Careful Planning Improves Impact Testing
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Successful modal analysis requires both sensible test preparation and good measurement technique. And while many of us have good measurement technique, sometimes we start making measurements without an adequate test plan. All too often, that means spending too much time fiddling with transducers, gathering unnecessary data and re-evaluating the measurement process as we go along. The result? A lot of wasted time, money and effort. Taking the time up front to plan your test and collect the right equipment will improve both the quality and the efficiency of your impact tests (see figure 1).

Start with a clear objective

Without a clearly written, comprehensive test objective, your chances of making clean, accurate modal measurements are rather slim. So do your homework. Put together a good test plan and set realistic goals for the measurement process.

In what frequency range do you expect to find trouble? How many points should you measure? How long do you need your test structure? Answer these questions in the test objective. Don’t wait until you start making measurements to define these issues. Modal testing is difficult enough without the added burden of designing a measurement procedure “on the fly.”

Moreover, a good test objective saves money. Modal testing is often done on prototypes or scale models that are in high demand elsewhere in the manufacturing facility. If you know ahead of time how long you’ll need the device-under-test, appropriate scheduling will minimize time conflicts. And a well-written test objective helps to focus the measurement process and lets you better estimate measurement time. (Don’t forget to allow extra time to verify transducer placement and to fix any last-minute problems before testing begins.)

Where appropriate, include hardcopy of preliminary measurements in the test objective. For example, if a noisy brake mechanism is the problem, be sure to include SPL plots (both narrowband and 1/3-octave) to outline the frequency range for the modal test.

On the other hand, if you have a more general test objective (such as determining the first five torsional modes of vibration) or are less certain about the cause of a noise or vibration problem, you’re going to need a lot more time with the device. At a minimum, expect test time to increase in proportion to the number of measurement points and frequency spans required for the test.

Select the right accelerometers

To select the right accelerometers for each test, you need to consider mass, sensitivity and frequency response.

Mass and sensitivity

A good accelerometer is lightweight, with a mass low enough to avoid affecting the structural modes being measured. But it must also be sensitive enough to measure the structure’s response decay and to take full advantage of the analyzer’s dynamic range.

Paradoxically, a sensitive accelerometer is usually heavy. This might seem like a problem, but the laws of physics are working in your favor. Smaller, lighter structures have modes at higher frequencies, where acceleration levels are higher. That means you can use lightweight, less-sensitive accelerometers because there is more signal to compensate for their low sensitivity.
In contrast, larger, heavier structures have modes at lower frequencies, where acceleration levels tend to be very faint. Therefore, heavier (but more sensitive) accelerometers can be used because their increased mass is relatively insignificant on heavy structures.

You should be aware that several manufacturers have recently introduced lightweight accelerometers with built-in, high-gain preamplifiers. Such accelerometers weigh only five or ten grams yet feature sensitivities on the order of 100 mV/g. With that kind of sensitivity, a peak response of 0.5 g would deliver 50 mV to the spectrum analyzer—a signal strong enough to take full advantage of the analyzer’s dynamic range.

**Minimum frequency**

Most accelerometers used for modal analysis cannot measure phase consistently below 10 Hz. Response below this is possible only with special accelerometers and preamplifiers that are tailored for low-frequency testing.

For example, if you are measuring flexible modes of vibration below 5 Hz, you should be aware of the limitations of standard accelerometers and expect to pay more for the specialized transducers you’ll need.

**Attach the accelerometer correctly**

Petroleum wax is the traditional means of attaching accelerometers. It’s fast, clean, easy to use, light-weight and safe on painted surfaces. However, wax can affect frequency response above 3 kHz, particularly if it’s applied too thickly. Cyanoacrylate adhesive is another excellent mounting material, although the surface finish of the test structure can be marred when the accelerometer is removed.

There’s also electrical isolation to consider. In some cases, you need to isolate an accelerometer from the test structure to reduce ground loops. Certain preamplifiers provide their own isolation. Some accelerometers have insulated cases (anodized aluminum, for example) but others may require a non-metallic mounting surface.

**Select the right impact hammer**

Most hammers are selected based on the size and weight of the test structure. For testing lighter structures (tennis racquets or mirror-mounting brackets, for instance), a hammer with a 0.2 pound head would be appropriate. For testing machinery and other heavy structures, a hammer with a 1.0 pound head might be the answer.

Generally, sensitivity is proportional to the weight of the hammer head. For example, a head that weighs 1.0 pound might have a sensitivity of 1 mV/pound and a peak-force rating of 5000 pounds. In contrast, a head that weighs 0.2 pounds might have a sensitivity of 50 mV/pound and a peak-force rating of 100 pounds.
Tip composition

The striking end of most impact hammers is threaded to accept different tips. The softness of the tip material determines the impact characteristic and must be appropriate for the range of desired excitation frequencies.

Very soft tips (plastic or rubber) produce lower peak force levels for a given impact but have a longer impact duration. This provides good energy at low frequencies but rather poor excitation for higher frequencies.

Conversely, a hard tip, such as solid aluminum, creates a short impulse with a high peak acceleration. This provides sufficient energy for high-frequency modes but a lower excitation of low-frequency modes.

Make sure the tip corresponds to the frequencies of the modes you need to excite. If all modes are lower than 200 Hz, then use a very soft tip to maximize the force. But if your test structure has high-frequency modes (for example, a solid metal structure such as a disc-brake rotor), you should use a hard tip.

Before you test, listen to the structure

Before you make any measurements or attach any accelerometers, make some test hits with the hammer at various measurement points. Listen carefully for any buzzes or rattles. Nonlinear noises such as these will contaminate the frequency response and invalidate your measurements.

If you detect any looseness, fix it with an appropriate adhesive such as wax, glue or putty. Don’t use too much adhesive—the goal here is to stop the noise but not add appreciable mass or stiffness. Figures 2 and 3 show before and after measurements on a structure that needed some carefully placed wax to calm it down.

Now you’re ready to fire away

If you’ve done your homework, the actual measurements should be fairly straightforward. With a clear test objective, careful transducer selection, and strict attention to silencing buzzes or rattles in the test structure, you can expect much-improved frequency response measurements.

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**Figure 3**

Here’s the same structure, measured again with wax inserted in the joints to quiet the rattling.