

Vibration Monitoring

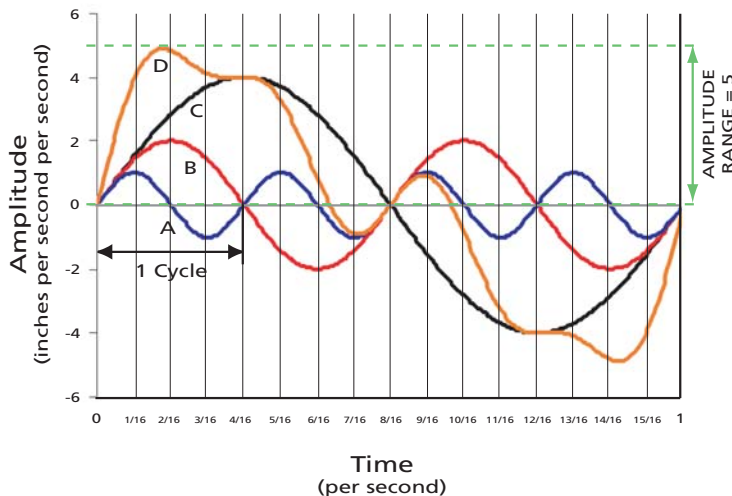
WHAT IS TIME-BASED VS. FREQUENCY-BASED VIBRATION MONITORING?

Vibration is measured with devices called accelerometers which supply an electrical output signal that is indicative of the magnitude of the acceleration at any point in time. This time based output can be displayed as a single waveform on a graph showing the magnitude (or amplitude) of the signal over time. (See Figure 1, Waveform D)



In reality this "overall" vibration is often comprised of multiple individual vibrations each having their own frequency and amplitude. These individual vibrations can be shown as sine waves on a graph. When added together these individual vibrations result in the overall vibration waveform.

FIGURE 1: ACCELEROMETER OUTPUT OVER TIME



Let's say for example one sine wave represents rotor pass frequency (A), the second is bearing defects frequency (B) and the third is compressor shaft end-play frequency (C). With overall time-based vibration monitoring only one waveform (D) is displayed; thus the data values displayed from this single waveform do not accurately identify the vibration source or potential component failures.

With time-based vibration monitoring, the overall amplitude is used to determine what action, if any is required. If the amplitude of the vibration is within the normal operating range, no action is taken. However, if the amplitude of the vibration exceeds the alarm set point, an alarm signal is generated. Similarly, if the amplitude exceeds the shutdown setpoint a shutdown signal will be generated.

In figure 1, the amplitude of the overall vibration would be 5. Therefore, if the shutdown limit was set to 4, the controller monitoring this overall vibration would stop the compressor. However, overall vibration provides no indication as to the source of the vibration, and it could result in nuisance shutdowns if the individual vibration sources (each by themselves are within limits) when added together result in high overall vibration.

To summarize, time-based or overall vibration measurement is the continuous monitoring of a single waveform; and unless this waveform is mathematically broken down into a series of individual vibration sources (sine waves), the vibration readings displayed are valueless.

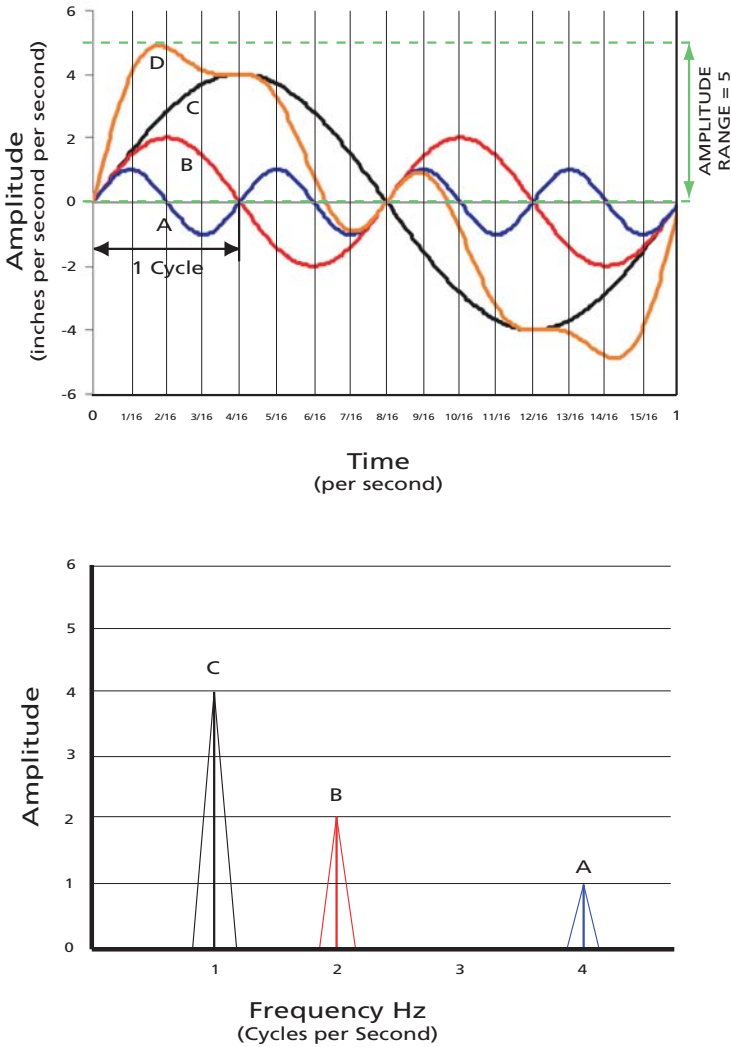
Now let's evaluate and describe frequency-based vibration monitoring. This type of vibration monitoring utilizes Digital Signal Processor (DSP) technology.

A DSP is a high speed signal processor that is designed for a specific type of mathematical computation. DSP's process signals by repetitively sampling a single waveform at precise intervals so detailed frequency analysis can be performed. By sampling a waveform in a repetitive manner and using Fast Fourier Transform (FFT), a great deal of information about that waveform is revealed.

An FFT operates on the principle that all waveforms, regardless of shape, can be broken apart into a series of sine waves. The FFT processes the repetitive samples using a lengthy series of mathematical functions to break the single waveform down into individual sine waves. The output of a FFT can be plotted to graphically represent the frequency spectrum as a series of bar graph displays.

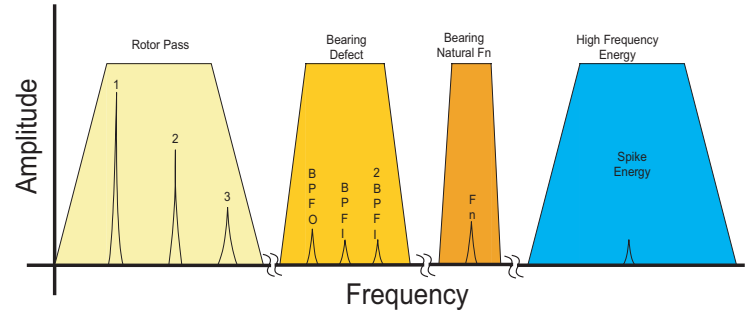
Each bar of the FFT graph represents a frequency and its relative amplitude of the individual sine waves. Staying with the original time-based example, Figure 2 shows how the time-based frequency waveform D is transformed into individual frequencies and their associated amplitudes. This overall vibration waveform is comprised of individual vibrations of 1 cycle per second with an amplitude of 4, 2 cycles per second with an amplitude of 2, and 4 cycles per second with an amplitude of 1.

FIGURE 2: TIME-BASED VS. FREQUENCY-BASED VIBRATION



This continuous monitoring of a single waveform that is mathematically broken down into a series of individual sine waves using FFT analysis techniques is referred to as frequency-based vibration monitoring. The frequency-based vibration data (or frequency spectrum) is then used to pinpoint component failures and/or the source of vibration (Figure 3).

FIGURE 3: FREQUENCY SPECTRUM ANALYSIS



Frequency-based vibration monitoring may be used as a diagnostic tool. Through vibration signatures specific to components such as bearings or rotors; repairs and maintenance can be more effectively scheduled, resulting in lower overall cost of ownership. By determining which frequencies are present and their relative amplitudes the DSP can examine the specific frequency bands of interest and reject those that are not of interest. The ability to reject unwanted signals is important because this eliminates false alarms and shutdowns, something that is not available with time-based or conventional vibration monitoring.

Figure 3 provides an example of how vibrations at various frequencies may be analyzed to determine their sources and expected amplitude.