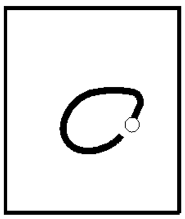
Field Application Note

STI Vibration Monitoring Inc.

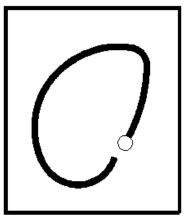
Bearing Failure Modes-Journal Bearings — JBFAIL

This application note presents specific failure modes associated with machinery having journal bearings. Signal measurements presented here are time waveforms that are collected with two orthogonally located Eddy Probes, or proximity type sensors. Although certain faults can be analyzed with spectrum analyzers, the majority of these faults can be diagnosed using orbit analysis alone.

BALANCE



RE–BALANCE NOT REQUIRED

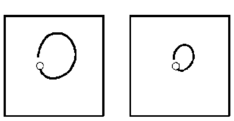


BALANCING REQUIRED

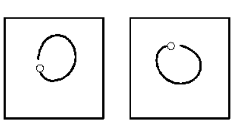
Diagnosis of a degrading balance condition is performed by concentrating on the synchronous amplitude, which coincides with the rotor speed. This can be accomplished by viewing the spectra from any single Eddy Probe sensor. A similar diagnosis can be made by viewing the filtered signals from two orthogonally mounted Eddy Probes sensors as orbits. As the balance condition deteriorates the size, and sometimes the shape, of the orbit will grow larger until the peak-to-peak amplitude exceeds acceptable limits.

CRACKED SHAFT

A crack in a rotor, or shaft, can generate several different effects on how the machine behaves: a change in the vibration level, a change in the operating phase angle, and/or a change in the resonance frequency as the machine starts or stops. Spectral analysis can be used to identify this fault, but observing filtered, synchronous orbits with the phase angle superimposed on the orbit allows rapid identification of this condition.



AMPLITUDE CHANGE



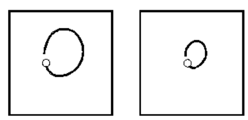
PHASE CHANGE

Changes in the filtered amplitude can be determined using orbits analysis. By superimposing the phase angle input signal onto the orbit a shift in this parameter can be easily determined. By noting the operating speed at which the resonance frequencies occur, a change in this frequency may indicate the "possibility" of a crack existing.

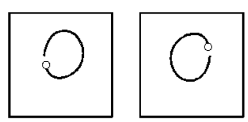
The "possibility" must be emphasized and carefully analyzed because many other causes can produce these changes, such as, a damaged or loose bearing support, foundation problems, loose rotating parts...basically anything that can influence the "system" mass, damping, and/or stiffness.

LOOSE ROTATING PART

A loose rotating part can generate unusual vibration signals. They may fluctuate in amplitude and the phase angle may shift, also. This fault is diagnosed easiest using filtered, synchronous orbit analysis. Imagine a mass, such as an impeller, which has come loose; it can rotate freely on the shaft independently.



CYCLIC AMPLITUDE VARIATION



CYCLIC PHASE VARIATION

As the loose part rotates it influences the balance condition of the rotor, which appears as a cyclical, increase and decrease in the synchronous amplitude. This is observable using a spectrum analyzer, but the changes may be too rapid for the sampling rate of the instrument. An oscilloscope set up to observe a filtered orbit will sample continuously so that the changes can be seen. The phase shifting can, also, be observed using an oscilloscope.

The inception of a loose part condition will produce a "nervous" filtered, synchronous orbit. The orbit will appear to vibrate slightly as this condition is created; the part may be slipping and then sticking on the shaft just prior to becoming a full fledged loose rotating part.

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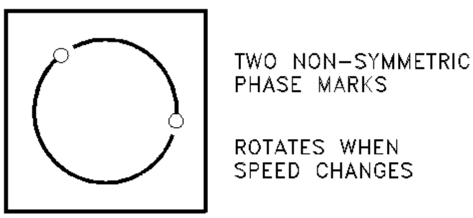
OIL WHIRL

Oil whirl and oil whip are sometimes listed as a single machine fault, but closer observation of the vibration signals and the machine conditions causing these signals will produce different, distinct signal displays for each condition. This fault is caused by a condition that prevents the rotor from creating a stable oil wedge on which ride. An improperly designed bearing is the usual source for oil whirl conditions, but a change in the fluid viscosity or machine alignment state are other possibilities.

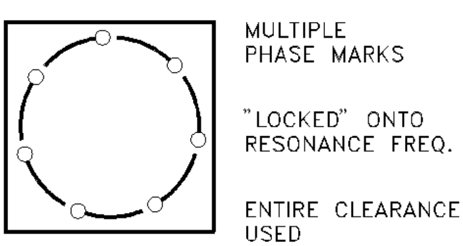
Generally, an oil whirl condition precedes an oil whip condition. Spectral and orbit analysis can be used to identify either condition. This phenomenon creates an individual sub synchronous frequency, which can occur within a frequency range from 35% to 48% of rotor speed, depending upon the machine/bearing design or construction. As the machine accelerates the whirl frequency will increase as machine speed increases.



Observing oil whirl as a filtered, synchronous orbit produces a distinctive display. The orbit will be more or less round in shape with amplitude that nearly approximates the bearing clearance, and when the phase angle is superimposed upon the display, the orbit will appear to have two-phase marks on it. This characteristic is due to filtering at shaft speed and the fault being generated at a sub synchronous frequency. The two-phase marks will not be displayed symmetrically on the orbit because the whirl frequency is not at exactly ½ machine speed.

OIL WHIP

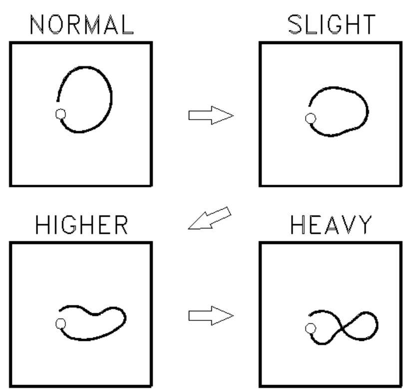
Oil whip occurs during the later stages of an oil whirl condition and it has a distinctive orbital display. The display, with the phase input superimposed on the display, appears to have several phase marks. This display will be round in shape and the amplitude will greater that the amplitude noted during oil whirl.



The size of the orbit be will larger because the shaft uses up the entire bearing clearance as an oil wedge can no longer be established by the rotor and the shaft is in direct metal-to-metal contact with the bearing. The orbit display will no longer rotate because the oil whirl frequency has coincided with the first natural resonance, or critical speed, and has "locked" onto this frequency. Oil whip is a dangerous condition because the rotor uses up the entire bearing clearance and is in direct metal-to-metal contact that will wear away the bearing rapidly and destroy the rotor if not corrected.

EXCESSIVE PRELOAD

All journal-bearing machines have some amount of preload so that a stable oil wedge can be established. The preload may be internally or externally produced. Internal sources of preloads are from gear meshing or hydraulic loading during pumping actions. External preloads may be from coupling misalignment or piping and support system thermal changes. These sources of preload create an elliptical orbit that is flattened in the direction of the preload vector.

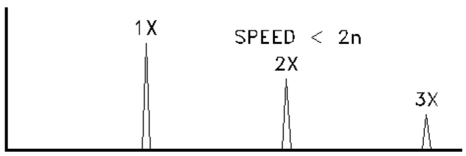


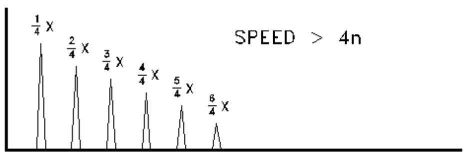
As the preload increases the orbit is further flattened. As excessive preload increases further the orbit begins to collapse to form a "banana" shape as the shaft tries to continue its normal rotation pattern and direction.

After the orbit has been flattened into the "banana" shape a 2X frequency is present on spectra displays. Heavy preloads further distort the orbit into a figure eight shape. As preload increases the shaft centerline will shift in the direction of the preload vector.

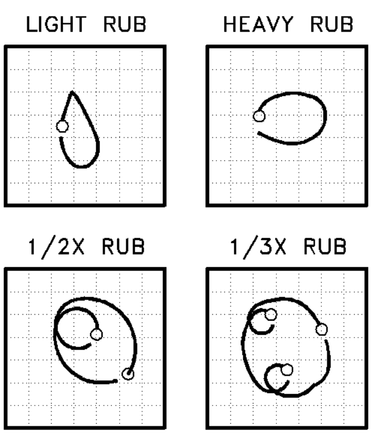
RUB

A common problem in newly rebuilt or modified rotors is a slight rubbing condition as the rotor is initially operated. Rotor rubs are not a phenomenon, which continues over an extended period; they usually increase the clearances until the rub has been cleared or, if not corrected, they will wear away the internal clearances until the machine cannot be operated. The shape of the orbit display will differ depending upon the relationship of the shaft speed to the first natural frequency and the severity of the rub.





Spectra displays of rub conditions are characterized by distinct frequencies that occur at multiples of a fundamental frequency. The fundamental frequency will depend upon the relationship of the shaft speed to the first natural resonance frequency. At shaft speeds up to twice the natural resonance frequency, the fundamental rub frequency will coincide with the shaft speed with multiples at 2X, 3X, etc. Between twice and three times the first natural resonance frequencies, the fundamental rub frequency will be ½ shaft speed with multiples at 1X, 3/2X, 2X, 5/2X, etc. Between three and four time the natural resonance frequency, the fundamental rub frequency will be _ shaft speed with multiples at 2/3X, 1X, 4/3X, 5/3X, 2X, 7/3X, etc.



The severity of the rub will affect the shape of the orbit. A light rub will produce a "tear drop" shaped orbit, with the point of the teardrop coinciding with the impact spot. As the rub gets heavier the orbit will flattened and may appear as an excessive preload.

At higher machine speeds (above twice the first natural frequency) the unfiltered orbits will begin to have internal loops with the fundamental rub frequency inversely proportional to the number of internal loops. These internal loops will have their own phase marks displayed and the loops will be located symmetrically on the display.

Bearing Failure Modes-Journal Bearings Checklist

1. Balance
2. Cracked Shaft
3. Loose Rotating Parts
4. Oil Whirl
5. Oil Whip
6. Excessive Preload
7. Rub

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