What information does an orbit analysis provide about the condition of a turbine?

The motion of a shaft within its journal bearings can reveal incipient problems and potential sources of vibration. With the right knowledge, experience, and historical data, a vibration specialist can predict when maintenance is needed. This is known as predictive maintenance. This article discusses the types of problems that can be identified through orbit analysis.

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What information does an orbit analysis provide about the condition of a turbine?

For determining the condition of a turbine, the path that the shaft follows within its journal bearings is a key source of information. Using an orbit analysis, causes of vibrations can be detected, allowing for corrective actions. To gain insight into the shaft's path, it is necessary to measure the vibrations of the shaft relative to the journal bearings, referred to as relative vibrations. To achieve this, two proximity sensors must be installed perpendicular to each other, both focused on the shaft.

With the right knowledge, experience, and historical data of the machine, predictive maintenance becomes possible. Based on the shaft's movement, emerging problems and potential causes of vibrations can be identified. This article explains what kinds of issues can be revealed through orbit analysis.

1. Imbalance

A machine that becomes increasingly unbalanced will show growing amplitudes in a spectrum (FFT) analysis, which align with the rotor speed. This can already be detected using a single proximity sensor, but that alone does not show the exact path of

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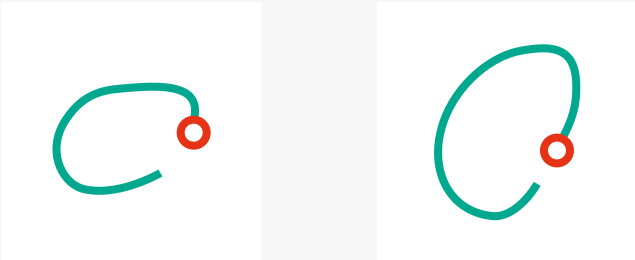

Figure 1. The orbit increases in size as a result of imbalance. Once the peak to peak amplitude exceeds a threshold, an imbalance is present and balancing is required.

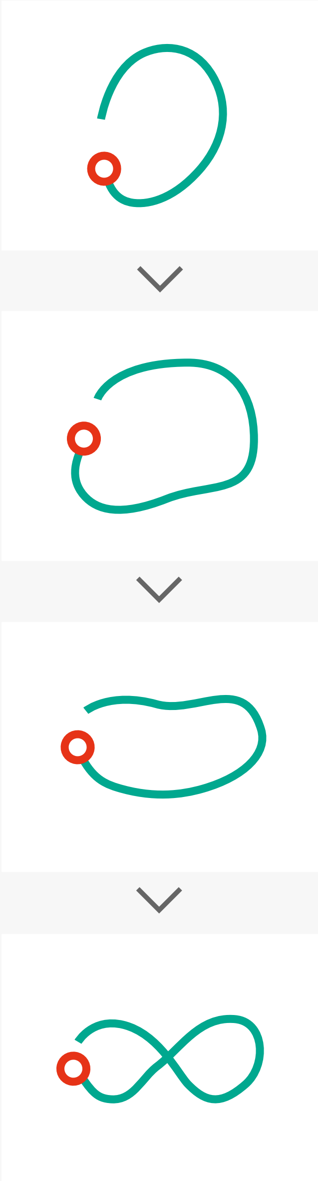

Figure 2. Different orbits resulting from varying degrees of preload. From top to bottom: normal, light preload, moderate preload (banana-shaped orbit), and heavy preload (figure-eight-shaped orbit).

the shaft and therefore does not reveal the underlying cause of a vibration. Measuring with two proximity sensors does provide the exact orbit, making the imbalance easier to explain.

As imbalance increases over a certain period, this becomes visible as a growing and sometimes changing orbit. This period can last weeks or months. When an imbalance is observed, the machine may continue to run until the peak to peak amplitude reaches the threshold.

"A growing or distorted orbit often indicates imbalance or excessive preload, both of which reveal themselves through the path of the shaft."

2. Excessive preload

All machines with journal bearings have some preload to ensure the formation of a stable oil film. This causes the shaft to follow an elliptical path, which flattens in the direction of the preload vector.

When preload becomes excessive, the shaft's path becomes increasingly flat, eventually taking the shape of a banana. Further increase of the already excessive preload will result in the shaft path forming the shape of an eight. During this increase, the centerline of the shaft continues to shift toward the preload vector.

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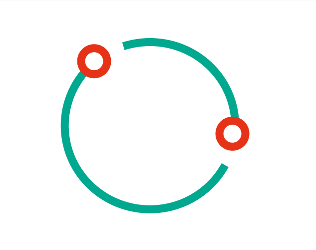

Figure 3. When oil whirl occurs, the orbit will be nearly circular in shape and have an amplitude approaching the bearing clearance.

3. Oil whirl

Oil whirl and oil whip are sometimes seen as the same fault. However, when examining the vibrations, each issue produces a distinct orbit. The most common cause of oil whirl is a poorly designed journal bearing. Other causes include changes in fluid viscosity or alterations in machine alignment.

When oil whirl occurs, the orbit is almost circular and the amplitude approaches the bearing clearance.

4. Oil whip

Oil whip occurs at a later stage than oil whirl and produces a unique orbital pattern. The orbit becomes circular with an even greater amplitude than seen in oil whirl. The shaft uses the entire bearing clearance because the rotor can no longer generate an oil film, resulting in direct contact between shaft and bearing (metal to metal contact). At this point, the whirl frequency coincides with the system's resonant frequency (critical speed) and locks onto it. This condition cannot be escaped from, even at higher speeds. It causes rapid wear, which in turn increases vibration levels. If not addressed in time, the bearing will wear quickly and the rotor may be destroyed by metal to metal contact.

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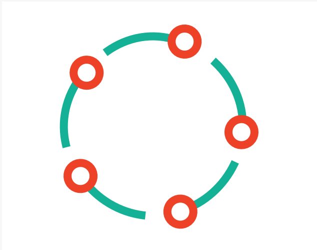
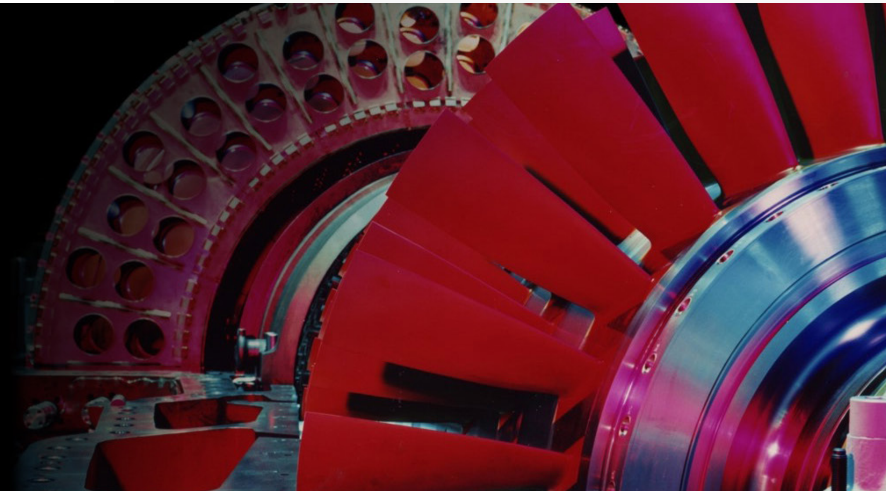


Figure 4. When oil whip occurs, the orbit will be circular in shape and have an amplitude equal to the bearing clearance.



5. Rub

A common issue in new or recently overhauled machines is light rubbing. These rubs do not last long: they often increase the clearance in the bearing until the rubbing stops. If not corrected, the internal clearance will be gradually worn away until the machine becomes unusable.

"A light rub will typically result in a teardrop-shaped orbit, with the tip of the teardrop indicating the point of impact or contact."

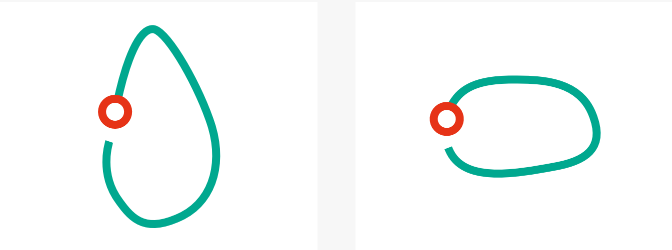


Figure 5. In the case of light rubbing (left), the orbit will take on a teardrop shape. As the rubbing increases, the orbit will increasingly resemble the pattern caused by excessive preload.preload.

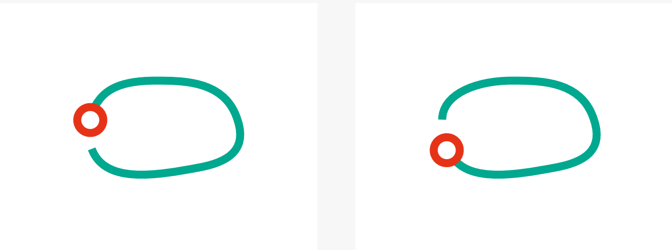


Figure 6. With rubbing, the shaft's direction of rotation can reverse due to repeated contact with the bearing wall.

Rubbing is characterized in spectrum analyses by multiple frequencies that are harmonics of the original frequency. This original frequency depends on the relationship between shaft speed and the first resonance frequency.

The effect of rubbing on the shaft's orbit depends on its severity. Light rubbing results in a teardrop-shaped orbit where the tip of the drop indicates the point of impact. As rubbing becomes more severe, the orbit flattens and may resemble the pattern caused by excessive preload.

6. Loose rotating components

Loose rotating components can cause unusual vibrations. This includes loose rotors or impellers. These vibrations often fluctuate in amplitude and the phase angle will also shift. This cause can be identified most easily through orbit analysis because the development of a loose component can be detected early. Initially, the component may intermittently slip and stick on the shaft before fully detaching (figure 7 & 8).

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Figure 7. Amplitude change possibly caused by loose rotating machine components.

Figure 8. Phase angle change possibly caused by loose rotating machine components.

Figure 9. Amplitude change possibly caused by a cracked rotor or shaft.

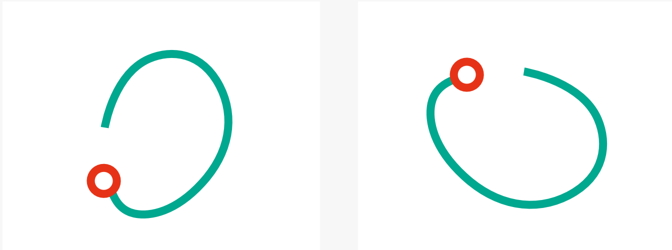

Figure 10. Phase angle change possibly caused by a cracked rotor or shaft.

7. Cracked shaft

A crack in a rotor or shaft can affect machine behavior in various ways. This can manifest as a change in vibration behavior, a shift in phase angle, and or a shift in resonance frequency during start-up or shutdown.

These vibrations can be seen in spectrum (FFT) analysis, but by overlaying the phase angle from the orbit analysis and comparing it to historical data, it becomes clearer that a change in the phase angle has occurred, indicating a possible crack. Running the machine at operational speed and observing changes in resonance frequency can also suggest a potential crack.

The term "possible" crack is used deliberately, as many other factors can cause these changes. These include loose supports, foundation issues, and loose rotating parts. Essentially, any factor affecting the mass, damping, or stiffness of the machine can alter phase angle and resonance frequencies.

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