BETA MACHINERY ANALYSIS

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In This Issue

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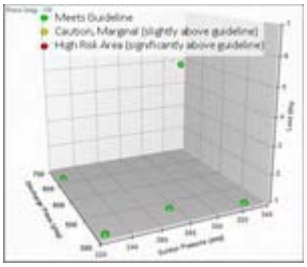
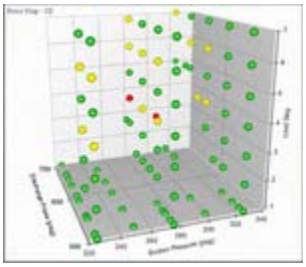
Look What DM2 Uncovered



Often, a vibration study evaluates only a few conditions. See plot at right; only five design points are evaluated to represent the compressor's operating envelope.
As we well know, vibration risk varies widely across the entire operating map, so, to properly design a compressor, a vibration study should not be limited to only a few points.



BETA's new DataMiner2 (DM2) analysis tool allows us to quickly evaluate the compressor's entire operating envelope. As shown at left, DM2 reveals important information that allows for more reliable designs.
One big advantage of using DM2 is that you can evaluate vibration risks in far more detail, allowing 'real operating conditions' to be efficiently integrated into the design process.

CASE STUDY: Evaluating Compressor Operating Risks

Reciprocating gas compressors usually operate across a range of suction pressures, discharge pressures, and flow rates. This operating flexibility is one of the benefits of reciprocating machinery.

Achieving this operating flexibility requires problem-free operation over the entire operating envelope. Too often this is not the case; it is common to find a compressor system that works well at a few conditions, but not at others. As outlined below, these problems are easily avoided.

Compressor Selection Using a Few Design Points

Engineers often select a compressor based on a few points. The goal is to ensure the compressor will meet the required capacity and pressures. For example, these five points were used on a recent project to size a 4500 HP

compressor (Figure 1). The figure shows the 2D and 3D view of the compressor's operating map, illustrates the range of suction and discharge pressures, and the required loads steps (3D view, vertical axis).

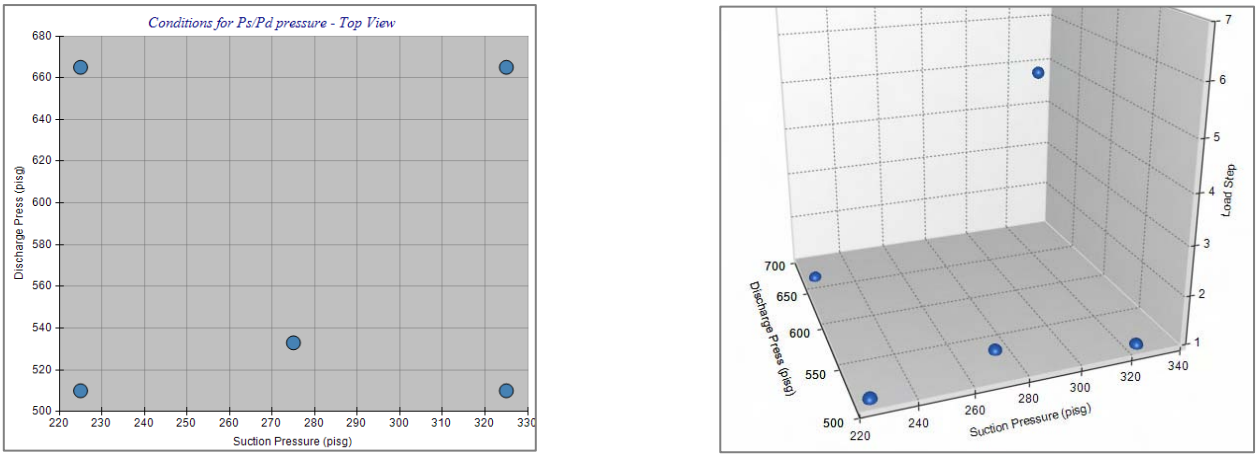


Figure 1: Operating Map (suction vs. discharge pressure vs. load step). Left, 2D View, Right, 3D View

Vibration Varies Across the Operating Map

Traditionally, these few design points are used to analyze pulsation and vibration risks and provide a vibration solution including pulsation control. Figure 2a shows these five points. The green circle indicates that pulsation forces have been reduced below the API 618 guideline.

The problem is that at other operating conditions, vibration problems may occur. For this project, Beta Machinery Analysis (BETA) evaluated 100 conditions across the operating map. Figure 2b illustrates the pulsation forces – and as you can see, there are many conditions where pulsation forces are marginally above guideline (yellow), or significantly above guideline (red). By evaluating the overall map, BETA is able to design a more reliable vibration solution for their customers.

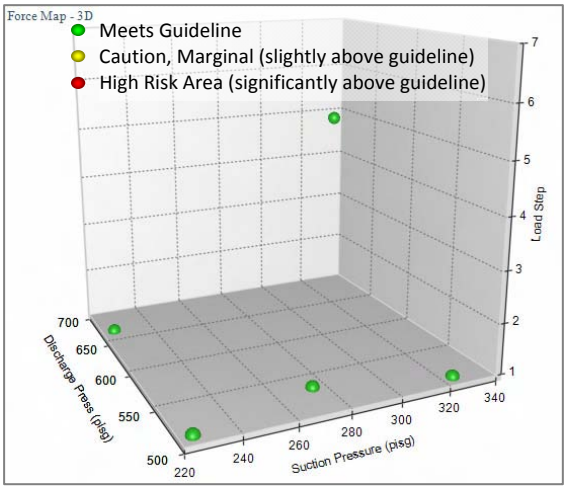


Figure 2a: Pulsation Force Map for 5 Points

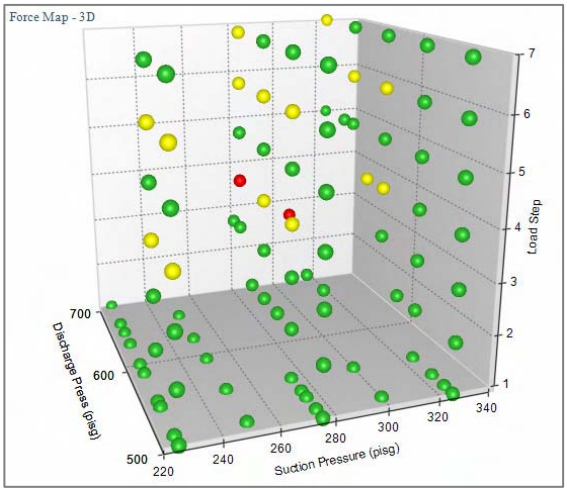


Figure 2b: Pulsation Force Map over the Entire Operating Range

The key point is that the vibration risk varies widely across the compressor operating map. Therefore, a vibration study should not be limited to only the few points used to size the compressor.

BETA DataMiner Toolkit - A New Approach to Evaluating Operational Risks

Evaluating the complex vibration information can be a daunting task. For a typical report, there can be over 300 pages of plots to document the pulsations and other operational data across the piping system, when you consider the frequency range, compressor speed, and operating parameters.

Many consultants will only evaluate a few conditions to avoid the complexities associated with a thorough analysis.

BETA has developed a proprietary modeling toolkit called DataMiner. This allows BETA to easily (and cost effectively) evaluate the overall operating map – from 20 to 1000 operating conditions. This evaluation is now popular with complex compressor installations including gas storage, pipeline, and other situations which require a wide range of operation (Figure 3).

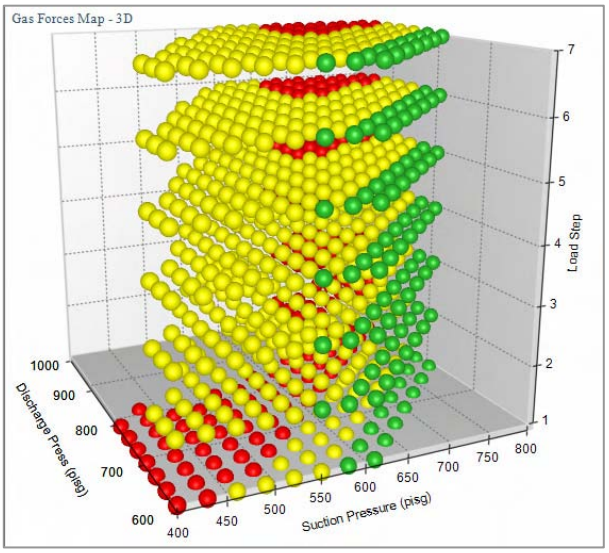


Figure 3: Cylinder Gas Force Map. Over 800 conditions assessed for this existing compressor installation. BETA's Force Map is a valuable tool for identifying excitation forces and resolving vibration problems.

DataMiner can produce a wide variety of 2D and 3D plots illustrating how these variables change over the operating map: Some examples include:

- Pressure Pulsation Map
- Pulsation Force Map
- Cylinder Gas Force Map
- Performance Map (capacity, load, etc.).
- Pressure Drop Map

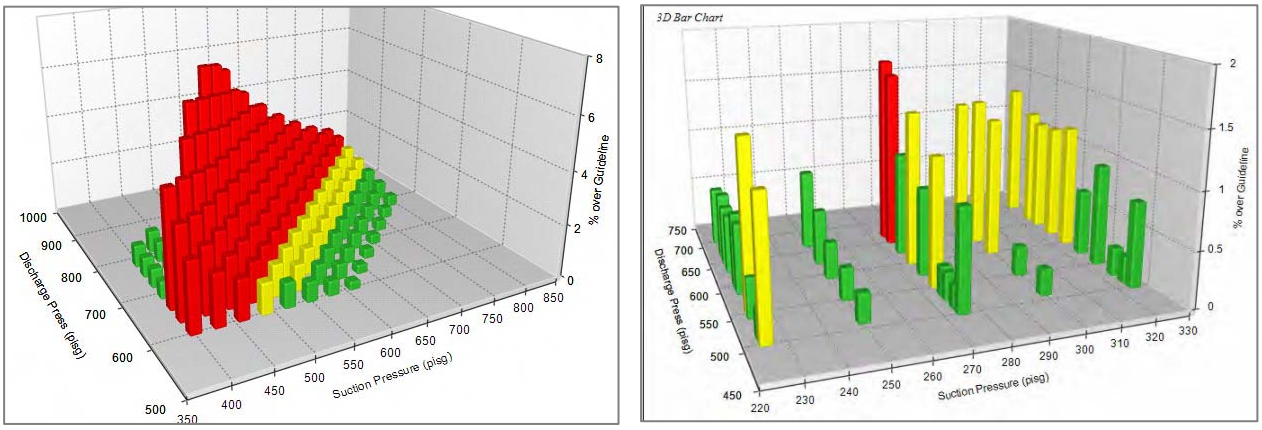


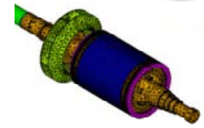
Figure 4: Examples of other DataMiner plots used by customers to assess their compressors.

Ask the Expert

Q: Do you have any torsional recommendations when using a motor on a reciprocating compressor package?

A: When selecting a motor for a reciprocating compressor, the following four rules of thumb should result in a more robust drive train that may result in a less expensive torsional solution:

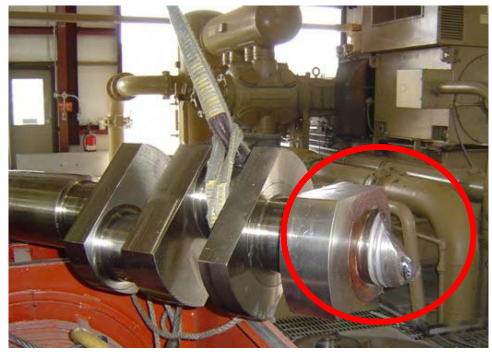
#1 The motor's minimum shaft diameter on the drive side should be at least as large as the stub diameter of the crankshaft.



#2 The ultimate tensile strength of the motor shaft material should be at least that of the compressor crankshaft.

#3 It may not be practical to hold off purchasing of the motor until the torsional analysis is completed, but it should not be manufactured or finalized before the torsional analysis is complete, so that more options are available to the torsional analyst to modify the motor if needs be.

#4 Complete the torsional analysis early in the process!



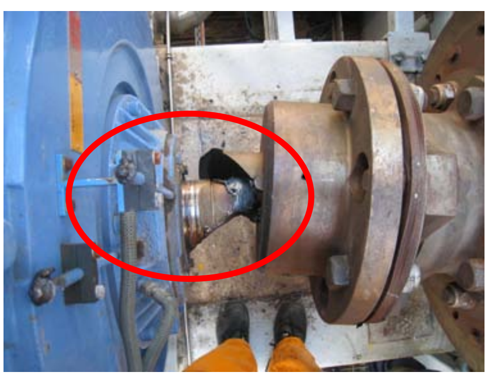
Rule 1 and 2

The main reason for rules 1 and 2 is that if the compressor crankshaft is capable of handling the torque/stress (based on geometry), then the motor should also be able to handle the same amplitudes if built in a similar fashion.

If the motor isn't sized correctly, the standard approach of intertuning (placing the 1st torsional natural frequency, or TNF, between harmonic orders) may not be enough to provide a satisfactory design. By properly sizing the motor upfront, there is a higher chance that a less expensive solution is required.

Rule 3

For rule 3; the motor manufacturers usually wait for a confirmed order before spending the time to design the internals (shaft, core, etc.). These values are critical to the torsional analysis and are required in order to properly perform the analysis. It is recommended that the fabrication of the motor is delayed until the torsional analysis is complete. That way, it should still be possible to make changes (shaft material, shaft diameter, radius of curvature at diametrical changes) if required.



It should also be noted that reciprocating compressors are a severe service for motors. When requesting a motor this should be made clear to the vendors. There are often different versions of internal components (such as, fans, rotor bars and end rings) that may be used in a given motor frame. Motors designed for higher torques, stresses, accelerations, etc., are preferable to help prevent failure of these components, which are beyond the scope of a torsional analysis.

Rule 4

For rule 4; it is much more cost-effective and straightforward to make changes, such as, adding a flywheel and modifying the shaft, before the system is built. Required modifications after that are more expensive, more complicated and will most likely result in delayed delivery of the unit.

The torsional analysis is a smart engineering check. For more information about these rules of thumb and to help with your next project, you can reach BETA's team of torsional experts through info@BetaMachinery.com. You can also see the torsional analysis page on our web site.

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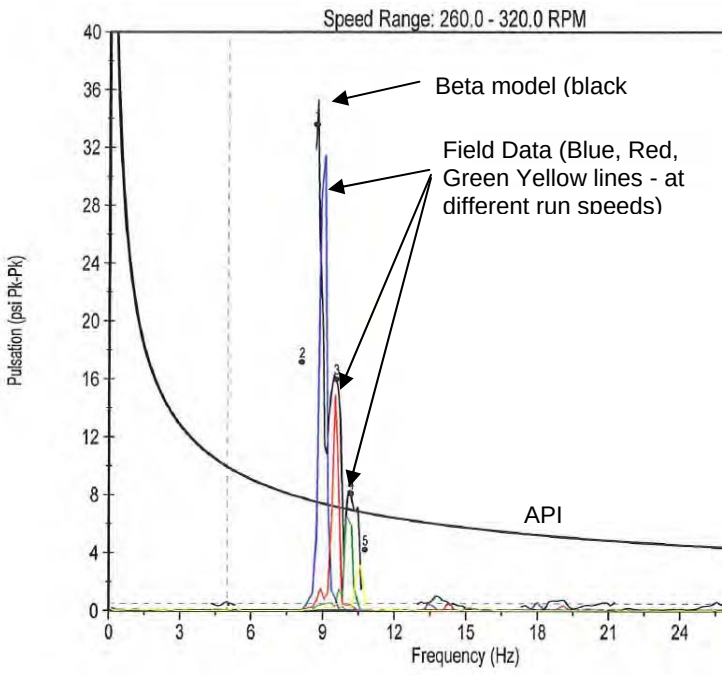
Case Study – Gas Pipeline Modifications Cause Big Surprises

This example shows how relatively small piping modifications created a large (and expensive) vibration problem. This unexpected consequence illustrates the impact that pulsations have on piping vibration.

A large compressor station had several compressors including a Clark TVSV integral compressor (approximately 11,000 HP). A 20 inch connecting line was installed between two existing pipelines, approximately 1000 feet away from the compressor building. Vibrations were not significant when units 1 through 4 were running. Once unit 5 (The Clark integral) came online, the vibrations in the downstream piping were over 10 times our guideline in the axial direction.

Vibrations were well above guideline levels, especially at the lowest speed. The vibrations occurred at the 2nd order of run speed (between 9 and 11 Hz). Horizontal and vertical vibrations were minimal.

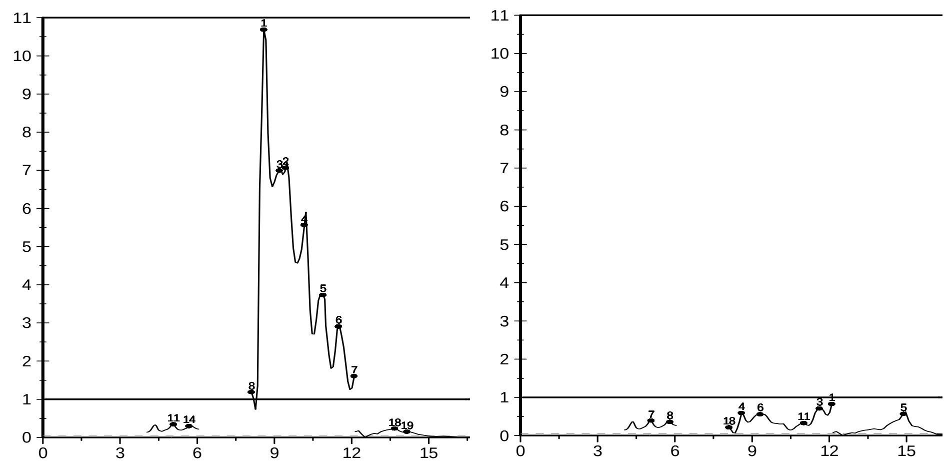


Beta's pulsation model matches field data

The facility had been running for decades without significant vibration problems. Once the modification was made, it came as a surprise to experience vibration problems. BETA performed a field visit to assist in troubleshooting and, based on the collected data, it became clear that large unbalanced forces were acting in this connecting pipe.

Using BETA's MAPAK software, the acoustical model was built for the piping system. Predicted pulsations matched the field measured data, illustrating the accuracy of BETA's time domain, non-linear pulsation model. The high pressure pulsations in this large diameter pipe are responsible for the excessive vibration.

The ideal solution would be to redesign the pulsation bottles in order to suppress these pulsations. The reality is that this solution would be too expensive. The alternative is to install a side branch resonator. By installing this dead leg of piping BETA was able to cut the pulsations and forces by 90%. This option was deemed to be much more cost effective.



Pulsations significantly reduced using side branch resonator

This short example illustrates that relatively minor piping changes can create large unbalanced forces. Pulsation analysis is the recommended technique to assess proposed piping changes, highlight vibration concerns and analyze alternatives.

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Free Bottle Sizing Service UPDATE

After turning on this free web-based software application early this year, we now have over 150 registered users and have assisted customers with over 500 projects. This response is very positive and we're really pleased with all of your comments and suggestions.

Based on your feedback we have made a few improvements to the program, including eliminating unused form fields and expanding the frequently asked questions (FAQ) section to help guide users through the program and explain some of the theory behind bottle sizing.

We have outlined some tricks and tips to utilize this free software application in the FAQs. We can also provide a one hour, web-based training presentation to users interested in more information about pulsation bottle sizing. Please contact Chris Harper if you have any suggestions, or, if you would like to book, or participate in, a training session. (CHarper@BetaMachinery.com).

For more information about this service, visit www.Solutions.BetaMachinery.com.

Thanks for all your input and support of this service!

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Did Someone Say Wine?

Thank you to all who made our first ever customer Wine Tasting Tour and Discovery event a success. In May, we celebrated our new and expanded Calgary headquarters, now located at 118, 4242 7th St. SE, Calgary, AB T2G 2Y8.

Our guests made their way through our office by way of several different stations where they sampled Argentina appetizer and wine pairings and participated in interactive presentations about the most popular services in our design, field troubleshooting, and monitoring areas. Non-alcoholic beverages and vegetarian options were also available.

Highlights included a bump test, a small bore piping vibration demonstration, a wine lesson that gave guests an opportunity to make their own blends, and a buffet featuring an Argentinean barbecue. Guests were able to see our new office, chat with our staff, and learn about BETA in an informal, fun, and relaxed environment.

Upcoming Training & Events

We have been invited as lead presenters later this summer for:

GMRC Training Event: Compressor Station Vibration and the Impact On Performance, Cost & Reliability
August 30, 31 and Sept. 1, 2011 in Houston, TX.

Training resumes this September in our Calgary classroom with:

Reciprocating Compressor Training
September 28, 29, 2011 in Calgary, AB

Come and see us at the **40th Turbomachinery Symposium Booth 542**
September 13-15, 2011 in Houston, TX.

We'll be at the **GMRC 2011 Gas Machinery Conference and Expo (GMC) Booth 411**
October 2-5, 2011 in Nashville TN.
Where we're presenting technical papers, "Evaluating Compressor Reliability – An Operator's Perspective of Assessing Vibration Risk Across the Operating Envelope" and "A Recommended Approach to Piping Flexibility Studies to Avoid Compressor System Integrity Risk. We're also co-presenting short courses, "Comprehending Compressor Related Reports – Acoustic/Vibration, Torsional and Thermal Studies" and "New API Publication: RP-688 Recommended Practice for Pulsation and Vibration Control."

Contact us if you're interested in seminars or lunch and learns at your office (or ours) to help you with your rotating equipment issues.

Your comments and suggestions are welcome! If there's a topic you'd like to see addressed in the Beta Bulletin, please send an email to Jackie Walters, jwalters@BetaMachinery.com.

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