MODAL SPACE - IN OUR OWN LITTLE WORLD

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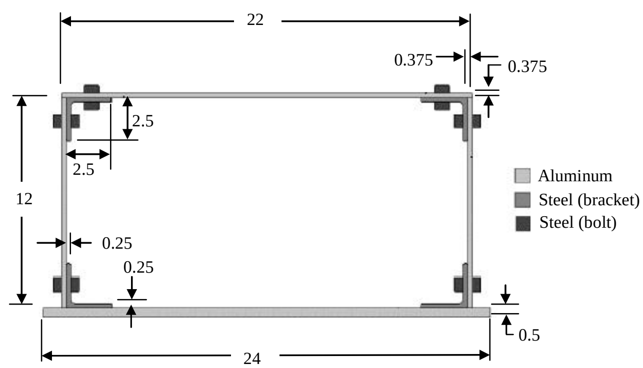
Illustration by Mike Avitabile

Bolted joints are common in structures. Can the frequency change significantly due to joints?
Now there are several things to discuss here.

Bolted joints are common in many applications. This connection mechanism is found just about everywhere and may be a significant contributor to the frequencies of the system. Now if the structure is assembled very carefully and in a repeatable fashion, then the structure frequency may have relatively small variation in the structure's frequency. However, if the joint is not assembled in a consistent fashion, then there may be considerable difference that may cause a significant variation in the frequency of the structure. Obviously, there will be many variations possible depending on the joint configurations used in each particular application.

While there may be analytical models that may be developed to study the effects of the joint configuration, these models will have many of their own assumptions which may cause variation. For instance, the element type, mesh density, joint configuration and actual connection configuration will all contribute to the variation that may be seen. In fact, a detailed study of some of these parameters shows that there are many issues to be understood.

Rather than discuss all of the analytical modeling issues that may need to be addressed, an actual configuration of a portal frame with bolted joints will be used to show some of the frequency variations that may result due to bolted joint configurations. This portal frame has been used for many different studies including effects of bolted joint arrangements (and has been used in the Los Alamos Dynamics Summer School program for a variety of different studies). The portal frame used for this study is shown in Figure 1. The structure will be tested with a normal well assembled joint and then the structure will be assembled with very deliberate joint mis-orientation to show the change in the frequency of the structure.



Notes:
All dimensions in inches
Depth into plane = 2 in., except base plate = 6 in.
All four brackets are identical with thickness of 0.25 in.
The two sides are identical with thickness 0.375 in.

Figure 1 – Portal Frame Configuration

Generally, there is care in the development of any joint in a structural system. But what if the structure assembly is not properly performed or if there is some manufacturing variation that causes difficulty in assembling the structure. In addition to the normal assembly of the joint, two cases are considered here. One case allows for a misalignment in the angle bracket and another case considers a shim to force a misalignment. The three different configurations are shown in Figure 2. A properly mated assembly is shown in Figure 2a, a sloppy assembly with misalignment is shown in Figure 2b and a shim assembly is shown in Figure 2c.

(a) (b) (c)

Figure 2 – Three Joint Configurations Studied

Now each of these configurations were assembled to determine the frequencies for the first three modes of the structure for comparison. A typical drive point measurement on the upper beam of the portal frame in the vertical direction was made for comparison. Figure 3 shows the original measurement for the properly mated assembly (black - top), a sloppy assembly due to misalignment (red - middle) and the shim assembly (blue - bottom). Even with the naked eye, there are observed differences in the peaks of the frequency response functions for the three different configurations. Generally, the amplitudes are very similar but the frequencies are definitely different.

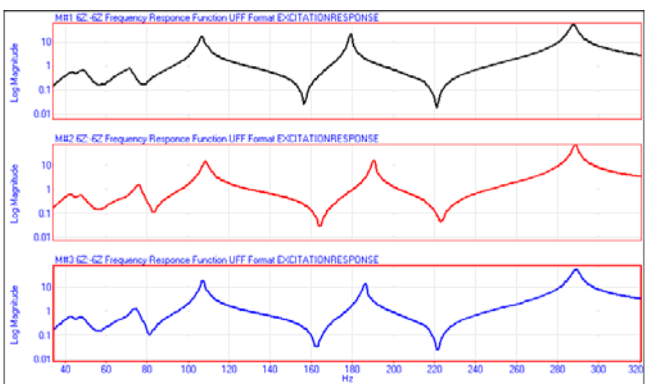


Figure 3 – Frequency Response Functions for Normal Assembled (upper), Misaligned (middle), and Shim (lower)

For each of the frequency response measurements shown in Figure 3, modal parameters were estimated using a frequency domain polynomial approach. The resulting frequencies and damping for each of the configurations are shown in Table 1.

Table 1 –Frequencies/Damping for Three Configurations

Normally Mated Assembly

Mode	Frequency (Hz)	Damping (% Critical)
1	71.7	2.65
2	106.	1.08
3	179.	0.334

Sloppy/Misaligned Assembly

Mode	Frequency (Hz)	Damping (% Critical)
1	75.7	2.15
2	108.	1.07
3	190.	0.364

Shim Assembly

Mode	Frequency (Hz)	Damping (% Critical)
1	74.4	2.53
2	107.	0.843
3	186.	0.425

So from this data, it is very easy to see that an improperly assembled joint can have a change in the frequencies of the structure. This needs to be very carefully evaluated to understand the variation that may result from the assembly process if care is not exercised in the manufacturing/assembly process.

In this quick study, only a few configurations were shown to illustrate what could happen with just a few very simple alterations to the joint assembly configuration. The results show differences and need to be carefully assessed and evaluated.

Bolted joints pose very significant effects that may need to be evaluated in much greater detail than that shown here. But I hope that these simple cases illustrate some of the variation that may result. If you have any more questions on modal analysis, just ask me.