By: CLIFF KNIGHT, Owner/President
KnightHawk Engineering

The challenge of structural dynamics

It's another day at the plant and you pass that same old turbine deck on the way to your office area next to the unit. Your office is elevated within the structure and you can feel what mode of operation the plant is in just by the familiar vibration that passes through your chair as you sit in it. In today's petrochemical environment, all kinds of process equipment is elevated in structures for a variety of reasons. Typical reasons are shortage of real estate, economics or process requirements. This can lead to some interesting structural dynamics issues. The real challenge is to predict how the equipment will function in the structure and implement measures upfront to prevent unwanted vibration.

Typically, when vendors design process equipment such as turbines, compressors, fin-fan coolers, blowers and shakers, all aspects of support design are not considered and it's not necessary. What is important is the designer of the structure has some idea as to how the equipment functions in various modes of operation. There are also challenges when running high-pressure piping from reciprocating compressors and pumps. The pulsation can cause high-forced vibration and, in some cases, resonant vibration due to acoustics. Another good example is pressure relief valves. The transient pressure-momentum conditions can lead to high "kick-down" forces and cause structural failure. A solution may be as follows:

1. Lay out the equipment on a plot plan. It is a good idea to consider what the forcing functions are for the equipment so an economical design may be considered. If large horizontal loads are expected, the load could be distributed to adjacent structures.
2. Try to locate any equipment with potential vibration issues as close to the ground elevation as possible. If that's not possible, put it as close to primary members as possible.
3. Meet with the process and mechanical folks to review potential vibration problems. Also, tour any plant facilities with similar equipment and learn from the past.
4. Perform preliminary sizing of structural members and lay out the structure.
5. Define any known or calculable vibration forcing functions or "exciters."
6. Develop a simple structural dynamics model of the system. The model needs to be detailed enough to obtain accurate results yet not so complicated it takes forever to run. The model should be executed with loads steps. This will save time and also assist in the determination of what load is the challenging part of the problem. Make sure to check all input in detail prior to executing the model. Garbage in, garbage out applies here.
7. Assess the results.
8. Sometimes the vibration may be so high that isolators, or "inertia blocks," might have to be installed. In any case, it is easier to tweak a model than modify on the fly during the start-up of a plant. A variable speed driver to detune the system might also be a solution.
9. Meet again with process, production and mechanical folks and see if things make sense. It is easier to review the Auto-CAD model with the team than get complaints on the actual design once it is installed in the field.

But there is the other scenario, which is getting back to your office in the structure. How does one address the vibration problems of an existing system? You need knowledge of the process, mechanical equipment and structural design. There may not be a quick fix. It always amazes me the college try for the quick fix. Sometimes you're lucky but more often not. However, a structural problem can be fixed in a reasonable amount of time and cost for most all applications. The following is a plan of attack:

1. Define the driving forces.
2. Develop a structural dynamics model, preferably with the finite element method.
3. Perform a field study of the problem.
4. Normalize the finite element model.
5. Revise model as required to solve the problem.

These are ideas on structural design with the purpose of getting you thinking. Don't let structural dynamics problems bite you. As with every problem, have a professional engineer review and approve the design.

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