MODAL SPACE - IN OUR OWN LITTLE WORLD *by Pete Avitabile*

Illustration by Mike Avitabile

Once I have set up a good measurement, is there any reason to watch the time and frequency results for every FRF? Let's discuss this.

This question brings up a very important topic. Once a test has been set up and care has been taken to make sure that the measurement is good, you should always monitor all of the measurements made on the system. This is a must!

I have seen some people take a great deal of care measuring the impact force and response, measure the input spectrum, FRF and coherence for just one point and then just disregard monitoring all the points for the rest of the test. The general feeling is that once the drive point measurement is made, the force spectrum is checked and the coherence is acceptable, then the test should proceed without any major difficulty. The problem is that just because one point seems to be very good, doesn't necessarily mean that all of the points will be measured the same. I have seen many tests where measurements made on various parts of the structure have had very different measured characteristics than might be expected.

So let's start with a typical measurement scenario and identify what could possibly go wrong if attention is not given to every measurement made during the test. A bracket that was in the lab was used to acquire some measurements. Obviously, the time and frequency data should be reviewed from some measurement points. Typically, the drive point measurement may be acquired as a starting point. For the structure under consideration, an impact excitation was used and the time input force and time response are shown in Figure 1. The response seems to almost decay to zero by the end of the sample interval so possibly a light exponential damping window could be used to minimize the slight amount of leakage that might occur.

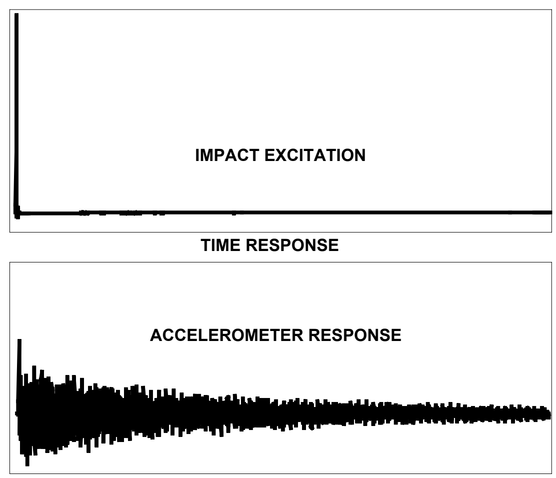

Figure 1: Force Excitation and Accelerometer Response

Next the input force spectrum is checked to make sure that a sufficient amount of force is applied to the system over the frequency range of interest; usually this input spectrum should be reasonably flat over the spectrum with approximately 10 to 15 to possibly 30 dB roll-off over the desired frequency range. (Notice that I said the "desired" frequency range which may not be the entire spectrum measured.) The coherence is checked to make sure that there is reasonably good causal relationship between the measured input force and the output response to assure that a good measurement is made. And of course, the FRF is checked for peaks in the measurement indicating modes of the system. These are shown in Figure 2 and this measurement looks very good. In addition to the magnitude of the FRF, it is a very good idea to also check the complex parts of the FRF.

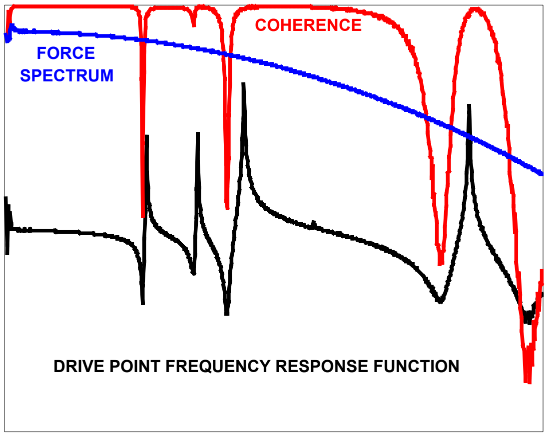

Figure 2: FRF, Input Force Spectrum, Coherence

The real and imaginary parts of the FRF should be inspected to make sure that the measurement looks as expected. Figure 3 shows a good representation of this.

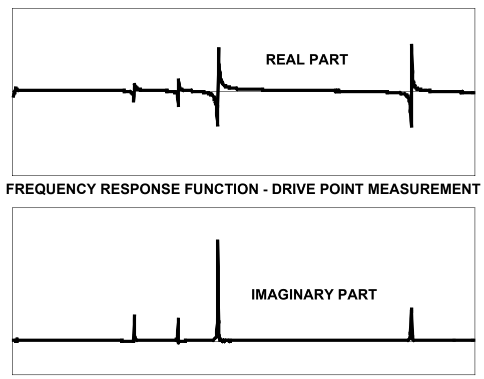

Figure 3: Real/Imaginary FRF – Drive Point Measurement

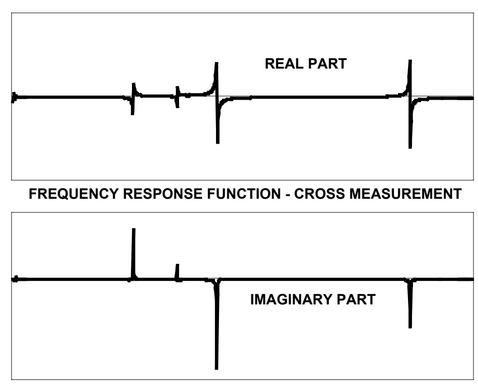

Figure 4: Real/Imaginary FRF – Cross Measurement

However, a note of caution. Many times people only look at the drive point measurement at the start of a test. While this is a critical measurement of the system especially for mode shape scaling considerations, it is not the best measurement to look at all the time. For instance, the peaks of the imaginary part of the FRF will always have the same phase relationship. But if two modes are very close to each other than it is sometimes very difficult to determine how many modes really exist in the data. Many times it is better to check one of the cross measurements as shown in Figure 4. Notice that all of the peaks in the imaginary part of the FRF do NOT have the same phase relationship. This is very useful in determining peaks of closely spaced modes and should always be taken during preliminary testing setup. So once this is done, is there any real need to continuously monitor the time and frequency data for all of the measurement locations. The measurement shown in Figure 5 will help to show why constant monitoring is needed.

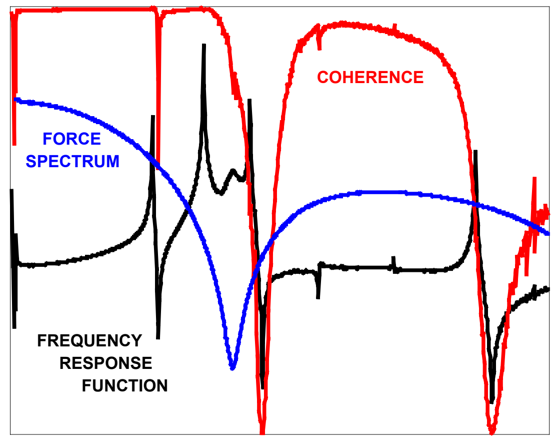

Figure 5: FRF, Input Force Spectrum, Coherence

If just the FRF and coherence were measured, then part of the picture is lost. With just the FRF and coherence, it may be seen that the measurement was poor and possibly blamed on nonlinearities, noise, complex damping and a host of other well-known problems that can affect data. But the real culprit for this measurement is none of those. The input spectrum which was reasonably flat for all the other measurements has a much different force spectrum than in earlier measurements. For this particular structure, impacting at certain locations, there is a dramatic change in the local compliance in the structure and it is very difficult to maintain a fairly uniform input spectrum. It is just a "quirk" of this structure but can happen on any structure. So if you aren't going to check every measurement during the test, make sure that each measurement is saved for every point measured – and that includes all the parts of the measurement not just the FRF and coherence. Because you can see from this case, the input spectrum had important information that was critical to interpreting the measurement in Figure 5.

I hope I have shed a little more light on different aspects of running a test and possible items that need to be addressed. If you have any other questions about modal analysis, just ask me.