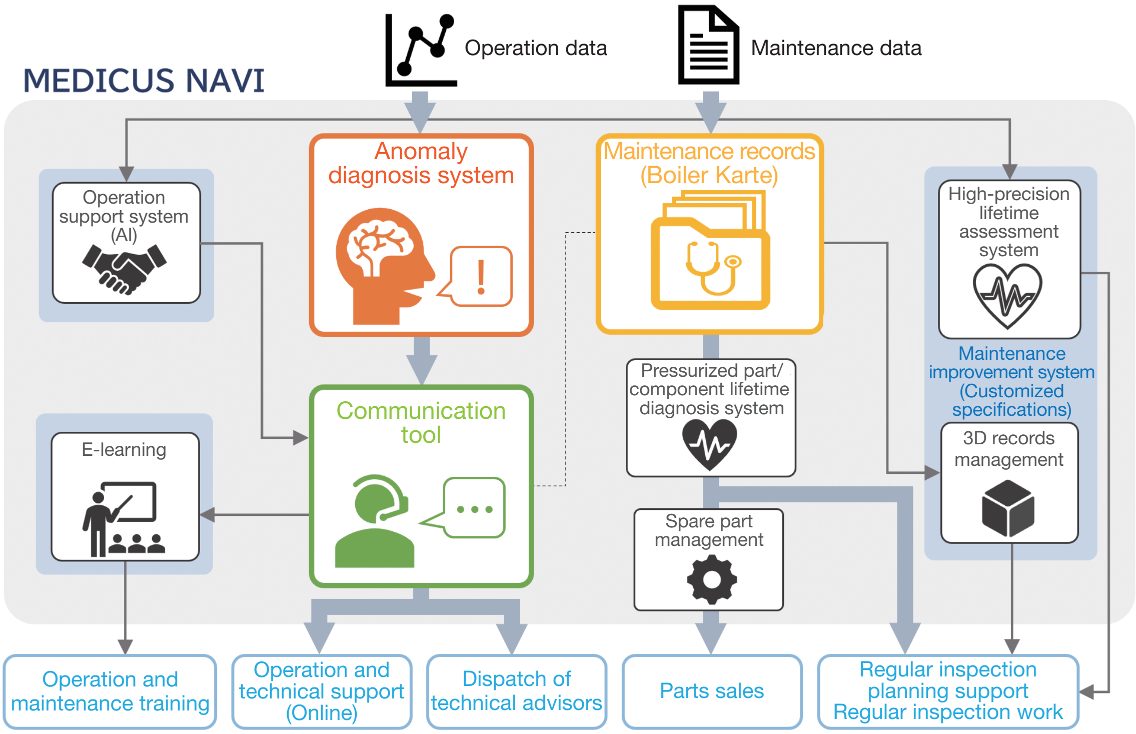
Efforts of Maintenance and Operation Support for Thermal Power Boilers

MEDICUS NAVI®, an operation and maintenance support system using remote monitoring technology, and a new inspection and assessment technology

The operation and maintenance support system MEDICUS NAVI uses remote monitoring technology to assess the operating states of boilers, which leads to the improvement of operating efficiency and operability of thermal power plants. In addition, our new inspection and assessment technology checks the soundness of thermal power plants, contributing to increasing their operating rate.



Schematic diagram of MEDICUS NAVI system

Introduction

Because thermal power plants play a role for the stable supply of power, their stable operation is required for the time being while society goes through the process of decarbonization. In addition, in order to increase the operating rate of thermal power plants, prolonging the intervals and shortening the periods of regular inspections are required.

Amid this situation, IHI is making efforts to improve the efficiency of maintenance by utilizing digital technologies and a new inspection and assessment technology. This article describes the operation and maintenance support system that uses remote monitoring technology to contribute to the improvement of operating efficiency and operability of thermal power plants, and the new inspection and assessment technology that leads to increasing their operating rate.

Operation and maintenance support system MEDICUS NAVI

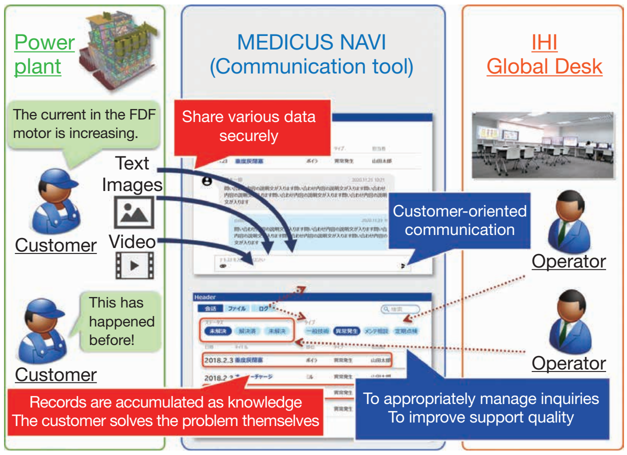
Operating a boiler is critical to operate a thermal power plant. The boiler combusts fuel to supply steam that is used to generate power. IHI has a long history as a manufacturer of boilers and has delivered them all over the world. With the recent acceleration of decarbonization in the world, the number of newly constructed thermal power plants has decreased, and the current main issue for plant facility manufacturers is how they can maintain competitiveness in the maintenance and modification of existing plants. Moreover, in Japan, reduction in CO_2 emissions from power generation and quick response to power generation adjustments according to changes in power demand are required at the same time. Thus, there is an even greater need to operate thermal power plants stably than before. Therefore, aiming at providing operation support to thermal power plants based on remote monitoring technology, various manufacturers are developing new systems for these plants so that they can increase the operating rate and power generation efficiencies, reduce CO_2 emissions, and improve the responsiveness to power demands.

IHI has come up with the idea of providing services specific to boilers using the engineering expertise accumulated thus far. Based on this idea, IHI has developed MEDICUS NAVI, a system that connects IHI with customers so that they can share the huge amount of operation and facility maintenance data and come up with the best solutions together. MEDICUS is a Latin word meaning "medical practitioner." The MEDICUS NAVI system was developed for the purpose of reaching out to customers and guiding them as a "doctor of boilers" until their boilers' symptoms improve. As of 2022, it works as an anomaly diagnosis system, communication tool, and maintenance record keeper for boilers. Its demonstration experiments were carried out at thermal power plants in Malaysia and the assessment of its operation status is underway.

(1) Anomaly diagnosis system

The anomaly diagnosis system of MEDICUS NAVI detects a small anomaly in a thermal power plant based on the operation status, and then sends that information to the customer along with advice on how to respond before a serious alarm related to operation stops goes off. This reduces the frequency of emergency stops of the thermal power plant, contributing to increasing the boiler operating rate.

This system diagnoses anomalies in a thermal power plant while it is in operation. It analyzes the operation data and onsite measurements of the plant to set anomaly indices, and then sends notification of an anomalous state when it deviates from normal. This buys the operator some time before a sudden emergency stop occurs, allowing them to start preparing to stop the anomalous operation such as by switching operation of the plant.



Conceptual diagram of communication tool

Setting the various anomalies to be detected must be done according to the configuration of the thermal power plant facilities. MEDICUS NAVI helps the customers who operate thermal power plants determine the necessary detection items.

(2) Communication tool

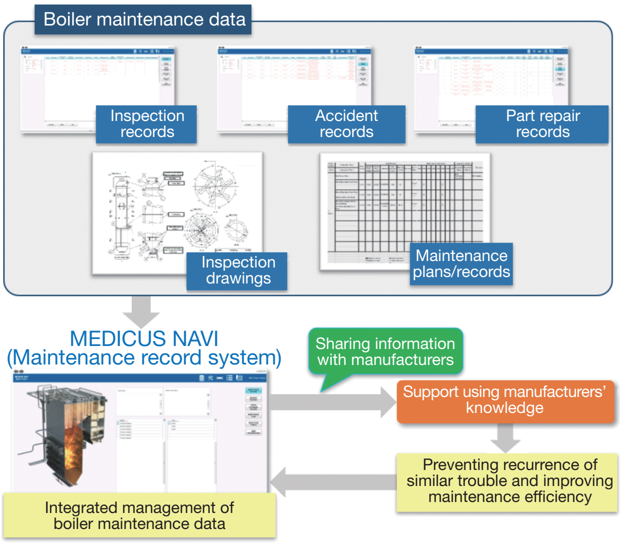
MEDICUS NAVI has a communication tool for responding to customers' inquiries to give them the support they need. This tool has a chat function to provide a quick response while checking the status of the thermal power plant. Managing and utilizing the records of this tool make it possible to suppress the recurrence of similar trouble. Phone calls and emails have been used to communicate with customers in the past, but this tool offers a chat format. In addition, data such as images and videos can easily be shared with customers.

Moreover, the accumulated past inquiries are collected and stored systematically to turn information into knowledge. We will improve this system so that customers can search for similar past abnormal phenomena themselves and can analyze and respond to abnormal incidents independently.

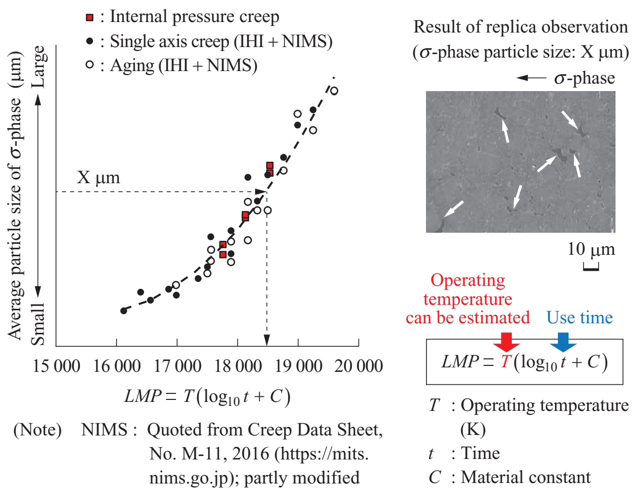
(3) Maintenance records (Boiler Karte)

Utilizing the maintenance record function enables integrated management of past maintenance data and organization of the maintenance records, which makes it easy to search for information and create a maintenance plan based on the boiler degradation data.

In the past, when maintenance data were recorded on paper, cumbersome information processing work was needed for each maintenance plan, including finding records on each area and chronologically ordering the records. Integrating maintenance data with the maintenance record function leads to eliminating the difficulty in linking data between different systems where each piece of equipment uses its own data recording system, and it enables handing over the maintenance data of a plant in long-term operation to the next operator without having to reorganize them.



Schematic diagram of maintenance records (Boiler Karte)



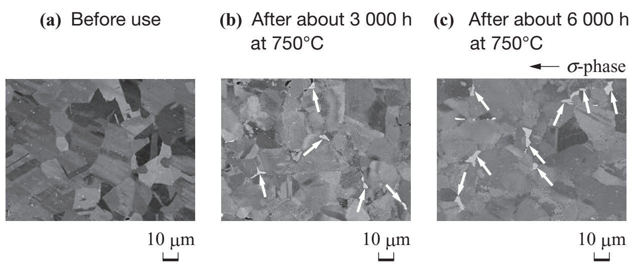
Temperature estimation curve of 18Cr-9Ni-3Cu-Nb-N steel (KA-SUS304J1HTB, ASME Code Case 2328)

New inspection and assessment technology leading to increase in operating rate of thermal power plants

(1) Lifetime assessment method of stainless steel

Excellent in high temperature strength and high temperature oxidation resistance, stainless steel is used for the heat transfer tubes of ultra-super critical boilers (USC boilers). Operation of USC boilers started more than 20 years ago, and some cases of creep damage in stainless steel have been reported in recent years. For this reason, in order to ensure stable operation of boilers, it is extremely important to establish a creep life assessment method of stainless steel. In general, the creep life depends on stress and temperature, temperature having the greater effect. The lifetime can be accurately evaluated based on creep rupture data if the operating temperature of the material is estimated. Therefore, we studied how to estimate the operating temperature by focusing on the change in microstructures of stainless steel while in use under a high temperature.

A type of stainless steel known as 18Cr-9Ni-3Cu-Nb-N steel (KA-SUS304J1HTB, ASME Code Case 2328), was used to conduct creep rupture tests, and then the cross-sectional observations were conducted. In the results, σ-phase (intermetallic Fe-Cr compound) was observed



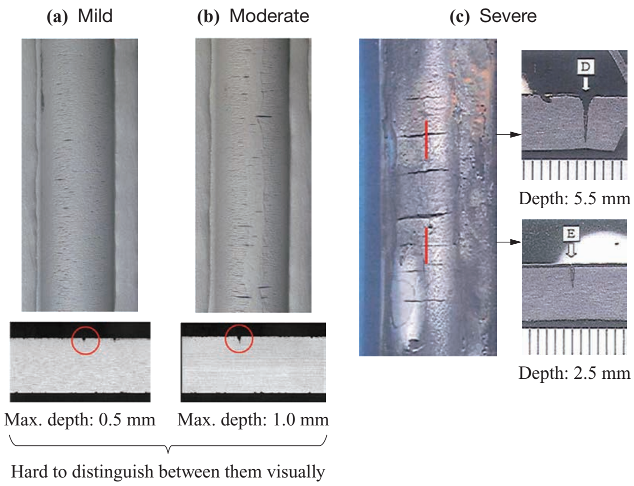
Microstructural changes of stainless steel during creep tests

on grain boundaries, and the particle size of the σ-phase was larger for longer test hours. Quantitative measurement of the σ-phase particle size on grain boundaries revealed that the particle size of σ-phase follows the Larson-Miller parameter (*LMP*), which is a function of temperature and time, regardless of the stress state. Therefore, the operating temperature (T) of a heat transfer tube can be estimated using the σ-phase particle size and the use time (t) of the tube. Also, based on this estimated temperature, the stress applied on the tube and the creep rupture data, a lifetime assessment of the heat transfer tube can be conducted. This assessment method can be applied using the replica method. The replica method is a nondestructive inspection method that transfers the metal structure of a real sample surface to a replica film. The σ-phase can be distinguished from other precipitates by its size, shape, and precipitation position.

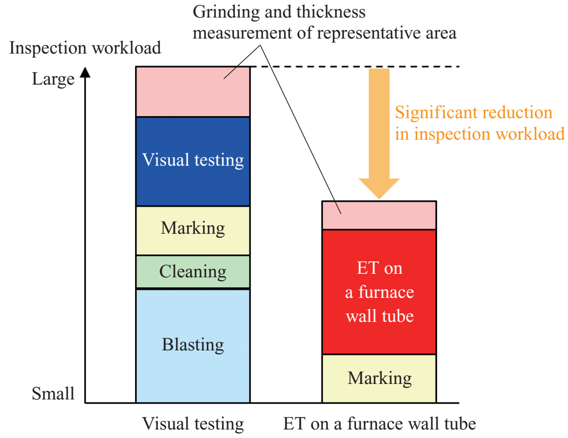
The description above shows that this method can accurately conduct lifetime assessment of stainless steel without destroying actual components.

(2) Fire crack inspection using eddy current testing

Because furnace wall tubes are used under a hot and corrosive environment in thermal power boiler, they often suffer from damage such as sulfidation corrosion and fire crack (elephant skin). Among them, fire crack, which is a type of corrosion fatigue, is caused by a corrosive environment in the furnace, fluctuations in heating by fire and the like. Inspection for fire crack is often conducted visually after ash and scale are removed by blasting or in other ways. However, assessing crack depths by visual testing is difficult and blasting takes time. We found that this problem can be solved by applying eddy current testing (ET) to furnace wall tubes. Its verification results are described below. ET is a method of inspecting the surface layer of an object by detecting changes in eddy currents caused by electro-magnetic induction. Cracks on a surface cause disturbances



Typical examples of fire crack



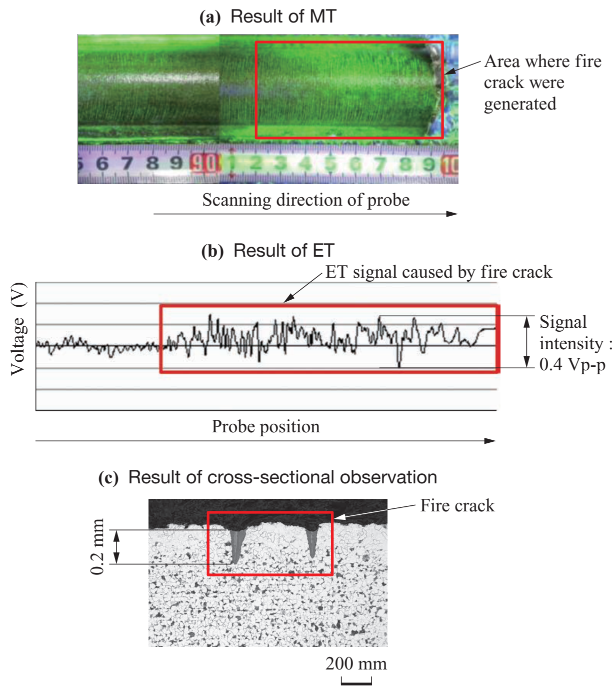
Reduction in inspection workload using ET

of eddy currents, which are then detected with a coil.

First, crack detectability and the assessment of crack depths were verified under the condition that ash and scale were deposited. For this verification, we prepared three test pieces with slits to simulate cracks. And the pieces were coated to different thicknesses by thermal spraying. Signal intensity was measured before thermal spraying. After that, signal intensity of test pieces made to simulate the deposition by thermal spraying was measured. Scanning a detecting probe produced signals at each slit and the signal intensity corresponded to the slit depths. The signal intensity obtained from thermal-sprayed test pieces was about a half of that from test pieces before thermal spraying, while there were little differences in signal intensity due to coating film thicknesses.

Next, ET was applied to the material extubated from the actual plant where fire crack was observed. ET signal intensity increased at the area where some indications were observed by magnetic particle testing (MT). Cross-sectional observation was conducted at the position with high signal intensity. In the result, cracks were observed at the outer surface, and their depths measured up to 0.2 mm. This value was about the same as the crack depth estimated from the previous tests on the thermal-sprayed test pieces. These results show that ET can detect fire crack and assess its depth.

Applying ET to the inspection of fire crack on furnace wall tubes can eliminate hours of work for blasting and cleaning that were conducted before visual testing. This can achieve maintenance with significantly shorter inspection time.



Example of application to a real component

Conclusion

Amid the accelerating transformation to a decarbonized society, thermal power plants as energy sources are facing difficult challenges. Forecasting the degradation of thermal power plants will be difficult in the future because the changes in operation will prolong the intervals between regular inspections. IHI will obtain operation status using digital technologies, utilize new methods of inspection and assessment, and new repair technologies. In addition, the ideas, know-how, and algorithms of optimization and remote monitoring of operation and maintenance established in MEDICUS NAVI for thermal boilers will be utilized and expanded to carbon solution businesses in the future.