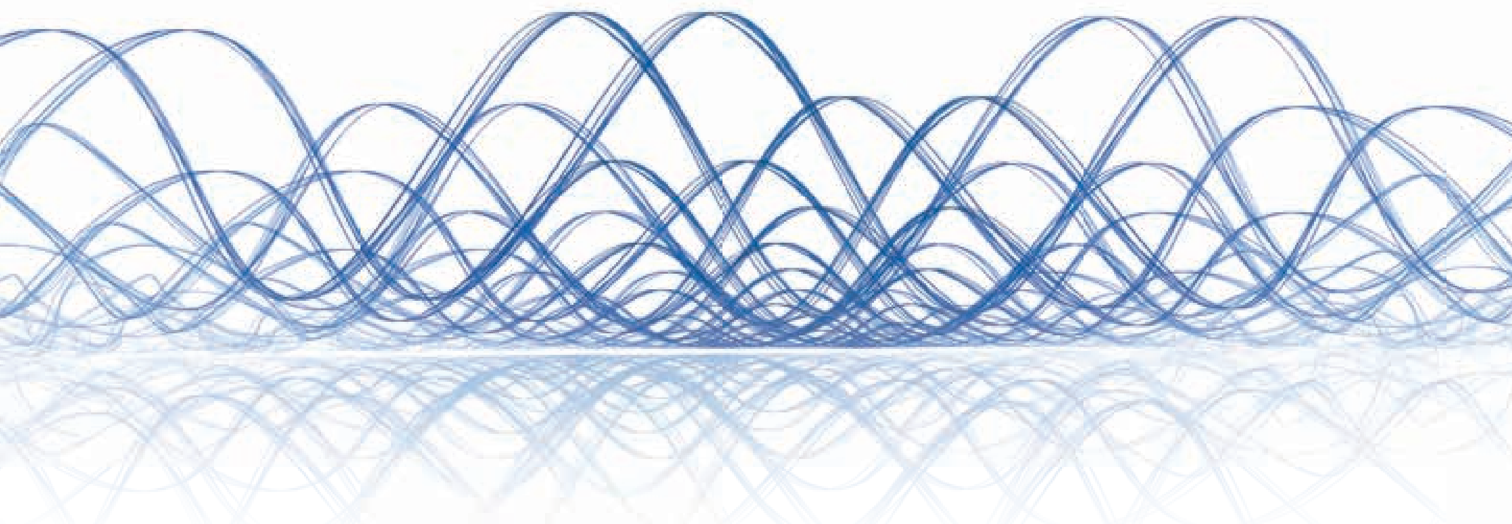
Vibration Amplitude Criteria

Use actual vibration data to baseline machine condition BY BILL WATTS, P.E



A basic principle of machinery vibration analysis is evaluating whether specific vibration amplitudes are excessive and, if so, to what degree. Many criteria provided by manufacturers and other entities simply say that no single spectral peak should exceed a prescribed amplitude. Others are even more basic and establish overall broadband limits for a given machine or test location. Still others get more specific and creative by establishing amplitude limits within each of a handful of frequency bands.

There also are long-established severity charts that present contours of amplitude versus frequency, with provisions that account for machine type (reciprocating, etc.) and size. A major problem with simplified approaches is that serious discrepancies can occur. One machine can appear to be bad because it produces one very high vibration tone, which is proven to be benign. Another machine can easily meet general amplitude criteria while producing a strong series of high-frequency ball bearing tones indicating serious bearing wear.

The solution is to let the machines dictate what is acceptable.

Consider a group of eight identical machines, say, large motor-driven centrifugal pumps. Each is set up for vibration testing using identical variables, including two frequency ranges. Each has two test locations on the motor and two on the pump. Permanently attached bronze pads provide consistent triaxial data with good frequency response.

It is important to establish consistent and repeatable test operating conditions to achieve an apples-to-apples comparison. Instead of using a fixed frequency scale (in CPM or Hz), the spectral data need to be order normalized with respect to the rotating speed of a reference shaft. Order normalization allows the various spectral peaks associated with rotating forcing frequencies to line up. While this approach doesn't apply to fixed-frequency excitation from electrical or external sources, the resulting shift on an orders scale can be mitigated by using consistent test speeds.

Collect one set of initial data from the eight pumps. It is possible to directly compare vibration signatures for each test location. This procedure requires as much art and judgment as logic. If five of the eight vibration signatures look relatively similar, those five test samples are assumed to represent machines with no significant problems. Appropriate software then incorporates the five samples into an average baseline signature and computes the average amplitude and the statistical standard deviation (one sigma).

Additional rounds of testing add more samples to this baseline after applying comparative judgment. The baseline construction can stop after about 20 or 25 test samples are taken because the values of average and sigma change very little with additional samples.

The sigma value accounts for natural variations of specific amplitudes. As an analogy, assume that the average daily high temperature is 80°F while the actual temperature ranges from 70°F to 90°F for 85% of the time. Would the weather be abnormally hot if the temperature is 89°F one day? If, one day, the temperature is 71°F, is the weather abnormally cold?

The answer to both questions is "no." If, on the other hand, weather statistics show a more narrow range, say between 75°F and 85°F, then 89°F becomes abnormal. Similarly, it's wise to use the average plus sigma vibration amplitude as a criterion, as opposed to using a simple average value. It's not worth arguing whether the baseline amplitude criterion should use one, two, or three sigma. As long as the criteria are applied consistently and empirically, the system can work.

This is the optimum approach for establishing amplitude criteria if a monitoring program covers multiple identical machines. It's particularly beneficial if a site has only one machine of a specific model, but the same model is installed at other sites. Using test samples from multiple sites to construct a single set of baseline signatures for one model solves the problem of establishing a reliable baseline. A mature average baseline signature allows an analyst to assess machine condition according to what one expects to see (logical) and what one has seen in the past (empirical).

The approach of using average plus/minus one sigma has been applied to a wide variety of machines. The accumulated experience with these signatures yields the idea that perhaps this complex set of criteria can be regressed to a more general tool for amplitude evaluation. In other words, it would be advantageous to have some basis for evaluation the first time you perform a vibration test on a machine. Is it possible for one set of vibration signatures to serve as a generic baseline for a component type?

There are two major obstacles to this concept. Consider centrifugal pumps. First, some pumps are inherently noisy, while others are inherently quiet. Using a single set of signatures to assess all centrifugal pumps could result in overstating or understating fault severity. Second, forcing frequencies can vary (number of pump impeller vanes, for example). A six-vane impeller can have normal but prominent vibration at 6x, 12x, and 18x rotational speed but much less vibration at other 1x harmonics. A pump with a five-vane impeller will produce a different set of prominent peaks at 5x, 10x, etc.

The same situation arises with motors (rotor bars cause frequency sidebands at twice electrical line frequency) and gearboxes (at gear tooth counts). This second problem can be solved at least in part by means of an active-baseline synthesizer.

Machinery vibration analysis, whether performed manually or by diagnostic software, requires some sort of baseline. That baseline needs to exhibit realistic amplitudes at various forcing frequencies and noise floors. The ideal baseline is derived from empirical test data from machines of the same model.

If that's unavailable, a synthetic baseline can be derived from similar components, but it is a generic and less precise alternative. A reliable baseline of amplitude criteria not only facilitates specific machine fault diagnoses, but more importantly, leads to more consistent and accurate severity assessment and trending over time.

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