MODAL SPACE - IN OUR OWN LITTLE WORLD by Pete Avitabile

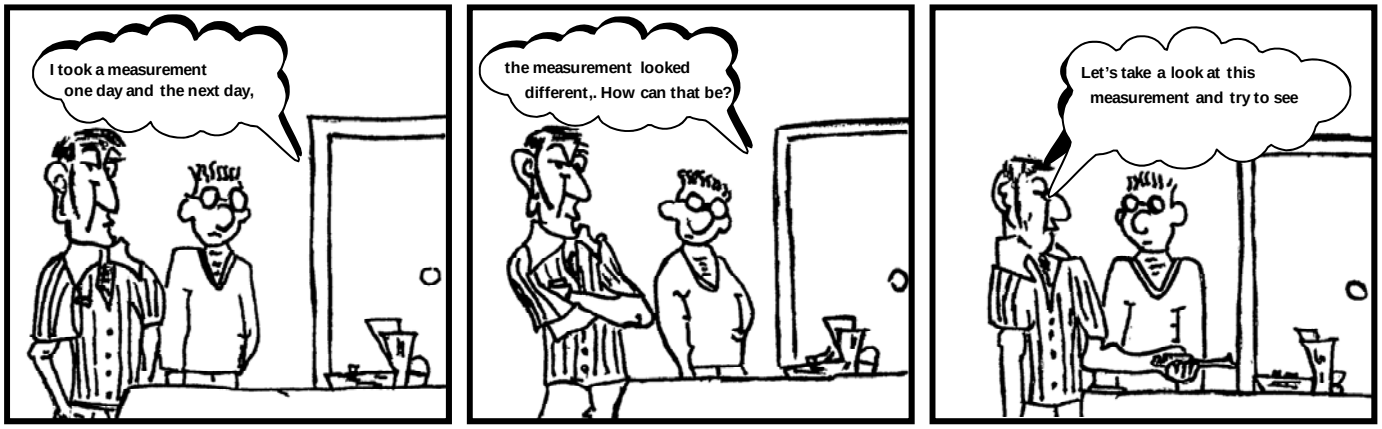

Illustration by Mike Avitabile

I took a measurement one day and the next day the measurement looked different. How can that be? Let's take a look at this measurement and try to see what's happening.

So we have talked about a lot of different measurement problems in the past but this one is really one that needs some attention. Of course there are always differences between measurements from one day to the next or hour to hour or even week to week; these are typically small differences that we need to live with when we test structures – this is normal variability.

But the measurement you showed me is quite different than what we normally see as variation we would expect to see. In this particular measurement, there was very small variation in the lower frequency range and then there was a very significant and dramatic difference in the higher frequency range.

So let's step through this particular measurement that was made and discuss what happened. The main item that we will home in on is that the fixturing for the test may have played a very significant effect in the measurement for the system.

The measurement that was made was for a small wind turbine blade. The blade was to be tested in a "built-in" or "clamped" condition. The blade itself weighs less that two pounds and is attached to an 800 pound optical table. Now the optical table is certainly large enough to be able to adequately simulate a built-in condition for the blade. In fact, an analytical model was available for the structure and the anticipated built in modes were available from the model. While the analytical model is never perfect and has approximation that are made when the model is developed, a model for this type of simple structure is expected to be reasonably accurate given the simple geometry for the configuration.

So the first frequency response function was made with the blade attached to the optical table. Normal impact measurement methodologies were employed for the impact and response measurements with an FFT analyzer. The blade was attached to the optical table with a solid mounting block and some threaded rods to attach the block (as a spacer) between the turbine blade and the optical table; this was necessary due to the curvature of the blade geometry to allow for clearance between the cantilevered blade and optical table.

Overall the measurement looked acceptable and the coherence for the measurement was also acceptable. The frequency response function is shown in Figure 1 with a picture of the test set up. The low frequency portion of the measurement was not of interest and is hidden behind the picture of the test set up.

So the first measurement taken appeared to be acceptable. Now this measurement was taken on a Friday afternoon followed by additional testing to be performed the following week. As good practice on Monday morning, the measurement was repeated prior to the balance of testing to be performed. This second measurement also looked acceptable overall. The frequency response is shown in Fugure 2 with a picture of the test set up. Again the low frequency portion of the measurement was not of interest and is hidden behind the picture of the test set up.

But the measurement taken on Monday morning did not look the same as the measurement taken on Friday which had several people scratching their heads. Figure 3 shows the comparison of two measurements overlaid.

Fortunately someone recognized these dramatic differences and stopped testing to determine what could have possibly caused such a dramatic difference in the measurement. Figure 3 clearly shows that the lower frequency modes are essentially the same with normal variation which is to be expected. But the higher frequency range had a dramatic difference in the measurement, almost as if it was from a completely different structure.

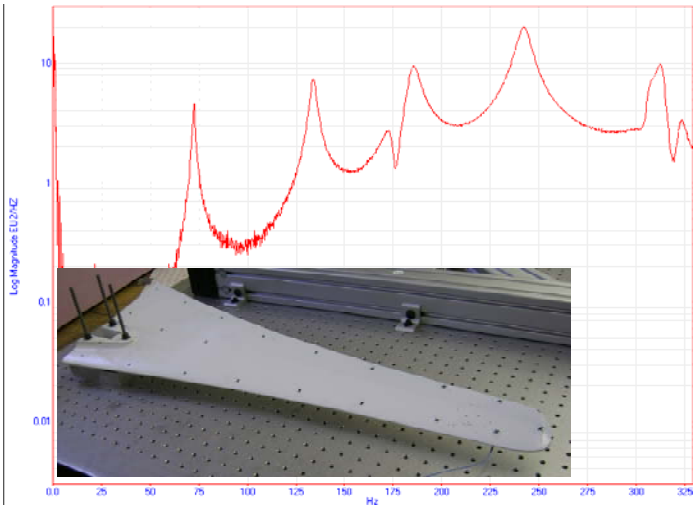

Figure 1 – FRF and Test Set Up - friday

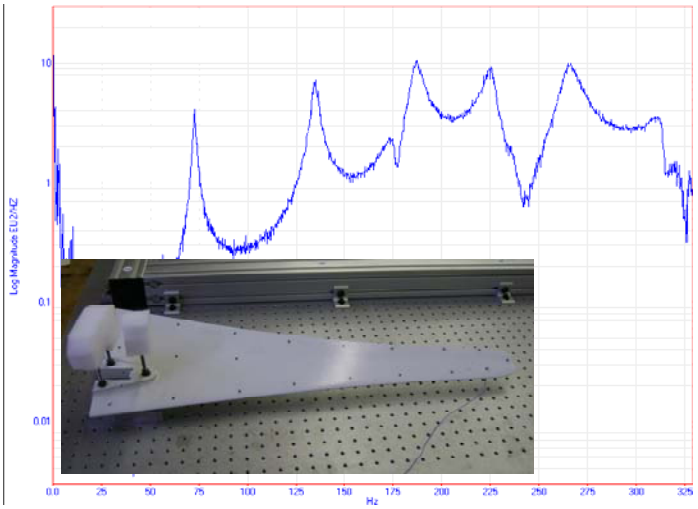

Figure 2 – FRF and Test Set Up - Monday

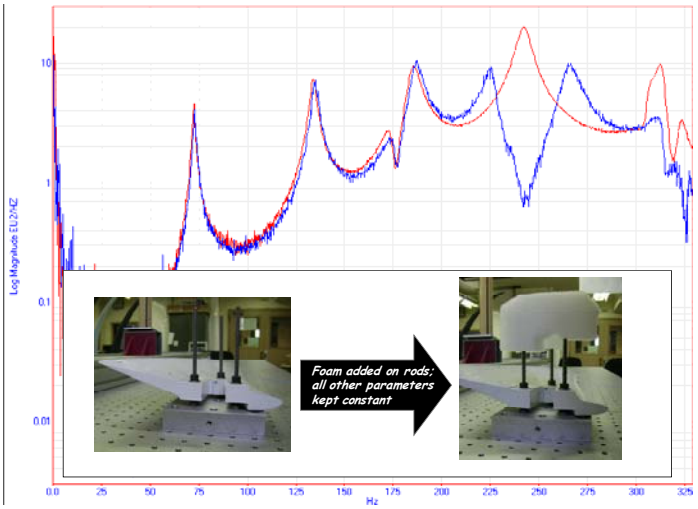

Figure 3 – Comparison of Friday and Monday Measurements

Obviously the first thoughts are directed to the fixturing that attached the blade to the optical table. But inspection of the joint and tightening and reassembly of the joint did not make any appreciable difference.

So when I first saw this measurement, I immediately suspected that there was likely something different in the two tests that might be attributed to some sort of tuned absorber effect. The reason why I jumped to this conclusion is because there is a general shifting of frequencies in the lower frequency range that could result from a tuned absorber effect.

So after a little detective work and asking some general questions as to what could be different between the two tests, some thoughts emerged as to what could be the problem. After a few more questions and some close interrogation of the pictures of the test set up, there is one thing that caught my eye.

Well as it turns out, the lab manager was very concerned about safety and the three threaded rods that protrude from the blade and block attaching it to the optical table could cause some injury if someone wasn't careful around the test set up. So as a precaution, the lab manager had some soft foam pushed onto the long threaded rod. (Now this foam is basically the soft packing foam that you find in packaging of electronics and is extremely light and really has no structural effect whatsoever.) BUT…

That foam does have a very, very small amount of mass and at the end of the long threaded rod has the effect of changing the cantilevered mode of the threaded rod. And oddly enough, the effect of shifting that cantilevered rod frequency just happened to coincide with one of the natural frequencies of the blade. This then caused the two modes to split in a very traditional tuned absorber effect. And this effect was very dramatic for sure.

And if you don't believe that this could possibly happen and that this was in fact the cause of the problem, then please rest assured that the structure was tested about five more times with and without the small piece of packing foam attached to the threaded rod and both sets of measurements from Friday and Monday were replicated each time the test was conducted.

So the bottom line here is that fixturing in any dynamic test can have an effect on the measured data. In this case the effect observed was very dramatic for the fifth mode of the blade. Care must be exercise in all fixturing for all dynamic tests performed. You never know what can happen! If you have any other questions about modal analysis, just ask me.