Online performance monitoring

THIS CRUCIAL ELEMENT OF CONDITION-BASED MONITORING CAN HELP INCREASE PLANT PROFITS

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Every plant needs a preventative maintenance program of some kind. A program that incorporates the condition of critical equipment rather than its operating time offers real benefits to plant bottom line. Instant feedback on how the equipment is running is as important as knowing plant profits on a real-time basis.

On-line performance monitoring helps turbomachinery operators to know instantly when something goes wrong or is starting to go wrong. The data provided help schedule maintenance and troubleshooting of failures. Basing the maintenance program on equipment condition rather than operating time will save money. If the equipment is running fine, why spend the time and money to open it and replace all the wearing parts?

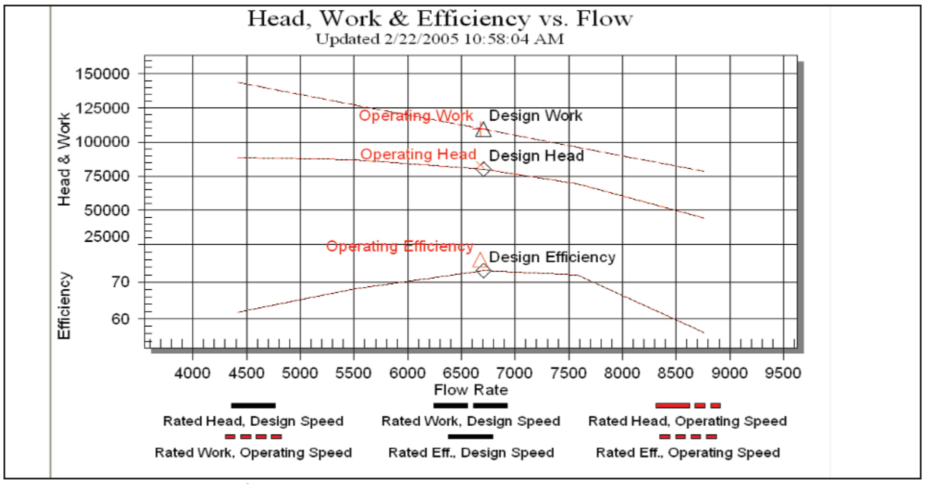

Figure 1: Live data chart from a process gas compressor showing design vs. actual (operating) head, work and efficiency. The operating work input falls right on the curve, indicating that the instruments are accurate and gas analysis is good

Equipment condition

Online performance monitoring can benefit energy industries and process plants by confirming if the equipment is performing as promised by the manufacturer. Maintenance scheduling, such as cleaning and major turnarounds, can be based on equipment condition (Figure 2). Current and historical performance data provided by these systems will be invaluable when re-rates to increase capacity are considered.

By telling operators where the machine is operating on its curve, online monitoring can help prevent mechanical problems. Information, such as where the compressor is operating on the performance curve, can help prevent impeller failures or help in troubleshooting efforts. Recording of surge and choke events may help find the root cause of failures. The data help operators to change operating procedures and prevent future failures.

Startups and other transients, such as trip situations, will remain unknown unless online monitoring is implemented. Normal performance testing will not show these transients since performance tests are usually conducted during stable, steady state conditions.

In online performance monitoring systems, compressor health is measured by comparing current performance with manufacturers' data. Raw operating data, such as discharge pressure or pressure ratio, are not sufficient indicators of compressor performance, as these parameters can change with inlet temperature and pressure. But head and efficiency are accurate indicators of compressor performance and are not affected by process conditions. To calculate head, the BWR (Benedict, Webb & Rubin) equation of state should be used. This is a comprehensive equation that defines gas parameters accurately.

Calculating work input helps to confirm that the input data are accurate. Work input represents the energy transferred from the compressor impeller blades to the gas. Any degradation in the interstage seals, corrosion or fouling will show up as a loss in efficiency and head, but the work input remains the same regardless of these losses.

To determine work input, head and efficiency, raw data such as pressures, temperatures, speeds and flow rates are processed by a performance calculation software (Figure 3, sidebar). These values are then displayed on a chart along with the OEM performance curves (Figure 1). From this, the difference between actual and predicted values can be noted. Logging the difference (delta efficiency, Figure 4) over a period of time can help determine any change in compressor conditions. This log also helps to formulate maintenance schedules and troubleshooting.

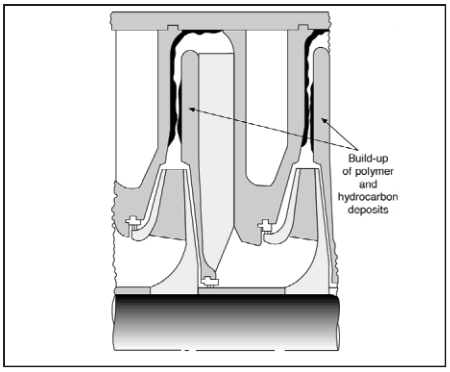

Figure 2: Online monitoring will show the rate of decay in compressor performance and aid in scheduling maintenance. Above schematic shows polymer buildup in the diffuser passage of a cracked gas compressor

Raw operating data are often available from existing plant data collection systems. However, some old plants do not collect all the necessary data. Here, existing data collection systems would need to be enhanced before monitoring systems can be installed. The data are transferred from the collection system via a Dynamic Data Exchange (DDE) connection to the performance calculation software where they are processed.

	Inlet	Discharge
Direction	Inlet	Discharge
Pressure	52.1 PSIA	223.64 PSIA
Temperature	521.5 R	794.2 R
Flow Rate	1,047.1 Lb/Min	
Volume Flow	6,348.78 Ft^3/Min	2,248.3 Ft^3/Min
Mass Flow	1,047.1 Lb/Min	1,047.1 Lb/Min
Compressibility	.9615	.9633
Total Mole Weight	17.031	
	Inlet Section 1	
Compressibility	.9615	
Temperature	521.5 R	
Volume Flow	6,348.78 Ft^3/Min	
Mass Flow	1,047.1 Lb/Min	
	Discharge Section 1	
Compressibility	.9633	
Temperature	791.3 R	
Volume Flow	2,248.32 Ft^3/Min	
Head	82,407.02 Ft-Lb/Lb	
Efficiency	77.00	
Gas Power	3,395.85 HP	
Total Head	82,407.02 Ft-Lb/Lb	
Total Efficiency	77.	
Total Gas Power	3,395.85 HP	
Surge Margin	43.638%	
Choke Margin	27.517%	

Figure 3: The table shows live compressor information being received by the performance monitoring software from the plant historian software and the results of calculations

Compressor health

Online performance monitoring is now a key part of the machine reliability program at Dakota Gasification Co. (www.dakotagas.com), located northwest of Beulah, North Dakota. Started in 1984, this plant currently produces more than 54 billion standard cubic feet of synthetic natural gas annually, using more than six million tons of coal. Other products from the coal gasification process include phenol, liquid nitrogen, methanol, naphtha, carbon dioxide, krypton and xenon gases, and ammonium sulfate and anhydrous ammonia.

This equipment-intensive plant has 22 critical, unspared compressor trains — those that cannot be stopped without directly affecting the plant revenue stream — as well as other spared compressor and expander trains. The compressors are used in air separation for production of oxygen and nitrogen, gas methanation, production of anhydrous ammonia, compression of carbon dioxide, and product gas delivery to the pipeline. The raw gas produced in the gasifiers is cleaned up by a process that uses ammonia refrigeration compressors. Critical compressors in the plant consume more then 250,000 hp.

Most of the machines are over 20 years-old, and, currently, 14 machine trains including ammonia compressors are fully instrumented to support online performance monitoring. Data required for online monitoring include inlet and discharge pressure, temperature at each compressor section nozzle, flow rate and speed. The process gas is also accurately analyzed for composition. This is input along with the predicted performance curves supplied by the compressor manufacturer for reference.

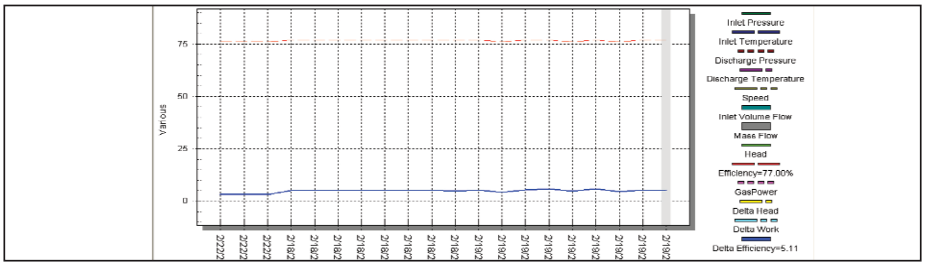

Figure 4: A time series chart showing compressor efficiency and delta efficiency trended over time. Other data (right of trend chart) can all be trended similarly

Accurate data are essential to obtaining good results with any condition monitoring program. To assure this, all instruments are routinely calibrated. Work input is monitored to confirm that the data are accurate.

The data are pulled from the plant historian software (Aspen Process Explorer in the Beulah plant) to a spreadsheet. From there Flex Live, the performance monitoring software (see sidebar), takes it via the DDE connection and to Gas Flex that processes it to obtain the appropriate compressor parameters such as head and efficiency (Figures 1, 3 and 4).

Since only a single point is displayed on the performance curve the curves are compensated for speed (Figure 1). A historical trend tracks data vs. time to show degradation of compressor efficiency (Figure 4). This aids maintenance scheduling. Tracking the delta efficiency (the difference between the predicted and the actual efficiency) gives a good indication of compressor health.

Benefits of online monitoring

Continuous monitoring of machine vibration, thrust, and bearing temperatures is essential for reliable and safe operation of turbomachinery. But these alone do not tell operators everything they need to know to maximize revenue and minimize maintenance expenses. At the Dakota Gasification Co. plant, real time performance data have been integrated with mechanical parameters (vibration data, bearing temperatures and oil condition), so that operators can better select operating regimes and maintenance schedules.

Key benefits of the plant's online monitoring system include:

- Faster troubleshooting that helps to minimize downtime and loss of production
- The trending of machinery performance that helps to isolate the operating points that may have caused the machine's current condition
- Immediate evaluation of the effects of process changes
- Extended scheduled maintenance and overhauls of machines that are well-designed and in good operating condition. Knowing machine performance along with vibration, thrust bearing temperature, and oil condition enables this
- Providing information that helps operators justify to insurance carriers decisions they make on extending the time between overhauls. This also helps to minimize insurance premiums. TI

Flex Live

Flex Live works with Gas Flex to continuously process data from compressors via the plant data collection system. Flex Live is designed to read data from an Excel spread sheet or directly from a data source. Gas Flex calculates compressor performance, using BWR equations of state — respected in the industry as the most accurate for process gases. Flex Live is available for one compressor or for multiple compressors including sidestream refrigeration compressors. Pricing is based on the number of compressors monitored and starts at $2,500. See www.flexwareinc.com for more details.

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