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

Illustration by Mike Avitabile

Someone told me that you must have multiple references to identify pseudo repeated roots.
Let's talk about this.

First, let me say that repeated roots are generally rarely found in the majority of structures we test. But recently, I have seen many tests with what are referred to as "pseudo repeated roots". This refers to modes with two or more frequencies that are present in one discrete Δf spectral line of the measured data. Therefore, the observed peak is comprised of the sum of two or more modes in the response function measured.

In order to see the peaks as distinct individual peaks, finer frequency resolution is needed. Of course, this may not be feasible. Many times to obtain this resolution would require excessively long time blocks which may not be easy to obtain. But what happens if sufficient resolution is not available. Typically, most people would state that if multiple roots exist, then multiple references must be acquired otherwise the roots cannot be extracted. Now this is a very strong statement and I do not necessarily agree. The modal parameter estimation algorithms (curvefitters) are very robust and there is really no reason to think that the algorithms are deficient when it comes to extracting pseudo-repeated roots (two examples will be shown). Multiple references are actually not always necessary in these situations.

First, let me make sure that there are no misrepresentations here. I fully advocate using multiple reference data collection when conducting an experimental modal test. With multiple channel acquisition systems commonly available, it is easy to acquire multiple reference data. Typically with a 4 or 8 channel data acquisition system, multiple accelerometers can be placed at a variety of different locations as references for an impact test (MRIT - multiple reference impact test). Then, the impact data can be collected at all the measurement locations with the multiple stationary acceleometer locations. (Of course with a shaker excitation modal test, multiple reference data can be more work if multiple shakers are not available. But, typically multiple reference data can be collected.) But the question really is this - Is multiple reference data required to extract multiple roots?

As far as I am concerned, the answer is not necessarily so. If the data collected is good measured data, then the frequency response function is the sum of all the modes and the modal parameter estimation algorithms can extract multiple roots accurately from the measured data. Two structures are evaluated to show the results of extraction of multiple roots (two distinct modes within one Δf of the analysis spectral resolution) from measured data. In both cases, there appeared as if only one root existed as indicated by the available mode indicator tools (SUM, MIF, etc). In one structure, only a handful of cross directional FRFs from a total of over 100 measurements showed some indication of two frequencies. In the other structure, none of the measurements revealed the fact that the first two "peaks" in the FRF contained multiple roots at each peak!

The first structure was a prototype composite spar from a wing structure. The geometry typified a taperd beam (with a type of I shape) which had no geometric symmetry. A typical impact measured FRF is shown in Figure 1 with a photo of the structure.

The measurement is reasonably good with some noise seen on the measurement over the frequency range. A frequency domain polynomial curvefit algorithm was used to extract mode shapes. (Actually, three different commercially available modal packages were used with essentially identical results). The second peak in the function actually contains two separate roots. The curvefitter extracted the two roots at the second peak with no difficulty whatsoever even though there appeared to be only one peak present. Clearly, the modes extracted show two well defined mode shapes shown in Figure 2. Even though only one

reference was available to extract modal parameters, two modes were very successfully extracted!

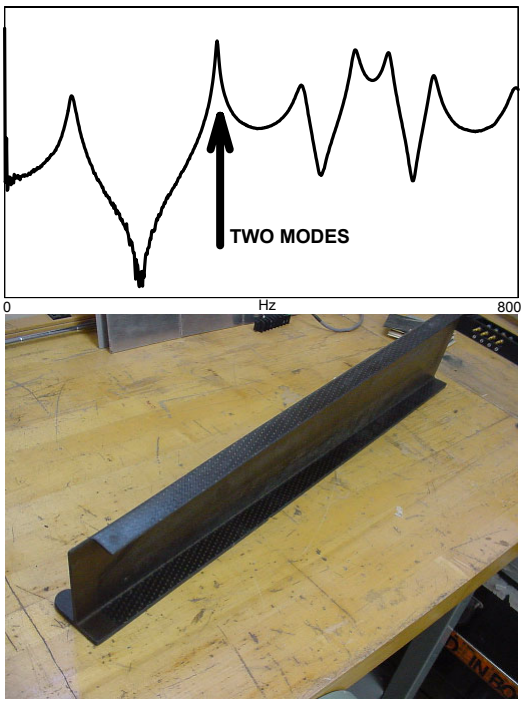

Figure 1 - Typical FRF and Photo of Structure

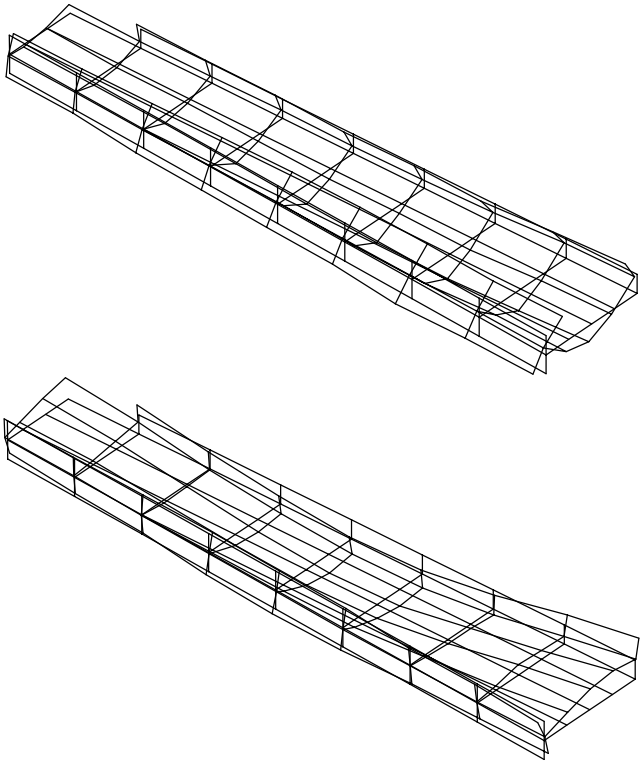

Figure 2 - Pseudo-Repeated Mode Shapes at Second Peak

The second structure was a simple magnesium shaker table slip plate. The geometry was such that multiple roots were not actually anticipated. A typical impact measured FRF is shown in Figure 3 with a photo of the structure.

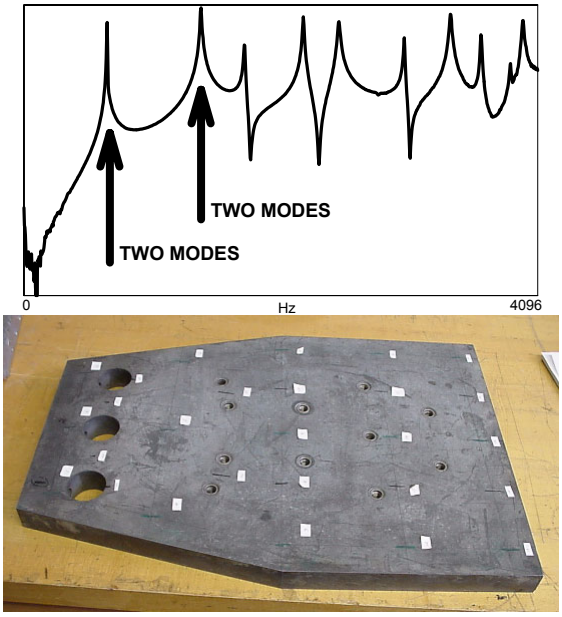

Figure 3 - Typical FRF and Photo of Structure

The first peak appeared to be a single mode for all of the FRFs obtained; to some degree the second peak had similar characteristics. The mode indicator tools also indicate that only one mode is expected. However, estimating parameters assuming only one mode does not provide the "expected" mode shapes. Upon refitting the data with two modes at each peak reveals the mode shapes expected; the shapes are shown in Figure 4.

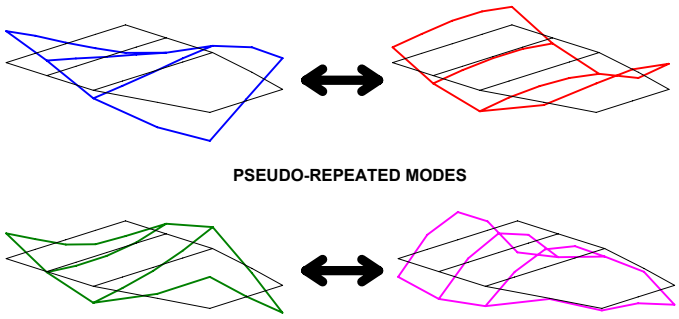

Figure 4 - Pseudo-Repeated Mode Shapes

Now in both cases, the mode indicator tools did not necessarily indicate multiple roots. User intervention was required in order to extract the multiple roots. Also notice that the multiple roots were very successfully extracted with single reference data - multiple reference data was not required! Please understand that multiple reference data is extremely useful - but is not always required in order to extract multiple pseudo-repeated roots.

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