October 2015

ASK THE EXPERTS: Accurate Rod Load Determination

QUESTION: My compressor control system provides rod load and reversal data. Is that the same as the information that we get from our Windrock portable and online systems?

No, it is not the same information! Protecting a reciprocating compressor against catastrophic failure is a complex endeavor. One critical measurement is the load on each piston rod as it moves through its cycle. Load limits are related to the material and design of the rod and are specified by the compressor manufacturer. Only an online monitoring system that measures in-cylinder pressure and calculates rod load for each degree of revolution will adequately protect a recip compressor and provide warnings and shutdowns under all circumstances. Calculating rod loads from line pressures is not adequate.

The compressor piston rod is alternatively under compression and tension forces, and being of a relatively narrow cross-section, is subject to high mechanical loads and high cyclic fatigue stresses. Continuing to operate a machine while exceeding the manufacturer's stress limits will generally lead to complete failure (breakage) of the rod.

The gas load forces are usually the limiting factor when considering the rating of the compressor rod. In some cases, the inertia effect of the piston and sometimes piston rod mass may be applied to the measurement to offset the pure gas load calculations. Some OEMs may also use additional inertia forces of the crosshead assembly if their rod load limits are calculated at the crosshead pin and bushing.

In any of the referenced methods, the gas loads must be calculated accurately.

In simple calculation methods, the gas rod load is based on the differences in the cross sectional area of the ends of the piston and the appropriate differences in the suction and discharge line pressures.

CRL = (HEa*P2) – (CEa*P1)
TRL = (CEa*P2) – (HEa*P1)

CRL =compression rod load (pounds force)
TRL = tension rod load (pounds force)
HEa = bore^2*.7854 (sq in)
CEa = (bore^2-rod^2)*.7854 (sq in)
P1 = suction pressure (psi)
P2 = discharge pressure (psi)

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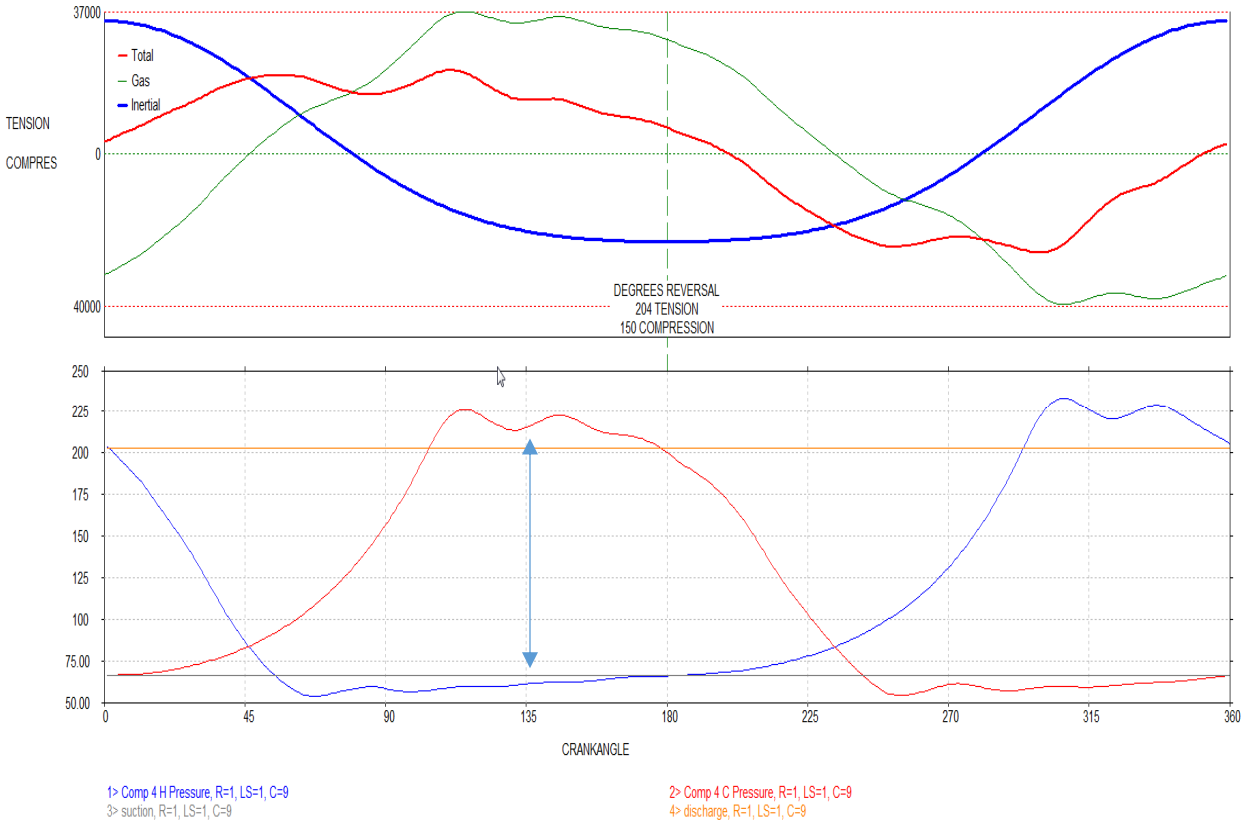
In reality, the gas rod load is the force in pounds applied to the piston rod due to internal cylinder pressures and area differentials across the piston ends. These pressures are measured internally and the pressures are found by measuring the maximum differential pressure at the same crank-angle degree. The suction pressure used in the above equation then becomes the minimum internal cylinder pressure at the point of maximum differential pressure and the discharge pressure then becomes the maximum internal cylinder pressure at the point of maximum differential pressure.

The differences in the rod loads calculated by the two different methods can be significant and are illustrated from actual data below.

Using only Line Pressures:



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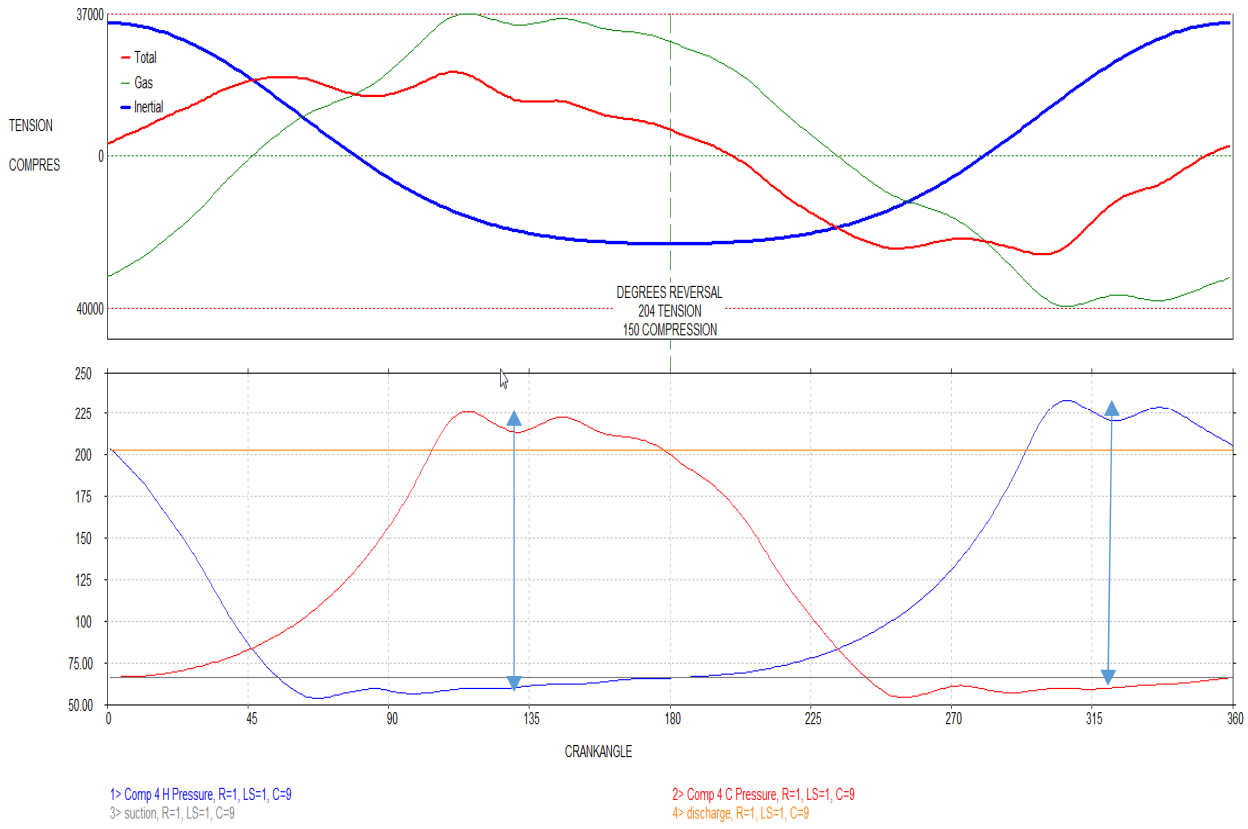
Unit Id:	Model:	Date: 6-09-14 10:08:17
Unit Mfr:	Serial No:	Run No: 1

Load Step		1						
		Rod Load						
		Absolute Load (lbf)		Percent Load (%)		Rod Reversal (deg.)		
Cylinder	Stage	Comp.	Tension	Comp.	Tension	Comp.	Tension	
2	3	19324.5	16310.6	48.3	44.1	171	183	
3	1	18387.5	18009.0	46.0	48.7	190	164	
4	2	31807.8	29872.2	79.5	80.7	150	204	
Notes:	Rod load limits are 40000 compression, 37000 tension							

Using the line pressures, the CRL is 79.5% and TRL is 80.7%.

Using Internal Cylinder Pressures Measured Degree by Degree:



Unit Id: Model: Date: 6-09-14 10:08:17

Unit Mfr: Serial No: Run No: 1

Load Step 1

Cylinder	Stage	Rod Load Absolute Load (lbf) Comp.	Rod Load Absolute Load (lbf) Tension	Rod Load Percent Load (%) Comp.	Rod Load Percent Load (%) Tension	Rod Reversal (deg.) Comp.	Rod Reversal (deg.) Tension
2	3	21889.1	20232.3	54.7	54.7	171	183
3	1	19755.0	22747.9	49.4	61.5	190	164
4	2	39586.3	37136.7 *	99.0	100.4 *	150	204

Notes: * = limits exceeded

Rod load limits are 40000 compression, 37000 tension

Using the maximum differential pressures at the same degree, the CRL is 99% and TRL is 100.4% and the rod load limits are actually being exceeded.

The above example is not uncommon when comparing measured piston rod gas loads versus calculated rod loads from observed line conditions.

The differences can become even more pronounced when there is an increase in valve restriction due to contamination restricting the valve flow areas.

In addition, depending where the line pressure instrumentation is located, there can be significant differences in the pressures used versus what the pressures actually are at the cylinder suction and discharge flanges. Restricted construction screens in the suction lines can cause severe pressure drops between the suction pressure instrumentation and the actual cylinder inlet pressure. Increased flow rates because of changes in line conditions or removing clearance volumes by closing a pocket can cause higher power loss and increase the internal cylinder pressures. Higher gas gravities will also increase internal flow restrictions and differential pressures.

Measuring the internal cylinder conditions degree by degree gives accurate results in all cases including changes in mechanical condition and external pressure drops.

Furthermore, determining occurrence of proper crosshead pin and bushing reversal forces is accomplished by using internal cylinder pressure forces in conjunction with the inertia forces of the reciprocating masses.

Failures in reciprocating compressors due to rod overload and non-reversal are frequently catastrophic in nature, leading to very costly repairs and months of downtime. Protection systems that rely on line pressures assume perfect operating and mechanical conditions. It is only by monitoring internal cylinder pressures that a compressor can be protected continuously under all conditions.

If you have more questions about rod load and reversal or would like information about another topic, please email **sales@windrock.com**.

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