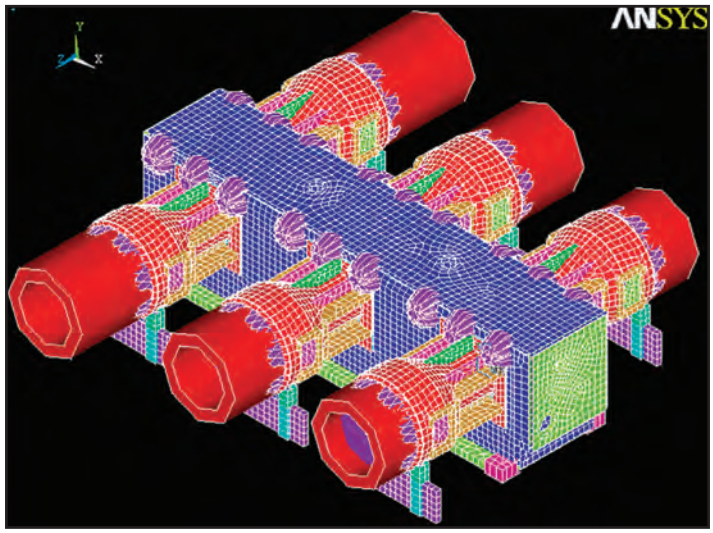


■ Beta maintains a database of compressor frames for performing mechanical studies. In this particular case, a six-cylinder Ariel compressor frame is shown.

MONITORING, ANALYSIS AND OPTIMIZATION

Beta Machinery Analysis Adds New Program to Its Design, Operation and Maintenance Offerings

By Neil Purslow

Beta Machinery Analysis provides specialized engineering services relating to the design, operation and maintenance of reciprocating and rotating equipment used in a variety of applications, such as oil and gas facilities, pipeline compressor stations, refineries, LNG terminals, oil sands plants and power generation.

"We currently have over 40 staff and associates operating from offices in Houston, Texas [U.S.A.}, and Calgary, Alberta [Canada], providing services around the world," said Russ Barss, president of Beta. "If a business involves machinery, we have the personnel, experience and analytical tools to keep those machines running smoothly by designing, commissioning and providing ongoing support for critical machinery systems."

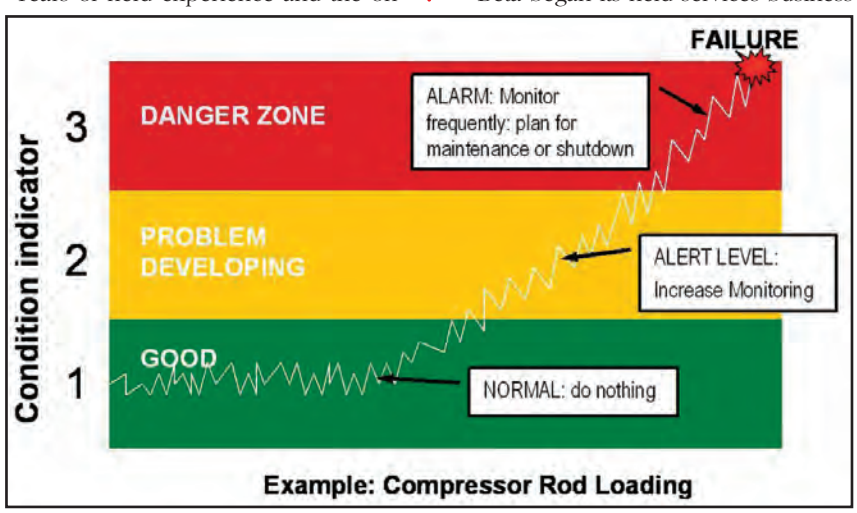
Beta offers consulting services in three areas — engineering and design, field services and optimization. The engineering and design services group provides pulsation and vibration studies (API 618, 619, 674); torsional, lateral and thermal analyses; structural and piping studies; and dynamic foundation and skid analyses on new machinery and revamps and upgrades. New proposed and existing machinery designs are evaluated with design improvements recommended by Beta to ensure the smooth operation of equipment.

All studies are inter-related. This ensures that the machinery and associated processes, including the piping and vessels, operate reliably and efficiently. Beta uses a mix of commercial software, which has been adapted to reflect Beta's field experience, as well as custom-developed programs to predict the performance of machinery systems. Ongoing development of the software tools continually expands their functionality and ensures their accuracy. Laboratory and field measurements are used to confirm and fine tune the algorithms.

"The roots of our acoustical simulation software go back to 1973," said Bryan Long, director of business services for Beta and the individual who led the software's early development. "Years of field experience and the ongoing evolution of our modeling software have resulted in our ability to thoroughly and accurately predict the behaviour of modern high-speed compressors over a wide range of conditions."

Beta works with operators, engineering companies and compressor package fabricators by modeling machine systems and providing improvement recommendations. The primary focus of the engineering and design group is to optimize machinery system designs to ensure performance and reliability while minimizing capital cost.

Beta began its field services business



■ Beta has developed appropriate condition indicators (CIs) for each type of machine. For example, CIs for a reciprocating compressor could include rod loading, discharge temperature deviation, inter-stage pressure deviation and power utilization. For each CI, ranges of results have been pre-determined using Beta's field experience. These ranges are then used along with the actual field results, to determine the health of the equipment.

■ Beta uses an array of sophisticated equipment to capture performance and other equipment data for assessments and analyses.

■ Multichannel data acquisition and analysis is one of the services offered by the company. Beta has been troubleshooting machinery problems in the field for 38 years.

38 years ago troubleshooting machinery problems. On-site service now includes a host of activities, such as commissioning, condition assessments, balancing, alignments and performance checks. Beta has an extensive inventory of diagnostic and test equipment used to analyze all types of machinery.

Each Field Service engineer performs a range of services, from a one-day assessment of machinery to more comprehensive project analyses. Assignments can include vibration analyses, pulsation studies, performance tests and reliability assessments. Once the machinery's current "health" has been determined, the engineer or technician works with the local maintenance and operations staff to solve problems and to address improvement opportunities. Although Beta does not perform welding, fabrication or mechanical work, the company will supervise the providers of those services to ensure changes are completed accurately.

Field services is also involved in revamping compressor packages. Working with producers and packagers, Beta analyzes and optimizes complete packages to ensure that they operate reliably. Start-up checks are often performed after the revamp is completed to confirm success and establish a baseline for future monitoring.

Optimization services offers reliability engineering support, inspections, assessments and monitoring. Beta performs on-site field inspections and analyzes equipment to help keep it running smoothly. Inspection services include running inspections, in which deviations are identified in mechanical condition or performance; or internal engine wear assessments, in which Beta's patented B-Probes measure wear of internal engine components. This service allows customers to extend the overhaul intervals on engines, which saves maintenance costs and increases availability. The company also offers Vibro-Meter's Online Condition Monitoring system for the protection of critical rotating equipment.

In May 2005, Beta added another optimization service — the Monitoring, Analysis and Optimization (MAO) program — which is designed to provide operators with a cost-effective program for monitoring and optimizing equipment. Its purpose is to identify performance problems, deliver improvements, optimize equipment and reduce equipment downtime. MAO was designed for compressor fleets, gas plants, pipelines, refineries and other facilities with rotating, reciprocating and non-machinery assets.

"The MAO program provides for regular health checks for a machine, or fleet of machines," said Tom Van Hardeveld, senior reliability engineer for Beta. "Through monitoring, machine efficiency can be evaluated and problems identified early to prevent secondary damage to the equipment. The program is applicable to all machines in a plant, whether the equipment is deemed critical or not. For instance, a gas-treating solvent circulation pump may not be classified as critical, but failure could cause a gas plant to unexpectedly shut down."

The first step in MAO is monitoring. In this step, information on a customer's machines is collected. Sources of data can include operator log sheets; SCADA or DCS operating parameters; and vibration readings from bearings, gears, impellors, rotors or other sources.

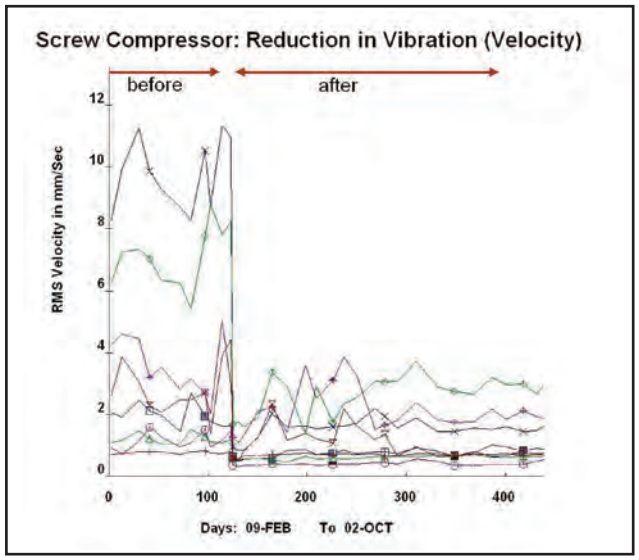
The company works with customers to review existing sources of data, and helps determine where additional information should be collected. The program generally focuses on two types of data. The first is vibration-based monitoring, which is used to detect mechanical faults that over time will become failures. Examples include bearing wear, gear damage, unbalanced and misaligned components.

The second type involves operational data (such as pressures, temperatures, flow rates), which can reveal information about the performance and efficiency of equipment. Depending on the instrumentation used, it may be possible to quantify a loss of throughput, an increase in energy consumption or some other indication of impending failure. The data gathering process generally involves front line operators and maintenance personnel, and is tailored to be as easy as possible for them. Personnel are trained on the processes used to gather accurate information data.

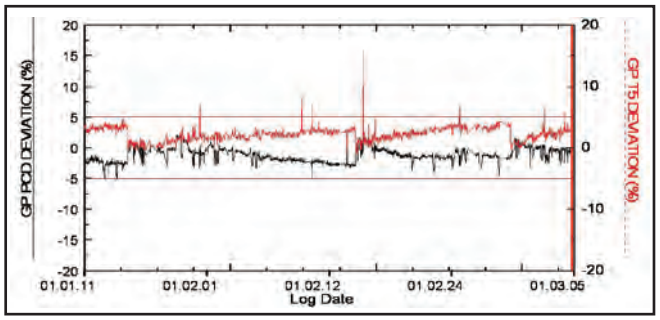
The company's approach to data gathering is to minimize additional work for operations staff, and to avoid expensive monitoring hardware, software and additional data collection methods. Gathered data are sent to Beta by faxed log sheets, e-mailed files or web-based input forms, data files from control systems, or as hard copy or digital forms. Beta also collects field operating information on behalf of customers, if requested.

Beta uses the information to analyze the condition and performance of the machinery. For each piece of equipment, condition indicators have been developed based on Beta's field experience. These indicators provide an effective way to track the current condition of a machine. Indicators vary with the type of machine being analyzed. For reciprocating compressors, indicators may include deviations in efficiency, gas re-circulation, excessive rod load, underutilized capacity and high discharge temperature. For gas turbines, measures may include EGT spread deviation, intake air filter pressure drop and compressor efficiency deviation (due to fouling). Unique measures have also been created for reciprocating engines, centrifugal compressors, electric motors and non-machinery assets.

Actual data are then processed to produce key indicators for each piece of equipment. Analyses often involve



■ **A dramatic drop in vibration is experienced by this screw compressor after the equipment had been analyzed by Beta and adjusted by the operator in consultation with Beta.**



■ **This trend graph shows the performance degradation of a gas turbine and the restoration of that performance through blade washing. Trend deviations in discharge pressure are shown by the black line and temperature deviations by the red line.**

trending, correlating key variables and determining deviations from baseline performance. The analysis software is flexible. It calculates operating and performance metrics for all types of equipment. Condition indicators are continually tracked by the software, with Beta personnel regularly reviewing results. If a condition changes beyond an established threshold, operations staff at the affected facility are immediately notified.

A concise equipment score card is regularly prepared showing the status of the indicators for each equipment item. Key indicators are shown with a colored background to indicate the status of the equipment. A green background shows normal operation, a yellow background indicates a warning, and a red background signifies danger. The colors provide an easy visual cue to the reader.

Recommendations for improvement are included in the comments section of the score card and referenced to the appropriate indicator. The score card also provides an estimate of the cash flow impact for the cost of failure. Included in the cash flow impact are production losses, maintenance costs and other applicable losses.

A reporting package prepared for the customer includes the score cards for the equipment and trend graphs showing details of the condition indicators that are in yellow and red. For example, the condition indicator for the winding temperature of an electric motor may be in the danger zone and therefore red on the score card. By analyzing the accompanying trend graph, an operator will see that the motor has been running progressively hotter than its baseline for a period of time, indicating that remedial action is required to correct the condition.

Report packages are tailored to suit the needs of individual customers. They can be provided at the plant, fleet or individual equipment item level, or as requested by the customer. Timing and frequency of reports are tailored to meet the needs of each facility. Report packages are available from a secured area on the Beta website.

The optimization phase of the MAO program contains suggestions for increasing the operating efficiency and performance of the machinery. Optimization can be performed in three ways.

Performance analysis is a process that tracks key performance indicators (KPIs) and economic indicators for each machine. From those indicators, Beta recommends improvement opportunities for the machinery. System inefficiencies identifies constraints and bottlenecks in production systems. Fleet management identifies and ranks assets based on asset management priorities to improve performance and/or reduce costs.

After the initial MAO set up is complete, Beta generally visits the customer's site to review reported results. This approach is important in ensuring acceptance from operators and maintenance staff and to make adjustments to the program. Set-up information and data can be sent to Beta for analysis from all over the world.

The company stated that in most cases, MAO will result in increased equipment utilization and availability, increased production and reduced maintenance — which translates to an increase in cash flow. The outsourcing of this analysis approach is especially important in oil and gas production facilities, since production volumes decline and equipment must be modified to maintain efficiency. It also allows operators to focus on more critical areas and alert them to potential problems.

"We've developed MAO to assist operators and engineering personnel who do not have in-house staff, or are not trained in the analysis and optimization of equipment," said Barss. "The program can be used on any type of equipment over its entire life cycle. We maintain all gathered data for a piece of machinery for its lifetime, which enables us to provide historical trends and long-term benefits through increased equipment reliability and availability." ■

Methods of Detection for Equipment Failure
Monitoring, Analysis and Optimization (MAO) Program

Type of Failure	Method of Detection	
	Vibration Data	Operating Parameters
bearing degradation	Y	
worn and damaged gears	Y	
rotors unbalanced	Y	
shaft misalignment	Y	
resonance	Y	
pump impellor damage	Y	
motor rotor faults	Y	
pulsation in fluid and piping	Y	
frame and foundation degradation	Y	
decreased efficiency		Y
loss of throughput		Y
overload		Y
excess component temperatures		Y
opportunity costs		Y
improper control system performance		Y
underutilization of capacity and power		Y