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

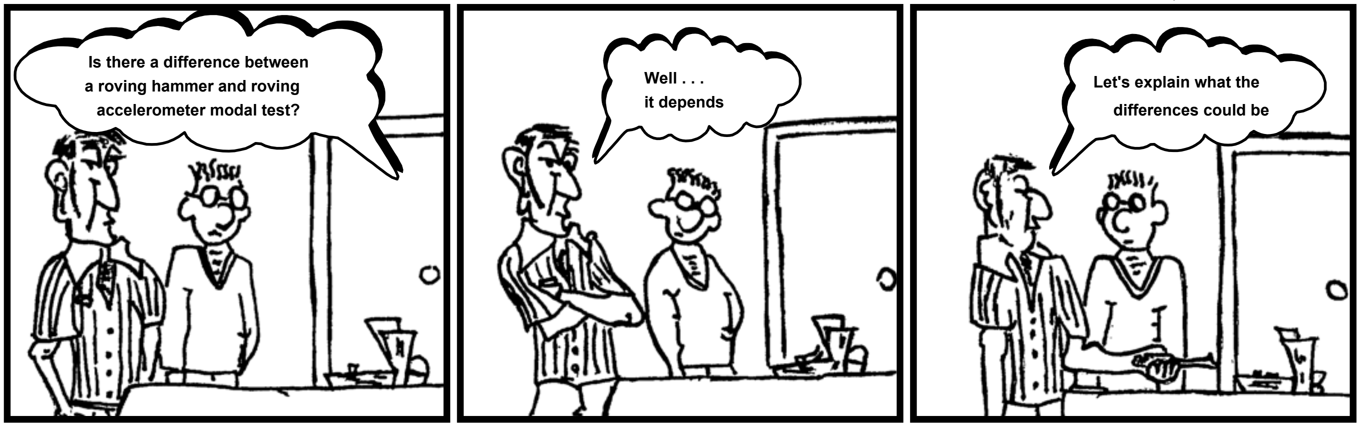


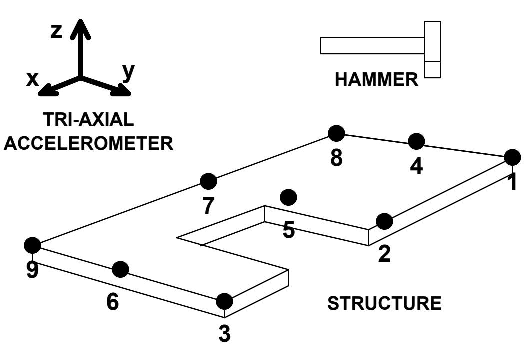
Illustration by Mike Avitabile

Is there a difference between a roving hammer and roving accelerometer test?
Well ... it depends
Let's explain what the differences could be.

Basically, there is no difference between a roving hammer and roving accelerometer modal test. This is true providing the same measurements are collected. Let me explain by discussing this seemingly simple but tricky fine point about a modal test.

Back when we performed a modal test with a 2 channel analyzer, it was fairly straightforward to perform an impact test. Usually, the hammer roved around the structure with a stationary accelerometer. Typically, we impacted the structure at every point in the x, y, and z directions to obtain FRFs relative to the reference location of the stationary accelerometer. But when we started using multichannel analyzers to perform the same test, there are some slight differences that need to be addressed. Let's consider an impact test for the 9 points shown on the structure. Let's also assume that I have an impact hammer and a tri-axial accelerometer with a 4 channel FFT analyzer or acquisition system.

MODAL TEST CONFIGURATION



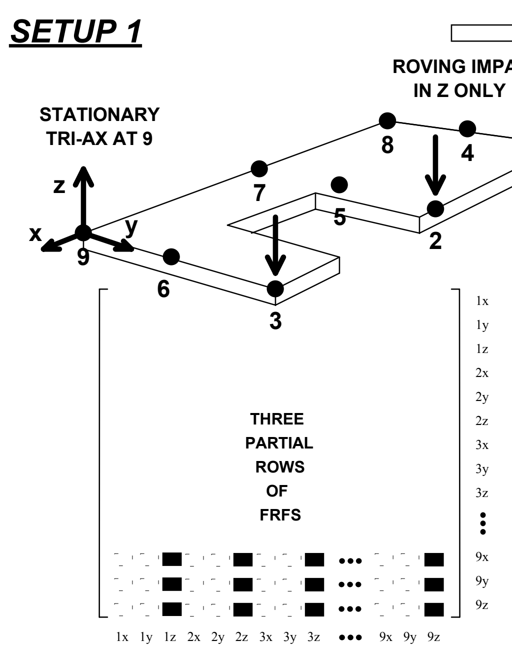
One way to run the test is to place the tri-axial accelerometer at a fixed location and impact, in one direction, at all 9 points. We would then obtain 27 FRFs for the structure. Another way to run the test is to impact at one point, in one direction, and have the tri-axial accelerometer rove to all 9 points. Again we would collect 27 FRFs. So in both cases, we measure 27 FRFs by impacting in only one direction.

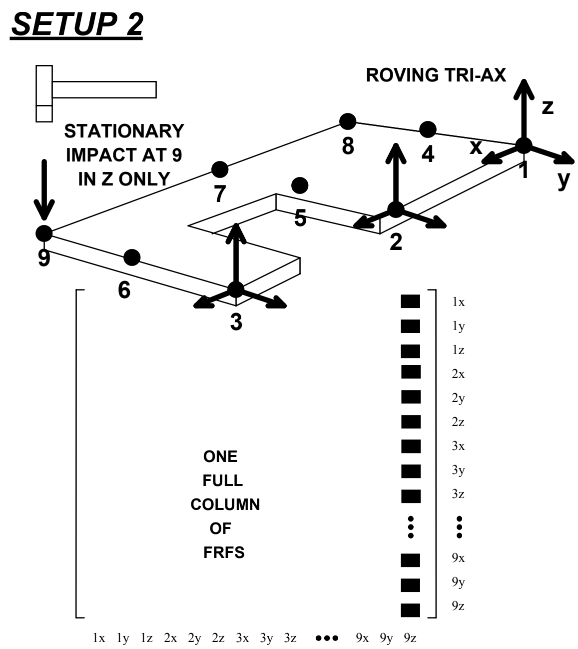
But are the two tests the same? At first glance, you would think that both test setups should produce the same results. In order to confirm whether this is true or not, let's step through the measurement process and list out what measurements are actually being made for each test setup.

Test Setup #1

Let's say that we want to run a modal test shown in setup #1. In this test, the tri-axial accelerometer is stationary at point 9 and measures x, y, and z outputs. The input hammer force is applied in the z direction only and roves to each of the 9 points shown.

Now let's list each of the FRFs that will be collected from this test setup. When we impact point 1 in the z direction, the response is measured at 9x, 9y, and 9z. So the FRFs measured are 9x/1z, 9y/1z, 9z/1z for the first measurement made. Next we impact point 2 in the z direction and the response is measured at 9x, 9y, and 9z. This set of FRFs are 9x/2z, 9y/2z, 9z/2z. We can continue on here but I think you get the hang of it. But what did we actually measure? Let's arrange all of these measurements in the FRF matrix to see what we have.





When we take a close look at the FRF matrix, we notice that we have measured only parts of three different rows of this matrix. So we only have three partial descriptions of the characteristic of the system. But in each of the partial descriptions, we can only see the characteristic information in the z direction. This would be fine if there was only motion in the z direction. But what if there was significant motion in the z direction when the structure is excited in the x direction? We have only measured response due to excitation in the z direction!

<u>Test Setup #2</u>

Now let's say that we also want to run the modal test shown in setup #2. In this test, the hammer impacts only in the z direction at point 9. The tri-axial accelerometer roves to each of the 9 points shown for this test, measuring the x, y, and z directions.

Let's list each of the FRFs that will be collected from this test setup. When we impact point 9 in the z direction, the response is measured at 1x, 1y, and 1z. So the FRFs measured are 1x/9z, 1y/9z, 1z/9z for the first measurement made. Next we move the accelerometer to point 2 and the response is measured at 2x, 2y, and 2z. This set of FRFs are 2x/9z, 2y/9z, 2z/9z. So what did we actually measure? Again, let's arrange all of these measurements in the FRF matrix to see what we have.

Now we notice that we have measured one complete column of the FRF matrix. Now we can describe the response of the system in a more complete sense. We have now measured enough FRFs that we can describe the response of the system for all points. Of course, I'm assuming that the reference location at point 9 in the z direction is not the node of a mode!

<u>So what should I do?</u>

So while it appeared on the surface that both tests were the same, there actually is a difference!!! So how could I change these test setups so that the same data is measured. Well, there are two ways. First, Setup #1 could be changed as follows. Instead of using a tri-axial accelerometer, we could use a single uniaxial accelerometer to acquire data at 9z, for instance. But the difference would be that the impact excitation needs to be applied in the x, y and z directions. Then the data collected would be a row of the FRF matrix with 9z as the reference. This is exactly the same data as collected in Setup#2 provided that reciprocity holds true.

The other way to make sure that the same data is collected is as follows. In Setup #1, the impact hammer needs to be used to excite the x, y, and z direction. So the roving hammer needs to impact in all three directions. In Setup #2, the stationary impact at point 9 would need to be used to excite the structure in all three directions. Both tests would then produce 3 complete rows or columns of the FRF matrix.

Now you still may be a little confused by this. I know it's not easy to comprehend the first time you hear it. The best way to convince yourself is to write out all the FRF measurements that you intend to collect to assure that at least one complete row or one complete column of the FRF matrix is acquired.

I hope this simple explanation helps to clear up your question. You need to carefully think about the measurements you are going to make. Remember what I always say: "Thinking is *not* optional!" If you have any more questions about modal analysis, just ask me.