Accelerometer Mounting Considerations

An accelerometer is an instrument that senses the motion of a surface to which it is attached, producing an electrical output signal precisely analogous to that motion. The ability to couple motion, (in the form of vibration or shock), to the accelerometer with high fidelity, is highly dependent upon the method of mounting the instrument to the test surface. For best accuracy, it is important that the mounting surface of the accelerometer be tightly coupled to the test surface to ensure the duplication of motion, especially at higher frequencies. Since various mounting methods may adversely affect accuracy, it is important to understand the mechanics of mounting the accelerometer for best results.

Calibration

Throughout the article we will refer to “back-to-back” calibration at times. It will be informative to explain what is meant by this and to show how this type of calibration is performed at Dytran.

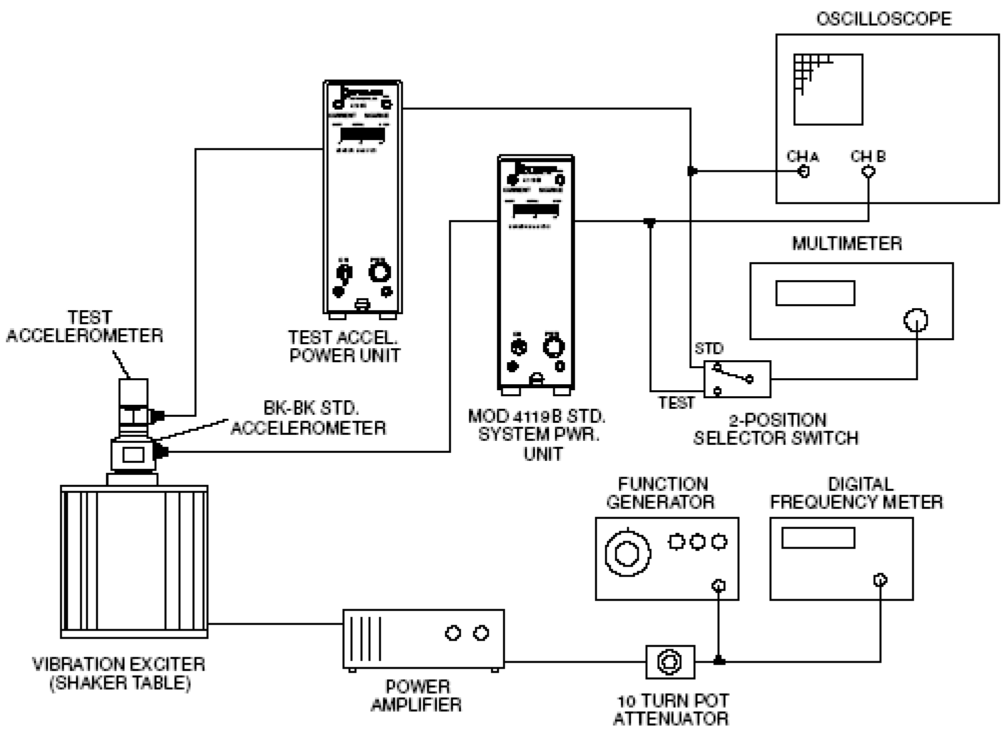

Figure 1: Back-to-back calibration set-up

Figure 1 illustrates the components of a simple accelerometer calibration system utilizing the Dytran Model 3120BK back-to-back accelerometer calibration system, a small electrodynamic shaker, a signal generator, a power amplifier and the readout instruments.

To perform a calibration, the test instrument is attached to the top surface of the back-to-back standard accelerometer, (model 3120B) using the method to be used in the actual application, i.e., adhesive or stud mount. At each frequency of interest, the input amplitude (in g’s RMS) is set precisely by the back-toback standard system and the corresponding output from the test system is recorded. To learn more about this topic, refer to the article “Back-to-Back Accelerometer Calibration” in this series.

For purpose of analysis, a piezoelectric accelerometer may be considered to be a second order spring-mass system with essentially zero damping. (Refer to Figure 2).

The spring (K) is the crystal stack and the mass (M) is the seismic mass that stresses the crystals to produce an electrical output proportional to acceleration. The dynamic characteristics of this system determine the frequency response of the accelerometer.

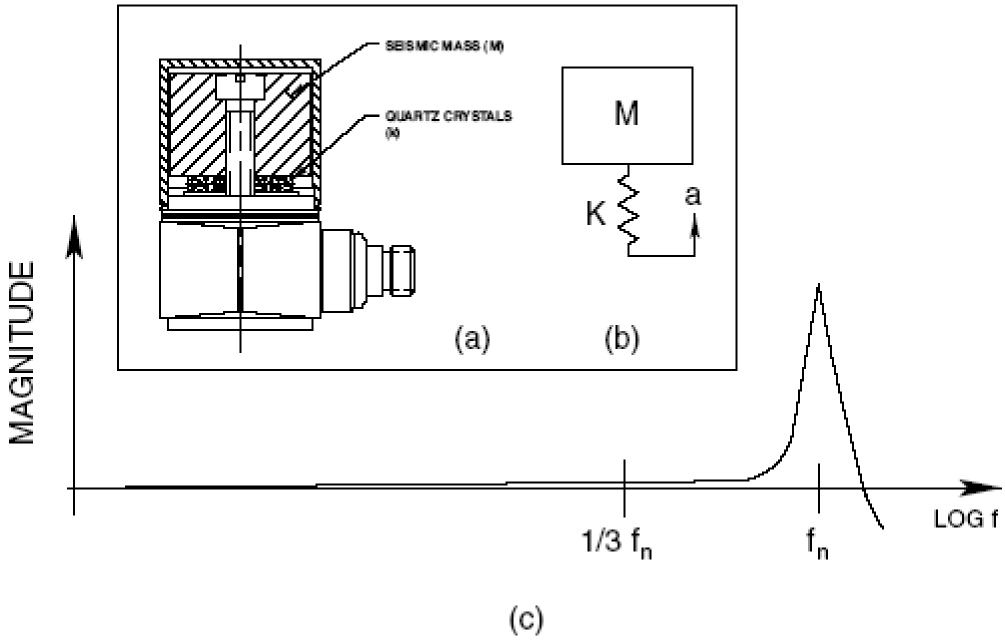

Figure 2: The accelerometer as a spring-mass system.

Figure 2a illustrates the accelerometer. Its spring-mass analogy is Figure 2b and Figure 2c is a typical frequency response plot for such a system. The plot is obtained by graphing accelerometer output vs. frequency with input vibration level held constant at each frequency setting. Every such system has a mounted resonant (or natural) frequency, fn characterized by a very high peak of output at resonance. The solution for the differential equation of motion yields the definitive expression for the resonant frequency as follows:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{M}} \qquad \text{(Eq 1)}$$

where: f_n = system natural frequency (Hz)
K = spring constant of the crystal stack (lbs/in)
M = mass of the seismic system (Slugs)

Examination of the response graph (Fig 2b) shows that the lower frequency portion of the curve is sufficiently flat to provide a useable range up to approximately 1/3 of the resonant frequency. This will not be the case however, if, during the mounting, other “springs” are inadvertently interposed between mating surfaces creating secondary spring-mass systems with lower natural frequencies than that of the accelerometer itself. The following section is an attempt to explain how this can happen if care is not exercised during mounting of the test accelerometer. We start by exploring the various mounting methods commonly used to mount accelerometers.

Stud Mounting

The preferred method of mounting an accelerometer to the test object is the stud mount method. (See Figure 3). The stud may be integral, i.e., machined as part of the accelerometer or it may be separate (removable). The stud mount method yields the best results because when the instrument is installed in this fashion, the accelerometer and the test surface are essentially “fused” together by virtue of the high clamping force of the stud, ensuring the exact duplication of motion of both bodies at all frequencies.

The inclusion of a thin layer of silicone grease between mating surfaces aids in the fidelity of motion by filling in any voids due to slight imperfections in the mounting surfaces.

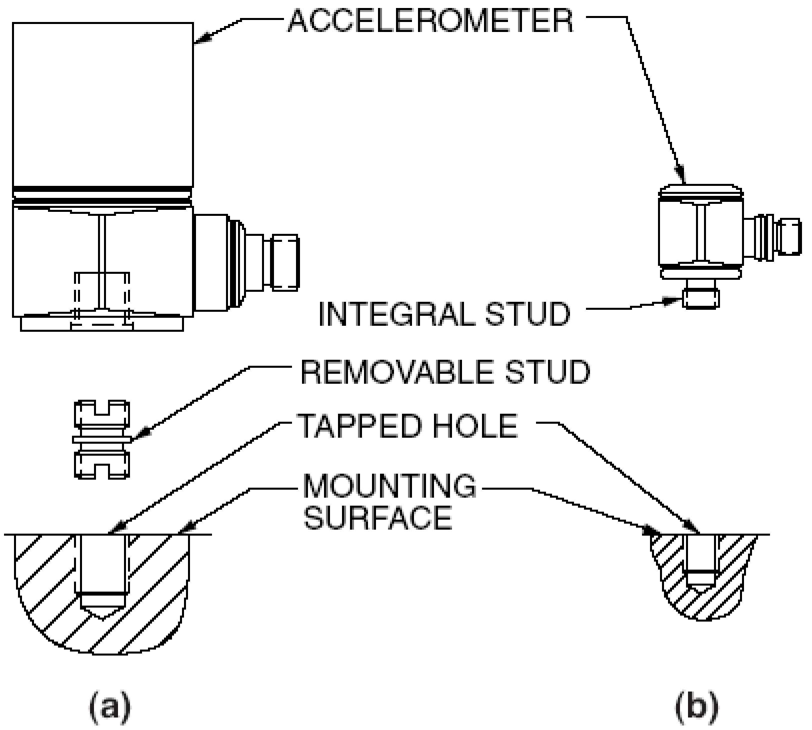

Figure 3: The threaded stud mount

Two stud mount designs are illustrated in Figure 3, the separate stud in Figure 3a and the integral stud in Figure 3b. The separate stud style accelerometer is the most popular for several reasons:

1. The removable stud allows easy access to the mounting surface of the accelerometer for restoration of surface flatness should this become necessary. Even with normal care, in time, after many installations, the mounting surface of the accelerometer may become worn or damaged to a point where it is no longer flat enough to affect a satisfactory mount and frequency response will be compromised. It is a simple matter to restore flatness if the stud can be removed and the accelerometer base can be applied directly to a lapping plate for restoration of flatness. When the stud is integral and cannot be removed, refurbishment of the mounting surface becomes very difficult and can only be performed at the factory.

2. If the integral stud is broken or the threads become stripped or otherwise damaged, the instrument may be essentially destroyed. On the other hand, the separate stud can be easily replaced.

3. At times, with radial connector style accelerometers like the model 3100B, it is important during installation, to orient the connector so that nearby obstacles may be avoided. By exchanging mounting studs, the desired orientation may be obtained.

4. The separate stud type accelerometer may be adhesive mounted without using a mounting adapter, should this be desired.

The Mounting Stud

The mounting stud itself is a very important factor of the performance of the accelerometer. Most Dytran mounting studs are fabricated from heat treated beryllium copper because of its high tensile strength and its low modulus of elasticity. This means that the stud will be very strong and relatively elastic, a perfect combination for the task of holding two surfaces together under a high preload.

The collar that is machined into the stud (see Figure 3a) prevents the stud from bottoming in either mounting hole. This ensures that the stud will be centered between the two mounting holes so that both sides have adequate thread engagement.

All Dytran accelerometers have a recess machined into the mounting surface to accommodate this collar allowing both surfaces to be in intimate contact.

When installing the stud, it is best to first thread the stud into the accelerometer to ensure that the stud enters the threaded port fully, then thread the accelerometer into the mounting port until the surfaces meet and torque in place.

In the design of miniature accelerometers such as the models 3030B, 3144A and the 3200B et.al., interior space is at a premium and the only alternative for stud mounting is the integral stud as shown in Figure 3b. This style of accelerometer with reasonable care, will provide a long lifetime of normal operation.

When Mating Surfaces Are Not Flat

As previously stressed, flatness of mating surfaces between accelerometer and mounting surface, is of prime importance for best frequency response.. Here we will examine the mechanics of a poor mount and its effect on frequency response.

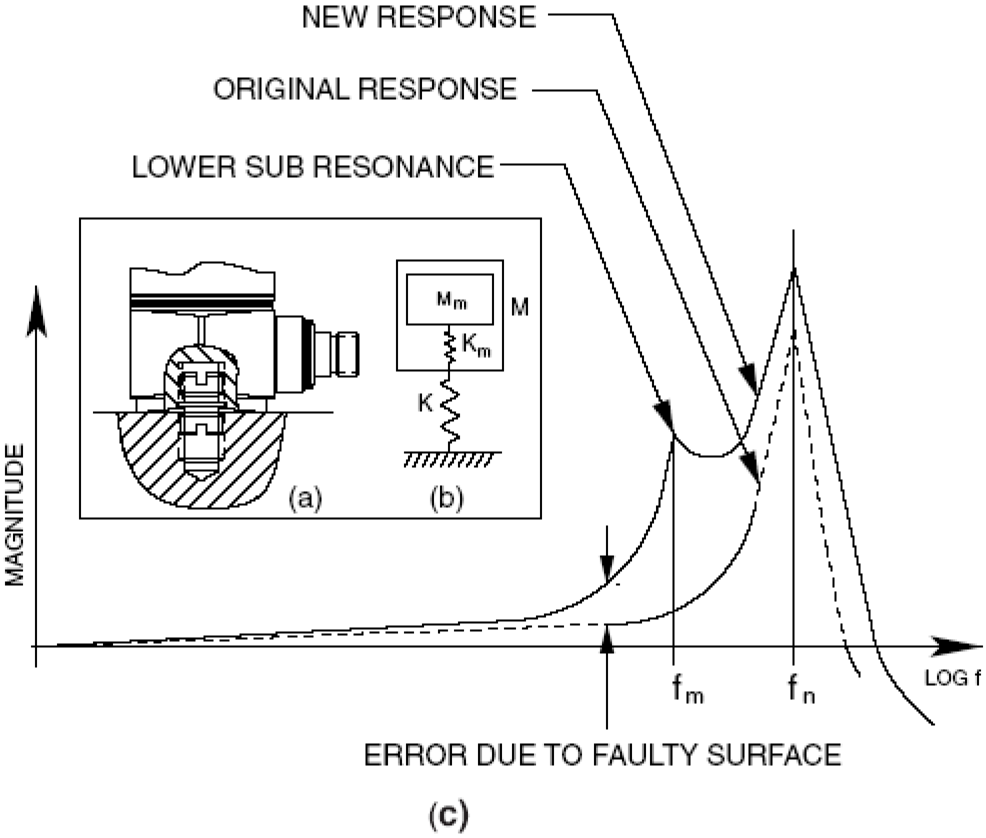

Figure 4: Non-flat accelerometer mounting surface

Figure 4a illustrates schematically, a condition where the accelerometer has acquired a "dished" shape thru heavy usage. The mechanical analogy of this is a leaf spring with spring rate Km as shown in Figure 4b. There are now two spring-mass systems with this type of anomaly and both will affect frequency response.

The new spring-mass system is formed by spring Km and the mass of the entire accelerometer Mm. The resonant frequency fm of this new system will most likely be lower than that of the accelerometer and may affect the response curve as illustrated in Figure 4c.

Even though the new resonant frequency is higher than the actual resonance of the accelerometer, its effect will be to increase the output of the accelerometer at the high frequency end of the accelerometer response.

We have chosen for purpose of this explanation, a hypothetical non-flat condition to illustrate the mechanics of response degradation. This analogy can be extended to include other situations where mating surfaces are precluded from intimate contact such as when foreign particles are entrapped between mating surfaces or when other types of surface irregularities exist. The results of all such imperfections will be more or less similar in nature to the example chosen here.

Surface Preparation

It is difficult to overemphasize the importance of flatness of mating surfaces in the mounting of piezoelectric accelerometers, especially with regard to frequency response. All Dytran accelerometer mounting surfaces are lapped optically flat where possible or machined to very tight flatness tolerances. The test object surface must be as carefully prepared. Although lapping is usually not possible, other machining processes such as spotfacing, grinding, milling, turning, etc., can produce acceptably flat mounting surfaces (flat to .001 TIR).

After machining the surface and preparing the tapped mounting hole, clean the area thoroughly with compressed air and a solvent to remove all traces of metal chips, cutting oil, and any other surface contaminants. Before installing the accelerometer, spread a light coating of silicone grease on either mating surface. The grease will lubricate the surface and ensure intimate contact by filling in tiny surface imperfections, maximizing high frequency transmissibility to the accelerometer.

Mounting Torque

Although every Dytran accelerometer is designed to minimize the effect of mounting torque variations on sensitivity, it is good practice to set the torque level, using a torque wrench, to the value recommended on the installation drawing provided with the instruments. This will ensure that the instrument is properly mounted and will preclude the expense and delays that may result from overtorquing and breaking or stripping the threads of mounting studs. This practice will also eliminate one of the main causes of calibration inaccuracy.

Adhesive Mounting

Situations often arise where the stud mount method is impractical, even impossible, such as when mounting the accelerometer to thin sheet metal or to other surfaces where drilling a mounting hole is not allowable. In such cases, an adhesive mount installation can be the only practical way to install an accelerometer.

Some accelerometers are designed to be adhesive mounted directly to the test surface. (models 3115A, 3105A, 3053A, etc.). Others utilize mounting adapters or bases for adhesive mounting. These adapters are normally first glued to the test surface, then the accelerometers are stud mounted to them.

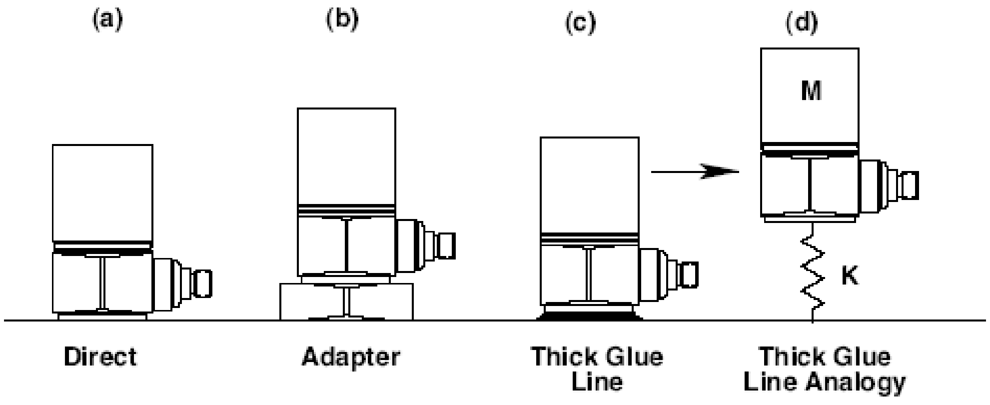

Figure 5: The adhesive mount, direct and with adapter

Figures 5a and 5b illustrate two adhesive mount installations, one direct mount and the other with adhesive adapter. Figure 5c shows the undesirable thick glue line and figure 5d illustrated the mechanical analogy of the thick glue line mount. The thick layer of adhesive is actually a spring and has the effect of creating a new spring mass system as previously described in the section “When mating surfaces are not flat”, with a similar result as shown in figure 4c.

To avoid the thick glue line, we recommend the use of a cyanoacrylate adhesive, sometimes known as “Instant Bond” adhesives. These types of adhesives are readily available and are recommended because:

1. They set very quickly,

2. Not much adhesive is required for a strong bond so glue lines will necessarily be very thin,

3. Cleanup is easy because these types of adhesives are easily dissolved with acetone.

Some users report good results with dental cement. Because of its high rigidity, acceptable transmissibility can be obtained even with the slightly thicker glue line that results. However, the problem with dental cement lies with its tenacity. We know of no solvent that readily dissolves it so removal of the accelerometer can result in damage to the instrument.

Removal (unmounting) of Adhesive Accelerometers

Many accelerometers and adhesive adapters have been damaged or destroyed by improper removal. The only sure way to avoid such damage is to torque the accelerometer or adapter with a wrench using the flats provided. Adhesives are generally weakest in shear strength and will yield under steady torque. Under no circumstances should you strike an accelerometer or adapter to remove it. The accelerometer would most likely sustain damage and may, at best, change calibration after such trauma. All Dytran adhesive mount adapters have hex or other flats to facilitate removal.

Electrical Isolation Bases

Isolation bases are used to electrically insulate the housing of an accelerometer from the test surface. This may be necessary to avoid annoying “ground loops” which can interfere with the measurement process when the test surface is an elevated electrical potential.

Be aware of the fact that the use of any such base will effect the high frequency response in the same manner as previously described in the section “The Adhesive Mount”. Again, we recommend calibration with the actual adapter to determine the effect on high frequency response.

The model 6220 is an example of a well-designed isolation adapter with some exceptional features. The design incorporates stainless steel upper and lower bases with an insulating anodized aluminum disc sandwiched between them under high preload. The lower base has an integral threaded stud and the upper has a 10-32 tapped hole. The upper and lower bases are interlocked together to withstand high levels of mounting torque without damage. Both upper and lower bases can be refinished to restore flatness without affecting insulation.

Several anodized aluminum bases are also available for less demanding applications, (models 6226, 6244, 6245, and 6261 for example). These bases must be handled carefully to avoid scratching the anodized surfaces that will compromise the insulating properties.

Magnetic Mounting Adapters
Magnetic mounting adapters are used to attach accelerometers to ferromagnetic surfaces such as machinery and structures where the instrument is to be moved quickly from place to place. The accelerometer is attached to the magnetic adapter (usually by stud mount) and the assembly is applied to the test surface. While this method is certainly convenient, the user may be misled by this convenience.

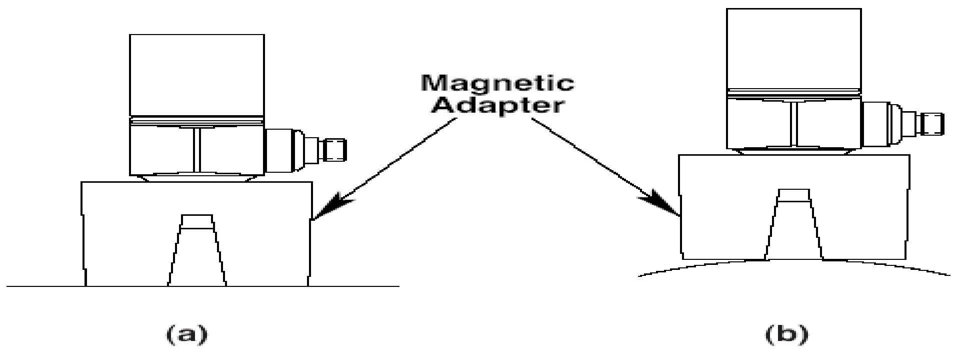

Figure 6: Magnetic mounting adapters

In general, magnetic adapters should be used with caution and rarely trusted at frequencies above 1 kHz. Expect response degradation in direct proportion to the weight of the accelerometer. There are some things the user can do to ensure the best possible accuracy from the magnetic mount installation:

1. If possible, attach the magnet to a flat, bare, ferromagnetic metal surface (See Figure 6a). A thick layer of paint on the test surface will lessen the holding force of the magnet and could lower the effective high frequency response.

2. Clean the mounting area to remove any oil, grease and other foreign matter which could preclude the intimate contact necessary to ensure a strong magnetic bond.

3. Select a flat area if possible, to achieve maximum surface contact. Avoid situations as illustrated in Figure 6b.

4. Attach the magnet to the test surface CAREFULLY. Remember that the pull of a magnet rises sharply just before contact with the ferromagnetic surface and this force could pull the assembly from your grip resulting in a very severe metal-to-metal impact. This could overrange the accelerometer beyond its maximum shock range and permanently damage it.

If possible, calibrate the accelerometer/magnet assembly by use of the back-toback calibration method.

Mounting Wax
Mounting wax is very convenient to use but we do not recommend this method as a viable means of mounting an accelerometer. It should only be used when no other alternatives are feasible. The inconsistency in thickness and the low modulus (rigidity) of wax make the results unreliable at higher frequencies. As previously mentioned, calibration with the exact wax to be used will give the best indication of the expected results.