Mechanical Measurements III

Measuring Self Excited Mechanical Resonances

Structural resonance in rotating machinery often increases noise and vibration levels and can lead to premature failure. LeCroy oscilloscopes can be employed to find and measure self excited resonances. The key features required of the oscilloscope for these measurements are long memory, multiple zoom displays, and frequency domain analysis.

Figure 1 shows a typical setup for measuring self excited resonance in a cooling fan. The instrumentation is identical to that required for characterizing rotational vibration and dynamics. The difference in this application is the analysis performed in the oscilloscope.

The fan is started and the speed is allowed to run up from 0 rpm to its operating speed of 1400 rpm. The oscilloscope captures 10 second records of both the rotational speed, from the tachometer, and the vibration level, from the accelerometer. The upper trace (ch 1) in figure 2 is the tachometer output. Using the Jitter and Timing Analysis (JTA) option and the rescale math function the oscilloscope displays a plot of rotational speed, in rpm, as a function of time. This plot is shown in trace B. Trace C is the vibration data scaled to read acceleration in g's.

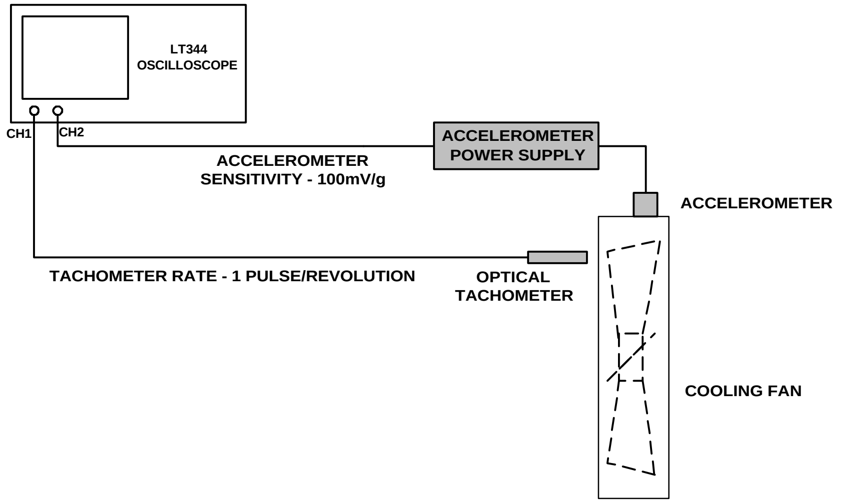

Figure 1 - Block diagram of a test setup to measure self excited mechanical resonance in rotating machinery structures

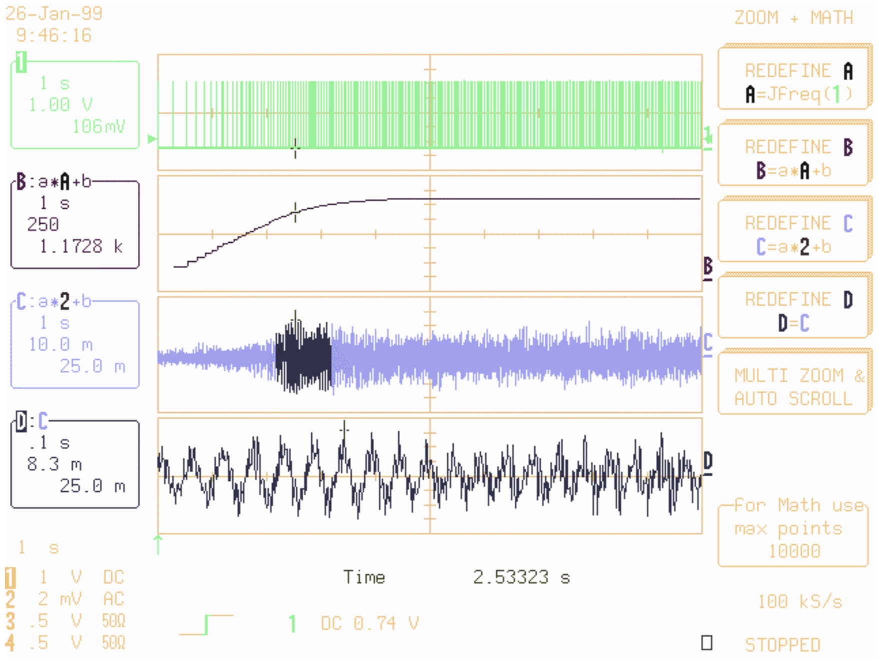

Figure 2 – Running the fan up from 0 to maximum speed excites a structural resonance in the fan housing.

Note that the resonance, indicated by a peak in vibration level, is highlighted in trace C.

This section of the vibration waveform is shown in great detail in zoom trace D. A Cursor reads the peak vibration level as 8.3 10^{-3} g's at a speed of 1173 rpm.

The Fast Fourier Transform (FFT) of the vibration signal, computed over a 0.1 second window, is viewed as the window is slowly scanned over the entire waveform. This technique, shown in figure 3, is automated using the oscilloscope's auto scroll feature. As the window moves through the waveform the spectral components of the FFT vary in amplitude. Spectral components related to the fan's rotation move to the right as the speed increases. The resonance however, is fixed in frequency and its amplitude increases at certain machine speeds. The box in figure 3 highlights the resonance at 100 Hz. The cursor marks the rotational speed as 857 rpm (14.29 Hz). At this speed the blade passing frequency of this 7 bladed fan is 100 Hz (14.29 X 7 = 100).

Figure 4 illustrates another increase in the vibration level when the fan's speed reaches 1200 rpm (20Hz). At this speed the 5th harmonic of the motor speed is exciting the resonance at 100 Hz. This is the principal resonant response and is easily seen in the vibration waveform in the form of an amplitude peak.

As the motor continues to increase in speed the spectral peak at 100 Hz again decreases in amplitude. The two main spectral components include the rotor speed 1400 rpm (23 Hz) and the blade passing frequency 161 Hz (7 X 23= 161).

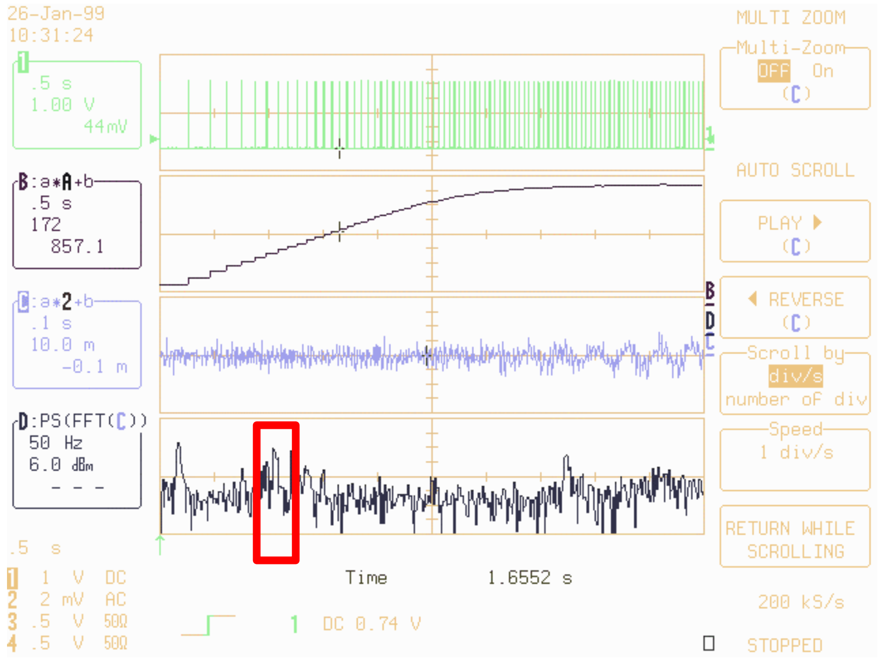

Figure 3 – Using the FFT of the vibration signal to determine the frequency of the resonance.

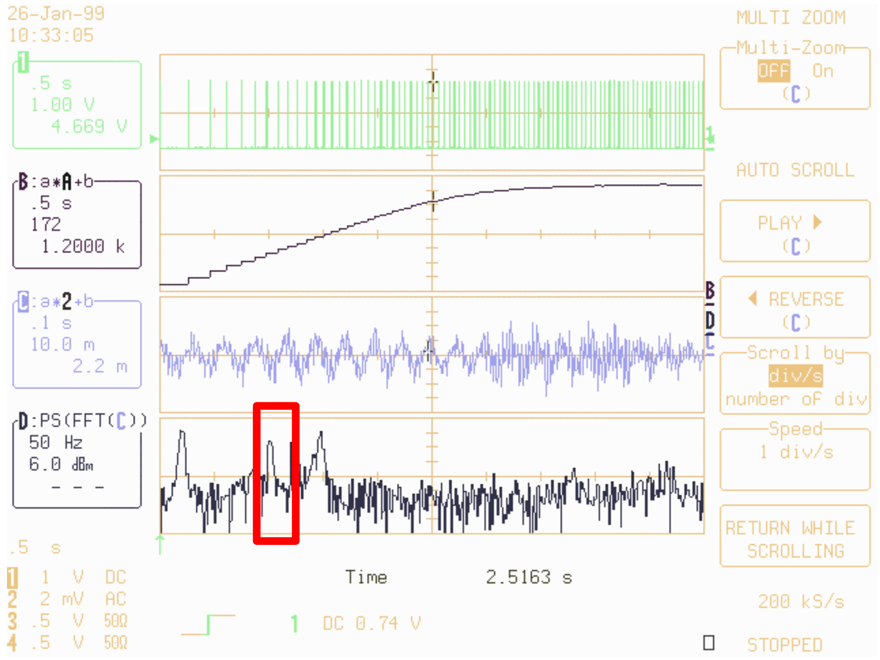

Figure 4 – The structural resonance at 100 Hz is also excited by a harmonic of the fan motor running at 1200 rpm (20 Hz)