RECIPROCATING COMPRESSOR MALFUNCTION DIAGNOSIS THRU DISTRIBUTED CONTROL SYSTEM .

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Abstract:Reciprocating compressors are highly reliable machines designed to perform in a broad range of process and conditions. However , if they are not properly operated controlled and maintained , high maintenance costs and significant down time can result. Monitoring system can help avoid these problems by collecting information on selected parаters that are indicative of the machines condition.

Past studies within the Hydrocarbon Processing Industry (HPI) indicate that the maintenance costs for reciprocating equipment are approximately 3.5 times that of centrifugal equipment. Substantial savings in maintenance costs and an increase in run time may be achieved through basic monitoring of some of the Machine Parameters. Large reciprocating machinery users such as gas transmission and storage companies refineries and petrochemical industries use condition-based maintenance. This maintenance strategy allows not only cost reduction by reducing the number of maintenance interventions to only those actually needed, but also provides efficiency improvements through dynamic analysis of the equipment as well. Achieving higher reliability requires continuous monitoring of the reciprocating compressors. Basic monitoring of some of the Reciprocating Machine parameters are described below.

Frame Vibration The most important vibration parameter of a successful monitoring program is Frame Vibration. When properly applied, monitoring Frame Vibration will help prevent catastrophic failures. In the event of a failure, the damage to a reciprocating machine can be reduced. For the greatest benefit, a Frame Vibration Monitoring system should be wired to an automatic machine trip. To decrease the possibility of a false trip, two case mounted accelerometers should be mounted on the frame relatively close to each other. The outputs from the two transducers are signal conditioned, and their trip circuits are "AND" voted. In other words, before a trip is initiated, both of the transducers with their monitors must sense a high vibration level.

Valve cover monitoring -Suction and discharge cylinder valves are subject to ring breakage or malfunction due to dirt or solid accumulation.The resulting backflow of gas causes an increase in the temperature of the valve, valve covers and cylinder body temperature can also rise due to prolonged unloaded operation of the cylinder.

Monitoring of the temperatures with thrmoelements installed in the valve covers provides a direct indication of proper cylinder operation.If a valve shows abnormalities,it is possible to detect and quickly identify the cause.

Main bearing monitoring-Abnormal lubrication conditions cause temperature increase that overheat all sliding parts.Continuous temperature monitoring helps operators maintain optimal lubrication and avoid damage to the main bearings. RTDs are installed directly on the main bearing caps near the bearings.All temperature readings are acquired and compared with the corresponding design and normal operating specifications in order to detect potential malfunctions.

Cylinder packing monitoring-The packing provides the seal between the piston rod and the cylinder.It includes a series of cups,each having several rings,the intermediate cups allow oil to enter the box through an axial hole.Gas that has leaked out of the box can be recovered and recycled or sent to flare.Gas leaked from the compressor to the environment causes an increased pressure in the last outer cup,this can be deteted as a packing temperature variation. RTDs are directly installed on the cylinder packing flange.All temperature readings are acquired and compared with corresponding design and normal operating specifications in order to detect potential malfunctions.

Rod drop monitoring-The piston rod assembly drops during operation due to normal rider band wear.Sometimes due to dirt or liquid in the gas stream,cylinder valve problem,insufficient lubrication,cylinders running unloaded over prolonged periods of time can cause drastic and sometimes sudden reduction in rider band life.Rider bands must therefore be changed periodically to prevent contact between the piston and cylinder,as this would seriously damage both components and result in expensive repair.Replacement of rider bands solely an hours of operation is not the most efficient method.A non contact proximity probe is mounted on the packing flange installed under each piston rod.Its electrical output signal is proportional to the probe- rod distance which can therefore be measured with great accuracy.

Rod Run Out- Whereas Rod Drop is a measurement of rod position, Rod Run Out is a measurement of the rod's actual dynamic motion as it travels back and forth on its stroke. The amount of Rod Run Out is highly dependent on the cylinder alignment with the Crosshead. Due to inherent looseness in the Crosshead and thermal growth of the machine, higher readings of Rod Run Out are allowed in the vertical direction. The horizontal direction allowances are much less and high readings are attributed to misalignment. Eddy Probes can make this measurement while the machine is operating. This provides a highly accurate measurement of the actual dynamic motion of the rod under full load conditions.

Reciprocating Compressor Dynamic Analysis – Reciprocating compressor dynamic analysis is based on the interpretation of deviation of its operating parameters from ideal conditions. Parameters to be analyzed include cylinder internal pressures, volumes, temperatures, phase, vibrations and rod drop. The analysis also includes calculated parameters such as power, efficiency, rod loads and losses.

Continuous online monitoring of reciprocating compressors through dynamic analysis allows malfunction diagnosis, improving the time and cost to repair and provides continuous protection from catastrophic events such as rod or cylinder rupture.The Pressure x Volume (PxV) diagram is the best way to represent the energy cycle in a reciprocating machine. Theoretical P x V diagrams superimposed on the actual diagrams supply important compressor diagnostic information.

Flow Balance –

Only part of the compressor stroke is used for either suction or discharge. Suction volumetric efficiency is expressed by the equation

$$VE_S = \frac{SuctionVolume}{SweptVolume}$$

Discharge volumetric efficiency is expressed by the equation

$$VE_D = \frac{Discharge\ Volume}{Swept\ Volume}$$

All the mass of gas admitted into the cylinder, except that remaining as described above, is discharged. The ratio between the gas mass admitted and the gas mass discharged (Flow Balance), is a function of the ratio of volumetric efficiencies, and ideally is equal to 1. This ratio is one of the most representative parameters of the compressor condition.

Suction and Discharge Valve Leak Diagnosis

In the case of leaking suction valve(s), faster than ideal pressure reduction occurs during the suction stroke. This happens because the gas in the cylinder is at a pressure higher than the pressure of the suction line. Because the suction valve(s) is leaking, the gas flows toward the suction line, causing the cylinder internal pressure to equalize with the suction line pressure sooner than would occur in the ideal cycle. This faster expansion can be easily noticed when the actual P-V diagram is superimposed to the ideal diagram .In a similar manner, the cylinder internal pressure would rise slower in case of leaking suction valve(s). Superimposing the ideal PxV diagram to the actual PxV diagram can easily show this.

The leaking suction valve(s) increase the suction volumetric efficiency and reduce discharge volumetric efficiency. As a result,the flow balance is higher than 1.

In the case of leaking discharge valves, the gas expansion is slower than ideal because the higher pressure gas from the discharge line is admitted into the cylinder through the leaking discharge valves. The slower expansion causes the reduction of the suction volumetric efficiency.

Similarly, for leaking discharge valve(s), the cylinder internal pressure will increase faster during the compression. Superimposing the actual PxV diagram on the ideal PxV diagram easily shows this . The flow balance is consequently lower than 1.

Realistically, 100 percent leak-proof valves do not exist and the Flow Balance is almost never exactly 1. Typically Flow Balances between 0.95 and 1.10 are considered acceptable.

Reciprocating Compressor Online Monitoring.

Although the concepts presented in the previous section are relatively simple the actual pressure and volume measurements are challenging because a large number of PxV correlated points must be collected during each compression cycle to allow effective compressor diagnosis.

Temperature transmitters collect suction and discharge temperatures for each cylinder. Temperatures are needed for the compressor thermodynamic performance assessment.

Vibration impulse signals with crankshaft phase reference are also collected for each cylinder. Vibration information can confirm PxV diagram diagnoses as well as monitor mechanical looseness.

Although not absolutely necessary for compressor dynamic analysis, rod drop can also be collected. When correctly applied, rod drop can supply additional piston ring, rider ring and crosshead shoe wear information .

Systems that monitor only parameters such as rod drop or valve cover temperature are able to diagnose only a small portion of the failures shown here.

Dynamic analysis enables diagnosing the most common defects in reciprocating compressors.

The following parameters can be calculated and monitored:

Power – Power required to complete the gas compression cycle. This value is used to determine if the compressor is overloaded and is also used in conjunction with ideal isentropic power to calculate isentropic efficiency.

Capacity – Capacity is calculated as the average of suction and discharge conditions and also can be calculated at standard conditions.

Flow Balance – As previously discussed, flow balance is used as the first indication of compressor anomalies.

Rod Load – The reciprocating compressor rod is subjected to a combination of loads because of cylinder internal pressures and inertia of the moving parts. Rod load can be influenced by changes in suction and discharge pressure, compressor unloading, valve leaks, and other causes. Overloading a compressor rod is very dangerous and must be avoided because of potential catastrophic failure, including risk of personal injury.

Rod Reversal – The rod load varies from compression to tension and vice-versa along the piston stroke. To assure adequate lubrication of the crosshead pin, the load vector should change direction during the piston stroke.

Cylinder Maximum Pressure – Cylinder overpressure indicates presence of liquids or restrictions to the gas flow.

Theoretical Discharge Temperature – This temperature is calculated assuming isentropic compression of the gas. Generally a difference between theoretical and actual temperatures above 20oF is indicative of excessive recirculation caused by valve(s), piston rings, or unloader anomalies .

Valve Losses – The additional energy required to force the gas through the valves is calculated and can be expressed as total energy percent or cost, provided the unitary energy cost is known.

All the above parameters can be monitored continuously or periodically. Computer networks greatly enhance the possibility of online monitoring.

Periodic monitoring is done using portable analyzers and instrumentation. Periodically, qualified analysts install temporary pressure, temperature vibration, and phase sensors; then connect the analyzer and collect the necessary data. The analyzer is programmed to calculate the parameters mentioned above. Modern analyzers can display graphical results that are easier to interpret and diagnose.

The main advantage of periodic monitoring is its flexibility to collect additional data if needed. This flexibility is very important for experimental analysis and greatly improves diagnostic accuracy.

Continuous online monitoring is done using permanently installed intelligent transmitters for pressure, temperature, vibration and phase signals. The transmitters calculate the parameters mentioned above and, because they are connected to computer networks, allow remote analysis of the data.

The same intelligent transmitters also can be connected to PLC-based controllers or DCS systems, enabling the machinery protection to be integrated with process controls and protection. The intelligent transmitters also have optional relay outputs that can be used by the plant protection systems.

CONCLUSION –

The main advantage of continuous monitoring is continuous protection of the machine(s). Critical situations in the operation can be detected in the early stages. This service supports you to minimize costly unplanned shut-downs and to ensure long-term effective utilization of compressor components. Fast on-site availability of service partner in case of emergency situations will also be arranged.