Back-to-basics

Shaft centerline radial position

There are two components of radial movement of a shaft in the bearing clearance. The first component is the average radial position of the shaft centerline and the second is the dynamic motion of the shaft about that average position. The first component, the radial position, represents a very important piece of information that has been underutilized. The second component is the orbit of the shaft and has become Bently Nevada Corporation's logo. Both of these motion components are measured with XY proximity displacement probes; the radial position information is obtained from the dc probe gap.

Shaft centerline position provides information about the condition of the oil film in a bearing, bearing stability, the alignment of the shaft/bearing system, and radial forces on the shaft.

Oil Film

As a shaft begins to turn, oil is pulled by the shaft into the area where the shaft is closest to the bearing surface. The developed oil pressure begins to lift the shaft away from the bearing surface. The constriction is opened up and the shaft is pushed to the side until the system more or less reaches equilibrium. Figure 1 shows the expected movement of the shaft. If the radial position doesn't follow this general pattern, close attention should be paid until the cause of the unusual behavior is understood. For example, if the bearing is not properly lubricated, insufficient radial motion will indicate the lack of an oil film during the start of the machine. In fact, as the bearing is worn, the measurement will show the shaft sinking into a position where it should not be (outside the radial bearing clearance).

The relationship between bearing stability and radial position has been researched extensively by Bently Rotor Dynamics Research Corporation. (See Reference 1.) In general, when the lubricant film forces are able to overcome the preloads on the shaft, the shaft may become unstable and go into whirl or whip as the film pushes the shaft around the bearing. The lubricant film forces become larger as the lubricant supply pressure is reduced, the speed of the shaft increases, or the clearance of the bearing changes in certain ways. At the same time, the preloads on the shaft can become smaller as misalignment forces, forces from the main flow in fluid handling machines, or other radial forces result in a decrease in the preload force. For the radial position of the shaft, there is an area of instability which is established by the net preload and the direction of rotation of the shaft. Figure 2 shows this area. For horizontal machines, the dominant preload is often gravity, but in vertical machines the dominant preload comes from other sources.

The closer the centerline of the shaft comes to this area, the more likely the shaft is to be unstable.

Misalignment

When the shaft/bearing system of a machine train is misaligned to the extent that shaft preload results from the stiffness of the shaft rather than the normal gravity preload, the shaft centerline may move in the direction shown in Figure 3. This motion is caused by the building of the oil wedge in the top of the bearing instead of the bottom. If the misalignment arises from thermal growth of the machine components, the centerline movement varies following changes in the net preload. In the case of a vertical pump, the shaft centerline motion shows the effect of side loads from the fluid dynamics in the pump system, and it can be determined when a particular pump is not behaving normally. In Reference 2, Mr. Charles Jackson outlines the study he conducted on the radial position of the bull gear of a gear box that was not performing properly. ►

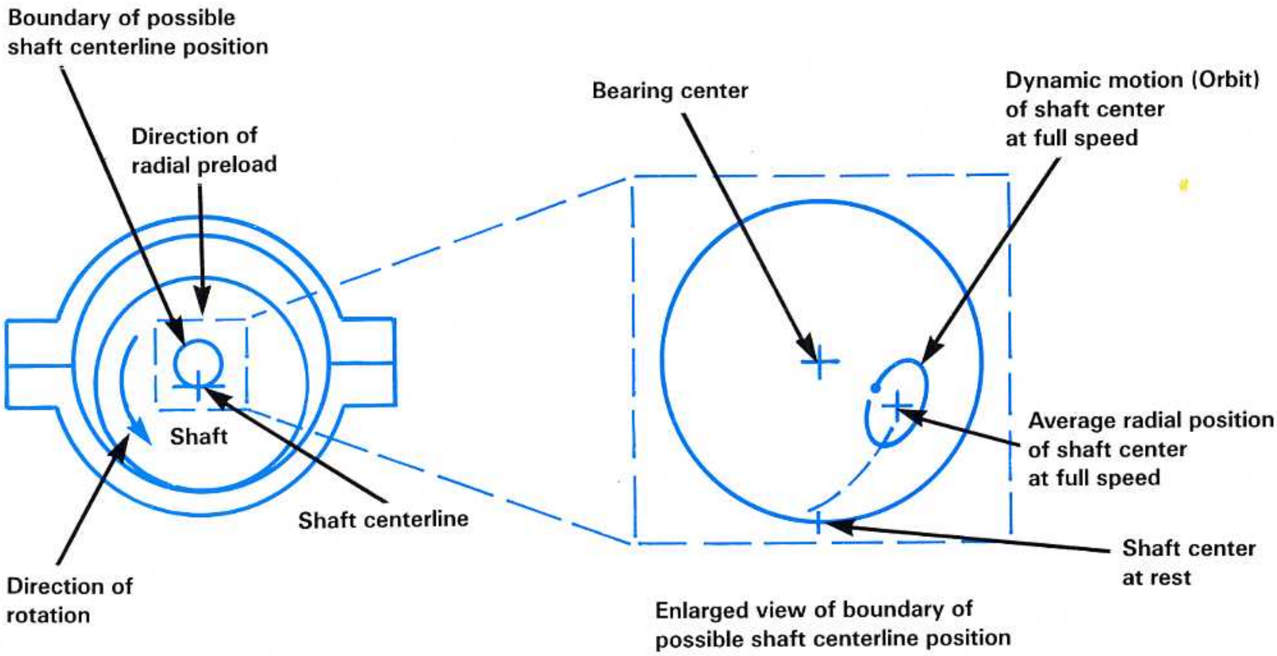

Figure 1

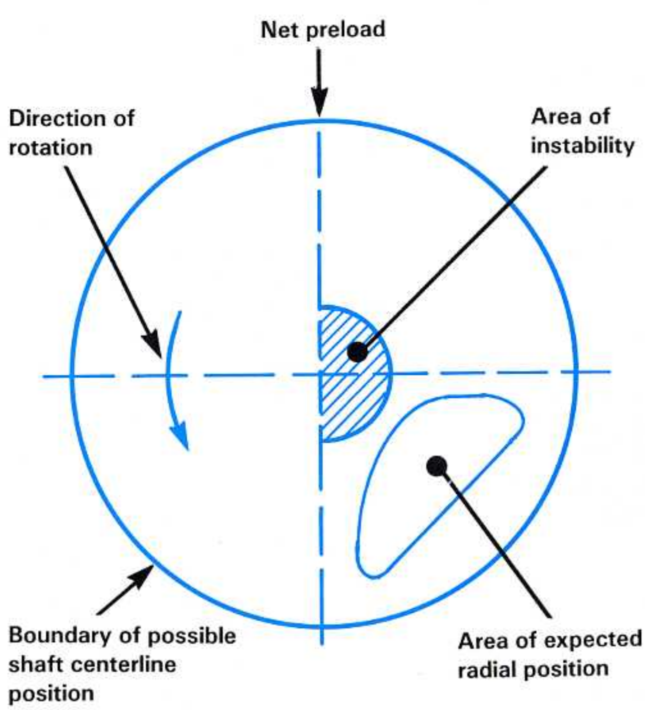

Figure 2

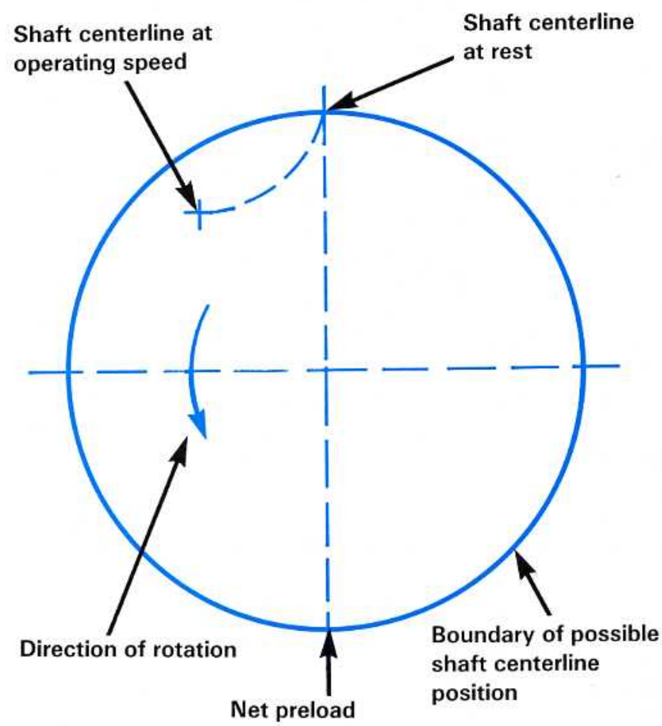

Figure 3

Not all misalignment is bad. "Friendly misalignment" is the minimum misalignment which helps stabilize a machine. However, when misalignment increases, it results in continuous flexing of the machine shaft when it rotates. This flexing can easily cause fatigue failure. (See Reference 3.) Figure 4 shows the relationship between shaft centerline position and the effect of an "unfriendly misalignment".

Examples

The first case is a good example of professional management of machinery resources, and the second is an example of what can happen when the radial position information is ignored. During a recent commissioning of a group machines, a consultant was hired to help a petrochemical company with the start up. There were several success stories where this particular consultant, Mr. Bob Eisenmann, saved money and helped efficiently manage the start up. One was a case where a compressor started up with apparently normal vibration characteristics. During the start up, Bob noticed that the dc probe gap did not shift normally as the shaft began to turn. Following his convictions, he had the machine shutdown.

When the bearing was disassembled, it was found that two of the tilting pads were installed backwards. Assembly problems had lead to improper lubrication and extremely tight clearances in the bearing. Because Bob noticed the problem at a early stage, the machine didn't develop the inevitable high vibration as the bearing system deteriorated, and extensive machine damage was avoided. Some of the bearing parts were worn and had to be replaced but the shaft was not harmed and the machine was able to start up with little loss of time.

The second example does not have such a happy ending. This machine had been in service for many years. During a shut down, some minor work was performed on the lubrication system. When the machine was restarted, severe vibration was experienced shortly after the start up. The machinery specialist became preoccupied with the spectrum of the vibration and did not look at the radial position information. The machine was restarted multiple times and each time a high vibration level caused a shut down. When it was noticed that the bearing area of the machine had become too hot to touch, the start ups were discontinued and the machine was disassembled. During disassembly, it was noticed that the lubrication system was configured in a manner that no lubrication was being supplied to the bearing. Subsequent review of the data showed the lack of dc probe gap shift during start up and an actual drop in the vertical position as the babbitt of the bearing was worn away. This incident resulted in a costly and time consuming major repair of the machine.

Past, present, and future.

When proximity displacement relative position transducers became available for the industrial environment, machinery specialists began logging the dc probe gaps and using the data to determine the behavior of machines. Today, ADRE® 3, Dynamic Data Manager®, Transient Data Manager®, and the 3300 Vector Monitor are available to log the probe gaps and display the information. Tomorrow, as dedicated systems become more useful, radial position information must be an essential part of the system data to determine a machine's operating condition.

References

1. Bently, D.E., Muszynska, A., *Fluid-Generated Instabilities of Rotors*. Orbit April, 1989.
2. Jackson, Charles, Leader, Malcom, *Design, Testing and Commissioning of a Synchronous Motor-Gear-Axial Compressor.* Texas A&M, 12th Turbomachinery Symposium, Houston, Texas, November 1983.
3. Bently, D.E., Muszynska, A., *Detection of Rotor Cracks,* Texas A&M 15th Turbomachinery Symposium, Corpus Christi, Texas, November 1986. ■

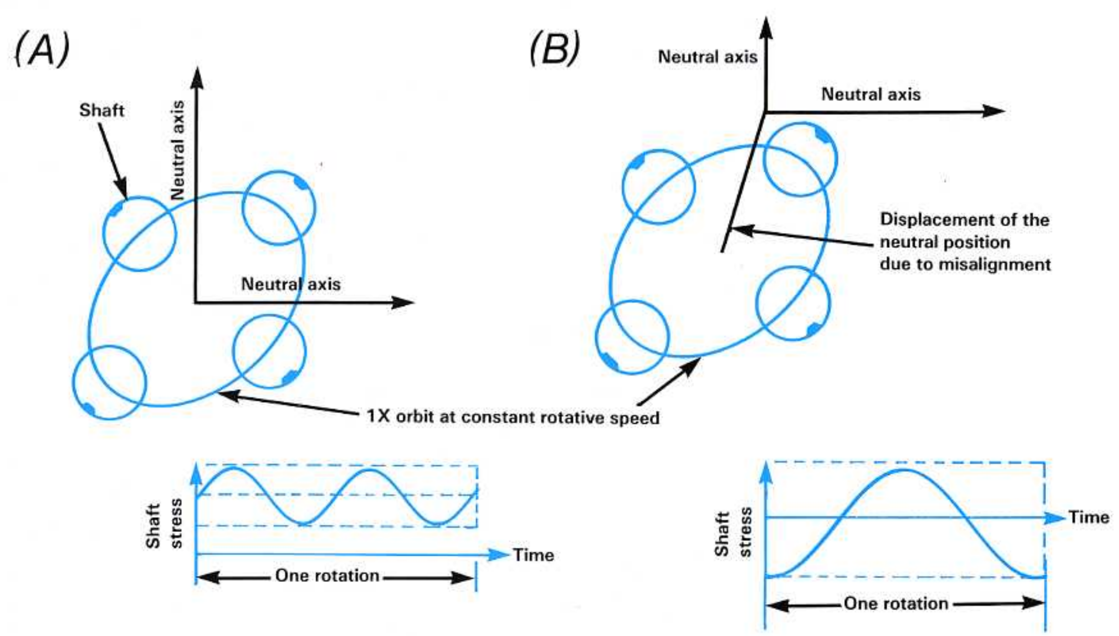

Figure 4

(A) Shaft is under constant deformation with small 2X frequency component

(B) Shaft is under reversal deformation with 1X frequency component