MODAL SPACE - IN OUR OWN LITTLE WORLD

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Illustration by Mike Avitabile

Should I always use a hard tip for impact testing . . .
so the input spectrum is flat over all frequencies?
Well . . . too hard a tip may cause problems.

For some reason, everyone thinks that the input spectrum should be flat over the whole frequency range of interest when performing an impact test. But what do we mean by "flat" anyway. Well, it would be better to say that the input spectrum should be "reasonably flat" over all frequencies with "no significant drop-outs or zeros" in the frequency spectrum. So what does that mean.

Basically, we want the input spectrum to have sufficient, fairly even excitation over the frequency range of concern. If the input spectrum were to completely drop off to zero, then the structure would not be excited at that frequency which is not desirable. I use the words "reasonably flat" to allow for some engineering judgment as to what is acceptable.

Of course, many times people don't like engineers to use judgment, so they identify specific criteria or limits to force the situation to be controlled. At times, specifications have been written with specific criteria such as "the input spectrum should roll-off no more than 3 dB over the FFT analysis frequency range". This is a very specific requirement which does not allow the engineer to think. It just forces him to follow a rule without thinking. A criteria like this one may force a poor measurement to be made. But if we don't have to think (or are not allowed to think) then inappropriate measurements could be acquired.

Now you asked about using a hard tip for all your impact tests. I'll answer that in a minute but first let's discuss some basics about the selection of hammer tips for an impact test. First of all, let's remember that the input force spectrum exerted on the structure is a combination of the stiffness of the hammer/tip as well as the stiffness of the structure. Basically the input power spectrum is controlled by the length of time of the impact pulse. A long pulse in the time domain, results in a short or narrow frequency spectrum. A short pulse in the time domain, results in a wide frequency spectrum.

Let's look at some cases and see what this means from a measurement standpoint. (In all the following figures, black is the FRF, blue is the input spectrum and red is the coherence).

Now let's use a very soft tip to excite a structure over an 800 Hz frequency range. As shown in Figure 1, we see that the input power spectrum (blue) has some significant roll-off of the spectrum past 400 Hz. We also notice that the coherence (red) starts to drop off significantly after 400 Hz and the FRF (black) does not look particularly good past 400 Hz. The problem here is that there is not enough excitation at higher frequencies to cause the structure to respond. If there is not much input, then there is not much output. Then none of the measured output is due to the measured input and the FRF as well as the coherence are not acceptable.

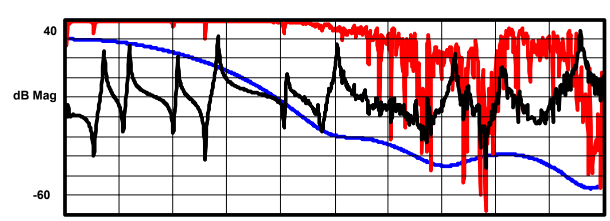

Figure 1 - Very Soft Tip

Now let's use a very hard tip to excite a structure over a 200 Hz frequency range. As shown in Figure 2, we see that the input power spectrum (blue) is extremely flat over all frequencies of interest. We also notice that the coherence (red) is not particularly good for this measurement. The problem here is that there is too much excitation at higher frequencies causing all the modes of the structure to respond. (We'll discuss this further in a moment.)

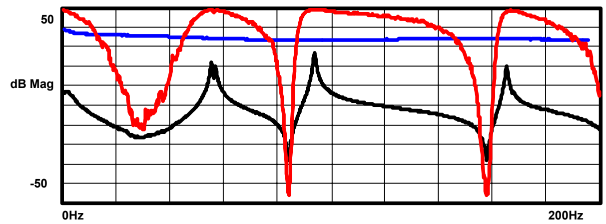

Figure 2 - Very Hard Tip

Now let's use a medium hardness tip to excite a structure over an 200 Hz frequency range such that the input force spectrum does not drop off significantly by the end of the frequency range of interest. As shown in Figure 3, we see that the input power spectrum (blue) rolls off by 10 to 20 dB by 200 Hz. We also notice that the coherence (red) looks especially good at all frequencies over the 200 Hz band with the exception of anti-resonances. The drop off of the coherence is fully acceptable at these frequencies since the structure is non-resonant (anti-resonant) at these frequencies. This means that there is no response to measure so the coherence is expected to drop here. This is a good measurement.

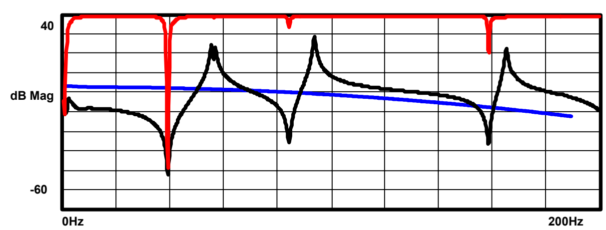

Figure 3 - The Right Tip

Notice that the input spectrum is not perfectly flat as you suggested it should be. In fact, when the input is almost perfectly flat as shown in Figure 2, the measurement is not as good. Let's explain why this happens. Consider the measurement shown in Figure 4. This measurement was taken over a 400 Hz bandwidth. The hammer tip used had approximately 20 dB rolloff over the 400 Hz band which is probably acceptable for this measurement.

Now let's say that I wanted to only measure to 128 Hz and that I wanted to impose a restriction that the input spectrum could not roll off more than 3 dB. Well look at Figure 4 with the 128 Hz bandwidth specified. The input force spectrum rolls off approximately 2 to 3 dB over this 128 frequency band. So the measurement should be acceptable. But what you have to realize is that while the analysis frequency band is only 128 Hz, the response of the structure is based on the energy imparted to the structure. So the structure responds well past 128 Hz because the input force excites all of those modes - *even though I might not be interested in those frequencies.*

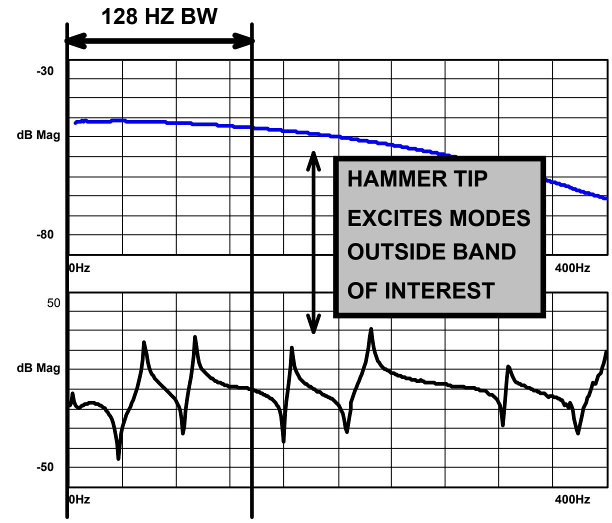

Figure 4 - Exciting Modes Outside the Band of Interest

The accelerometer, mounted on the structure, measures all that response and outputs a voltage which is input to the analyzer. Just doing a quick eyeball of the total area under the curve of the FRF, it appears that only one-third of the energy is associated with the bandwidth of interest. The rest of the energy is associated with something that I'm not interested in measuring. But the accelerometer senses that energy! The ADC on your analyzer may need to be setup such that an overload does not occur due to the total response of the structure.

If the signal is not analog filtered before it reaches the analyzer, then the ADC may need to set excessively high to avoid a potential overload. *Remember, most of the energy of the signal is probably outside the 128 Hz bandwidth of interest!!!* This results in a quantization problem in the ADC. This can easily be corrected through the use of an impact tip that does not needlessly excite modes outside the bandwidth of interest.

So now you can see why I don't like to use a hard tip all the time for impact testing. Sure it gives a good flat input force spectrum. The problem is that it excites more modes than desired and may cause a poor measurement. Think about it and if you have any more questions about modal analysis, just ask me.