How to Avoid Scrubber Vibration

Introduction

Scrubbers are present in most reciprocating compressor packages to separate liquid from the gas stream. Scrubbers can be a vibration problem if they are too tall, too skinny, or if the base is too flexible. This Application Note discusses scrubber vibration problems and provides recommendations for compressor designers.

Problems

During field troubleshooting assignments we often find scrubbers with vibration problems. The vibration problems can be limited to the scrubber or they can cause extreme vibration of the piping and other components connected to the scrubber, such as instrumentation (see Figure 1 for examples).

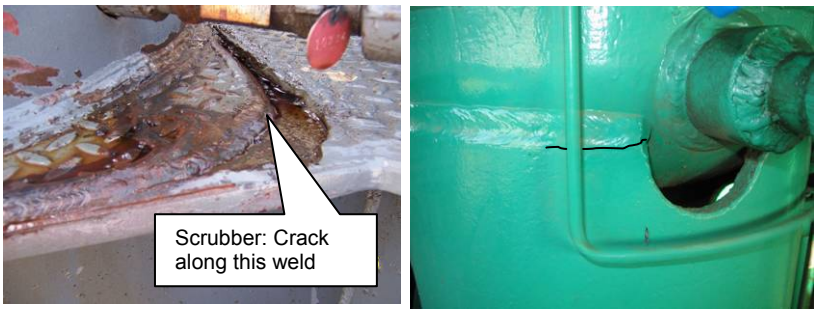

Figure 1: Cracked Scrubbers

Excessive vibration leads to premature wear or failure of components that can compromise the safety of the installation and can result in a gas release. Fixing a scrubber vibration problem in the field is often expensive and can result in unplanned production downtime.

Figure 2 illustrates a typical scrubber vibration problem requiring field analysis and bracing. The scrubber base did not have enough stiffness so a brace was required to minimize scrubber vibration.

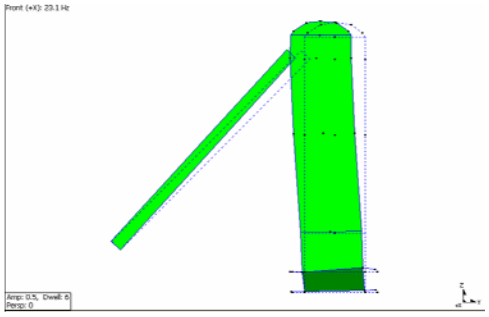

Figure 2: Scrubber requiring large brace. An ODS analysis shows scrubber vibration (dotted line shows scrubber's non-deformed position).

Another example is shown in Figures 3 and 4. In this case, the scrubber vibration has a peak of 5.6 inches per second, as shown in red in Figure 3. This vibration is more than 10 times the guideline, as shown in blue.

The vibration in this example is at 900 RPM (15 Hz), which is the first order of compressor run speed. Many dynamic forces are present at the 1st and 2nd order of run speed[1].

Figure 4 shows the scrubber's mechanical natural frequency (MNF), which occurs at 15.6 Hz. The MNF and the first order of run speed are too close together, resulting in resonance. At resonance, the scrubber motion becomes amplified to produce very high vibration. [For more information on resonance, visit www.BetaMachinery.com or attend our vibration training seminars.]

API 618 (5th edition) guideline requires the scrubber MNF to be above 2.4 times maximum run speed, to avoid risk of excessive vibration. This is especially important when the compressor operates over a wide speed range (engine or VFD).

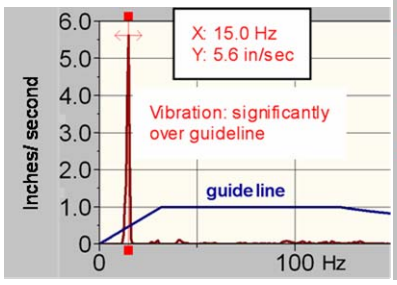

Figure 3: Vibration on scrubber

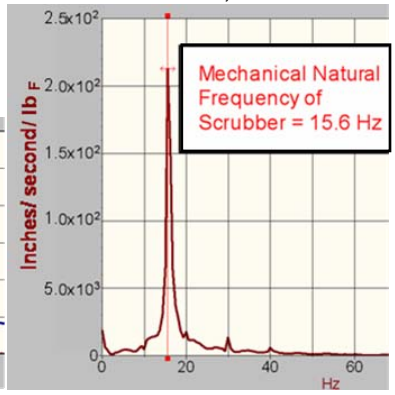

Figure 4: MNF of scrubber

Recommended Scrubber Design

Scrubbers should be designed so their MNF is above 2.4 times compressor run speed.

Several variables affecting the scrubber MNF are:

- Overall height
- Outer diameter
- Weight
- Stiffness of scrubber base
- Stiffness of skid underneath scrubber

Beta can provide recommended scrubber designs (e.g., height vs. diameter ratio) to avoid resonance and to have MNFs greater than 2.4 times run speed. This service is included as part of our pulsation/ mechanical design services.

Other important recommendations include:

- The scrubber skirt and scrubber shell should be approximately the same thickness.
- The scrubber skirt must connect directly to the skid beams (either by welding or bolting).
- Four beams should be arranged in a box shape underneath the scrubber skirt, spaced approximately 90% of the outer diameter of the scrubber skirt, to ensure the skirt crosses the beam web at 8 locations.
- The skid below the scrubber should be grouted down to concrete, or at least two piles should be attached to the skid beams underneath the scrubber.

If scrubbers cannot be designed to the recommendations listed above (including height and diameters specified by Beta), some alternatives are:

- Add braces to raise the MNF of the scrubber. Adding bracing in the design stage is more cost effective than in the field.
- Add more beams and gussets to the skid below the scrubber.
- Add concrete below the scrubber.
- Add gussets to the scrubber skirt.
- Intertune the scrubber to fall between the 1st and 2nd orders of run speed (see below).

Intertuning Scrubbers

Intertuning scrubber MNFs is a final option that is possible in some cases. Intertuning refers to adjusting (or tuning) the scrubber MNF between the first and second orders of run speed (see Figure 5).

Intertuning is only possible if the scrubber skirt is welded (or bolted) to the skid and the minimum speed divided by the maximum speed is greater than 0.75. This is done to minimize the likelihood of high vibration; however the actual vibration levels on the scrubber are not known.

Follow up intertuning with either a field startup check or more detailed computer simulations to ensure that the actual scrubber vibrations are acceptable.

Detailed computer simulations are not part of the typical API 618 mechanical studies but are available as part of Beta's advanced mechanical modeling service.

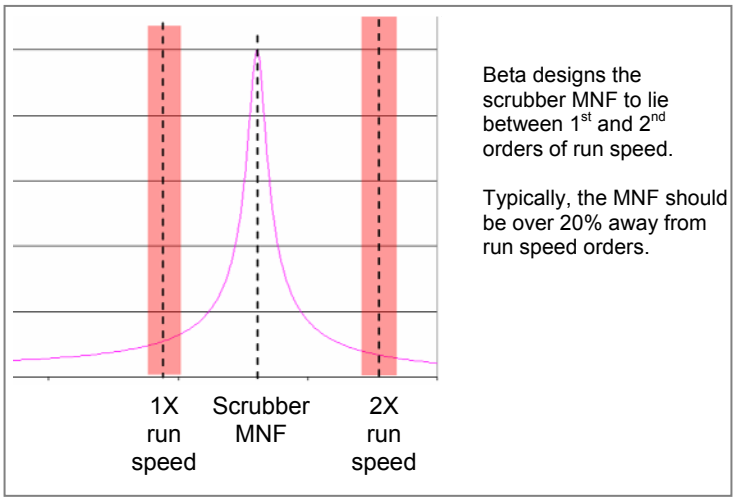

Figure 5: Example of intertuning scrubber

Mechanical Design (API 618, Design Approach 3)

The objective for the mechanical design is to provide accurate MNF calculations. Beta calculates the MNFs for the main vessels and scrubbers and determines if vibration problems are likely. The accuracy of this calculation is affected by piping, mounting, and skid details.

Some consultants apply a "simplified" approach (or short cuts) to the FEA models. This produces greater error in the MNF calculations. Because a simplified model overestimates base stiffness, calculated MNFs will generally be too high. Consequently, there is a significant risk that a severe resonance (high vibration) problem will be encountered where no such problem is predicted. Beta's more accurate model reduces this risk considerably. The following example illustrates the impact of simplified modeling:

FEA Model of Scrubber	**Scrubber Stiffness (Calculated vs. Actual Measurements)**
1. Simplified approach (e.g., does not include base details)	40% variance
2. Beta's standard approach (incorporating skirt connection to skid, skid members, foundation connection)	5% variance

Customers can avoid these risks by correctly specifying the Design Approach 3 study. Refer to Beta's Application Note 1b for the specifications to improve accuracy of your mechanical design.

Summary

Beta recommends that scrubber MNFs should be above 2.4 times compressor run speed to avoid potential resonance and vibration issues. When designing a new compressor package, call Beta early in the design phase for scrubber recommendations. As discussed above, there are other mounting details that are important to prevent vibration problems.

To achieve the recommended MNF, the scrubber should be designed as recommended by Beta, or bracing will likely be required.

[1.] Pulsation and gas forces are present at higher orders of run speed. These forces can be addressed through the pulsation control solution and mechanical design (recommendations from a Beta Design Study).