Changes in operating noise can indicate abnormal friction, surface damage, or developing bearing defects.

Combining these techniques provides a more reliable assessment of bearing condition than relying on a single inspection method.

8. Bearing Installation and Replacement

Correct installation is essential for achieving the expected bearing service life.

Before installation, technicians should inspect the shaft, housing, mounting surfaces, and associated components. The bearing must correspond to the required dimensions, load capacity, clearance, and operating conditions.

The main installation requirements include:

- Maintaining cleanliness throughout the installation process.
- Using appropriate mounting tools.
- Avoiding direct impact on rolling elements.
- Applying the correct mounting force.
- Ensuring proper lubrication.
- Checking shaft alignment and bearing clearance.
- Verifying free rotation after installation.

Depending on bearing design, mechanical, hydraulic, or controlled heating methods may be used for installation.

After installation, the equipment should be inspected and tested to verify correct operation, temperature, vibration, and noise levels.

9. Bearing Service Life and Maintenance Strategy

Bearing service life depends on operating conditions, load, rotational speed, lubrication, installation quality, and environmental factors.

Manufacturers commonly specify bearing life using the L10 rating, which represents the operating life that 90% of a sufficiently large group of identical bearings are expected to achieve or exceed under specified conditions.

However, actual bearing life may differ significantly from calculated values because of contamination, improper installation, lubrication problems, and unexpected operating conditions.

A reliable maintenance strategy should include regular inspections, lubrication management, vibration monitoring, temperature checks, and timely replacement of damaged components.

Rather than replacing every bearing at fixed intervals without considering its condition, industrial facilities can use condition-based maintenance to determine the appropriate time for intervention.

Conclusion

Bearings are critical components of industrial machinery because they support rotating shafts, reduce friction, and maintain stable equipment operation.

Their reliability depends on proper selection, installation, lubrication, inspection, and operating conditions. Bearing failures can result in significant production losses and increased maintenance costs.

Therefore, bearing maintenance should be integrated into the overall preventive and predictive maintenance strategy of an industrial facility.