MODAL SPACE - IN OUR OWN LITTLE WORLD

by Pete Avitabile

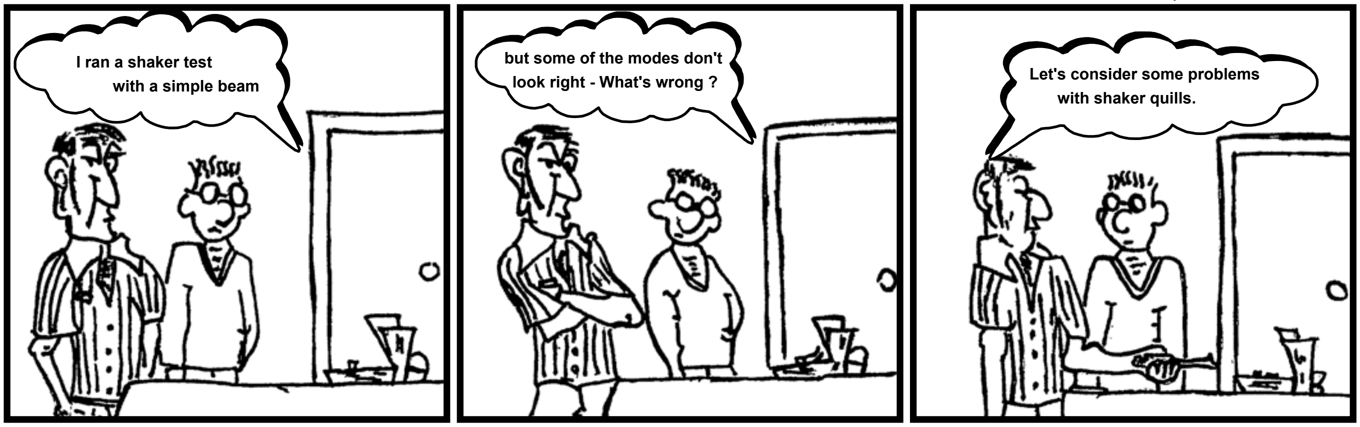

Illustration by Mike Avitabile

I ran a shaker test with a simple beam but some of the modes don't look right – What's wrong?
Let's consider some problems with shaker quills.

Shaker testing for experimental modal analysis can pose some special difficulties if care is not taken in setting up the shaker and attachment device commonly called a "quill" or "stinger". Typically a system is setup as shown in Figure 1. The idea of the stinger is to allow for axial motion to be imparted into the structure which is measured by the force gage for simple compression and tension type loads.

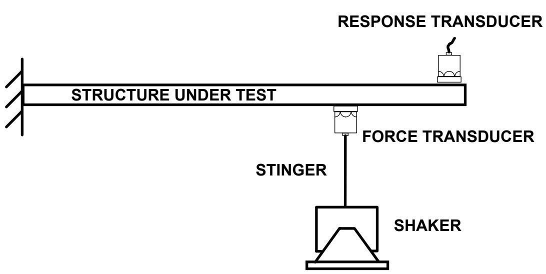

Figure 1 – Typical Shaker Setup

The purpose of the stinger is to allow for loads in the direction of excitation but to minimize the lateral loads that may be imparted into the system. Essentially, a free body diagram concept allows us to know the force imparted into the structure at the attachment point. Therefore, all the dynamic effects of the shaker system and stinger are not included in the dynamic characterization of the structure under test. At least that's what is happening from a theoretical standpoint. Of course this assumes that the stinger has essentially no lateral stiffness and does not have any significant contribution to the overall dynamic characterization of the system. This is extremely important because the force gage only measures the axial load applied – if there is any other loads (lateral or moment) that occur, the force gage does not measure them.

The measurement that was made is described next. (This measurement was received from an outside source). A relatively flexible beam was set up for testing with a shaker similar to that shown in Figure 1. However, the stinger was relatively short and there was a possibility that the rotational stiffness of the stinger may affect the beam flexible modes.

So now let's take a look at some of the measurements that were made. Figure 2 shows an FRF measurement that was taken with a shaker system attached to the structure with a stinger that was possibly too short. This then caused the rotational stiffness of the stinger to be more pronounced – especially relative to the flexible beam that was being measured. A modal test revealed that there was a classical 1st and 2nd bending mode for the first two peaks as expected. However, the next two peaks revealed essentially the same classical 3rd bending mode of the beam. FRF measurements were obtained only for the structure under test but none on the stinger.

Subsequent tests (and additional measurements on the stinger itself) revealed that the two peaks were actually the result of a tuned absorber effect. The stinger was actually in phase with the structure mode shape at 3rd peak of the FRF and out of phase with the structure motion at the 4th peak of the FRF.

The force gage only accounts for the axial motion imparted by the shaker excitation – there is no measurement of the rotational effects associated with the beam rotary stiffness introduced by the stinger in the test setup. But the stinger actually looks like a rotational spring relative to the beam at the attachment point.

In order to confirm the observation, a longer stinger was utilized in a second test of the structure. The longer stinger effectively minimizes the effect of the rotation stiffness imparted to the structure under test.

Figure 3 shows the FRF with the longer stinger attached. It is clear that the FRF is much cleaner and follow the expected pattern of beam like mode response. A brief modal survey was conducted and the first three peaks correspond to the first three classical mode shapes for a cantilever beam.

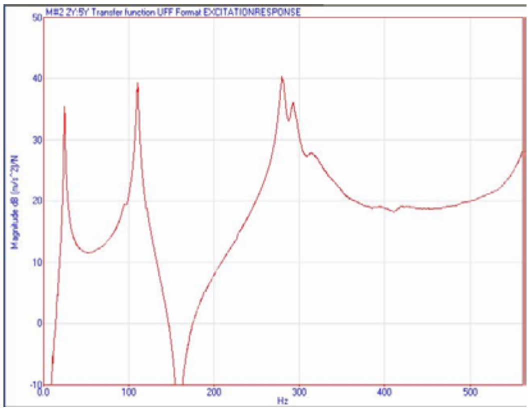

Figure 2 – FRF with Short Stinger

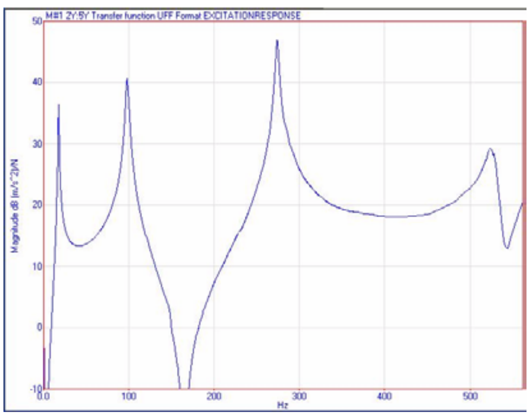

Figure 3 – FRF with Longer Stinger

Clearly, the first two modes see a shifting of frequency due to the different stinger configurations. This can be due to a variety of reasons which might be mass loading effect, stinger effect, different test setup, etc. (These are measurements that were provided by an outside source so I can not be sure of the actual test setup – but the effect is very clear). The third peak is significantly different. There is a splitting of the main peak as is typically seen in tuned absorber applications – there is also a significant reduction in the overall amplitude of the measured response (as is seen in tuned absorber theory).

Figure 4 shows the expected shape that would result if this stinger acted as a tuned absorber to the measurement system. (Again these measurements were provided from an outside source and are used to illustrate the effect that is expected to exist here). Obviously the rotational effects of the stinger at the attachement point on the structure will be more pronounced as the stinger is shortened. If the stinger happens to have the same frequency as one of the modes of the main structure, then the coupling would definitely produce FRFs as shown in Figure 2.

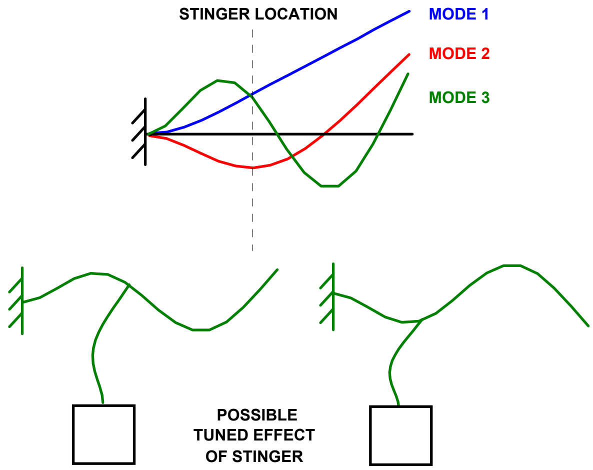

Figure 4 – Stinger Tuned Absorber Effect
(Note: Shapes not to scale; shapes sketched to show expected effect of stinger rotational stiffness coupled to main structure)

Clearly, the effect of the shaker stinger length plays a very important role in the measurement of accurate FRF measurements. If the stinger is too short then there is a general stiffening effect that can be seen in the measured response function. For this particular case, there is a general tuned absorber effect that can be easily seen. This tuned absorber effect may not occur in every stinger application but was observed in this particular measurement setup.

Figure 5 shows an overlay of the two FRF measurements acquired – one with the short stinger and one with the longer stinger. Comparing the two measurements shows significant differences on all the modes of the system measured.

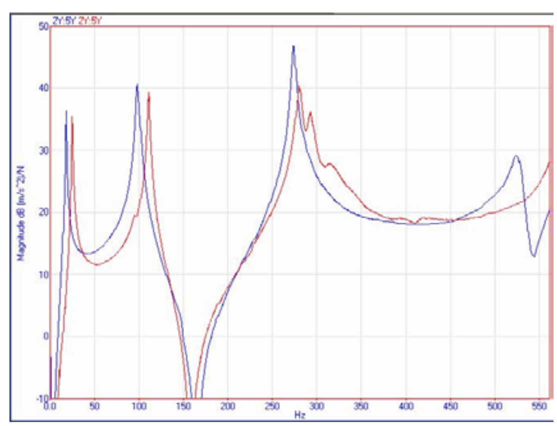

Figure 4 – Comparison FRF

I hope that this little discussion has shed some light on this problem regarding shaker stinger setup. If you have any more questions on modal analysis, just ask me.