Part 3

Detecting Bearing Faults

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In the two previous articles (Dec/Jan 2011, Apr/May 2011), the focus has been on how the vibration changes when a "typical" bearing fault develops. We have explored spectrum analysis, time waveform analysis, and a raft of high frequency detection techniques. But there are a number of fault conditions related to rolling element bearings that will not necessarily change the vibration patterns in the ways described thus far. Thus, in this article we will explore fault conditions that relate to poor installation (cocked on the shaft or on in the housing), current flow through the bearing (EDM damage), skidding, and slipping.

Poor installation: cocked bearing

Bearing installation is very important. If a hammer is used to pound a bearing into place, the rolling elements and raceways can be, and almost surely will be, damaged. Poor installation can also damage the shaft or the raceways via surface gouging or scratching. Those damaged areas will cause the vibration to change in ways described in the previous two articles; periodic stress waves and vibration will be detected at the key forcing frequencies (depending on the damage inflicted on the bearing).

However, if the outer race of the bearing is cocked in the housing, or the inner race is cocked on the shaft (i.e. there is an angle between the outer race and the housing or between the inner race and the shaft), then with time the additional load on the rolling elements and raceways will cause excessive wear and premature failure of the bearing. But we can detect this situation so that it can be corrected before damage is done!

Vibration amplitude will be higher than normal in the axial direction; however, instead of generating vibration at the bearing defect frequencies (BPFI, BPFO, BSF, and FT), the vibration will be generated at the speed of rotation, i.e. 1X. The vibration at twice running speed (2X) and at harmonics can also increase in amplitude. The only problem is that vibration at these frequencies can be elevated for other reasons, including unbalance, misalignment, and a bent shaft. (Figures 1 and 2)

Figure 1: Inner race cocked on the shaft

Figure 2: Outer race cocked in the housing

Phase analysis can aid in this diagnostic process. In the case of the bearing cocked on the shaft, with each rotation you have a "wobble" motion. Phase analysis would reveal that as you move an accelerometer around the face of the bearing at different clock positions, the phase reading would change accordingly. For example, if the phase reading (compared to a tachometer reference or a second accelerometer) was 0 degrees at the 12 o'clock position, the reading would be *approximately* 90° (or 270°) at 3:00, 180° at 6:00, and 270° (or 90°) at the 9:00 position. (Figure 3)

If the outer race is cocked in the housing, the phase readings will depend on how it is cocked (i.e. which point on the bearing is furthest from

Figure 3: Phase changes when the bearing is cocked on the shaft

Figure 4: Phase changes when bearing is cocked in the housing

the machine face, and which is closest). By moving the accelerometer around (safely), the analyst would find a 180° phase difference between those two points. (Figure 4)

Fluting or EDM

If current flows between the inner race and outer race, through the rollers or balls, a fluting pattern will be etched onto the bearing surfaces. The pattern is quite unusual, although very recognizable, as shown in the photograph. (Figure 5)

Current flow can occur for a variety of reasons (including poor grounding when welding is performed, insulation breakdown, brush problems on DC drives, and other reasons). The fault condition is common in DC motors, and it is now increasingly common to see this problem on variable frequency drives.

Figure 5: Typical pattern seen on a bearing experiencing fluting

Because of the "washboard" pattern on the bearing surfaces, a series of peaks is often seen clustered together up in a high-frequency band, typically between 100,000 CPM and 180,000 CPM. It is believed that the peaks appear in this range because they are exciting a bearing resonance; therefore, where they *actually* appear will depend upon the bearing. The peaks may be separated by BPFO, BPFI, or sometimes BSF; however, they are often *not* observed in the lower frequencies (i.e. at BPFO, BPFI, etc.). (Figure 6)

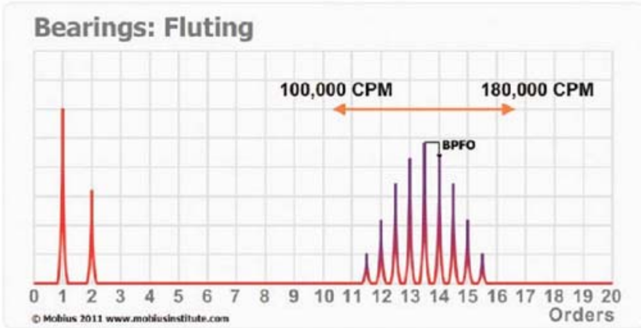

Figure 6: Sample of the vibration pattern witnessed when fluting (EDM) occurs

Skidding

If a bearing is correctly selected for its application, the lubricant is functioning correctly, and there is adequate load on the rolling elements, then the rolling elements should continuously roll around the raceways. However, it is not uncommon for the rolling elements to slide or skid from time to time when these conditions are not met. This is more common on non-drive-end bearings, especially on vertical machines, and far more commonly with cylindrical roller bearings (as against deep groove ball bearings). In many cases, when skidding is observed, a shot of grease may stop the bearing from skidding, but minutes or hours later the skidding will resume. In some cases the skidding will occur when the machine is started, or on cold days because the lubricant is more viscous.

There are actually a number of situations in which skidding, sliding, or smearing can occur, but for now the focus is where the rolling elements skid through the unloaded portion of the bearing (i.e. opposite the load zone). I think it goes without saying that skidding is very harmful to the bearing. The metal-to-metal contact causes excessive wear, and heat is also generated. In more than one case fire and/or explosions have resulted.

The vibration pattern will change when a bearing is skidding. The recording must be taken, however, when the skidding is occurring (which can be intermittent). It is common to be able to hear a high-pitched sound from the bearing when skidding occurs. That should be enough to get your attention; however, an acceleration time waveform also will show high G levels; often above 10 Gs. High-frequency "noise" is generated, which will excite the bearing resonance (as described when fluting occurs); however, in this case we may expect to see a "hump" in the spectrum, like a mountain. It is not uncommon for peaks to emerge out of the hump that are separated by BPFO.

If the surface is damaged, peaks may be observed at the defect frequencies. You may notice that the peaks become "smeared" (broader and shorter), because the frequency of vibration is not consistent.

Sliding and loose fit

Another fault condition you may encounter is where the inner race slides on the shaft, or the outer race slides in the housing, due to a loose fit. It is not uncommon to see a 3X peak (and harmonics) rise in amplitude when the bearing is slipping on the shaft, and you may also witness an increase in the 4X peak when the bearing is loose in the housing.

Observe the bearing

It is highly recommended that you look closely at the surface of a bearing when it is removed from the machine. It will tell you a great deal about the failure mode. All of the major bearing suppliers offer application notes with images that allow you to recognize the markings on the bearing surfaces, helping you to determine the root cause. If a bearing is slipping on a shaft or is loose in the housing, or if the rollers are skidding, the surfaces of the bearing will provide tell-tale signs. (Figure 7)

Figure 7: Seizing marks in the inner ring bore as a result of inner ring creeping on the shaft – FAG Publ. No. WL 82 102/2 ED

Using a stroboscope

If the cover of the bearing can be safely removed so that the rolling elements can be observed, a stroboscope can help to diagnose the slipping and skidding faults conditions discussed in this article. If you synchronize the strobe to the shaft speed, you should not see relative movement between the inner race and the shaft. If the strobe is synchronized to the cage frequency, the cage should appear to be stationary, unless skidding occurs. The relative position of the outer race to the housing should not change.

Conclusion

There are a number of fault conditions related to rolling element bearings that can be detected with vibration analysis. As always, serious thought must be given to the root cause of these fault conditions. You need a good vibration monitoring program, but you also need to adopt precision maintenance practices. In the fourth and final article we will explore how vibration analysts can contribute to reliability improvement.

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