How To Analyze Gear Failures

**Failure Conditions**

When gears fail, there may be incentive to repair or replace failed components quickly and return the gear system to service. However, because gear failures provide valuable data that may help prevent future failures, a systematic inspection procedure should be followed before repair or replacement begins.

The failure investigation should be planned carefully to preserve evidence. The specific approach can vary depending on when and where the inspection is made, the nature of the failure, and time constraints.

**When and Where**

Ideally, the analyst should visit the site and inspect failed components as soon after failure as possible. If an early inspection is not possible, someone at the site must preserve the evidence based on instructions from the analyst.

**Getting Started**

The failure conditions can determine when and how to conduct an analysis. It is best to shut down a failing gearbox as soon as possible to limit damage. To preserve evidence, carefully plan the failure investigation and conduct in-situ inspections and plan to become involved in gearbox removal, transport, storage, and disassembly. If the gears are damaged but still functional, the company may decide to continue operation and monitor damage progression. In this case, be certain to become involved in establishing the gear system monitoring process. In most applications, inspection and monitoring include visual inspection and temperature, sound, and vibration measurements. Additionally, for critical applications, nondestructive inspection of the gears (e.g., magnetic particle inspection) should ensure the absence of cracks before operation is continued. Before the system is restarted, be certain to collect samples of lubricant for analysis, drain and flush lubricant reservoirs, and replace the lubricant. Examine the oil filter for wear debris and contaminants, and inspect magnetic plugs for wear debris.

**Time Constraints**

The high cost of shutdown frequently limits time available for inspection. Such cases call for careful planning. Dividing tasks between two or more analysts may reduce time required and provide varied insight into the failure analysis task. In most applications, inspection and monitoring include visual inspection and temperature, sound, and vibration measurements. Additionally, for critical applications, nondestructive inspection of the gears (e.g., magnetic particle inspection) should ensure the absence of cracks before operation is continued. Before the system is restarted, be certain to collect samples of lubricant for analysis, drain and flush lubricant reservoirs, and replace the lubricant. Examine the oil filter for wear debris and contaminants, and inspect magnetic plugs for wear debris.

**Class/Mode: Overload/brittle fracture**

**Definition:** Fracture by rapid crack propagation without appreciable plastic deformation

**Morphology:** Bright, flat, granular surface. Scanning electron microscopy shows cleavage facets or intergranular facets.

**Cause:** Stress intensity (tensile stress and flaw size) exceeds fracture toughness.

**Remedy:** Increase toughness. Avoid flaws and shock loads. Reduce tensile stress.

**Class/Mode: Overload/ductile fracture**

**Definition:** Fracture by tearing of metal with appreciable plastic deformation

**Morphology:** Gray, fibrous surface with shear lips. Scanning electron microscopy shows shear dimples.

**Cause:** High load, low yield strength, or low fracture toughness.

**Remedy:** Reduce load. Increase yield strength. Increase fracture toughness.

**Class/Mode: Overload/mixed-mode fracture**

**Definition:** Fracture by both cleavage and microvoid coalescence

**Morphology:** Surface exhibits both ductile and brittle characteristics.

**Cause:** High load, low yield strength, or low fracture toughness.

**Remedy:** Reduce load. Increase yield strength. Increase fracture toughness.

Excerpted from *Gear Failure Analysis: A Textbook for the Gear Failure Analyst*, used in the GEARTECH seminar *Gear Failure Analysis and Troubleshooting*. Photographs reprinted from *Gear Failure Atlas* © (GEARTECH, 1999). Text and photographs used with permission from GEARTECH.
cases the old saying “time is money” is worth remembering.

**Prepare for Inspection**

Before visiting the failure site, the analyst should interview a contact person and explain the failure analysis process and outline specific needs. Work to develop a good relationship with the contact person, avoid any perception that you might be attempting to place blame, and emphasize the need to inspect the gearbox, interview personnel, examine equipment, and assess working conditions.

A skilled technician should be requested to disassemble the equipment under the direction of the analyst. However, if safety permits, it is best if no work is done on the gearbox until the analyst arrives. This means no disassembly, cleaning, or draining oil. Otherwise, a well-meaning technician could inadvertently destroy evidence. Emphasize that failure investigation is different from a gearbox rebuild, and the disassembly process may reveal significant facts to a trained observer.

Verify that gearbox drawings, disassembly tools, and adequate facilities are available. Inform the contact person that privacy is required to conduct the investigation, and access to all available information is necessary.

Ask for as much background information as possible, including specifications of the manufacturer, service history, load data, and lubricant analyses. Send a questionnaire to the contact person to help expedite information gathering.

**Inspect In Situ**

Before starting the inspection, review background information and service history with the contact person. Try to interview those involved in design, installation, startup, operation and maintenance, and anyone present when failure of the gearbox occurred or was discovered. Encourage the interviewees to share everything they know about the gearbox and associated systems even if they feel it is not important.

**External Examination**

Before removing and disassembling the gearbox, take photographs and thoroughly inspect the exterior. Use an inspection form to ensure that important data (data that may be lost once disassembly begins) is recorded. For example, the condition of seals and keyways should be recorded before disassembly or it may be impossible to determine when these parts were damaged.

Before cleaning the exterior of the gear housing, inspect for signs of overheating, corrosion, contamination, oil leaks, and damage, and photograph the areas of interest. Photographic documentation is frequently a key to any good failure analysis, including a gear failure analysis.

**Gear Tooth Contact Patterns**

To observe the condition of the gears, shafts, and bearings, clean the inspection port cover and the immediate area around it, and then remove the cover. Be careful not to contaminate the gearbox during cleaning or during the removal of the port cover.

The way gear teeth contact indicates how they are aligned. Record tooth contact patterns under loaded or unloaded conditions. No-load patterns are not as reliable as loaded patterns for detecting misalignment, because marking compound is relatively thick and no-load tests do not include misalignment caused by load, speed, or temperature. Therefore, fol-