Comparing Vibration Readings CVR

Comparing vibration level readings taken by different types of instruments and transducers can be very confusing and can lead to mistrust of the systems involved.

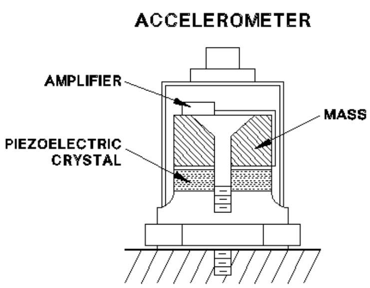
Knowledge of how to properly compare readings is required before comparing any readings is attempted.

This application note explains the variables involved in some detail and will act as a guideline as you compare vibration readings.

Transducer Type

Three (3) basic types of vibration transducers are available which correlate with the three (3) types of measured physical motion, Acceleration, Velocity and Displacement.

Accelerometer

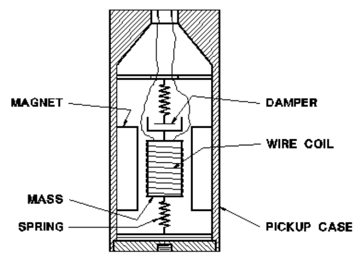


Accelerometers are a piezo-electronic (crystal) device. A pre-loaded crystal is charged with current and as the crystal is compressed or de-compressed by vibration an output proportional to g's (gravity) is provided. A "g" is equal to 9.80 meters/second^2 or one (1) standard earth gravity.

Accelerometers are normally used for high-frequency bearing cap vibration readings (Case/Bearing Cap Absolute on machines using rolling element bearings. Usually the output is integrated electronically to velocity (in/sec or mm/sec). Other applications include monitoring Gears and High Frequency Applications.

Velocity Pick-up

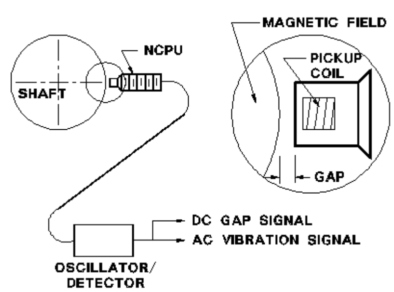
Two (2) types of Velocity Sensors exist, mechanical and electronic. Mechanical types are the most common and are made up of a spring-mounted coil mounted inside a magnet. Vibration causes the coil to move in relation to the magnet, which produces a voltage output directly proportional to Velocity. Electronic Velocity Sensors are Accelerometers with an electronic integrator built in to the unit. Output of a Velocity Sensor can be expressed in many different terms, inches/second (in/sec) or millimeters/second (mm/sec) being the standards.



Velocity Transducers are normally used for Bearing Cap Vibration Monitoring (Case/Bearing Cap Absolute) on machines with rolling element bearings. They have the advantage of high outputs and the signal is read directly in velocity (in/sec or mm/sec).

Eddy Probes (Proximity)

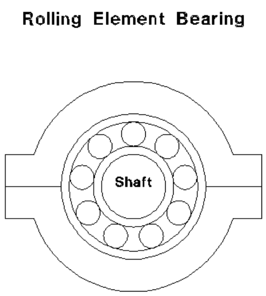
Eddy or Proximity Probes are a displacement device that measures the relative motion between the probe mounting location and the target (shaft). Output is directly proportional to displacement and is usually measured in mils (.001") or millimeters (mm).



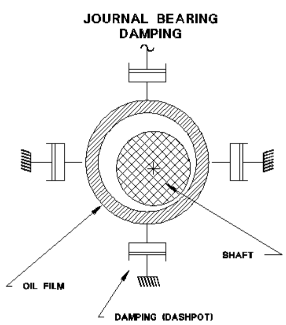
Eddy Probes are used on machines with Journal (Sleeve) type bearings. Where the measurement of motion between the Bearing and Shaft is critical.

Bearing Type

Two primary types of bearings are in use today, Rolling Element Bearings and Journal or Sleeve Bearings.



Rolling Element Bearings are zero (0) clearance devices. All vibration of the shaft is transmitted directly to the bearing cap.



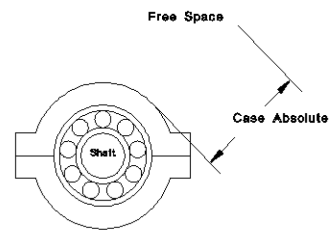
Journal or Sleeve Bearings are designed so that the oil film provides damping. The shaft is free to vibrate within the bearing. Due to the damping provided by the oil film very little of the shaft vibration is transmitted to the bearing cap. The oil film damping provides even higher levels of attenuation to higher frequencies.

Measurement Type

Only measurements of the same type can be compared. Bearing Cap or Case Vibration cannot be directly compared to Shaft Relative or Shaft Absolute and visa versa.

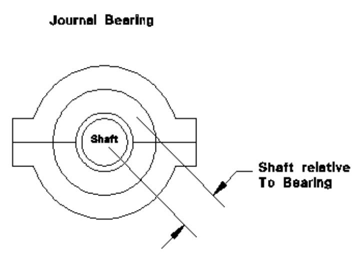
Case Absolute

Case or Bearing Cap Absolute is the measurement of the Case or Bearings Caps (Location of Transducer) motion relative to free space (or absolute motion). Case or Cap Absolute is usually used for monitoring Rolling Element Bearings.



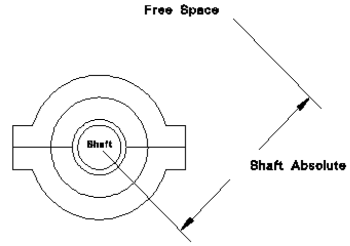
Shaft Relative

Shaft Relative is the measurement of motion between the Shaft and whatever the measuring devise is mounted to. This measurement is normally taken with a NCPU or Proximity Sensor. Shaft Relative measurements are used for Journal or Sleeve Bearing Applications.



Shaft Absolute

Shaft Absolute is the measurement of the shaft's motion relative to free space (or absolute). Shaft Absolute can be measured two (2) ways, the first being electronically summing the signals of both a Eddy Probe measuring shaft relative and a accelerometer measuring case absolute, the second being using a shaft rider which is a spring mounted device that physically rides on the surface of the shaft, normally a velocity sensor integrated to displacement is mounted on top of the shaft rider. Shaft Absolute is normally used where the rotating assembly is five (5) or more times heavier than the case of the machine.



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Engineering Units

0 to Peak (0-P)

Both Velocity (in.sec, mm/sec) and Acceleration (g's) by definition are measured in 0 to Peak or one/half the Peak-to-Peak signal as viewed on an oscilloscope.

Peak to Peak (P-P)

Displacement by definition is measured in Peak-to-Peak or the actual Peak-to-Peak Motion of the Shaft.

Root Mean Square (RMS)

Root Mean Square (RMS) is a popular method of measuring Case or Bearing Cap Vibration as many vibration engineers have found that RMS is more indicative of actual rolling element bearing condition. Although rarely found in vibration wave-forms a pure sine wave RMS would be .707 times the 0 to Peak Value.

Transducer Considerations

Frequency Response

The frequency response of a vibration transducer is very important when comparing readings. Transducers with a wider or broader frequency response will typically see more vibration if it is present than a narrower bandwidth transducer. How different vibration frequencies contribute to overall values is dependent on their phase relationship to each other, some may add, some may subtract from the overall value.

Eddy Probes	Displacement	200 mv/mil
Velocity (Mechanical)	Velocity	500 mv/in/sec
Velocity (Piezoelectric)	Velocity	500-1000 mv/in/sec
Accelerometer	Acceleration	100 mv/g

Mounting

How a transducer is mounted is also critical to comparing measurements. Accelerometers are extremely sensitive to the method of attachment. Differences in bandwidth can be measured between hand-held, magnet attached, epoxy, and stud-mounted installations.

Installation instructions must be followed precisely to obtain the manufactures transducer specifications. Accelerometers not mounted perfectly perpendicular to the surface or on a flat surface will produce stress risers, which will also produce false signals.

Measurement Location

When comparing readings it is essential that all readings be taken at the same location and the same plane. Even small differences in location can effect the overall readings. All vibration transducers are single plane devices and only measure in the plane in which they are held or are mounted.

Instrument Considerations

All Instruments handle signal is different ways. Different instruments have their own frequency response and filtering. Knowledge must be gained on the instruments used before the outputs can be compared even when they use the same transducer.

Conversion Formulas

Displacement, Velocity and Acceleration are mathematically related to each other as a function of frequency. Electronic integrators or differentiation are also used to change one term to the other. Once again it must be understood that the readings be of the same type or they will not agree.

D = Displacement, P-P, Mils.
V = Velocity, 0-P, in/sec.
A = Acceleration, 0-P, g's.

$D = 19.10 \times 10^3 \times (V/CPM)$
$D = 70.4 \times 10^6 \times (A/CPM^2)$

$V = 52.36 \times 10^{-6} \times D \times CPM$
$V = 3.87 \times 10^3 \times (A/CPM)$

$A = 14.2 \times 10^{-9} \times D \times CPM^2$
$A = 0.27 \times 10^{-3} \times V \times CPM$

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Summary

In General it is difficult to get any two readings to precisely agree with one another. Even when care is taken to insure that transducers and locations are the same and that the measurement type is the same, agreement within +-30% depending on the instrument is considered good.

Even though overall values will not agree precisely spectrum Data or frequencies will be comparable within the limits of the bandwidth of the different instruments.

Checklist

1. Is Transducer Type the same
2. Bearing Type
3. Is Measurement Type the Same
4. Engineering Units the same
5. Frequency Response of Transducer
6. Mounted Transducer Frequency Response
7. Where Readings Taken at the same location
8. Where Readings Taken in the same Plane
9. Instrument Frequency Response