

Taking Accurate Vibration Measurements

Written by Greg Lee, Ludeca, Inc.
Tuesday, 01 June 2004 08:32

Have you ever talked to a vibration technician who is upset because vibration readings from a new data collector are different from those of an older unit or different brand? On the surface it seems logical that they should agree. An overall velocity reading is an overall velocity reading, right? Not so fast.

Filter settings, frequency ranges, overall calculation from a spectrum, and accelerometer ranges are just a few of the factors that can influence the apparent amplitude of a measurement.

As an example, a customer at a large oil refinery was concerned that his recently purchased cooling tower monitor indicated 25 mils of vibration at the output shaft. The monitor card was designed to display the correct amplitude for the 67 rpm fan. Two other portable systems indicated 8 and 10 mils of vibration using the same permanently mounted velocity transducer.

Some investigation showed that when the portable instruments integrated to displacement, they were not linear at the 67 rpm fan speed. The manufacturers of the portable instruments provided multipliers to apply to the measurements and all was well. The adjusted portable instruments' measurements were within 2 to 3 mils of the monitor's readout.

Overall measurement filter settings

Many vibration instrument manufacturers use a spectrum to calculate the "overall" reading such as velocity. For example, if a spectrum is set from 0-24,000 cycles/min (cpm) or 0-13 orders on an 1800 rpm machine, the overall that is calculated will cover only the signals within that frequency range. If there were a large gear mesh frequency at 50,000 cpm, this measurement setup would miss it.

The calculation of "overall" using a spectrum is really an estimate of the overall filtered by the frequency range of the spectrum. The spectrum/calculation method for deriving "overalls" is often used to speed data collection, but there is a risk in taking such shortcuts for the sake of speed. One way to overcome the risk of missing a fault frequency is to measure multiple spectra with differing frequency ranges and resolutions. If this approach is implemented, the speed of data collection is significantly extended.

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A preferred method is to measure the “overall” separately from the spectrum. This is similar to how a voltmeter would measure voltage and is the method recommended by the International Standards Organization (ISO) 10816-3 vibration standards. Using this “overall filter out” method, the raw signal is still filtered, but with a broadbanded band-pass filter that has both a high-pass side and a low-pass side.

Using the same 1800 rpm machine with a large 50,000 cpm gear mesh component, the high-pass filter set to 10 Hz (600 cpm), and the low-pass filter set to 1000 Hz (60,000 cpm), the measurement would be much greater than indicated by the calculated “overall” method. For root mean squared (RMS) measurement of overall velocity and displacement, the ISO specification 10816-3 recommends the frequency range in [Table 1](#).

The ISO 10816-3 method is generally considered the safest method for taking “overall” measurements because it is less likely to result in an inadvertent exclude signal. Fortunately, the ISO also recognizes that 10816-3 does not cover all possible machinery fault frequencies. The ISO acknowledges that extending the filter frequency ranges and allowing additional measurements in units of acceleration may be necessary for some machines.

The important thing to remember is that the differences in measurement methods and filter settings can lead to large discrepancies between vibration instruments. These discrepancies alone do not necessarily mean that either instrument is inaccurate or out of calibration.

RMS vs 0-peak vs peak-to-peak

Another data collector setting that can make measurements look different is the amplitude method used in measuring the signal. For overall velocity measurements, the ISO recommends using an RMS measurement method to meet its standard. Traditionally in the United States, the 0-peak method has been used because some experts make a case that it is a better indication of the maximum vibration a machine experiences.

The ISO, and increasingly more experts in the United States, are turning to the RMS method as it is a better indication of the total energy being spent on vibration and thus relates better to the damage being caused by vibration. This can best be illustrated by thinking of a one-time sharp spike of vibration at 3.0 in./sec lasting only 1 millisecond. The 0-peak method would indicate 3.0 in./sec, which is high and would be cause for alarm.

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However, the same signal measured using RMS indicates only 0.25 in./sec. RMS is 0.707 times the 0-peak value of a sine wave. Since the 3.0 in./sec spike is not a sine wave, the total energy of vibration is more accurately represented by the RMS value of 0.25 in./sec. [Fig. 1](#) shows examples.

Peak-to-peak is generally used when measuring in units of displacement or mills. When monitoring journal bearings with proximity or eddy current probes that directly measure the gap across the journal bearing, clearance is the prime issue, not the energy of the vibration. If there should be 10 mils of gap in a journal bearing, yet a proximity probe is indicating 11 mils of displacement in peak-to-peak, there is a significant problem.

It is a common mistake to place an accelerometer on a journal bearing housing, integrate the signal to displacement, and compare the measurement to the proximity probe reading. These measurements are not the same.

Mounting accelerometers

Vibration measurements are sensitive to how the accelerometer is mounted and placed on the equipment. Measurements often change significantly when a vibration technician goes on vacation and another takes his place. A number of years ago it was common to see technicians taking measurements with a 9-in. probe screwed to the end of an accelerometer. There have been cases where a rolling element bearing failure was not detected because the mounted resonance of the 9-in. probe masked the bearing frequencies. By simply varying the pressure and angle of the accelerometer into the machine, the amplitudes of the measurement can be changed 30 percent or more.

Magnets are better than 9-in. probes, but they are not well suited for higher frequency events such as gear mesh frequencies and shock pulse measurement. Placement and cleanliness of the magnet also can have significant effects on the amplitude measurement. A magnet placed on a painted surface can have much the same effect as a 9-in. probe, masking bearing and gear frequencies.

Holding the magnet with one's hand when taking measurements can have an effect on the amplitudes as well. When a vibration from the machine happens to coincide with the mounted resonance of a magnet, large amplitudes can be generated that have little to do with the actual severity of machine vibration. The combined differences between the size of the magnet and the mass of the magnet/ accelerometer/cable assembly also can have large effects on the

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resulting amplitude measurement.

Stud mounting accelerometers is a good technique for transferring a wide range of frequencies through the mounting seam into the accelerometer. As stated earlier, using different accelerometers and accelerometer mounting methods can lead to large discrepancies between instruments. To make stud mounting more convenient, there are several cam lock and quick mount methods available.

Response curves, configuration

Accelerometers have a linear response over a specified frequency range. Some accelerometers are optimized to measure low-frequency ranges and others are better at high-frequency ranges. Because the design of accelerometers is driven by specific applications, the linear response varies between accelerometer models and brands.

In a comparison between two models of accelerometers, [Fig. 2](#) shows an accelerometer that is designed to measure low-frequency ranges down to 1 Hz and is not linear at high frequencies above 10 kHz. The response curve of

[Fig. 3](#)

indicates that this accelerometer is not linear at 1 Hz but it is linear between 10 Hz and 20 KHz. While there is an overlap of frequency ranges where both accelerometers are linear, at the extremes of high or low frequencies they will present differing results.

Measurements taken with different accelerometers will not necessarily disagree, but if the vibration is not in the linear frequency range of one accelerometer and is in the linear frequency range of another accelerometer, the measurements will differ.

Accelerometers can give different signal outputs, which if not properly configured in the instrument, can cause vastly different vibration readings. It is imperative that the vibration instrument is properly configured for the accelerometer, or the results could be grossly in error.

Ensuring reliability

There are many reasons two different instruments may not produce the same amplitude vibration measurements. Both instruments can be correct yet display different values. The ISO has tried to standardize many of the variables that lead to discrepancies between

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measurements. Some of these are controllable, such as filter settings, but some are more difficult, such as magnet mounting.

Until more vibration suppliers adopt or include the ISO vibration standards, significant differences will continue to be a reality. What can be done to ensure the safe measurement of the vibration?

1. Examine the frequencies the equipment will emit by calculating such things as rpm, bearing frequencies, blade/vane pass frequencies, and gear mesh frequencies. If there are components that can emit high-frequency wear noise like rolling element bearings, be sure to consider high-frequency measurements like shock pulse.

2. Make sure overall measurements have the band-pass filters set to include several multiples of the bearing frequencies.

3. Take multiple parameters such as velocity, acceleration, and shock pulse. This will help avoid missing higher frequency events such as gear mesh.

4. Look at the accelerometer's specification sheet and make sure it has a linear frequency range that includes the key fault frequencies calculated.

5. Use high-frequency measurements such as shock pulse to monitor the lubrication of rolling element bearings. Check with the data collector manufacturer for shock pulse compatibility, then verify which accelerometers and mounting methods are recommended.

6. Follow the ISO vibration tolerances whenever possible. This can be a great help when evaluating a new machine.

7. Use the measurement stud method of acquiring vibration measurements whenever possible. This will maximize the consistency of the measurements.

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8. Be extremely consistent when taking measurements. Simple things such as wiping dirt and metal shavings off the mounting surface of the accelerometers can make huge differences in measurements.

9. Do not despair if what appears to be the same measurements from different instruments do not agree. It is typically something simple like a filter range or an RMS vs 0-peak issue. **MT**

[Greg Lee](#) is a sales engineer at [Ludeca, Inc.](#), 1425 N. W. 88th Ave., Miami, FL 33172; (305) 591-8935

TABLE 1. ISO 10816-3 FILTERS APPLIED TO BROADBAND RMS VALUES OF VIBRATION VELOCITY AND DISPLACEMENT

Frequency Range From:

Frequency Range To:

Machine speed greater than 600 rpm

10 Hz

1000 Hz

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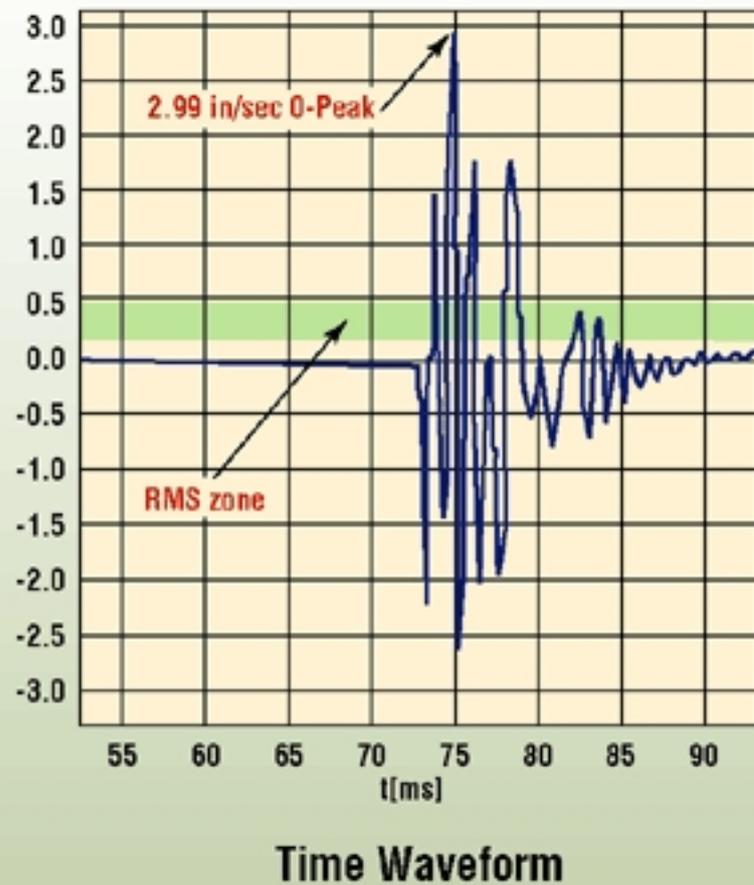
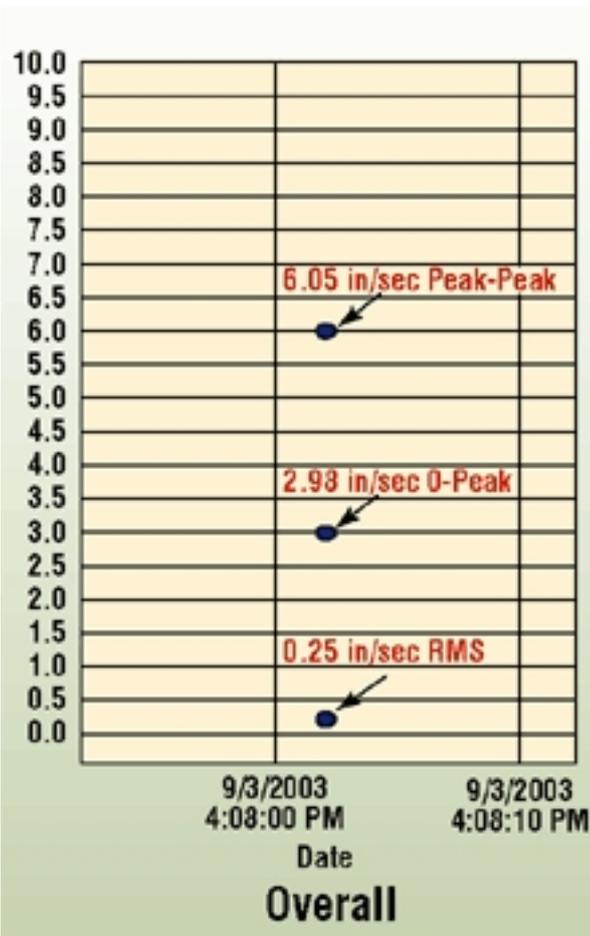
Machine speed less than 600 rpm

2 Hz

1000 Hz

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MEASURING WITH AMPLITUDE METHOD



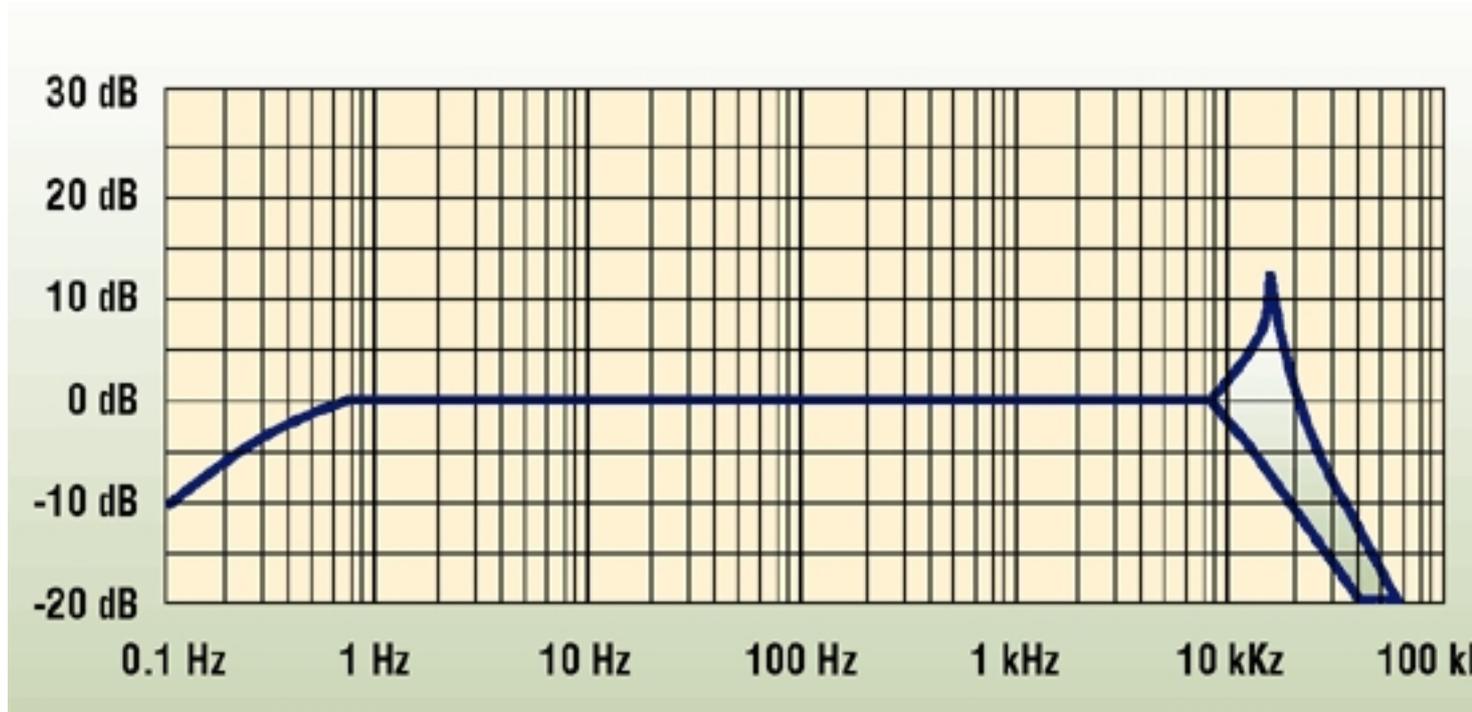
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Fig 1. Root mean squared is the preferred method of measuring the amplitude of the signal because it gives a better indication of the damage caused by vibration.

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FREQUENCY RESPONSE/THREADED OR BONDED MOUNTING



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FREQUENCY RESPONSE

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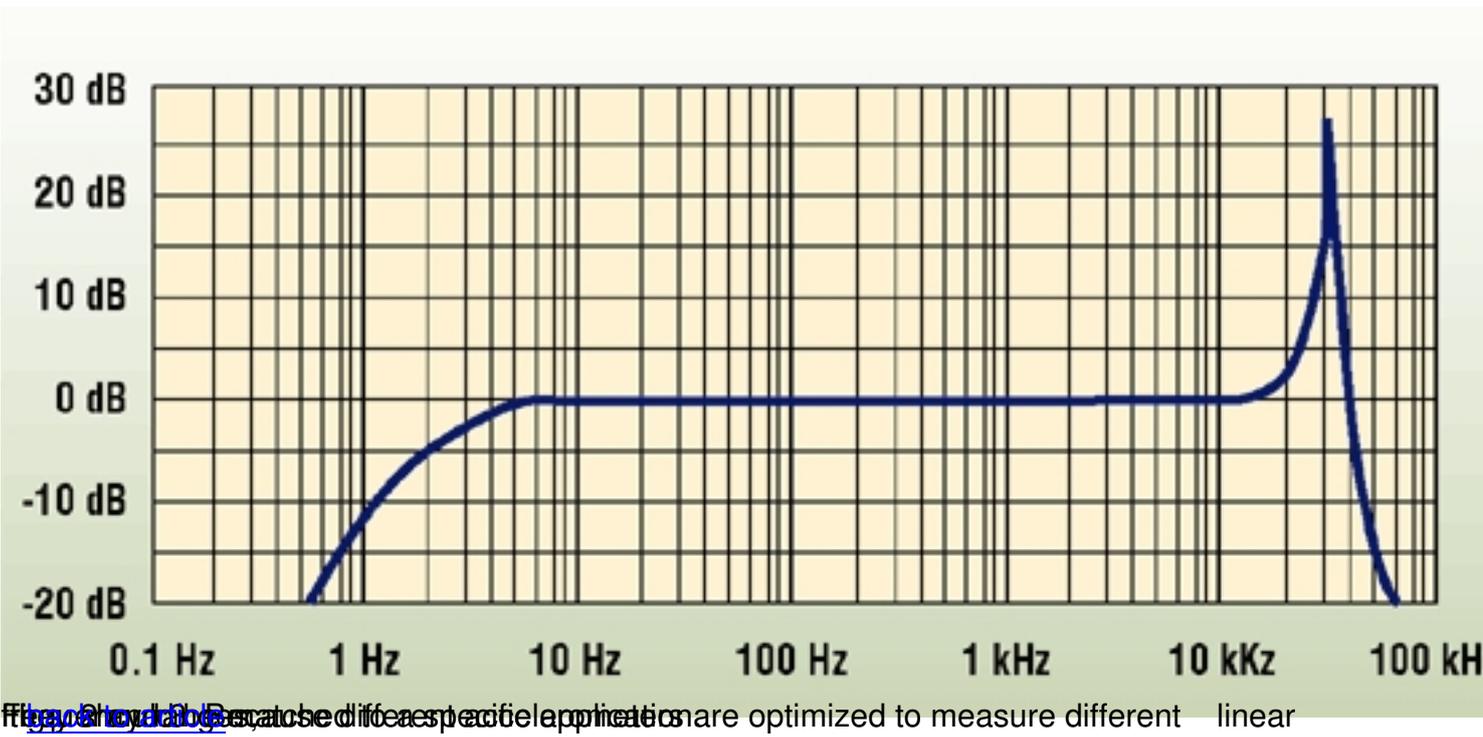


Figure 8: Crystal Oscillators used in different applications are optimized to measure different linear