1) Why monitor vibration?

Machinery vibration monitoring programs are proven to reduce the overall operating costs of industrial plants. These programs can prevent machinery damage and costly production delays due to unforeseen machinery failure. The vibrations produced by an industrial machine are a direct indication of the health of the machine. Machinery vibration monitoring programs employ vibration monitors to record the machine's vibration history. Monitoring vibration levels over time allows the plant engineer to predict problems and shut down a machine before it seriously damages itself or other machinery. Since the possible problem is discovered early, the plant has the freedom to schedule the downtime and maintenance in a cost effective manner. Vibration monitoring is also widely used as a diagnostic tool to determine the cause and location of a problem, and how to fix it.

2) How to choose between displacement, velocity and acceleration sensors.

The three primary types of motion detected by vibration monitors are displacement, velocity, and acceleration. The choice between these three different types of motion transducers depends on the frequencies of interest and the signal levels involved.

Displacement sensors are used for low frequency (1 to 100 Hz) measurements only and are useful for measuring very low amplitude displacements. They are employed in such applications as shaft motion and clearance measurements. Traditionally displacement monitors have employed non-contacting proximity sensors and eddy probes. Piezoelectric displacement transducers have recently been developed to overcome some of the mounting problems associated with non-contacting probes.

Velocity sensors are used for medium to low frequency (1 to 1000 Hz) measurements. Because they filter out high frequency signals, they are less susceptible to amplifier overloads which can compromise the fidelity of low amplitude, low frequency signals. Velocity transducers are useful for monitoring and balancing operations on rotating machinery. Traditional velocity sensors employed an electromagnetic sensor to pick up the velocity signal. Now harder piezoelectric velocity sensors are becoming more popular.

Piezoelectric accelerometers are the most commonly used motion sensors for vibration monitoring applications. They are useful over a wide band of frequencies from very low to very high frequencies (1 to 20,000 Hz) and are available in a wide variety of application specific designs. Accelerometers are the workhorse of vibration monitoring systems.
3) Why piezoelectric sensors?

Piezoelectric sensors are by far the best motion transducers available for most industrial applications. Their rugged, solid state construction enables them to operate under the most severe operating conditions. They are unaffected by dirt, oil, and most chemical atmospheres. They are also usable over a wide temperature range, and resist damage from severe shocks and vibrations. Piezoelectric accelerometers are unmatched for frequency range, and are highly accurate from very low to very high levels of motion amplitude. Internally amplified, piezoelectric transducers require only a power supply and readout equipment for operation.

The internal electronics convert the high impedance charge signal into a low impedance voltage signal. The Piezofet is a miniature hybrid charge amplifier with many unique features. The very low noise floor and low frequency response make low level measurements possible. Most Wilcoxon Research amplifiers are protected from mis-wiring, reverse polarity and overcurrent powering. It is also guarded from overloading, due to high frequency signal saturation.

The piezoelectric element in the sensor produces a signal proportional to acceleration. This acceleration signal can be amplified for acceleration measurements or converted within the sensor into a velocity or displacement signal. The piezoelectric velocity sensor is much more rugged than a coil and magnet sensor, has a wider frequency range, and can perform accurate phase measurements. Simple to use, the versatile piezoelectric sensor is the most popular motion transducer.

4) How to choose an industrial accelerometer.

When choosing an industrial accelerometer (or piezoelectric velocity sensor) many factors should be considered so that the best sensor is chosen for the application. By asking specific questions, the industrial accelerometer user will become more familiar with the sensor requirements and enable the sensor representative to be of better assistance. Typical questions to ask would be:

- What is the vibration level?
- What is the frequency range of interest?
- To what temperature variations will the accelerometer be exposed?
- Are any unusually corrosive chemicals present?
- Are intense acoustic or electromagnetic fields present?
- Is there a problem with electrostatic discharge in the area?
- Is the machinery grounded or not?
- What size or weight constraints limit the accelerometer?

Other questions must be considered concerning the connector, cable and any associated electronics:

- What cable lengths are required?
- To what temperatures will the cable be exposed?
- Should the accelerometer have an integral cable or a connector?
- What are the power supply requirements? What other instrumentation will be used?

Two of the main parameters of an accelerometer are the sensitivity and the frequency range. In general most high frequency accelerometers have low sensitivities, and conversely, most high sensitivity accelerometers have low frequency ranges. Thus when choosing an accelerometer a compromise between the sensitivity and the frequency response must sometimes be made. Given below are some tips on how to choose the sensitivity and the frequency range of an accelerometer.

5) How to choose the sensitivity of an accelerometer.

The sensitivity of industrial accelerometers is typically 10 mV/g or 100 mV/g~ higher and lower sensitivities are also available. In order to choose the correct sensitivity for the application it is helpful to have some idea of the range of vibration amplitude levels necessary to perform all of the relevant measurements.

If the machine produces high amplitude vibrations (>10 g rms), a low sensitivity (10 mV/g) accelerometer is definitely preferred. This is especially true if only the higher amplitude vibrations are of interest. Applications of this type would include systems where only the broadband vibration level is measured or the accelerometer serves only to trip a switch.

If low amplitude (<10 g rms) measurements are of interest a higher sensitivity (100 mV/g) accelerometer may be required. It must be remembered that if high amplitude vibrations outside the accelerometer's amplitude range are present they could overload the amplifier and cause signal distortion. One of the great properties of the piezoelectric accelerometer is its wide operating range, but this is useful only if the proper sensitivity is chosen for the particular application.
6) How to choose the frequency range.

In order to choose the frequency range of an accelerometer some determination of the frequency characteristics of the application must be made. Many times the required frequency range may be already known from previous vibration data taken from similar systems or applications. Other times the plant engineer has enough data on his machinery to calculate the frequencies of interest. Sometimes the best method is to place a test accelerometer at various locations on the machine and use the data collected to determine the best accelerometer for permanent installation.

The frequency range of the accelerometer itself is constrained by its mechanical resonance on the high end and the amplifiers rolloff filter on the low end. Many accelerometer amplifiers also filter the high end of the frequency range in order to attenuate the resonance amplitude and reduce electronic distortion. Given below are various considerations required for choosing the high and low frequency responses of an accelerometer.

![Typical Resonance Curves for Various Sensitivities](image)

Most vibrations produced by industrial machinery have frequencies below 1000 Hz (60,000 rpm) but often interesting signal components exist at higher frequencies. For example, if the running speed of a rotating shaft is known, the highest frequency of interest may be the third harmonic of the product of the running speed and the number of bearings supporting the shaft. Determine, if possible, the high frequency requirements of the application and choose the accelerometer with the greatest frequency range for the corresponding sensitivity and amplitude range. Note that accelerometers with larger seismic masses, (and lower frequency ranges), tend to have lower electronic noise floors. This increases the amplitude range and may be more important to the application than the high frequency measurements.

The low frequency requirements of an application may be easier to determine. Most accelerometers have a flat frequency response down to 5 Hz. Below 5 Hz consideration must be given to the amplitude level to be measured in order to insure that the accelerometer has enough sensitivity to perform the measurement. If the low amplitude, low frequency measurement is critical and high frequency measurements unnecessary, then a piezoelectric velocity transducer may be the best sensor for the application.

7) How does mounting affect the accelerometer?

Mounting accelerometers on a clean flat surface and with proper torque or adhesives is crucial for proper vibration monitoring. Improper mounting of the accelerometer onto the test structure can lead to both erroneous data and permanent damage to the accelerometer. Over torquing the accelerometer during mounting can strip the screw threads, break the studs, or even warp the base of the accelerometer. Mounting the accelerometer on a dirty surface will scratch the base and leave burrs which compromise the high frequency response of the accelerometer. This can cause improper coupling between the accelerometer and lower the useable frequency range dramatically.