VIBRATION ANALYSIS OF INDUSTRIAL STRUCTURES

Vibration problems are frustrating at best; dangerous at worst. Most industrial plants run vibrating equipment like screens, crushers, centrifuges, motors, and a host of other equipment. When the frequency of these machines aligns with that of the structure, things can get out of hand. We call this resonance as shown in Figure 1. Sometimes the machine is out of balance, and it's an easy fix. But if it's running properly, often the structure is the remaining option to address the problem.

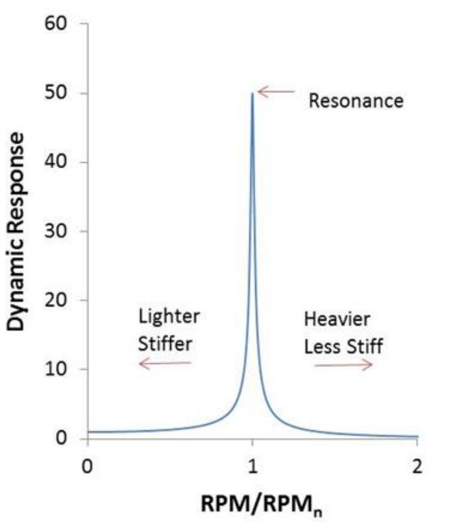

Figure 1—Dynamic response as a function of rotational speed

Let's get into the science a bit. Resonance occurs where the machine and structure share the same frequency. The closer these frequencies are, the worse the vibration will be. However, unlike strength, bigger isn't always better. We must know what side of the curve we are on. This will then tell us what options we have in fixing the problem.

Mass and stiffness are the only things that determine a structure's natural frequency. As stiffness (member size) increases, frequency goes up, as mass increases, frequency goes down. This makes the problem simple in a way. The trick comes from keeping track of the competing effects of mass, stiffness, and machine frequency.

Take a tower for instance, where we replace a crusher. The new one is lighter and runs slower than the old one. We also get rid of a very heavy magnetic head pulley drive feeding the crusher, and for grins take out one brace at the bottom of the structure to put and install a door, because all that bracing has to be overkill. We fire up the machine, and the top levels of the tower start swaying like a boat on the ocean. Slow and steady; but enough to make you sick to your stomach. You get a panicked call from your field guy, wondering what on earth is wrong with you, rather your design.

At this point, because we aren't going to replace the new crusher, we need to modify the structure. We have a choice of changing mass or stiffness, or both. How do we decide what route to go?

Most structural designs supporting vibrating equipment follow a paper written by screen manufacturer Allis Chalmers, in the 1960's. Two contradictory approaches in this paper leave one scratching their head, not to mention the absence of any guidance for horizontal vibration. So, we might run some calculations, add some bracing, or maybe pour concrete on the floor and hope for the best. And sometimes, get lucky and solve the problem, but often make the problem worse.

Figure 2—Vibrating screen causing resonance in a structure

Today's finite element software has brought us the ability to analyze the dynamic behavior of a structure and the effect a machine will have on it by allowing us to calculate all-natural frequencies of a structure (because there are more than one), which frequencies contribute the most to the vibration of it and compare this information to the frequency of the machine. This is what the low-cost software does. And most of the time it works well.

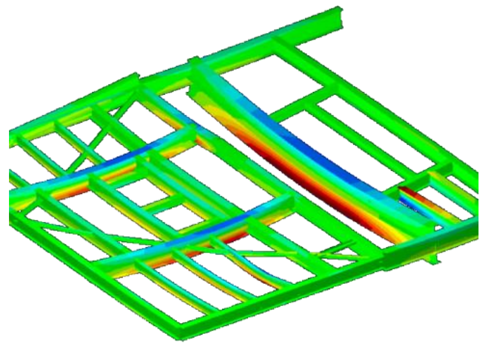

Figure 3—Analytical results of the floor supporting a vibrating screen

Taking it further, the fancier structural software can model the input of a vibrating machine and give us a plot of how the structure will vibrate over time. This can help us know if we have a beating condition, which will lead to fatigue. It also gives us the ability to compare our results with field vibration measurements, which is always really cool.

Ingenium Design specializes in vibration design for new and existing structures. We have been through the process numerous times, with many successful new builds and retrofits under our belts. And we don't just sit in the office waiting for you to send us the information that is hard to find. We get our boots on the ground and taste the problem. We field measure vibrations, pull tape if the drawings no longer exist, and work through options with our clients on the site. Then we get back to the desk and do the analysis.

Here are a couple of projects we have worked on recently. The first is a large vibrating screen that happens to have an operating frequency close to the natural frequency of the structure supporting it. This screen is several stories up and causes the floor to vibrate as it sways during operation. This screen has a very large mass and moves several inches in a Gyratory-Reciprocating motion. The screen is shown in Figure 2.

The structure was drawn in our 3D modeling software and imported into our engineering software for analysis. Figure 3 shows the results of this analysis. The red and blue areas show the tension and compression in the floor beams. This is only a snapshot in time, but our software shows

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us the alternating tension and compression in the beams as the equipment operates. From our analytical model we analyzed different options to reduce the vibration in the structure.

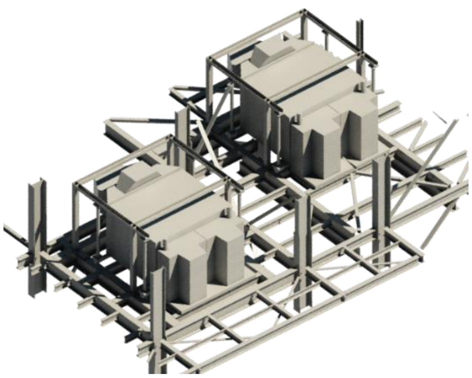

Figure 4—3D model and detailed engineering of modified support structure for vibrating screen.

Once the vibration in the model was reduced to an acceptable level, we provided detailed engineering of the structural modifications required. Figure 4 shows the 3D model with the proposed modifications to the structure. The modifications our team designed were implemented with incredible success.

Another project our team successfully implemented recently was a support structure for a vibrating screen and classifier. There were not any drawings for the existing structure, so we field measured and created a 3D model of the structure. We analyzed and designed a new structure to resolve the vibrational problems. Figure 5 shows the existing structure with the screen removed. Figure 6 shows our 3D model of both the existing structure and the new support structure we designed.

If you have a structure that sways or vibrates due to vibrating or rotating equipment, we can provide a real answer. Our solutions are practical and often simple. Sometimes it just comes down to a single brace.

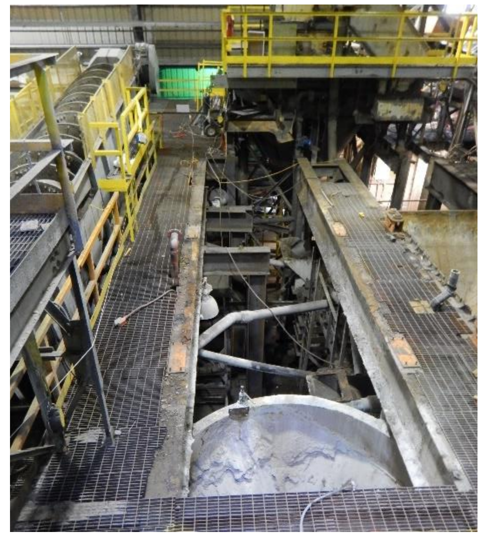

Figure 5—Location of new screen and spiral classifier structure

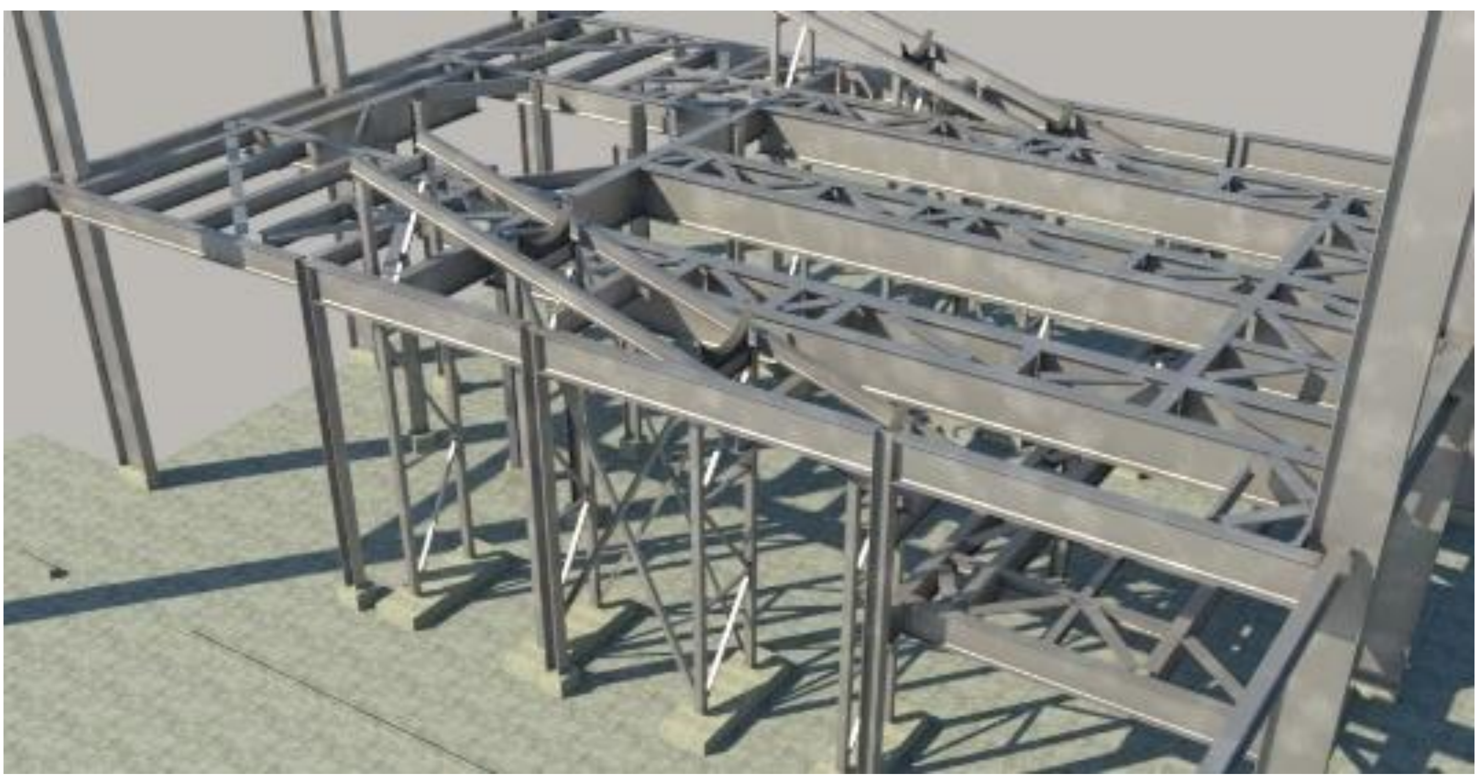

Figure 6—3D model and detailed engineering of new support structure for screen and spiral classifier