MODAL SPACE - IN OUR OWN LITTLE WORLD by Pete Avitabile

Illustration by Mike Avitabile

Sometimes when I have a double impact, I switch hammer tips to eliminate it. Is that OK?
Let's take some measurements to see what impact this has.

So we have talked about double impacts before but this is a different scenario. On the surface it sounds like this might be a way to mitigate the double impact but there may be some ramifications as a result of that. So let's take some measurements on the same structure we discussed in the last article to see what impact this has (no pun intended).

Last time we were discussing the rolloff of the hammer and we showed that the rolloff itself didn't significantly degrade the resulting mode shapes of the system but that there was some degradation of the FRFs measured as expected.

Now during that original test we were fairly careful to avoid any double impacts (with the harder tip). But we have gone back to that same structure and acquired some additional measurements and made sure that some of the measurements were acquired with double impacts. And in fact we took another whole set of data and specifically made sure that every one of the FRFs acquired came from impact excitation where double impacts were applied.

For reference, the typical input force spectrum for a single impact and a double impact is shown in Figure 1.

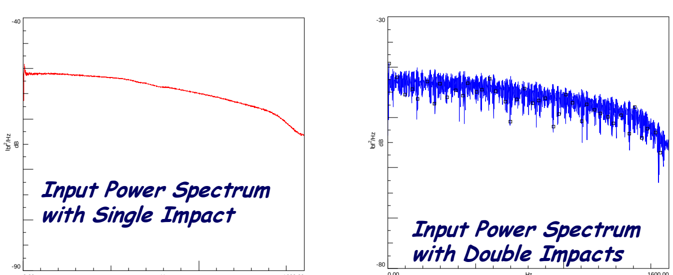

Figure 1 – Comparison of Single and Double Force Spectrum

While the double impact shows variation of the input force spectrum over the entire frequency band, it is important to note that there are no serious drops in the input spectrum which would be the major concern. And for reference, Figure 2 shows the typical mode shapes for the structure we are testing.

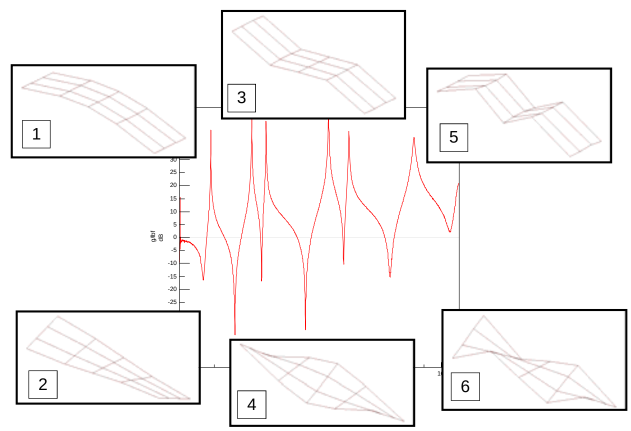

Figure 2 – Mode Shapes for Structure

Now what I am going to do is use the data set with the harder tip and no double impacts as the reference for the comparisons that we will consider here. And I am going to acquire some measurements in locations of the structure where double impacts could possibly occur and use the softer tip to acquire those measurements. (Just to make sure I document this properly, the outer 10 FRFs of the structure are measured with the harder tip and the inner 10 FRFs are measured with the softer tip.)

For comparison, two FRFs from each hammer tip are shown in Figure 3 and Figure 4 for the harder tip and the softer tip, respectively.

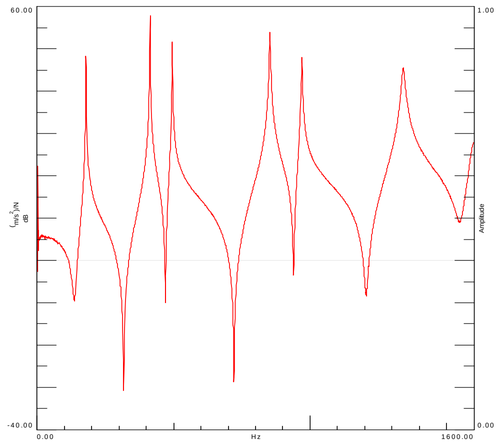

Figure 3 – Typical FRF for Harder Impact Tip

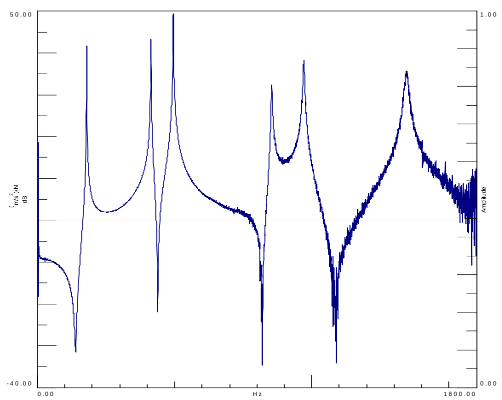

Figure 4 – Typical FRF for Softer Impact Tip

Now for the first comparison, the MAC was computed for the reference modal data set and the "hybrid" set of modal data where some of the measurements were made with the harder tip and some were made with the softer tip; the original idea was to minimize the double impact with the softer tip. The MAC is shown in Table 1 for this case.

Table 1 – MAC for Reference Test and Hybrid Data Set

Frequency	*179.270 Hz*	*413.356 Hz*	*495.121 Hz*	*852.661 Hz*	*970.418 Hz*	*1341.456 Hz*
179.304 Hz	*98.547*	*0.207*	*0.048*	*0.17*	*30.453*	*0.114*
413.501 Hz	*0.052*	*98.088*	*0.007*	*0.253*	*0.149*	*10.311*
495.105 Hz	*0.114*	*0.189*	*99.798*	*0.144*	*0.173*	*0.216*
853.646 Hz	*0.107*	*0.573*	*0.002*	*97.825*	*0.121*	*0.31*
970.634 Hz	*33.247*	*0.144*	*0.09*	*0.082*	*95.881*	*0.126*
1345.196 Hz	*0.122*	*9.725*	*0.07*	*0.431*	*0.132*	*97.921*

Notice that the MAC for the diagonal terms ranges from about 95 to 99 for the corresponding modes; the off-diagonal terms are not as critical to this evaluation because spatial aliasing is the main difficulty with such a limited set of data points.

But remember from the last article, when we compared all the harder tip modal data set with the softer tip modal test there was essentially no difference between the modes. So what has happened here?

Basically, as we switched the tip on the hammer we had an effective change in the input spectrum which essentially changed the calibration for the hammer. Because all the measurements were not collected with the same hammer tip, there is a bias on some of the measurements relative to the balance of the measurements. This means that we have created an imbalance in the scaling of the FRFs. So this directly implies that we really shouldn't switch the hammer tip in the middle of the test or else there can be a bias on the FRFs collected – unless if we calibrate to normalize that effect in the data acquired.

Now let's take this just one step further and use another set of data. While I am not an advocate of using double impact data, we have shown in the past that sometimes we might need to collect data with double impacts and maybe that data is not horrible to use – *as long as we use care to make sure that all the data seems reasonable with good coherence.* Now I am going to use the data set where all the FRFs were measured with some type of double impact but all FRFs were acquired with the same hard tip for all measurements.

Now another MAC was computed for the reference modal data and the modal data with some type of double impact at all measurement points. The MAC is shown in Table 2 for this case. Now notice that MAC for all the diagonal terms are all above 99. So this shows that the data was actually very good overall and the FRFs collected with double impacts are actually better than the data where we tried to minimize the double impact by using a softer tip at a subset of locations on the structure. I guess you would never expect that result but it makes sense if you consider that the double impact data was collected with a somewhat consistent input excitation whereas the "hybrid" data set was not.

Table 2 – MAC for Reference Test and Double Impact Test

Frequency	*179.454 Hz*	*414.166 Hz*	*495.463 Hz*	*855.208 Hz*	*972.122 Hz*	*1346.707 Hz*
179.304 Hz	*99.634*	*0.014*	*0.085*	*0.093*	*33.183*	*0.024*
413.501 Hz	*0.024*	*99.823*	*0.004*	*0.137*	*0*	*12.293*
495.105 Hz	*0.039*	*0.036*	*99.906*	*0.034*	*0.093*	*0.058*
853.646 Hz	*0.1*	*0.175*	*0*	*99.475*	*0.065*	*0.341*
970.634 Hz	*33.476*	*0.01*	*0.117*	*0.072*	*99.579*	*0.051*
1345.196 Hz	*0.018*	*11.365*	*0.06*	*0.216*	*0.009*	*99.292*

I hope this helps to illustrate that double impacts are maybe not as bad as you would have guessed. And the switching of the impact tip during the middle of the test, without accounting for the effective change in the input force spectrum, changes the calibration and needs to be considered. If you have any other questions about modal analysis, just ask me.