Lifetime Reliability • Solutions

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Rotating Equipment Health Diagnosis

GEARBOXES

Gearboxes provide the means of transmitting torque and changing direction or speed.

They are complex machines and do not make for easy condition monitoring or diagnostic analysis.

Gear mesh frequency (GMF) is the most observed vibration and the degree to which the mesh is worn, misaligned or damaged will determine the strength of harmonics in the spectrum.

It is often very useful to trend the growth of harmonic amplitudes, in particular the second mesh (GMF x 2), which is an indicator of incorrect backlash and profile wear.

Eccentricity of gears or bent shafts are identified by studying the side bands around GMF and its harmonics (refer to the notes on FFT analysis in Chapter 3). This technique can allow positive identification of the particular shaft and gearset causing the problem in a complex gearbox.

It is very useful to study the time domain in gear analysis, especially if a cracked tooth is suspected. Time synchronous averaging using a tacho pulse from the shaft carrying the faulty gear greatly enhances the fault amplitude above the general noise.

Time domain analysis is essential on slow speed gears such as mill pinions, slew drives and the like where the impact of the faulty tooth may occur so infrequently as to not be captured in the time samples for normal frequency analysis.

Mutual Mesh Frequency (MK4F) is worth calculating where two faulty teeth in meshing gears cause a modulation of the fault impact amplitude. The formula for MMF is as follows.

$$MMF = \frac{\text{Speed of Gear 1}}{\text{LCM of MatingGear2 Teeth}}$$

The monitoring of bearings in gearboxes calls for special techniques of which HFRD is the simplest. It is essential to be able to positively identify fault frequencies in the midst of all the other high frequency vibration activity.

Countless papers have been written by academics and researchers on other techniques such as the Hilbert Transform and Cepstrum to name just two. We have not found it necessary to use these techniques providing HFRD is carefully applied.

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As a final comment, gearbox fault analysis is usually well supported by wear debris analysis and again, providing the sampling is well done, can provide good confirmation of a vibration diagnosed fault.

DIAGNOSTIC NOTES FOR CENTRIFUGAL FANS,

The following notes relate specifically to centrifugal fans with backward sloping blades but have general application to any centrifugal or axial fans,

UNBALANCE:)
MISALIGNMENT:) **Refer to TOP 4 DIAGNOSTIC CHART**
LOOSENESS:)
FAULTY RIE BEARINGS:)

SURGE: Typically produces vibration at 0.1 to 0.5 x Shaft Speed. Amplitudes are unstable and parallel changes in fan noise may be heard. Check fan operating conditions against makers curves.

RESONANCE: (a) Structure. Fan structures are often lacking in required stiffness. Resonance will produce very directional vibrations. Check phase between horizontal and vertical on bearings. Axial resonance on bearing supports is common. That is, the 'rocking' stiffness of the bearing assemblies is insufficient. Check with bump test.
(b)Shaft. A shaft natural frequency near operating frequency will cause whirl and very high shaft x 1 vibration. Variable speed fans are very prone to this problem- Fine trim balancing in-situ can reduce vibration to acceptable levels.

***COCKED BEARING:** Inner race alignment to shaft is critical to a smooth running fan because of the high axial thrust. The combination of axial thrust and inner-race wobble will severely reduce bearing life.

RUB: Rubs will usually be heard. Vibration data will most-likely show rotational harmonics (x 1, x2, x3 etc) and possibly sub-orders and half-orders (x 0.5, x 1.5, x 2.5 etc).

UNEVEN AERODYNAMIC LOADING. Eccentric or wobbly runner can generate internal pressure waves, usually at Shaft x 1. Minor run-out errors are not usually significant.

BLADE-PASSING VIBRATION. Vibration generated at Shaft x n fan blades. Not usually a problem unless there are either structural or duct resonances present. Duct resonance can be determined by measuring the straight lengths of the duct **and** relating these dimensions to the celerity of sound and quarter, half **and** full wave reflection lengths.

DIAGNOSTIC NOTES FOR RECIPROCATING MACHINES.

Important: Vibration measurement of reciprocating machines can be a useful indicator of condition but it is important to remember that there are many failure modes that are not readily indicated by vibration. For all rotating machines periodic oil sampling and analysis is essential and thermography can be useful.

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RECIPROCATING ENGINES: Vibration measurements can be useful for monitoring balance and alignment conditions and possibly some aspects of looseness. However, vibration alone is of limited value for true condition monitoring. It is much better to take a 'Performance Monitoring' approach to engines and measure parameters that will give **an** indication of things such as loss of compression, faulty injectors, changes in temperature, etc.

RECIPROCATING COMPRESSORS: Again, vibration is of limited value but worth including as one of several measured parameters. Most common failure modes are valve leakage, cross-head wear, loss of compression due to ring wear, seal leaks and the like. Few of these will be seen in vibration data.

TURBO-MACHINERY

High-speed turbo machines are generally very reliable and maintenance is usually only required for seal wear, blade fouling and the like.

Most faults are generally bearing-related and require design changes. Oil whirl, oil whip, bearing looseness and the like can usually be designed out and never seen again.

Bearing cap data can be very useful for condition monitoring but is less useful for fault analysis. Obviously direct shaft position measurement via proximity probes and data acquisition systems provides for much more powerful diagnostics.

The diagnostic routines for machine fitted with proximity systems are will developed and readily available for reference.

Most data collector/machinery analysers are able to do single channel Bode and Nyquist plots which are different ways of displaying the amplitude/phase vectors as the machine runs up or down.

Orbit analysis (two channels plus phase) is most commonly applied to steady state conditions where the shape of the orbit gives vital information about alignment, balance, rubs, etc.

Shaft couplings are often gear-type and oil lubricated. They are a common source of problem due to poor capacity for axial float. Tooth wear or binding will often be evident on careful examination. Replacement is the only fix.