
SKF

# Inspection

# Introduction

Of the bearings that fail prematurely, many do so because they are subjected to unexpected loads in service such as imbalance or misalignment. Bearing condition is of prime importance when monitoring equipment health. A catastrophic bearing failure causes damage to associated components and may ultimately lead to machine failure.

The approach to bearing and machine maintenance typically follows one of three maintenance methodologies: reactive, preventive or predictive. There are advantages and disadvantages to each, but in general, a proactive approach, combining the best of the methodologies, is recommended.

Condition monitoring is a collective term covering any machine monitoring with instrumentation. Multi-parameter condition monitoring is the most practised technique, with vibration monitoring being the most widely used method of monitoring the condition of a machine. The advantage of using a multi-parameter approach is that it allows the monitoring system to not only consider the bearings, but to look beyond the bearings and consider the whole machine. This provides the opportunity to protect the bearings by correcting underlying machinery faults at an early stage of development.

Bearings and related machinery can be inspected during machine operation or shutdown, depending on the nature of the activity. The wide range of inspection activities are made possible by a large number of available advanced instruments.

For additional information about SKF condition monitoring, visit www.skf.com/cm or www.aptitudexchange.com.

For additional information about SKF condition monitoring instruments and SKF maintenance products, visit www.skf.com/cm and www.mapro.skf.com.

The SKF Reliability Maintenance Institute (RMI) offers a comprehensive range of training courses covering topics such as vibration analysis and thermography (→ *Training*, starting on **page 326**). Contact your local SKF representative for additional information, or visit www.skf.com/services.

## Maintenance methodologies

Experience shows that maintenance strategies vary considerably from plant to plant. However, the methodologies employed in implementation of all strategies can be generally classified under a number of common headings (→ **diagram 1**).

Reactive maintenance reflects an absence of an organized maintenance strategy but can, in some situations, be the only suitable maintenance approach. The nature of reactive activities is that they cannot be scheduled in advance. They can, however, be planned in advance to minimize disruption to any scheduled activities.

Preventive maintenance is a routine or scheduled process based on preventing unexpected malfunctions from occurring, by employing proper maintenance procedures and good maintenance practices. An understanding of machinery damage patterns and a maintenance strategy that specifically addresses these damage patterns have a profoundly positive effect on maintenance and operational performance.

Predictive maintenance (PdM) may be defined as a maintenance process based on machinery inspection, monitoring, and prediction. Machine condition monitoring comprises various instruments and techniques such as vibration monitoring.

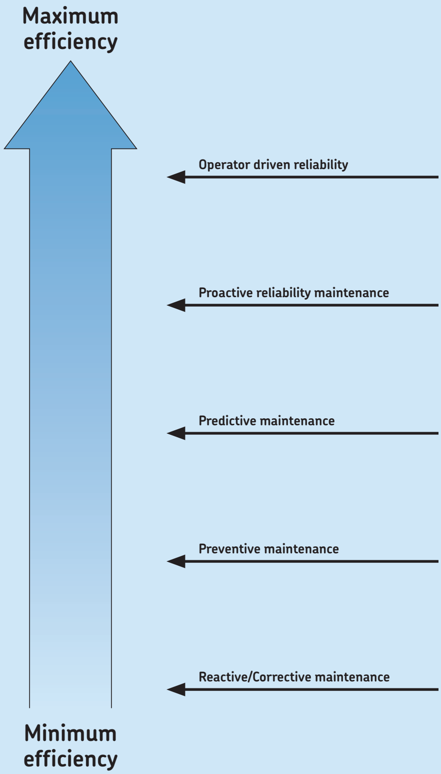
It is evident that none of the previously mentioned maintenance methodologies individually provide the ultimate maintenance solution. The real solution lies in a combination of these methodologies.

Proactive reliability maintenance is a structured and dynamic process for applying the appropriate blend of reactive, preventive and predictive maintenance methodologies.

For maximum efficiency, SKF recommends adopting a methodology that promotes the communication of machine information across the plant, driven by operator involvement and commitment.

Diagram 1

**Different maintenance methodologies**




**Operator driven reliability (ODR)**
Front line operators are empowered to "own" their machinery. They identify, describe and communicate machine information to the plantwide team to keep machinery up and running.

**Proactive reliability maintenance (PRM)**
Predictive maintenance is applied to help identify the root causes of machine and process problems; machines operate with virtually no unplanned shutdowns. Mean Time Between Failure (MTBF) on machines and components is significantly increased.

**Predictive maintenance (PdM)**
Machine condition is assessed using condition monitoring technologies; shutdowns are scheduled based upon machine problems, which are identified using sophisticated vibration and condition monitoring equipment; unplanned shutdowns are significantly reduced.

**Preventive maintenance (PM)**
Planned shutdowns are scheduled to overhaul equipment at pre-determined intervals; maintenance efforts are not based upon an assessment of the machine's condition while it operates.

**Reactive/Corrective maintenance**
Fix it when it breaks; unplanned shutdowns occur when the machine breaks.

# Inspection during operation

Bearings are a vital component in any machine with rotating parts and should be monitored closely. Early indications of bearing damage allow bearings to be replaced during regularly scheduled maintenance, avoiding otherwise costly unscheduled machine downtime due to bearing failure.

**NOTE:** Bearings in critical machinery or in harsh environments should be monitored more frequently!

Various instruments and methods exist for monitoring the performance of bearings and related machine components during operation. Important parameters for measuring machine condition to achieve optimum bearing performance include noise, temperature and vibration.

Bearings that are worn or damaged usually exhibit identifiable symptoms. Many possible causes could be responsible and need to be investigated (→ *Troubleshooting*, starting on **page 228**).

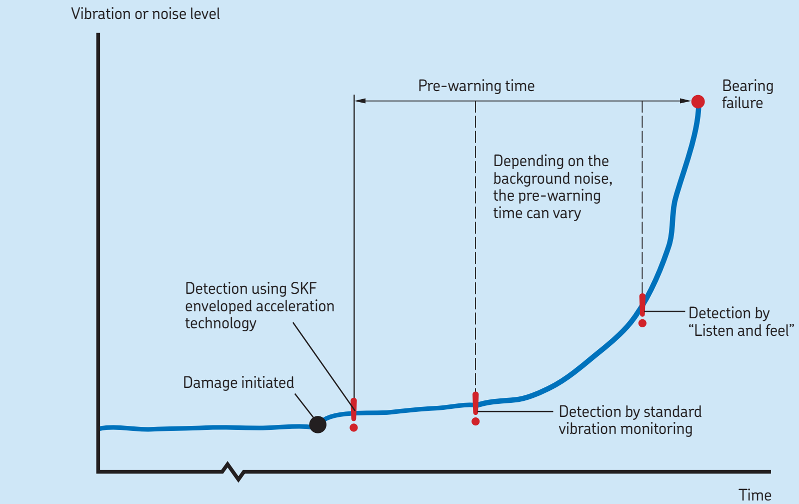
For practical reasons, not all machines or machine functions can be monitored using advanced systems. In these cases, trouble signs can be observed by looking at or listening to the machine. Using the human senses to detect machinery problems, however, has limited benefit. By the time sufficient deterioration has occurred for the change to be detectable, the damage may already be extensive. The advantage of employing objective technologies, such as vibration analysis, is that faults are detected at an early stage of development, before they become problematic (→ **diagram 2**).

For accurate measurements and reliable results, SKF recommends using professional condition monitoring instruments. For an overview of the basic condition monitoring instruments supplied by SKF, refer to **Appendix N** starting on **page 432**. For detailed information about these and related products, visit www.skf.com/cm and www.mapro.skf.com.

**CAUTION:** Don't confuse detection with analysis. Replacing a damaged bearing after detecting high levels of vibration only temporarily solves the problem! The root cause of the vibration should be found, analyzed and addressed.

Diagram 2

**The advantage of advanced condition monitoring**



## Monitoring noise

A common way to identify an irregularity in bearing performance is by listening. Bearings that are in good condition produce a soft purring noise. Grinding, squeaking and other irregular sounds usually indicate that the bearings are in poor condition, or that something is wrong.

The broad range of sounds produced by machines also includes ultrasonic short-wave components that are extremely directional in nature. Instruments, such as ultrasonic probes, isolate these airborne ultrasounds from the background plant and machinery noises, and pinpoint the source.

Another popular instrument for identifying troublesome machine parts or damaged bearings is the SKF Electronic stethoscope (→ **fig. 1**), which detects, traces, and diagnoses the source of all kinds of machinery noise.

## Monitoring temperature

It is important to monitor the operating temperature at all bearing positions. If the operating conditions have not been altered, an increase in temperature is often an indication of imminent bearing damage. However, keep in mind that a natural temperature rise lasting one or two days normally occurs immediately after bearing lubrication and each relubrication.

SKF contact thermometers (→ **fig. 2**) and non-contact thermometers can be used to measure temperatures. Non-contact thermometers are especially useful in areas where access is difficult or hazardous.

In addition, SKF Thermal imagers and SKF Thermal Cameras use infrared to 'see' thermal anomalies or 'hot spots' that the human eye cannot. Infrared thermal inspection can reveal potential problems, and pinpoint problem areas without interrupting production.

**NOTE:** In applications where the inner ring rotates, the bearing housing is typically 5 °C *(9 °F)* cooler than the bearing outer ring and 10 °C *(18 °F)* cooler than the bearing inner ring.

**Fig. 1**

**Fig. 2**

## Monitoring lubrication conditions

Bearings can only achieve maximum performance levels with adequate lubrication. The lubrication conditions of a bearing should therefore be monitored closely. The condition of the lubricant itself should also be periodically assessed. The best way to do this is to take a few samples (typically from different areas) and have them analyzed. The SKF Grease Test Kit (→ **fig. 3**) is a useful tool to check the grease properties in the field.

In general, lubricant analysis is undertaken for two primary reasons: to assess the condition of the lubricant and to assess the condition of the machine. Monitoring the condition of the oil for example, offers the opportunity to extend the interval between oil changes with subsequent savings in oil consumption and reduced machinery downtime.

SKF recommends the following general guidelines for lubrication-related inspection activities:

**1** Check the areas surrounding the bearing positions for lubricant leaks.

**2** Examine all lubricant leaks. Leaks normally result from worn seals, seal defects, damaged seal counterfaces, liquid contamination such as water in the grease, and loose plugs. They can also result from poor connections between mating parts, e.g. between a housing and an end cover, or from the free oil released by grease that has been broken down by churning.

**NOTE:** Rubber seals are designed to permit a small amount of lubricant leakage to lubricate the seal counterface.

**3** Keep protective collars and labyrinth seals filled with grease for maximum protection.

**4** Check that automatic lubricating systems are functioning properly and providing the appropriate amount of lubricant to the bearings.

**5** Check the lubricant level in sumps and reservoirs, and replenish as necessary.

**6** Relubricate bearings with grease, where and when applicable (→ *Relubrication*, starting on **page 192**).

For information about lubricant analysis, grease relubrication and oil changes, refer to the chapter *Lubrication*, starting on **page 178**.

Fig. 3

## Vibration monitoring for rolling bearings

The need for vibration monitoring comes from three fundamental facts:

- All machines vibrate.
- The onset of a mechanical problem is usually accompanied by an increase in vibration levels.
- The nature of the fault can be determined from the vibration characteristics.

Each mechanical problem generates a unique vibration frequency. Therefore, this frequency should be analyzed to help identify the root cause. To capture the vibration frequency, a transducer (a piezoelectric sensor) is strategically placed on the machine. There is a broad range of frequencies that can be generated by various machine faults:

- low frequency range, 0 to 2 kHz
- high frequency range, 2 to 50 kHz
- very high frequency range, > 50 kHz

Low frequency vibrations are caused, for example, by structural resonance, misalignment or mechanical looseness. High and very high frequencies include those generated by damage (defects) in rolling bearings. Therefore, by measuring the amplitude in terms of acceleration, it is possible to gain a very early indication of developing bearing problems.

## Taking vibration measurements

### Where to take measurements

Vibration measurements, using for example the SKF Machine Condition Advisor (→ **fig. 4**), should be taken in three different directions at each bearing position on a machine (→ **fig. 5**).

Horizontal measurements typically show more vibration than vertical measurements because a machine is usually more flexible in the horizontal plane. Imbalance, for example, produces a radial vibration that is part vertical and part horizontal. Excessive horizontal vibration is often a good indicator of imbalance.

Axial measurements typically show little vibration but if present, often indicate misalignment and/or a bent shaft.

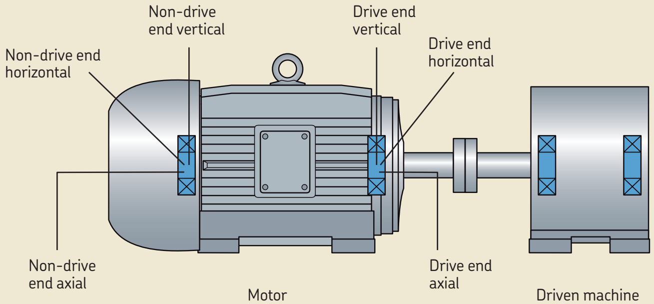
### When to take measurements

The best time to take vibration measurements is when the machine is operating under normal conditions, i.e. when the bearings have reached their normal operating temperature and machine speed is within specification. For variable speed machines, measurements should always be taken at the same point in the process cycle.

**NOTE:** For comparison purposes, the location and type of measurement, as well as the operating conditions, should be identical each time a measurement is taken.

Fig. 4

Fig. 5

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### Rolling bearing defect frequency analysis

Every bearing generates a low frequency signal. The frequency of the signal depends on the number and size of the rolling elements, the bearing contact angle and the rolling element pitch diameter.

Every time a bearing defect is over-rolled, a high frequency signal is generated, which causes a peak in the amplitude of the signal. The rate of these peaks is a function of speed as well as the position of the defect on the bearing and the internal geometry of the bearing.

To monitor the condition of a bearing, a technique called enveloped acceleration or enveloping is used. Enveloping isolates the high frequency signal generated by the defect from other naturally occurring rotational or structural frequencies in the machine (→ **diagram 3**).

#### Calculating bearing defect frequencies

Each bearing component has a unique defect frequency, which enables a specialist to pinpoint damage.

The following defect frequencies can be calculated:

- BPFO, ball/roller pass frequency outer ring raceway(s) [Hz]
- BPFI, ball/roller pass frequency inner ring raceway(s) [Hz]
- BSF, ball/roller spin frequency [Hz]
- FTF, cage frequency (fundamental train frequency) [Hz]

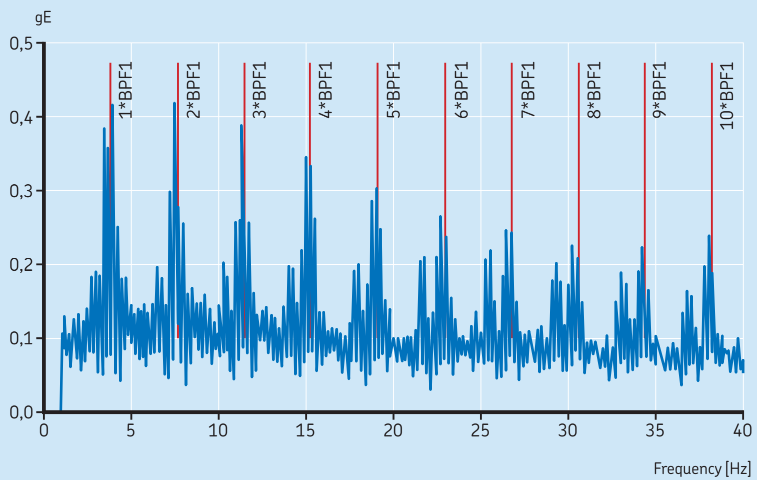
A program to calculate bearing defect frequencies and thereby pinpoint damage is provided in the *SKF Interactive Engineering Catalogue*, available online at www.skf.com.

## Inspection during a machine shutdown

When a machine is not operating, it is an opportunity to assess the condition of bearings, seals, housings, seal counterfaces and lubricant. A general inspection can often be done by removing a housing cover or cap. For a more

Diagram 3

Enveloped acceleration analysis



detailed inspection, the bearings first need to be cleaned. If a bearing appears to be damaged, it should be dismounted and thoroughly inspected.

Shaft and belt alignment as well as a thorough inspection of the machine foundation and exterior can also be done during a machine shutdown. Any condition, whether it is a missing shim or a deteriorating foundation, can negatively affect machine operation. The sooner any problem is identified, the sooner corrective action can begin.

For additional information about machine alignment, refer to the chapter *Alignment*, starting on **page 158**.

**CAUTION:** Replace bearings if they are damaged (and where applicable, the associated sleeves, nuts, washers and seals at the same time). Installing new bearings during a regularly scheduled shutdown is far less expensive than doing so during unexpected machine downtime due to a premature bearing failure.

## Inspecting the bearings

Bearings are not always easily accessible. However, when bearings are partially exposed, visual checks can be made. The most practical time to inspect bearings is during routine maintenance.

In cases where it is difficult or time consuming to gain access to the bearings for inspection, an SKF Endoscope (→ **fig. 6**) can be a valuable tool. This particular endoscope, for example, has a small diameter insertion tube, an LCD display and a picture recording function.

When inspecting a mounted bearing, SKF recommends following these general guidelines:

**NOTE:** Take photographs throughout the inspection process to help document the condition of the bearing, lubricant and machine in general.

**Preparation**

1. Clean the external surface of the machine to prevent dust and dirt from entering the bearing arrangement during inspection.
2. Remove the housing cover, or in the case of a split housing, the housing cap, to expose the bearing.
3. Remove some lubricant from the housing base, for lubricant analysis.

Fig. 6

**WARNING**
To minimize the chance of serious injuries, prior to starting any work, perform required lockout/tagout procedures.

4. For grease lubricated open bearings, take a few lubricant samples from different areas, for lubricant analysis. Visually inspect the condition of the lubricant. Often, impurities can be detected simply by rubbing some lubricant between the thumb and index finger. Another method is to spread a thin layer on a sheet of paper and examine it under a light.
5. Clean the exposed external surfaces of the bearing with a lint-free cloth.

**CAUTION:** Direct contact with petroleum products may cause allergic reactions. Use SKF protective gloves and safety goggles when handling solvents and cleaning bearings!

**Inspection**

**1** Inspect the exposed external surfaces of the bearing for fretting corrosion. If fretting corrosion is present but not severe, use fine wet and dry abrasive paper to remove it.
**2** Inspect the bearing rings for cracks.
**3** For sealed bearings, inspect the seals for wear.
**4** Rotate the shaft very slowly and feel for uneven resistance in the bearing. An undamaged bearing turns smoothly.

Where a more detailed inspection of grease lubricated open bearings is required, continue as follows:

**5** Remove all grease from the housing base.
**6** Remove as much grease from the bearing as possible using a non-metallic scraper.

**NOTE:** Keep a representative sample of the grease for further analysis (→ **fig. 7**).

**7** Clean the bearing with a petroleum based solvent by spraying the solvent into the bearing. Rotate the shaft very slowly while cleaning it and continue to spray until the solvent ceases to collect dirt and grease. For large bearings that contain a build-up of badly oxidized lubricant, clean them with a strong alkaline solution containing up to 10% caustic soda and 1% wetting agent.
**8** Dry the bearing with a lint-free cloth or clean, moisture-free compressed air.

Fig. 7

Fresh grease: brown colour

Used grease: yellow colour

**9** Use an endoscope to inspect the bearing raceways, cage(s) and rolling elements for spalls, marks, scratches, streaks, discolouration and mirror-like areas. Where applicable, measure the radial internal clearance of the bearing (to determine if wear has taken place) and confirm that it is within specification.
**10** If the condition of the bearing is satisfactory, apply the appropriate grease to the bearing immediately and close up the housing. If bearing damage is evident, dismount the bearing (→ *Dismounting*, starting on **page 252**) and protect it from corrosion. Then, conduct a full analysis (→ *Bearing damage and their causes*, starting on **page 288**).

**NOTE:** Certain large and medium-size bearings are suitable for reconditioning. For additional information, refer to the section *Remanufacturing and refurbishment*, on **page 331**.

## Inspecting the seal counterfaces

To be effective, a seal lip must run on a smooth counterface. If the counterface is worn or damaged, the seal lip will cease to function properly. This is particularly important when installing a new seal. If a new seal is positioned over a worn or damaged counterface, it will either not seal or it will fail prematurely.

Therefore, the seal counterface must be repaired before new seals are installed.

When inspecting the seal counterface, also check for fretting corrosion. If fretting corrosion is evident but not severe, use fine wet and dry abrasive paper to remove it.

Fig. 8

**NOTE:** Shafts and other components that have worn or damaged seal counterfaces do not necessarily have to be replaced. They can be built up and remachined. Where appropriate, an SKF SPEEDI-SLEEVE (for shaft diameters ≤ 203 mm) or a large diameter wear sleeve (LDSLV) (for shaft diameters > 203 mm) are an excellent and cost-effective way to repair wear grooves (→ **fig. 8**). For additional information about SKF wear sleeves, refer to the section *Repairing a worn shaft with an SKF wear sleeve*, starting on **page 152**.