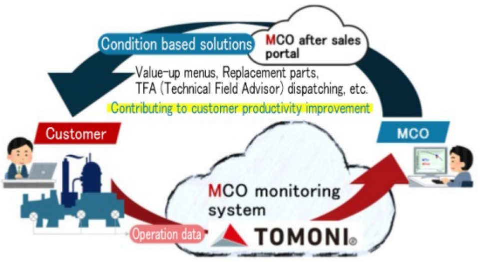
Proposal of Condition-based Solutions Using Remote Monitoring System

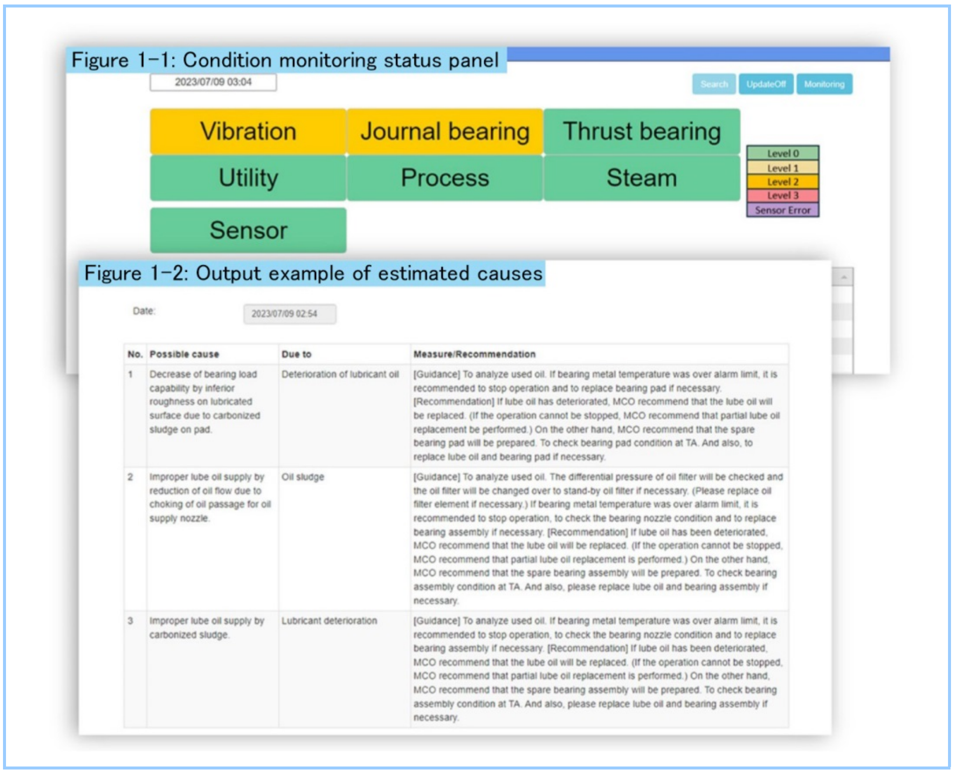


Sales Group
Customer Service Center
Mitsubishi Heavy Industries Compressor Corporation
https://www.mhi.com/group/mco/

Nowadays, digital transformation (DX) is attracting attention in the manufacturing industry and there is a growing need to provide new services and to change business processes with customers. Accordingly, Mitsubishi Heavy Industries Compressor Corporation (MCO) is aiming to introduce a remote monitoring system as a tool to provide better services to customers and to offer solutions that suit the actual operating conditions. MCO will provide customers with attractive services by using this remote monitoring system, which enables the detection and understanding of changes in machine conditions at an early stage, the quick analysis of the causes based on real-time data, and then the proposal of optimal solutions.

1. Menu of monitoring system operated by customer

This monitoring system is operated by the customer themselves. When the system detects signs of an anomaly, it sends a notification to the customer, and the customer can check in which area the anomalies are occurring and perform an emergency analysis of the cause by the customer themselves. When further detailed analysis of the cause is required, the customer can contact MCO, which will remotely propose countermeasures using real-time data. The available menu items of this monitoring systems are shown below, but the menu can be tailored to meet the needs of the customer.



No.	Possible cause	Due to	Measure/Recommendation
1	Decrease of bearing load capability by inferior roughness on lubricated surface due to carbonized sludge on pad.	Deterioration of lubricant oil	[Guidance] To analyze used oil. If bearing metal temperature was over alarm limit, it is recommended to stop operation and to replace bearing pad if necessary. [Recommendation] If lube oil has deteriorated, MCO recommend that the lube oil will be replaced. (If the operation cannot be stopped, MCO recommend that partial lube oil replacement be performed.) On the other hand, MCO recommend that the spare bearing pad will be prepared. To check bearing pad condition at TA. And also, to replace lube oil and bearing pad if necessary.
2	Improper lube oil supply by reduction of oil flow due to choking of oil passage for oil supply nozzle.	Oil sludge	[Guidance] To analyze used oil. The differential pressure of oil filter will be checked and the oil filter will be changed over to stand-by oil filter if necessary. (Please replace oil filter element if necessary.) If bearing metal temperature was over alarm limit, it is recommended to stop operation, to check the bearing nozzle condition and to replace bearing assembly if necessary. [Recommendation] If lube oil has been deteriorated, MCO recommend that the lube oil will be replaced. (If the operation cannot be stopped, MCO recommend that partial lube oil replacement is performed.) On the other hand, MCO recommend that the spare bearing assembly will be prepared. To check bearing assembly condition at TA. And also, please replace lube oil and bearing assembly if necessary.
3	Improper lube oil supply by carbonized sludge.	Lubricant deterioration	[Guidance] To analyze used oil. If bearing metal temperature was over alarm limit, it is recommended to stop operation, to check the bearing nozzle condition and to replace bearing assembly if necessary. [Recommendation] If lube oil has been deteriorated, MCO recommend that the lube oil will be replaced. (If the operation cannot be stopped, MCO recommend that partial lube oil replacement is performed.) On the other hand, MCO recommend that the spare bearing assembly will be prepared. To check bearing assembly condition at TA. And also, please replace lube oil and bearing assembly if necessary.

Figure 1 Anomaly sign detection alarm panel and output example of estimated causes

The monitoring system menu basically includes the following items.

1.1 Detection of anomaly signs

In order to take early countermeasures, the detection of anomaly signs at an early stage compared to alarm setting values set in a conventional DCS (Distributed Control System) is possible. The detection accuracy of anomaly signs is improved by the method described in Chapter 2 so that anomaly alarms are not issued frequently even with lower threshold values. This can be applied not only to centrifugal compressors and steam turbines, but also to other peripheral equipment. When anomaly signs are detected, the degree of anomaly can be recognized by the color on the status panel shown in **Figure 1**-1.

1.2 Cause analysis

After detection of equipment anomaly signs, cause analysis of the anomaly event is performed using the actual operation data and MCO's knowhow, and the top three estimated causes are output. The output includes recommended countermeasures for each cause, so that initial countermeasures can be taken. When further detailed analysis is required, the customer can contact MCO, which will analyze and make recommendations using real-time data. Figure 1-2 shows an output example of estimated causes.

1.3 Performance monitoring

This system, into which the planned performance curve data (or the performance curve data obtained in the performance test) of the centrifugal compressor and steam turbine showing healthy machine properties and gas composition and steam table database are incorporated, has a digital twin functionality that can evaluate the performance by comparing the planned and actual operating points through real-time calculation of the performance according to the gas composition, pressure, and temperature variations of the gas and steam. With this functionality, performance degradation is detected at an early stage, and evidence data is output that can be used to plan countermeasures such as cleaning the compressor impeller. **Figure 2** shows output examples of compressor performance monitoring.

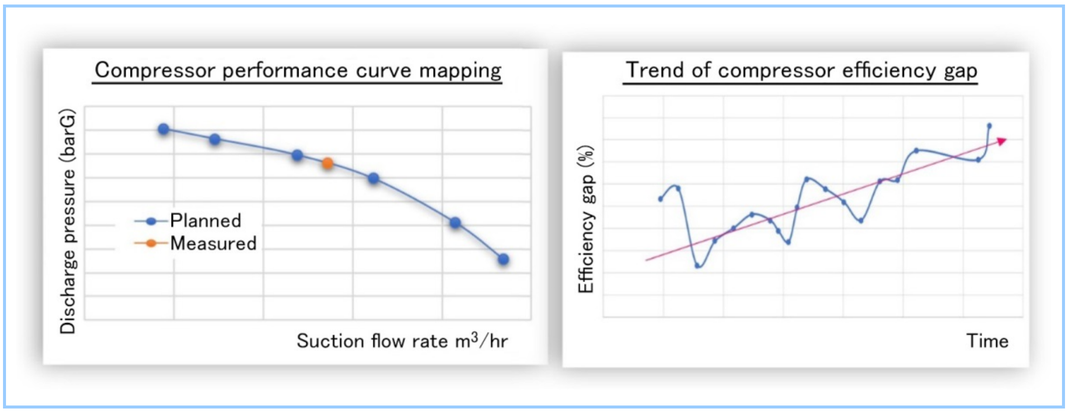


Figure 2 Example of compressor performance monitoring

2. Anomaly signs detection technology

In order to detect signs of machine anomaly at an earlier stage than alarm setting values set in the conventional DCS, a statistical method called the MT method (Mahalanobis-Taguchi Method) is used to detect differences from normal operations. However, the bearing temperature of a rotating machine fluctuates with changes in the rotating speed, so avoiding an alarm from being issued with false detection of anomaly signs due to this has been a problem. **Figure 3**-1 shows change in the rotation speed, and Figure 3-2 shows the MD value[(*)], which is the output of the MT method for the bearing temperature at this time. It is indicated that the bearing temperature rises as the rotating speed increases, and as a result, the MD value rises and exceeds the threshold value. To avoid false alarms caused by adherence to the rotating speed, a prediction formula using the rotating speed, etc., is prepared, and the gap between the predicted and measured values shown in Figure 3-3 is monitored to avoid false detection and improve detection accuracy. (Figure 3-4 shows the predicted and measured values.) Any difference from the normal operation is detected by the MT method, and, as with an engineer, whether the difference from the normal operation is a variation due to the rotating speed is checked using the prediction formula. The case shown in this example is a variation due to an increase in the rotating speed, not an anomaly of the machine. In this way, a mechanism to detect signs of machine anomaly based on the characteristics of the rotating machine is adopted.

Once anomaly signs are detected, the system can output the top three estimated causes and their recommended countermeasures upon specifying the date and time, so that initial countermeasures can be implemented based on the output.

* MD value: A numerical value that expresses the distance of the target operating point with respect to the reference set of learned data, called the Mahalanobis distance. The further away from the learned data set, the larger the value becomes. This system uses the MD value as an indicator of the anomaly degree.

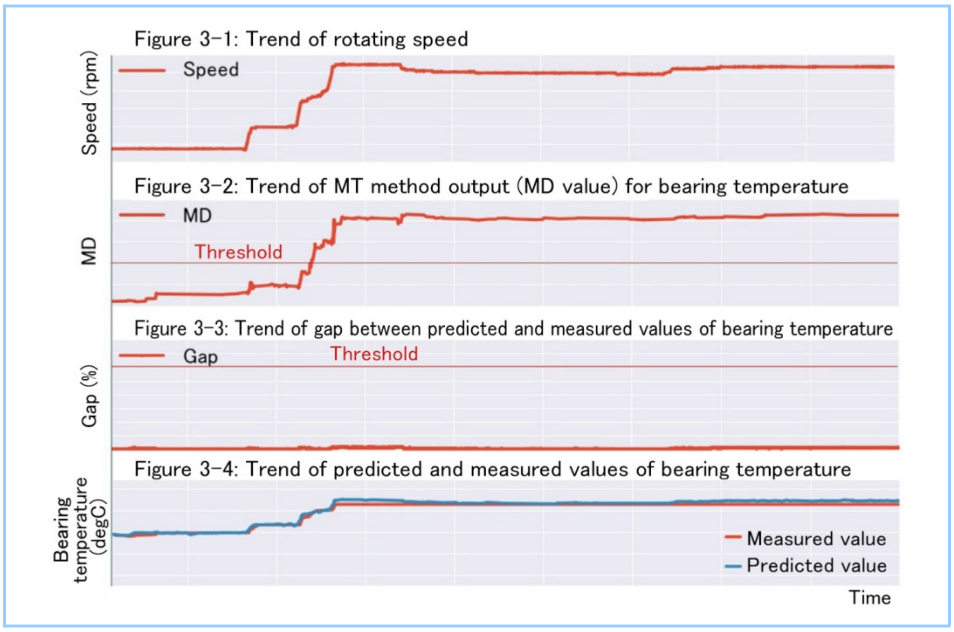


Figure 3 Variation of MT method output with change in rotating speed

3. Monitoring system and coordination with portal

MCO has an after-sales portal (hereinafter referred to as "AS Portal") as a contact point for customers, and uses it as a tool for information sharing and communication with customers. Once the monitoring system detects anomaly signs, the alarm information is sent to the customer via the AS Portal. The report also includes related information, such as a value-up menu that describes improved versions of the parts listed on the AS Portal and public information on similar events in the past, to provide the necessary information when it is needed. In addition, access to the monitoring system can be made through the AS Portal to view trend data and diagnostic results. By connecting the customers around the world with the MCO office, which is located remotely, via the AS Portal, MCO can communicate with them using real-time data and aim to provide services that make them feel close by.

The monitoring system uses the cloud environment of Mitsubishi Heavy Industries, Ltd.'s TOMONI® intelligent solution, which has been proven in power generation plants. This ensures the security required for critical infrastructure and satisfies the service level required for system maintenance and operation.

4. Future prospects

MCO will develop system menu items and services that will be appreciated by the customers and will provide services that will contribute to improving the productivity of their plants. In addition, MCO will consider introducing an automatic response system that can respond 24 hours a day, 7 days a week, aiming to provide services that do not keep the customers waiting.