Leveraging Remote Diagnostic Services (RDS) to detect performance degradation in variable-speed centrifugal compressors

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Operators across oil & gas and other process industries face several challenges in the coming years. Among these include the potential of having to maintain profitability in an uncertain price environment, tightening environmental regulations, and a loss of knowledge transfer due to an aging workforce.

Digital transformation has emerged as a powerful lever for combatting these issues. There are now countless examples where digital technologies have enabled organizations to improve production efficiency, lower OPEX, and reduce carbon emissions. This is particularly the case when they are applied to rotating equipment assets, like centrifugal compressor trains, which play a critical role in the safe, reliable, and efficient operation of many process facilities, including production platforms, gas processing and LNG plants, compression stations, refineries, etc. The consequences associated with unplanned downtime of compressors (e.g., lost production, lower revenue, higher greenhouse gas emissions, blowdown and increased flaring, etc.) also make them an attractive target for digital technologies.

This article looks at the role remote diagnostic services (RDS) play in the wider context of digitally-enabled centrifugal compressor trains. It also describes a novel method of detecting performance degradation in variable-speed compressors, which has historically been a challenge for the industry.

Remote Diagnostic Service (RDS) overview

Many operators today are leveraging real-time condition monitoring in combination with analytics based on technologies like artificial intelligence (AI) and machine learning to continuously optimize the performance of their compression trains. While the value these tools can provide on their own is not in question, it is important that they not be viewed as a direct replacement for original equipment manufacturer (OEM) expertise. Operational context is ultimately required to understand compressor operation and maximize the predictive window.

RDS addresses this by facilitating a collaborative, data-sharing model between the compressor OEM and plant operator. The OEM receives a continuous stream of real-time data from the unit(s). With full transparency, dedicated engineers can then act as a natural extension of the customer team by providing advanced troubleshooting and 24/7 remote support, along with recommendations for corrective maintenance, all without having to be physically onsite.

The ultimate objective of RDS is to establish an early warning system where plant operators are alerted to performance anomalies (indicating a need for maintenance) before a breakdown occurs. Analytics tools can continue to be used for decision support, for example, on how best to manage degrading performance until the next planned maintenance outage. Other key advantages include:

- OEM can screen false-positives and forward only true-positive identifications of abnormal behavior.
- Allows for comparisons between actual as-is and as-designed performance parameters, via the equipment design software packages.
- Provides operators with access to as-build knowledge of equipment, which only the OEM has access to.
- Access to operational data from compressor trains with identical configurations and operating regimes.
- Enables operators to employ more proactive/predictive maintenance regimes, which leads to lower costs and longer times between maintenance intervals.

OPERATING DIMENSION	MONITORING OBJECTIVE	INPUT TAGS	OUTPUT TAGS
COMPRESSOR PERFORMANCE MONITORING	To detect wear caused by fouling, as well as any internal leakage by increasing component clearances. Observed by degrading performance	■ Gas composition ■ Suction pressure ■ Suction temperature ■ Inlet flow ■ Speed ■ IGV position ■ Drive power ■ Discharge pressure ■ Discharge temperature	■ Actual mass flow compressor ■ Actual volume flow compressor ■ Actual polytropic head compressor ■ Actual polytropic efficiency compressor ■ Theoretic design polytropic head ■ Theoretic design polytropic efficiency ■ Delta polytropic head ■ Delta polytropic efficiency
SEAL GAS MONITORING	Detection of barrier seal and dry gas seal degradation. Observed by monitoring the ratio of the expected overactual seal volume.	■ Actual speed ■ Seal gas supply pressure ■ Seal gas supply temperature ■ Seal gas vent pressure ■ Seal gas vent flow ■ Composition	■ Expected DGS mass and volume flow per ring ■ Actual DGS mass and volume ■ Ratio DGS volume flow (expected/actual) ■ Expected barrier seal mass and volume flow ■ Actual barrier seal mass and volume flow ■ Ratio barrier seal volume flow (expected/actual)
GAS COMPOSITION MONITORING	Determination of actual gas composition to improve compressor performance.	■ Gas temperature ■ Gas pressure ■ Gas density ■ Sensing time period ■ Scrubber outlet temperature ■ Scrubber outlet pressure	■ Actual gas components and fraction
BEARING MONITORING	Detection of radial bearing abnormalities. Observed by comparing a unit's design specs with actuals. Generates an agent message when the value exceeds allowable tolerances.	■ Speed ■ Radial pad temperature ■ Oil supply temperature	■ Flagged deviation, anomaly, by rule-based Agent message

FIGURE 1 Compressor-specific remote diagnostic capabilities.

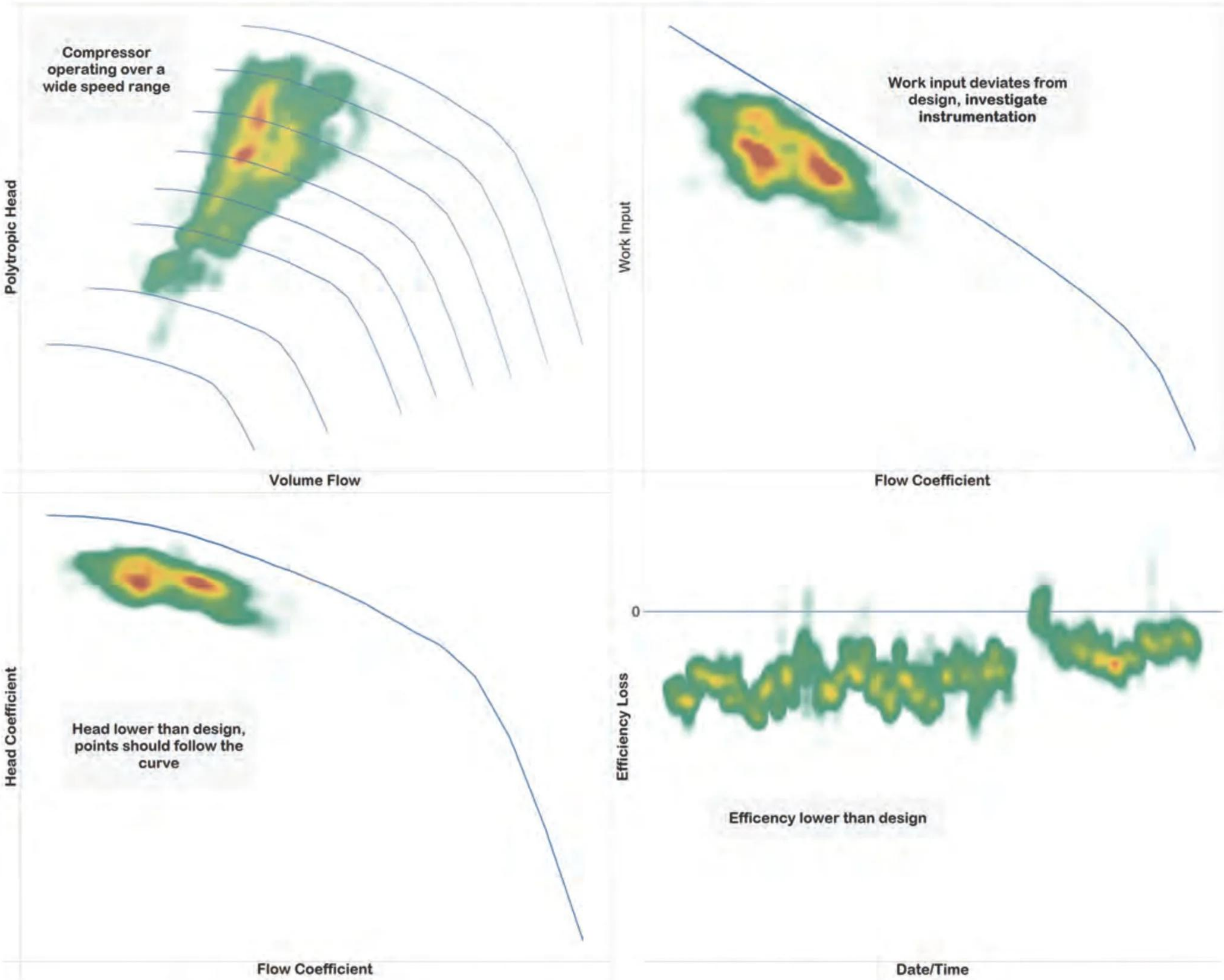
- OEM can provide recommendations to extend mid-life and full-life overhauls and improve train availability.
- In certain cases, it may be possible to eliminate the need for spare trains — and their associated capital and operating expenses.

Siemens Energy currently has more than 1,200 rotating equipment assets running with RDS in various applications across the globe. We have seen first-hand the incremental value it provides to customers.

In the case of compression trains, by averting trips and resulting forced outages via early detection of potential faults and preventive remediation, availability can be increased by as much as 3% (equivalent to 11 days over the course of a year) [1]. Extrapolated over a compressor's 20-year lifespan, that additional availability can add up to a rather significant avoidance in lost production and other related expenses, thereby reducing the unit's total cost of ownership.

Detecting performance degradation in variable-speed units

While RDS can be valuable for any type of compression train, it is especially advantageous when applied to variable-speed units, which are typically more difficult to diagnose and troubleshoot than fixed-speed machines. This is in large part due to the speed changes, which can obscure the relationship between polytropic head and efficiency and make performance degradation due



to fouling or internal recycle hard to identify.

Siemens Energy employs a method to address this problem by normalizing the compressor speed based on inlet conditions and looking at head and efficiency deviations. Additionally, by plotting performance metrics as non-dimensional parameters of flow coefficient, head coefficient, efficiency, and work input, it is possible to determine whether the loss of performance is due to internal recycling (whole curve shifted to the left) or internal fouling (curve dips down at higher flow coefficient).

Compressor performance is often plotted on a compressor map showing volume flow against either polytropic head or polytropic efficiency. This is a useful way to display where a compressor is operating in its' envelope, however, for a variable speed compressor, it is difficult for an operator to tell if the performance has dropped, or if the compressor is just operating at a different speed or pressure ratio (see Figure 2).

By using non-dimensional parameters, speed lines are eliminated and there is one line for head coefficient, efficiency, and work input. If the operating point starts to drop below the predicted line a performance issue is easily identified. Furthermore, deviations in the work input line can be used to identify changes in gas composition and issues with flow meters and other instrumentation.

Conclusion: Making digitally-enabled compressors the new standard

Although it is common practice today for new compression trains to be equipped with the requisite hardware and software to enable digital condition monitoring, rotating equipment OEMs have traditionally treated these capabilities as an "add on" feature. Thus, they come at an added cost to the customer.

Equipment providers can do their part to accelerate digital adoption by making "digital readiness" part of the standard offering on new rotating equipment packages. This is an approach Siemens Energy has adopted for most of our gas turbine-driven, steam

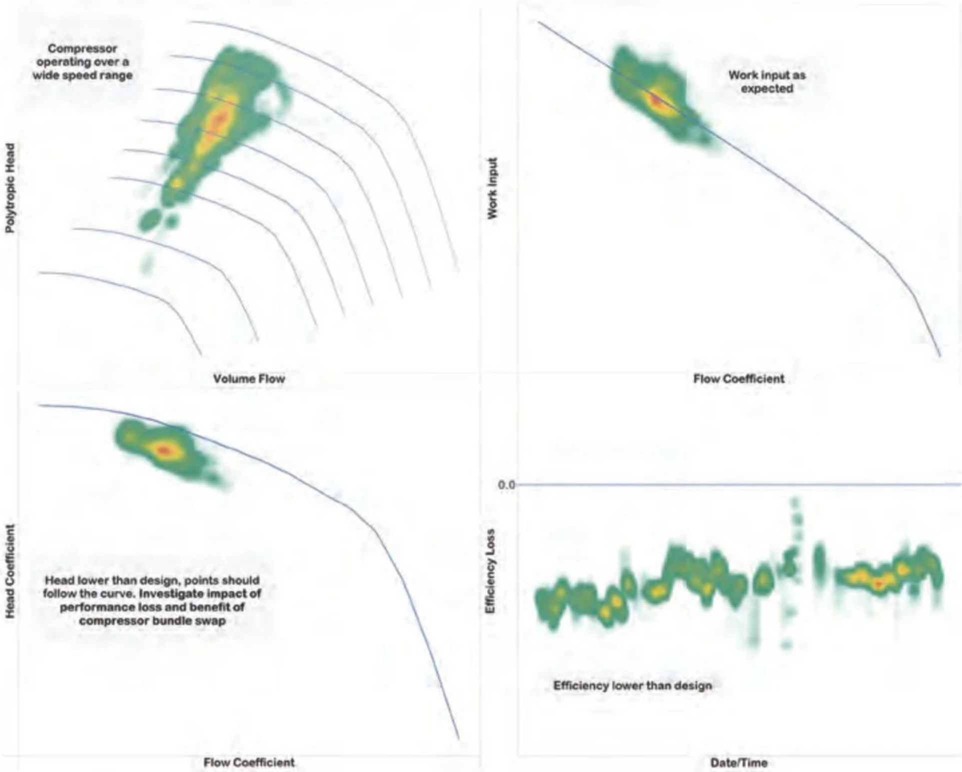


FIGURE 2 **Compressor maps showing deviations from design envelope.**

turbine-driven, and electric motor-driven (single shaft) compression trains. At no added expense through the warranty period of the unit, operators can access the health of their equipment remotely via a mobile app. The goal is to provide operators with a transparent and easy way to manage performance logs and planned outages, and to browse all the notifications issued for their compression trains. The data connection is included with the compressor train. However, it can easily be disabled depending on the operator's preferences. More advanced capabilities, like RDS, can be added to the service package if so desired. **CT2**

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