

Piezoelectric Materials for Vibration Sensors—The Technical Advantages of Piezoceramics Versus Quartz

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► *Low frequency accelerometers require very high sensitivity piezoceramics to overcome the electronic noise of the sensor amplifier and monitoring instrument*

► *Low frequency amplifier noise is inversely proportional to the charge sensitivity*

Piezoelectric sensors are used extensively for monitoring structural and machinery vibrations. Piezoceramic PZT and quartz are the most widely used sensing materials for accelerometers and piezovelocity transducers.

Piezoceramics and Quartz

Quartz occurs naturally in a crystalline form, however, the quartz used in sensor fabrication is artificially grown. Piezoceramic material is also produced in a laboratory environment through a highly controlled process specifically designed for accelerometer applications.

Lead-Zirconate Titanate (PZT) is a tailored piezoceramic that is capable of measuring much lower amplitude vibrations than quartz. For this and other reasons, PZT has been carefully selected as the best piezoelectric material for accelerometers by the worlds leading sensor research companies. Specially formulated PZT provides stable performance and long-term reliability for modern piezoceramic sensors.

Quartz is used by companies who historically manufactured force gauges and pressure sensors. The lower efficiency of quartz works well in these applications because of the high force levels measured in typical pressure and force gauge applications. However, quartz is not recommended for low frequency accelerometer applications.

Applications

Slow Speed Machinery

Slow speed machinery such as paper machines and cooling towers, require the higher charge output and broader frequency range of PZT based sensors. Manufacturers who traditionally used

quartz are now using PZT in many of their new accelerometer designs to allow for a variety of low frequency monitoring applications.

Low frequency Measurements

Very little machinery vibration, in terms of acceleration, is excited at low frequencies. For example: When monitoring a roll at 60 cpm, 10 mils pp of shaft movement (.03 ips) produces only .0005 g of acceleration. These low amplitude levels can approach the electronic noise floor of standard accelerometers. Furthermore, a standard 100 mV/g accelerometer presents only 50 μ V of output to the data collector and may introduce instrument noise into the measurement.

Low frequency accelerometers require very high sensitivity piezoceramics to overcome the electronic noise of the sensor amplifier and monitoring instrument. Low frequency amplifier noise is inversely proportional to the charge sensitivity. The charge sensitivity of PZT is 350 picoCoulombs per Newton (pC/N) contrasted to 2.2 pC/N for quartz. The use of PZT significantly lowers the accelerometer's contribution to low frequency "ski slope" noise and greatly improves the signal-to-noise ratio of the measurement.

Piezoceramics must be used for low frequency 500 mV/g accelerometers and piezovelocity transducers due to its low noise characteristics. PZT enables these higher output voltage sensors to overcome data collector noise and further decreases system noise for low level vibration measurements.

High Frequency Measurements

When monitoring higher frequencies the difference between PZT and quartz is less important. In terms of acceleration, the general velocity alarm level of 0.3 ips, is equivalent to 2.5 g at 30,000 cpm (500Hz). This excitation level is easily measured by most amplifiers and data collectors. However, the resonance frequency of a PZT accelerometer will be much higher than an equivalent charge output quartz sensor. This can extend the frequency range and give more accurate high frequency readings.

Temperature Considerations

Temperature considerations are very important in many industrial applications. Although quartz crystal is known for its temperature stability, once designed into an accelerometer it shares many of the same characteristics as piezoceramic sensors.

As temperature increases, the sensitivity of both types of accelerometers will change. The sensitivity of PZT and quartz accelerometers exhibit 5 to 7% sensitivity shifts from room temperature to 250°F as shown in Figure 1. In very high temperature environments, both materials are used successfully in applications exceeding 500°F.

Thermal Transients

Thermal transient effects must be considered in some applications such as low frequency monitoring. Transient changes in temperature cause thermal expansion of the sensor's metal housing.

Sometimes mistaken for the "pyroelectric" effect, thermal expansion produces false signals related to the strain sensitivity of the sensor. Accelerometers, whether PZT and quartz, should be designed for low mechanical strain sensitivity to minimize the effects of thermal transients.

Stability

Recalibration is rarely required for either type of sensor for normal industrial applications unless contractually required. Quartz is naturally stable and will not change unless mechanically overstressed. Modern PZT sensors are heat treated to stabilize the poling process and eliminate changes due to long-term temperature and shock exposure. Properly designed and processed sensors of both types have been field proven for many years.

Conclusion

Both piezoceramics and quartz are excellent materials for use in sensor design. Each material has a clear technical advantage over the other for different parameters. Quartz is the better material for measuring pressure and force due to the relatively high forces involved. Piezoceramics are clearly the choice for accelerometer applications due to the higher sensitivities required to monitor low level vibration. Piezoceramics coupled with an internal micro amplifier are the materials of choice for advanced accelerometers.

For greater detail, see the article titled, "Accelerometer Noise" by Fred Schloss printed in the March, 1993, issue of *Sound and Vibration Magazine*, page 22.

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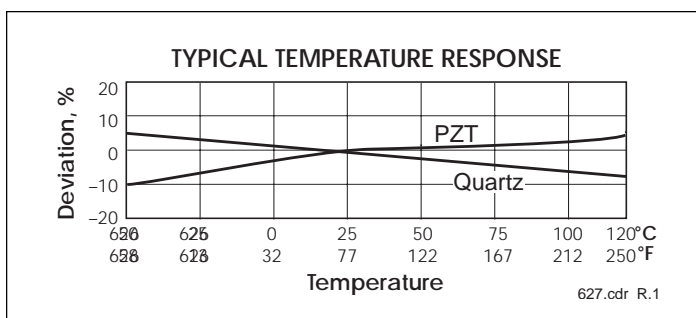


Figure 1. Typical Temperature Response of PZT and Quartz.