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

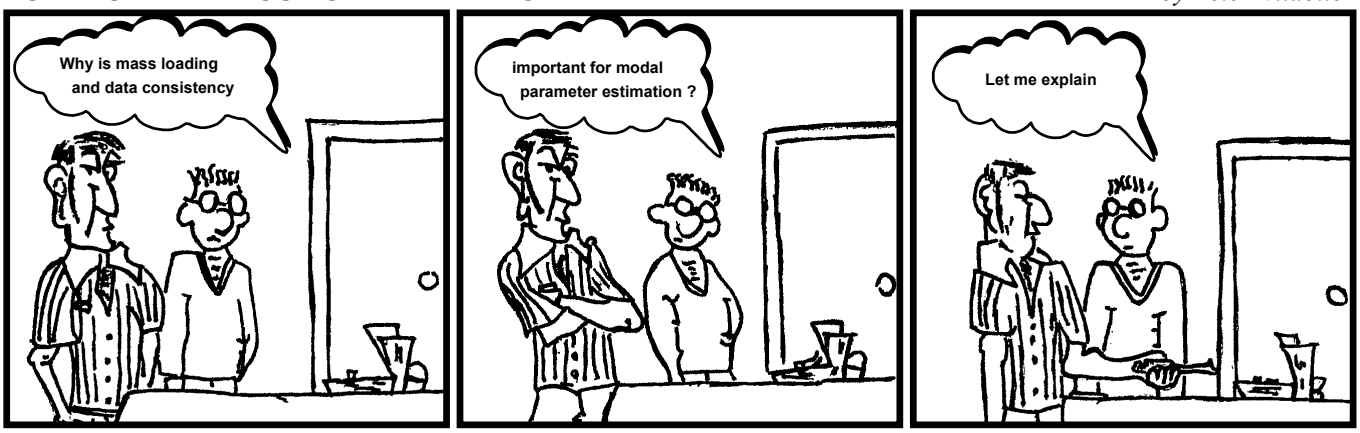

Illustration by Mike Avitabile

Why is mass loading and data consistency important for modal parameter estimation? Let me explain

This is other good example where people can get confused when performing modal parameter estimation. All too often when the curvefitting results are confusing or appear distorted, the effects will be blamed on noise or nonlinearities. This is often a blanket statement that many people use when they don't understand or can't explain something easily. Let's look at why data consistency is important and what effects mass loading will have.

The first thing to recall is that the model we use to fit data comes from a linear, symmetric set of equations where the poles (frequency and damping) are defined in terms of global quantities and reciprocity is assumed to be inherent in the formulation of the equations. Now as long as our data fits that model then everything is OK. But how does my testing and data acquisition have an effect.

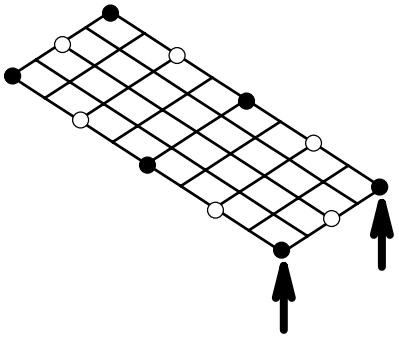

Fig 1 - MIMO Test Setup with 2 Sets of Points

Let's consider a simple plate test setup that is driven by two shakers for a MIMO test with an 8 channel data acquisition system. Now I'll acquire FRFs using good measurement techniques to assure the best possible measurements are obtained for the 6 accelerometers mounted on the plate shown in Figure 1 (the solid fill points are for the first test and the other points are associated with the second test and are obtained by roving the accelerometers on the structure).

The mode indicator function is shown in Figure 2 and the stability diagram is shown in Figure 3. The poles are extracted for the first two modes only (for illustration purposes). The stability diagram shows these two poles very clearly. Notice that as the order of the model increases, the poles are clearly identified (overlaid on the summation function). Once the poles are extracted, then the residues or mode shapes are obtained to provide modal data associated with these 6 measurement points; a typical curvefit is shown in Figure 4.

However, this first set of data only consists of 6 measurement points. In order to better define the mode shapes, more measurement points are needed.

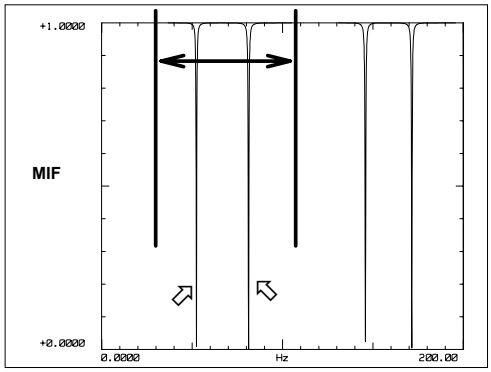

Fig 2 - MIF for Data from First Test

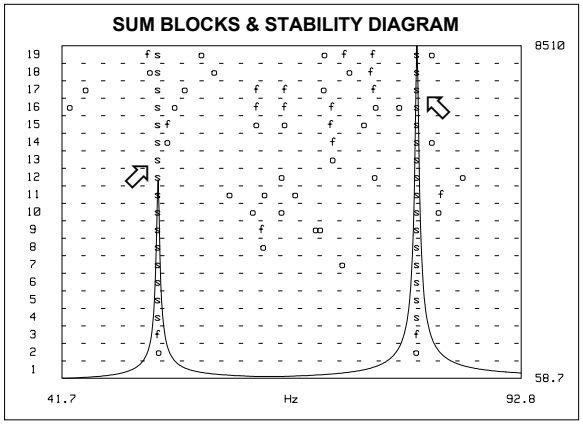

Fig 3 - Stability Diagram for Data from First Test

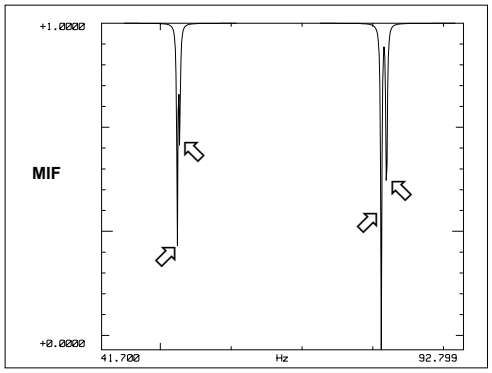

Fig 5 - MIF for Test 1 & 2 Combined

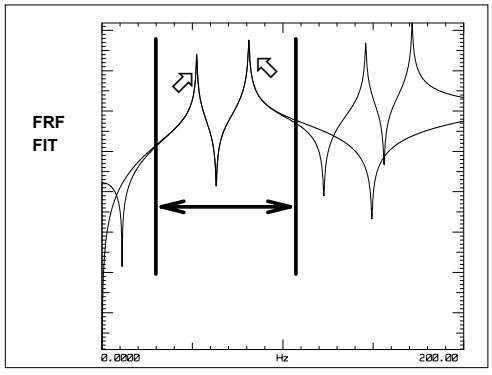

Fig 4 - Typical Curvefit from First Test

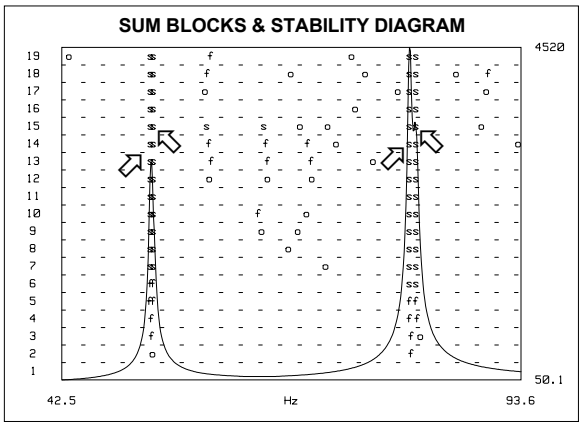

Fig 6 - Stability Diagram for Test 1 & 2 Combined

For the additional points, the accelerometers are relocated to the measurement points shown (non-filled points) and a second set of MIMO measurements were collected. Again, poles are extracted *using just this second set* of measurement points and a stability diagram obtained. Again the poles are clearly identified and mode shapes associated with these 6 points identified. (These results are not shown here but are similar to the first case.) *But the two sets of data were evaluated separately to estimate the poles and residues.*

Now let's combine the two data sets together and evaluate the data. The mode indicator function and stability diagram are computed again. Now instead of 2 distinct peaks as we saw earlier in the MIF, there are now 4 distinct peaks over the same band (Figure 5). The estimation of the poles for the same frequency band (Figure 6) used earlier now shows 4 modes instead of 2!!! How could this possibly be? The plate didn't change - did it?

Well, the plate didn't change - ***but the test setup sure did!*** The roving accelerometers have a mass effect that caused the modes to shift slightly. So when all the data is processed simultaneously, some of the measurements indicate the poles at a certain frequency and the other measurements indicate the poles at a different frequency.

So which is correct? It is likely that neither is correct. That's because the test setup had an effect on the measured modes of the system. The question is which poles are the correct ones to be used for the modal parameter estimation process. Well, you really can't identify a global set of poles for all the measurements since they are not "global" for all the measurements. Actually, the correct way to extract parameters in this case is to collect a "consistent" set of data by eliminating the mass loading effect by mounting all the instrumentation on the structure (or adding dummy masses) for the duration of the test. This will provide more "consistent" data which conforms to the model being used to fit the data. Of course, it is very important to point out that we have modified the structure due to the addition of all of the masses. But at least all the data will be consistent and will not distort the modal parameter estimation process due to mass loading effects.

Of course, real world structures have all kinds of measurement problems with respect to noise, linearity, time variability, etc. The modal parameter estimation process is complicated enough. Don't complicate the process further by letting simple items such as mass loading distort your data. I hope this helps to answer your question as to why mass loading and data consistency is so important. If you have any other questions about modal analysis, just ask me.