Rotating Equipment Vibrations

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While vibrations can be caused by many factors—the environment, operational conditions, natural phenomena, or external input—they're commonly associated with rotating equipment. By rotating equipment, we mean engines, pumps, compressors, fans, and any equipment which had an internal element that spins. For this discussion, the term 'element' will be any object attached to the shaft within the equipment that fulfills the equipment's function. Vibration in rotating equipment has been extensively studied, mostly because it's so common and because it's readily reproduced. Vibrations from a rotating element can be classed into different overlapping categories:

Synchronous Vibrations

Synchronous vibrations occur at the rotational speed of the equipment's shaft, expressed as rotations per minute (RPM). These appear in vibration analysis as amplitude peaks at the operating speed of the equipment or discrete multiples of that speed (1, 2, 3x the RPM). Synchronous vibrations are caused by problems with loads—unbalanced elements, eccentric elements, an unbalanced overhung load, uneven gear loading, or misaligned drive belts—or with the rotating shaft—bent shaft, offset shaft alignment, angular shaft misalignment, or a 'cocked', misaligned bearing. Vibrations from unbalanced overhung loads, uneven gear loadings, and misaligned drive belts can look the same—they're loads from the outside driving the shaft, which are causing fluctuations at the driven speed of the equipment.

Sub-Synchronous Vibrations

Sub-synchronous vibrations occur at fractions of the equipment's driven RPM. These appear at discrete fractions (1/2, 1/3, 1/4x the RPM) of the shaft speed—though mostly commonly at even fractions (1/2, 1/4, 1/8...) of the shaft speed. Causes for sub-synchronous vibrations include rubbing in the equipment, improper gear meshing, pole passing (in electric motors), belt natural frequency vibration (belt-driven equipment), or lubrication faults.

Harmonic Vibrations

Harmonic vibrations are a superset of synchronous and sub-synchronous vibrations. Harmonic simply means the vibration occurs at intervals which coincide with either a driven speed or the natural frequency of the object, or some multiple of that speed. Some other causes of harmonic vibrations can be the blade passing frequency for fans and pumps, or damage to a rotor bar in electric motors.

Non-Synchronous Vibrations

Non-synchronous vibrations have amplitude peaks that do not coincide with the RPM of the equipment or some multiple of that speed. Non-synchronous vibrations are often hard to find—the harmonic vibrations usually have large, distinct amplitudes, whereas non-synchronous vibrations can be diffuse and with smaller amplitudes. Causes of non-synchronous vibrations include the excitation of the natural frequency of an element, electrical line frequency (for AC motors), SCR frequency (for DC motors), turbulent flow or cavitation, the electrical pole passing frequency, drive belt frequency, and lubrication problems. It can also be problems with roller (anti-friction) bearings—fretting of the race, local overloading, out-of-round rolling elements, cage damage, or incorrect pre-load.

Radial Vibrations

When the vibration amplitudes are oriented horizontally and/or vertically relative to the axis of the shaft, then the cause is radial in orientation. Causes which show up as radial vibrations are all acting somehow to cause the shaft to vibrate out-of-plane—unbalanced elements, eccentric elements, rubbing, offset alignment, and belt natural frequencies can be considered.

Axial Vibrations

When the vibration amplitudes are oriented along the axis of the shaft, then the cause is axial in orientation. Causes that show up as axial vibration are acting in a way to cause the shaft to vibrate along its axis—misaligned bearings, angular misalignment, a bent shaft, misaligned drive belts, and an unbalanced overhung load will exhibit axial vibrations. If the vibrations are only axial, these are the main causes. Often, though, these will also manifest some degree of radial vibration.

When analyzing vibrations, it's important to make sure all possible vibrations are captured by using multiaxis accelerometers or accelerometers oriented in each axis. Ignoring an axis because that's not how the vibration seems to be acting can mislead the investigator. It's equally as important to examine the equipment before a vibration analysis so that one, the monitoring sensors are placed in an appropriate location, and two, the investigator can visualize the potential areas of concern.

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