S&V Questions and Answers

Checking Piezoelectric Accelerometers for Damage

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Question: **How should a piezoelectric accelerometer be checked for damage?**

Answer: There are two important things to understand about a piezoelectric accelerometer when checking it for damage:

1. The sensitivity and frequency response characteristics are **not** related (in contrast to condenser microphones discussed last month). This means that the sensitivity of a piezoelectric accelerometer can remain unchanged, while its frequency response (and thus its ability to make good measurements) has deteriorated or it's frequency response can be fine, while it's sensitivity can change.
2. A straight charge-type piezoelectric accelerometer is a lot easier to check for damage than one with internal amplification.

The minimum tests that should be done periodically for **any** piezoelectric accelerometer to check for damage are:

1. Check the sensitivity of the accelerometer using a single frequency vibration calibrator.
2. Measure the accelerometer's frequency response from a few hundred Hz up through the resonance frequency of the accelerometer.

These are really the only tests necessary for a noninternally amplified, pure charge mode, piezoelectric accelerometer. A lowering of sensitivity (there is no way the sensitivity of a pure charge mode piezoelectric accelerometer can increase) indicates that an over temperature condition occurred. However, the accelerometer can be recalibrated and continue to be used. A change in the high frequency response (the low frequency response is typically determined by the external amplifier used, not the accelerometer) or a decrease in its resonance frequency indicates a mechanically damaged accelerometer. When an accelerometer has been subjected to mechanical damage, the transverse sensitivity, transverse resonance, distortion and other specifications are in question thus a damaged accelerometer should never be used.

Figure 1 illustrates effects of mechanical damage to a piezoelectric (charge mode type) accelerometer's frequency response characteristics. Two accelerometers were tested using an accelerometer calibrator. The calibrator was used to measure a frequency response function (FRF) between an unknown accelerometer and a built in reference accelerometer that, in this case, has a resonance frequency of greater that 60 kHz. The two accelerometers tested were the same model with a resonance frequency of 16 kHz yielding a usable frequency range up to 4800 Hz. The transverse sensitivity is less than 4% with a transverse resonance of 4 kHz. The thicker curve in Figure 1 illustrates the FRF for a good accelerometer. The other FRF is for the same model accelerometer that is damaged. Notice the dramatic shift in resonance frequency, from 16 kHz down to 10 kHz, indicating mechanical damage. Even more disturbing is the series of large peaks at around 1.5 kHz. These peaks represent a dramatic shift in the transverse resonance from 4 kHz down to 1.5 kHz and a change in transverse sensitivity from less than 4% to greater than 50%. If this bad accelerometer were to be used to measure spectrums or FRFs in the 1.5 kHz range, one would measure large amplitude peaks that were only artifacts of the accelerometer and not of the device under test. When the sensitivities of these accelerometers were checked, with a standard single frequency (159.2 Hz) calibration exciter, they were within 3% of the nominal sensitivity for this model accelerometer. Thus, the only way we could tell that this accelerometer was bad and should **not** be used for measurements was by measuring the FRF of the accelerometers.

For internally amplified accelerometers (known in the industry as Internal Electronic PezioElectric [IEPE] accelerometers) there are many ways they can fail. The piezoelectric element can be damaged along with the internal amplifier. The problem is that it is difficult to check the internal electronic amplifier by applying an external vibration stimulus. At least the following should be checked in addition to the above two tests.

1. Compare the bias voltage of the internal amplifier to the original value. A change indicates a damaged internal amplifier and the accelerometer should be taken out of service. Make sure the power supply used with the accelerometer always has the same constant current supply level, since this may effect the bias voltage. Industry standard IEPE systems use a 4 mA current supply. Some "low noise" designs require 2 mA or less to remain "low noise."
2. Check the sensitivity of the accelerometer at a single fixed frequency. A change in sensitivity indicates a damaged internal amplifier and the accelerometer should be taken out of service. Unlike a pure charge mode piezoelectric accelerometer, it is possible for the sensitivity of an internally amplified accelerometer to increase as well as decrease. Any change indicates possible damage to the internal electronics.
3. Check the low frequency response down to the lowest frequency of interest. Older internally amplified piezoelectric accelerometers often exhibit a dramatic loss of response at low (below 20 Hz) frequencies.
4. Other custom tests pertinent to the specific use of an internally amplified accelerometer should be performed. Since there are many possible failure modes of the internal electronics, the user must be responsible for conducting tests pertinent to the specific application.

Generally, accelerometers are damaged through physical and/or environmental abuse. Some of the more common abuses and problems include:

1. Dropping an accelerometer onto a hard surface will cause internal physical damage. All accelerometers have a shock limit. If this has been exceeded, damage may occur.
2. Using an accelerometer above or below its temperature range is particularly important for the IEPE type because of the internal electronics. Note that basic sensing crystals can be "desensitized" when an accelerometer is used above its specified operating temperature for even a short period of time.
3. Loss of a hermetic seal results in internal moisture which presents a resistance path parallel with the normal capacitance of the crystal. This affects the low frequency response of the sensor. Moisture infiltrating the sensor can also provide an unintended resistance path between the cable shield and the accelerometer case in "ground isolated" designs. This can lead to "ground loops" introducing line-frequency contamination.
4. Damaged cables/connectors can add noise to the measurement. When using a pure charge mode accelerometer, a damaged cable can generate a "charge" caused by frictional effects within the cable due to separation and motion between the dielectric and shield of the cable. This effect is known as triboelectric noise.

The above problems can sometimes be suspected simply through visual inspection and/or keeping a 'use' log of your transducers. When obvious visual changes are noted, one should employ the checks summarized above.

In summary, a noninternally amplified, pure charge mode, piezoelectric accelerometer is easy to check for damage by a single frequency sensitivity calibration and measurement of the frequency response up through its resonance frequency. Internally amplified accelerometers have many more possible failure modes and need more comprehensive testing.

Next months Q&A column question

was suggested by Larry Meidell of Chadwick-Helmuth Co., El Monte, CA.: **What are the standard or most widely accepted definitions of "overall" and "broadband" measurements and are they the same?**

Send your questions or comments to:

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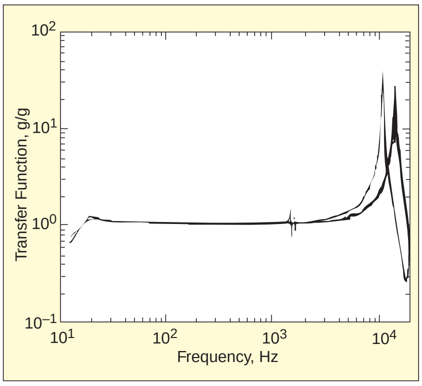

Figure 1. Frequency response characteristics of a good vs. damaged accelerometer.