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

Illustration by Mike Avitabile

I ran a modal test on a portion of a structure of concern and many modes look the same!
What did I do wrong?
Let's talk about this.

This is another common problem that I often see in experimental modal testing. Many times only a portion of the structure or component of the system is of interest to you or your company. So immediately you focus on only that portion of the overall structure since that is your area of responsibility or concern. This seems reasonable especially since you may not want to test the entire system. (Ahhh - if life could be so simple and easy!).

Unfortunately many times this may not be possible. Most times there is significant dynamic coupling between different components in the system or different portions of the system. It is not always possible to just measure the portion of the structure of interest to you. Of course, you can certainly measure only the portion of the structure of concern, but many times there may be significant dynamic interaction between the various components of subsystems in the system. If measurements for an experimental modal test are only collected over a portion of the structure, then the mode shapes may be confusing since the entire mode shape over the whole structure is not known. It is as if you have put blinders on your view to only look at a portion of the structure - this can leave the user fairly confused. Many times people will comment on this type of test data that there are two first bending modes or two first torsional plate modes, etc. Obviously this is entirely not possible! There cannot be two first modes of the system. But from your limited vantage point when only a portion of the structure is measured, it certainly appears as if there are two very similar modes.

Recently, I saw a modal test of a frame type structure that had various platforms at different levels. An experimental modal test was performed on one platform surface since some important equipment was mounted on one particular platform.

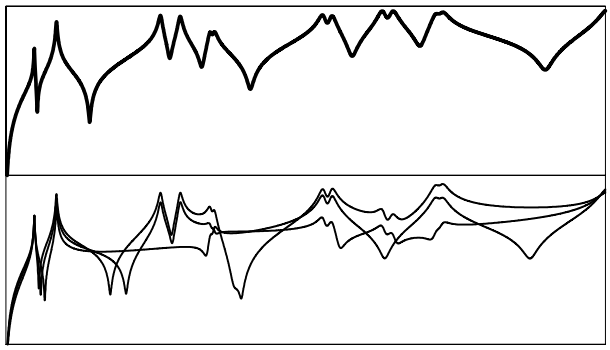

Figure 1 - Drive Point FRF and Typical Cross FRFs

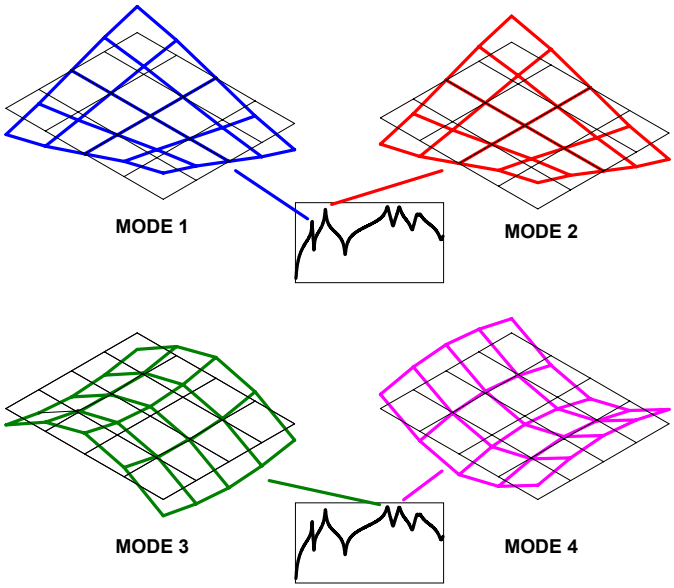

Figure 2 - Mode Shapes of Upper Plate Component

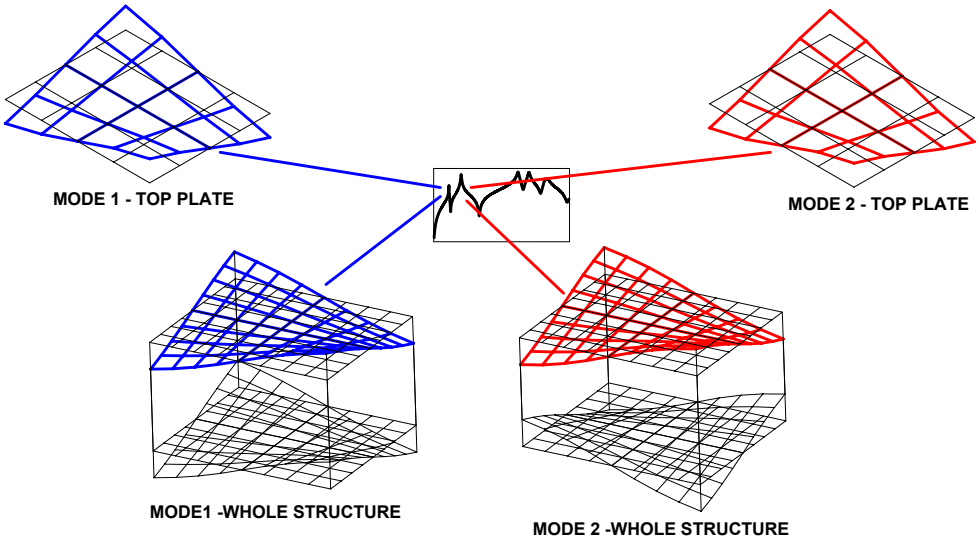

Figure 3 - Mode Shapes of Upper Plate Component along with Entire Structure

Since data was only collected only on that one platform, it appeared as if there were many similar (and almost exactly the same) modes. The problem clearly is that only a portion of the entire mode shape was identified and does not provide a clear understanding of the entire mode shape.

As an example of this problem, a simple two plate structure separated by support columns is used to illustrate typical FRFs and resulting mode shapes from an experimental modal analysis. In one case, only one plate was measured and in another case both plates were measured (but only vertical motion was considered to simplify the explanation of this problem). A typical drive point FRF on the upper plate along with some other typical cross FRFs are shown in Figure 1.

Upon reducing all the data (considering only the upper plate of the structure, the experimental mode shapes revealed two very similar torsion and two very similar bending modes for the first four peaks seen in the FRF. These shapes are shown in Figure 2. Obviously, this is not possible - but with the limited number of measurements on just a portion of the structure, this is entirely possible.

In order to better understand the 'actual' mode shapes of the structure, a more extensive array of points were used to describe the FRF matrix. These FRFs were used to determine the mode shapes of the entire system and are shown in Figure 3 for the first two peaks in the FRF. Clearly, the addition of the extra points clarifies the actual mode shapes of the upper plate in relation to the rest of the structure. This phenomena happens often in many structures when testing is performed for only a small portion of an entire structure or system.

In this simple example, it is clear that the mode shapes for the entire system must be obtained otherwise some confusion may exist. However, this also occurs many times when complicated structures are tested where access to the entire structure is not possible. This might happen with internal components that are not easily accessible for testing. These internal components may have significant modal energy related to one or modes of the structure or system. In these cases, only a portion of the entire mode shape is acquired since it is not possible to instrument interior portions of the structure. Just imagine in the two plate example if the lower plate were not visible or covered by some exterior shroud or covering. If the lower plate were not accessible, the measurements may only reveal the portion of the mode shapes related to the upper plate. In this case the same problem will exist.

This happens many times with structures where all significant portions of the structure are not available for instrumentation or where some disassembly is required to gain access to all the pertinent areas of the structure for modal testing. In these cases the same problem exists. So it is very important to be careful when testing structures where interior components or subsystems are not readily accessible for testing - there may be significant regions of the structure that contain critical information that identify the modal character of the system.

I hope this answers your question. If you have any more questions on modal analysis, just ask me.