THE IMPORTANCE OF HIRING FORENSIC EXPERTS TO ASSESS ROTATING MACHINERY FAILURES

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Highlights

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Rotating machinery is ubiquitous in industrial facilities. Motors, shafts, turbines, conveyors, compressors, pumps, and fans are common rotating machinery in industrial settings and are found in almost every HVAC system. Rotating machinery share commonalities in their rotating components, stationary components, and bearings to separate the stationary from the moving. Despite this simple description, the actual installation configuration, type, material, size, loading, application, and design of rotating equipment is varied, exceeding complex, and requires an expert experienced with the loss design and application.

Due to their vital importance in everyday systems, rotating machinery failures can cause substantial business interruption. Specialized knowledge and experience from a forensic expert can mitigate potential repeat or widespread failures and assure building and machinery operators when a failure occurs.

Most losses involving rotating machinery are caused by inadequate maintenance, poor operating conditions, or installation issues, but there is a multitude of causes that lead to rotating machinery failures. This whitepaper provides information to assist insurance professionals who become involved with rotating machinery losses and bearing failures.

Bearing Types and Components

Bearings are the interface between a stationary part, like a motor frame, and a rotating part, like the motor shaft. Because bearings are in contact with both stationary and rotating parts, they reduce friction and maintain the relative positions of shafts to their frames.

The simplest bearing is a plain bearing, which is essentially a solid ring of metal. Plain bearings reduce the amount of sliding friction between the rotating and stationary parts. They are often lubricated with oil or grease. A spherical plain bearing is a nested design where the inner ring can rotate relative to the outer ring, which allows the bearing to serve as a pivot point for the rotating component. Both regular and spherical plain bearings are shown below.

Some bearings have a separate rolling element, which further reduces friction as well as heat, noise and wear. Typical constructions consist of separate inner and outer races. Between the races are the rolling element which can be round balls, cylindrical or tapered rollers and can have multiple rows of rolling elements. A plastic cage structure holds the rolling elements in place between the races, and a cover or shield protects the balls and cage from dirt and debris. Below are examples of ball and roller bearings.

Materials in all types of bearings are required to withstand the demanding combinations of forces and temperatures. Most utilize the addition of fluid lubrication to aid in dissipating heat and reducing friction. Some bearings have special coatings in the absence of fluid lubrication similar to the non-stick coatings applied to cookware. There are even bearings that use magnets to levitate and position rotating shafts.

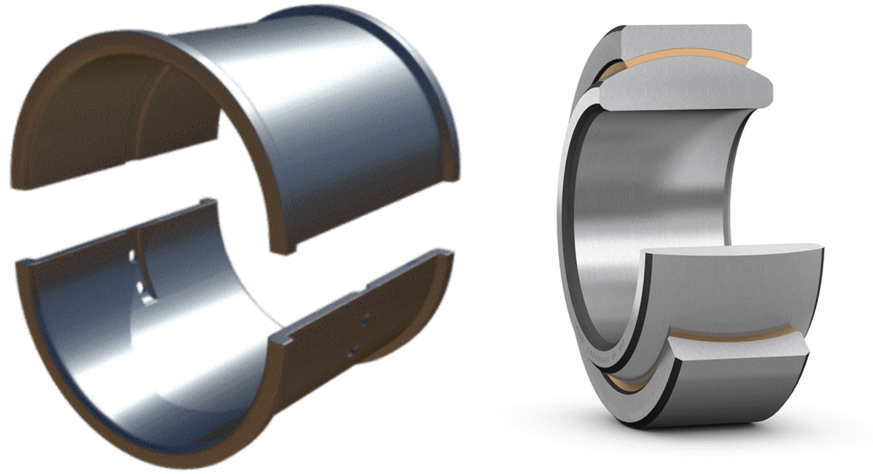

Figure 1 – Plain and Spherical Plain Bearings

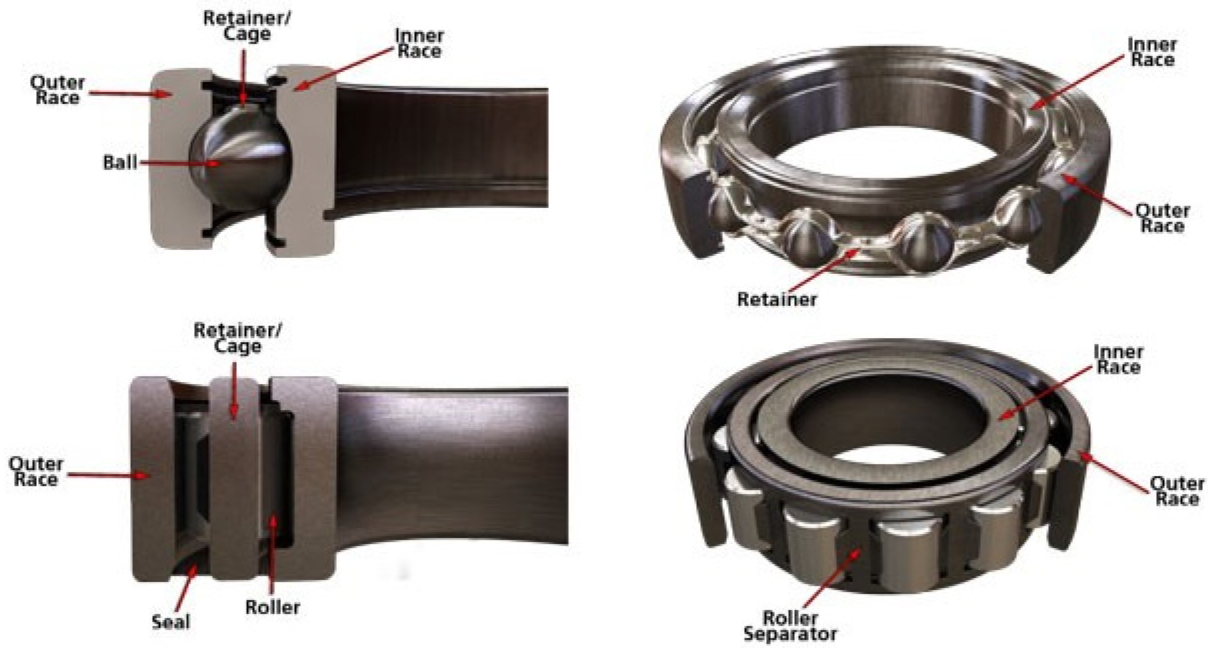

Figure 2 - Bearing Parts (Ball Bearing – Upper, Roller Bearing – Lower)

Bearing Failure Investigation

Some of the first signs of trouble in rotating machinery are excess vibrations and noise. Many people are familiar with getting their car wheels balanced to minimize vibrations. Those who have experienced hitting a pothole, causing a tire rim to bend, know what a nuisance driving with the resulting vibration or imbalance is.

Similarly, in rotating machinery, issues like a lack of lubrication can cause excess friction and heat, leading to excess and uneven wear. These conditions can negatively affect the bearing's mechanical and material properties by accelerating wear or localized hardening of the contact surfaces, increasing the risk of cracking.

Initial issues cause minor imbalances, but as the bearing wears, the forces get larger and the wear accelerates. It is essential to catch symptoms of poor performance early or failures can be imminent and catastrophic.

Even though it is common to run into rotating machinery failures where the cause originated outside of the bearing, the bearing failure is often the first sign of trouble. Nonetheless, a bearing inspection is a good place to start a rotating machinery failure investigation. On relatively simple assemblies, bearing maintenance may be as simple as refreshing the lubricant and visual inspections at regular intervals which, usually specified by the manufacturer. More complicated rotating machinery may have temperature sensors to detect excess heat and/or vibration monitoring. In the event of a loss, maintenance logs, service reports and supervisory equipment data loggers are excellent sources to investigate a rotating machinery failure.

Following a loss, it is important to check the specific bearing assembly clearances, often set in the factory. This data is non-destructive and provides a great start to investigate the failure cause. Additionally, destructive removal and inspection of the bearing components will reveal the potential bearing failure modes and aid in the overall failure investigation.

Bearing Failure Features

Like other mechanical components, bearings experience normal wear and tear, so it is crucial to distinguish the different failure feature characteristics. Bearing failures usually include more than one type of failure feature, which requires a forensic professional to conduct a detailed observation.

When looking at failed bearings, one of the first things that can be determined is if the damage pattern matches that of a rotating or stationary shaft, showing whether the rotating machine was operating or idle at the time of failure. It is always helpful to the investigator to have the operational history and access to the bearing before it is removed to note its location and orientation in the installed position.

Fatigue failures result from repeated loading below the material's yield or failure point. Micro cracks form, and the surface becomes rougher, which results in excess noise and vibration. Analyzing the wear pattern for its position and severity are key to determining if the wear has occurred consistently and if there may have been a recent acceleration to failure.

After a failure, raceways and rolling elements can have rough-looking surfaces that differ subtly depending on the cause of the wear:

- Foreign particle contamination leaves a different wear pattern than fatigue.
- Small, hard particles like sand leave a dull, abrasive pattern.
- Water intrusion, or even humid air, can contaminate the lubricant and cause corrosive damage to the metal alloys.
- Larger particles can leave deep scores and gouges.

Dark wear marks may result from fretting or brinelling where the surfaces are damaged from excessive loading and plastic deformation of the bearing components. Characteristics can include indentations in the races and flat spots on rolling elements.

One of the important roles that lubrication serves is cooling the bearing. A lack of lubrication causes excessive friction and heat, leaving a pattern of discolouration on bearing races and rollers. Rollers are more susceptible to hot spots because their geometry can cause localized deformation and grooves on the races. Excessive heat also alters the material properties of most plastic roller cages; they can become brittle and fail, allowing rolling elements to contact each other.

Bearing Failure Case Studies

Crane Slew Bearing Failure

Mobile cranes used at construction sites are fairly large and heavy vehicles, and for the machine to swivel 360 degrees, the top turret section sits atop a large slew bearing. In one case, a mobile crane bearing failed when an external seal had been compromised and allowed water to mix with the bearing lubrication. The compromised seal went unnoticed until debris accumulation damaged the bearing rollers and cage, resulting in a complete bearing failure and prolonged downtime of the entire mobile crane.

The crane operator reported the initial failure after noticing the tell-tale signs of increased noise and rougher operation. When a forensic expert disassembled the bearing, they found that the roller cage had failed and roller components had been overloaded and fractured. This case revealed the importance of the rubber seal and its role in protecting the grease from contamination.

Compressor Bearing Lubricant

Poor maintenance practices can lead to bearing failures, which was the case in a loss where a greased bearing operated beyond the recommended maintenance interval. Over time, the grease lubricant degraded, particularly in the presence of heat, increasing bearing friction. This increased friction caused more heat, creating a cycle that accelerated grease degradation and led to the ultimate bearing failure that seized the compressor.

The accumulating heat near the bearing was an additional hazard to the surrounding area. The compressor was connected to a motor, and when the bearing failed, the electrical breaker activated. These hazards were potential ignition sources, showing that a rotating machinery failure can have a cascading effect in an industrial setting.

In this case, the incident compressor was arranged with several others like it and operated in cycles. The other compressors were examined, specifically the other roller bearings, which served as exemplars. There was clear evidence of lack of lubrication in the other roller bearings, leading investigators to infer that the incident bearing's lack of lubrication was not a unique case. Additionally, the exemplar bearings showed damages that were consistent with them being in a non-operating state. This helped pinpoint the progression of failures and sequence of events.

Bearing Failure From Secondary Damage

Envista was involved with the sudden shutdown of a chiller that reportedly had a noisy motor bearing. The subsequent motor inspection revealed a deteriorated condition, though it was not immediately clear which damaged parts initially caused the shutdown.

Investigators inspected the bearing and determined that it had been overloaded. They redirected the investigation away from the bearing to the motor, which had electrical faults and caused the erratic chiller operation. This case was a good example of how issues with rotating machinery can be the first signs of imminent equipment failure.

Summary

Because rotating machinery can be a critical component of many industrial facilities, a failure of this machinery can cause significant downtime and businesses losses. It's crucial to work with an experienced forensic professional who can determine the circumstances and type of failure in rotating machinery.