Compressor Works

ACI Services, Inc.

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Re-Engineering Extends the Utilization of Pipeline Compressor Assets

Much of the compression equipment in the U.S.A.'s natural gas pipeline infrastructure was installed many decades ago. Although these compressors may have performed reliably for years, they are often no longer optimal. Pipeline conditions may have changed, automatic operation may be required, environmental factors may dictate a change in operating philosophy, or in some cases, reliability simply falls short of comparable newer equipment. Whatever the reason, it is often desirable and feasible to modify the engine and/or the compressor to make it more effective for current needs.

One such example was a recent project completed by ACI Services, Inc. A pipeline operator identified two 1950s era I-R KVG 3600 integral engine compressors (rated 660 BHP at 330 rpm) that needed to increase capacity. The original configuration had compressor cylinders on only two of the three compressor throws. The pipeline operator had determined that adding a cylinder to the third (center) throw would increase capacity significantly for the foreseeable operating conditions. ACI modeled alternative configurations using its eRCM™ compressor modeling software, which helped to quickly hone in on optimal configurations. Although adding a completely new third cylinder to each compressor was a good alternative, the lead time and higher cost of this option led to serious consideration of re-engineering a used cylinder.

Fig. 1 Cylinder as found condition.

Using the extensive, used equipment data base of www.CompressorConnection.com, ACI located two used process cylinders that had almost the same footprint as the existing pipeline cylinders. These cylinders, which had been stored outdoors, required extensive cleaning, inspection and hydrostatic testing to ensure that they were sound for the desired application. After confirming the used cylinders were sound and adaptable for the intended re-application, they were re-machined to accept new ACI designed and manufactured slip-fit liners, three-piece pistons, rods, and double-deck poppet valves, cages and caps. Also designed and produced were new outer heads with 1500 in^3 pneumatically actuated fixed volume clearance pockets, new pneumatic actuators for the existing body pockets, and modifications of the existing inner head and distance piece to provide the desired internal fixed clearance and fit-up dimensions for the cylinder to the pulsation bottle centerlines. The completed cylinder assemblies were again hydrostatically tested at 1800 psig for 8 hours to validate the intended 1200 psig MAWP rating.

Fig. 2 Cylinder Hydro-testing at ACI Shop.

Fig. 3 Completed KVG 3600 with the ACI re-engineered cylinder on center throw.

Bi-Con Services, Inc. provided all the site work, removed the suction and discharge header bottles and added the ASME welded nozzle connections for the additional cylinders. ACI, with support from alliance partner Beta Machinery Analysis, conducted a complete API 618 design approach II acoustic pulsation study on the existing station piping, bottles and new cylinder configuration.

With a very tight project schedule, the project details required careful management throughout. Unanticipated problems had to be resolved quickly. With the diligence and cooperation of all parties, the project was completed and the new configuration was operating within the operator's required completion dates for the two compressors. After completion of the re-engineered compressor configuration, each unit is capable of fully loading the engines while producing 43 to 95 MMSCD at pressure ratios of 1.13 to 1.30 and discharge pressures from 770 to 924 psig.

Inside this issue:

Look for ACI at these Events:

Sept. 25-28 Turbomachinery Symposium; Houston, TX

Oct. 2-4 Gas Machinery Conference; Oklahoma City, OK

Join us at the GMC for one of our short courses:

1. Monday, October 2nd Performance Control of Reciprocating Compressors: Devices for Managing Load and Flow.
2. Wednesday, October 4th Reciprocating Compressor Performance: Seeing the Big Picture.

Compressor Performance and Optimization: *Staying Within Rod Load Limits*

PLC controls are typically employed to regulate the operation of low, medium and high-speed reciprocating compressors. Too often the PLC will allow operators to engage load steps without first checking them for safety issues, or the PLC itself may engage unsafe load steps due to incomplete programming. Some limits, such as high temperatures and pressures, would eventually be detected and alarmed. However, other issues that cannot be easily measured directly, such as rod loads may not be detected until it is too late. Thus, these need to be calculated indirectly from other measured data.

T#	C: Flange	T: Flange	C: Internal	T: Internal
#1:	10 %	49 %	29 %	72 %
#2:	6 %	46 %	16 %	54 %
#3:	10 %	49 %	29 %	72 %
#4:	6 %	46 %	16 %	57 %
#5:	73 %	49 %	101 %	75 %
#6:	60 %	46 %	70 %	56 %

Fig. 1

Misapplication of rod load computation methods can create serious and potentially dangerous situations, as well as not likely meeting the warranty requirements of the compressor packager and OEM. As indicated by Figure 1, the differences in the two calculation methods (static flange method for slow-speed units on left and internal gas pressure method for high-speed units on right) can be dramatic. Throw #5 using the gas flange method indicates that the rod load is only 73 percent of the rated limit in compression, but the internal dynamic gas force method indicates that the unit has exceeded the compression rod load rating (101 percent).

When rod load methods are misapplied, a simple control panel's logic may shut down the unit even though it is actually operating in safe territory (if the static flange method is correct in this example). Or worse, the panel might allow the unit to run in unsafe areas (if the internal dynamic gas method is correct in this example), which can lead to catastrophic results.

The various methods most often employed for rod loads are:

- **Static Gas Flange Forces**: This is by far the simplest method to code for a control panel. It involves simply reading the gage pressures, adjusting them for pressure drops to the flange, and then applying those pressures against head end and crank end piston surface areas to determine the forces acting on the piston rod.

- **Internal Dynamic Gas Forces**: This method is used by some of today's high-speed compressor OEMs. Gage pressures are adjusted for pressure drops to the cylinder flange. Next, additional pressure drops are applied as the gas enters/exits the valves. Finally, based upon the crank angle position of the cylinder (compression event, discharge valve open event, expansion event, and suction valve open event) internal gas pressures for both head and crank ends are determined. These crank-angle specific pressures are then applied to the two piston surface areas and appropriate forces acting on the piston rod are determined. Throughout the 360° of crank angle rotation, the maximum compression and tension forces on the rod are determined. These maximum forces are then used to determine if the unit has exceeded its rod load limits.

- **Internal Dynamic Gas Forces with Dynamic Inertia Forces**: As the piston moves from outboard to inboard, it has a certain amount of inertia based on its reciprocating weight and its instantaneous velocity at each crank angle. This method not only applies the forces resulting from the internal dynamic gas pressures, but it also superimposes these inertia forces at each crank angle position. The combined maximum compression and tension forces are calculated and used to determine if the unit has exceeded its rod load limits.

Figure 2 shows a comparison of the three methods of rod loads for a two-stage unit at one particular load step. The red plot is based on the Static Gas Flange Forces method, the green plot is based on the

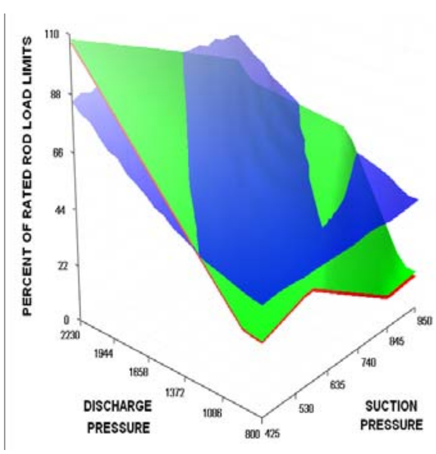

Fig. 2

Internal Dynamic Gas Forces method, and the blue plot is based on Internal Dynamic Gas Forces with Dynamic Inertia Forces method. In this sample case, the red and green plots match well with each other; however, the blue plot is noticeably different.

Figure 3 shows the same type of comparisons for a different compressor. This time, the red (static flange) and blue (full inertia) plots are more similar, with green (dynamic gas) being noticeably different.

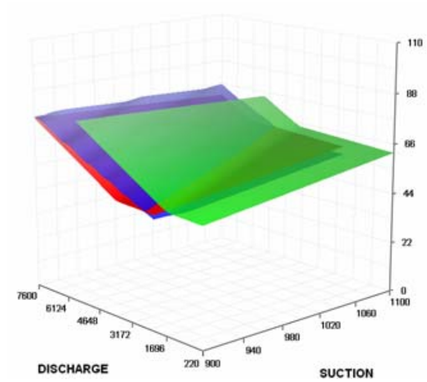

Fig. 3

This emphasizes the differences that can result from the different methods of calculation. The conclusion is that one should not try to generalize rod loads, based on just a few reviewed cases. In fact, a full rod load review across the entire expected operating map should always be a requirement when installing new equipment, or reapplying existing equipment.

Watch for the next article - *Compressor Performance and Optimization: Effective Comparison of Units and Units Arrangements .*

For more information, please feel free to contact Dwayne Hickman at (740) 435-0240 ext. 508 or send him an email at dhickman@aciservicesinc.com.

ACI Sales Network

ACI is proud to announce our latest alliance partnership agreements. The first is with Compressor Products International (CPI), located in Hungerford, England. This agreement allows CPI to be the exclusive distributor of ACI products outside of North America. Also, Arrow Industries of Jena, Louisiana is now an authorized ACI representative for the mid-continent and Gulf Coast market areas within the United States.

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Norm's Notes

As 2006 enters its final quarter, ACI Services is pleased to enjoy continued growth and success. Our team continues to grow too, as we welcome Mark Mayberry in production management and Michael Moses in engineering.

We are excited about the prospects of cooperation with two new alliance partners. Arrow Industries and ACI have agreed to cooperate in the mid-continent and Gulf coast market areas. Arrow complements ACI offerings with comprehensive field mechanical and machining services, while ACI provides Arrow with technical support and precision compressor components that complement their offerings. Together, we have turnkey capabilities for projects of almost any size. Compressor Products International (CPI) has become ACI's distributor outside North American where CPI has a strong presence, but a limited product line of its own. Domestically, CPI expands ACI's offerings with special materials for packing, ring and valve applications. We are already working together with both companies on a number of projects.

Locally, our new large machine shop started up over the summer, and we have large milling, turning, drilling and grinding capabilities in our Cambridge shop. This reduces our lead time and cost for reworking used equipment for projects or providing machining services to Eastern area customers. Our Nelsonville facility is now able to focus on competitive, higher volume component machining. In August we were able to implement our new Macola enterprise management system. We are grateful to Joe Reiheld, Tom Bauer and Mark Mayberry for leading this extensive project through implementation.

W. Norm Shade

***The secret of getting ahead is getting started. The secret of getting started is breaking your complex overwhelming tasks into small manageable tasks, and then starting on the first one* — Mark Twain**