Advanced Operation and Maintenance Service for Thermal Power Station by ICT

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IHI has developed the advanced operation and maintenance assistance system of the thermal power stations with customers by the latest digital technologies. The operation assistance services, in addition to the manual remote monitoring and consultation service by our operation experts, realize minimum unplanned shutdown period by the automatic diagnosis system. IHI aims to help determine the appropriate scope and schedule of the parts replacement with the maintenance assistance services. The system precisely estimates the residual life of the boiler parts to optimize the replacement interval. The three dimensional drawing system visualizes the repair and maintenance history of the parts to help judge which parts should be replaced.

1. Introduction

The latest digital technology has made it possible to analyze large amounts of operation data, display the data in easily understandable ways, and store past operation data that facilitates evaluation of the current operation condition; this provides thermal power stations, which operate while monitoring large amounts of data, with very useful information in a timely manner.

As before, thermal power stations serve as a baseload power source, but their responsibilities have grown because of the increasing proportion of renewable energy power sources resulting from accelerating decarbonization. For example, they also serve as a power source that complements renewable energy, whose output increases and decreases depending on weather conditions. In some developing nations, power generation facilities suffer from frequent unplanned shutdowns, resulting in an unstable power supply. In addition, there are cases in which fossil fuel consumption is increased in order to deal with decreases in generating efficiency, resulting in increased burden on the global environment.

IHI, as a supplier of thermal power boilers, has developed digital systems that support customers' boiler operation and boiler facility periodic inspection planning, enabling their thermal power stations to continue to operate stably. This paper gives a description of those systems.

2. Boiler operation support

2.1 Background and challenges of operation support

Mainly in Southeast Asia and Africa, IHI offers its customers operation support services to improve the utilization rate and efficiency of their facilities. **Figure 1** shows IHI Global Monitoring Centers. Operation data for each power station is collected at the centers in real-time, and monitored and analyzed by IHI's experts. While observing the power station operation data, IHI's experts provide advice depending on

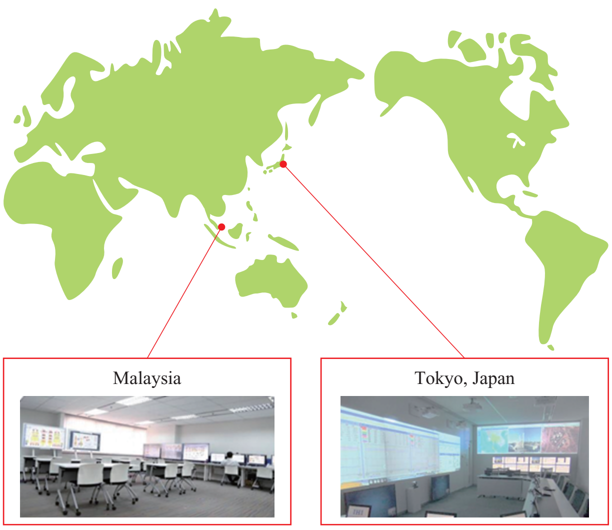

Fig. 1 Remote monitoring centers

relevant changing characteristics, and may go on site to make necessary adjustments. In addition, IHI offers solutions for the further improvement of utilization rate and efficiency by performing analyses using a combination of facility inspection results and operation data. However, manual monitoring leads to limitations on available time and the number of facilities that can be monitored. Therefore, IHI is aiming to provide more sophisticated monitoring with reduced manpower through automatic diagnosis with ICT.

2.2 Approaches to monitoring and support

IHI uses three approaches to operation monitoring: monitoring by IHI's experts, stability diagnosis (automatic), and immune diagnosis (automatic).

(1) Monitoring by IHI's experts

From power stations all over the world, operation data is collected at the monitoring centers and monitored by IHI's experts. If any problem with operation is discovered, these experts contact and visit the customer in order to offer full support for solving the problem. Because there is a limit to the monitoring that can be performed by humans, the following ICT systems are used to enable efficient monitoring.

(2) Stability diagnosis (automatic)

IHI independently developed a system based on statistical machine learning techniques[(1)]. The system automatically detects any operation condition that deviates from previously accumulated plant operation condition data. If an operation condition that has never been experienced occurs, then the plant's operation condition is evaluated by IHI's experts, as described in (1).

(3) Immune diagnosis (automatic)

An anomaly detection system based on problems that IHI has previously experienced automatically detects the recurrence of anomalies that have been experienced in the past.

2.3 Example of anomaly detection (coal ash problem)

The following is an example of anomaly detection using immune diagnosis. In boilers used in coal-fired power stations, ash is generated when fuel coal is burned, and accumulates on the heating surface. **Figure 2** shows the accumulation mechanism[(2)]. When no ash has accumulated, molten ash particles attach to the heating surface, but solid particles rebound from it. When ash has accumulated to a certain extent, the accumulated ash acts as a thermal insulator on the heat transfer tube, and melts as the surface temperature rises. This molten material captures solid particles, accelerating ash accumulation. The accumulated ash is removed periodically with the soot blower. However, if the accumulated amount exceeds a certain limit, the ash adheres firmly, hindering normal operation.

This kind of ash problem cannot easily be evaluated with existing monitoring systems, and may become a major cause of unplanned shutdown of a boiler plant.

Using this diagnostic system developed by IHI, the extent of heat transfer hindrance due to the ash problem can be directly expressed as an index which indicates how much

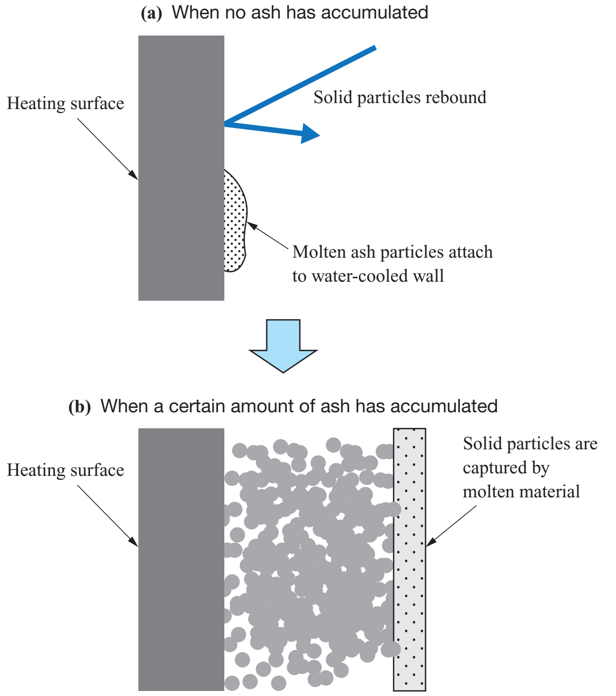

Fig. 2 Mechanism of the ash accumulation

each heating surface is fouled. **Figure 3** shows an example of the dirtiness index (the greater the value, the more heat transfer is hindered) indicating the state of the ash problem on heating surfaces. Lines 1, 2, and 3, which indicate the trend followed by the dirtiness index, show that severe ash accumulation on the heating surfaces caused an unplanned shutdown. The dirtiness index shows a higher value than for normal operation, and we confirmed that it enables visualization of the ash problem by quantifying the degree of fouling on heating surfaces. Based on this index, IHI proposes changes of operation conditions (e.g., increasing the output of the soot blower) so as to avoid unplanned shutdowns.

3. Support for boiler periodic inspection planning

3.1 Objective of support

The objective of support for periodic inspection planning is to present — in an easily understandable manner — the data that is necessary to appropriately determine the scope of inspection and renewal performed during the periodic inspection of a thermal power station.

If the scope of inspection and renewal is too wide, inappropriate determination could lead to a prolonged period of periodic inspection or increased maintenance costs. Conversely, if the scope is too narrow, an area where there is concern over possible damage may be overlooked. If damage occurs during operation, this will result in reduced operation time due to boiler shutdown and damage recovery. Therefore, thermal power stations are required to formulate appropriate maintenance planning for periodic inspections, and they are making a great effort aimed at achieving this on a daily basis.

In addition, boilers have a complicated structure and have

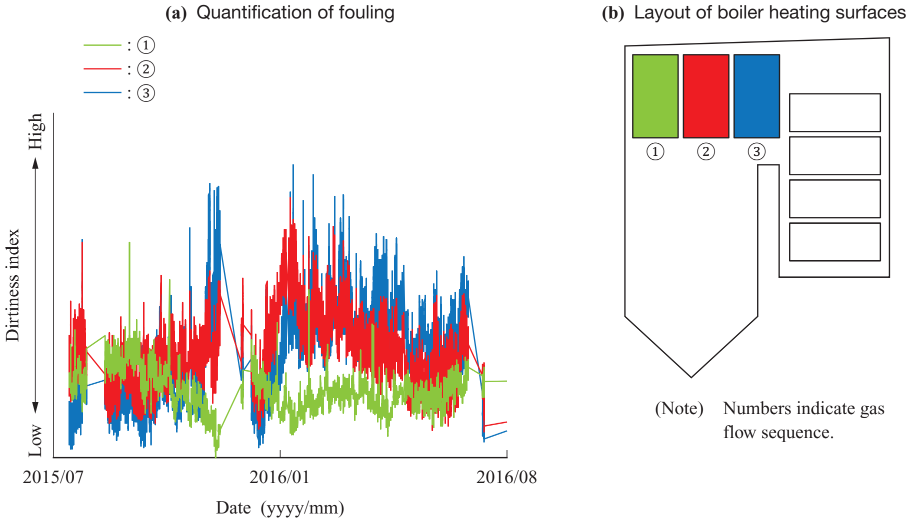

Fig. 3 Visualization of the ash accumulation

several paths for heat exchange, such as the economizer, furnace, superheater, and reheater. These paths consist of several hundreds to around one thousand heat transfer tubes. The tubes have a three-dimensional structure and are of considerable length, so that, for other than experienced personnel, it tends to be difficult to determine which tube and what part of the tube should be inspected or renewed. Therefore, in order to overcome this complexity, it is important to be able to express data in an easily understandable manner, and this poses a considerable challenge to our customers.

3.2 Boiler Maintenance Plan & Record

Boilers are used for 40 to 50 years or longer, during which repairs are necessary. Therefore, customers who operate thermal power stations record details of the maintenance conducted on all facilities, and maintain these records from the start of operation until the present time. These records, together with the situation during operation, are taken into account when planning details of the maintenance to be conducted during periodic inspection. Naturally, if unacceptable damage is discovered during periodic inspection, relevant repairs are carried out.

At the same time, IHI, as a boiler manufacturer, also records any damage that has occurred in the boilers it has delivered, together with corresponding repairs and details of preventive maintenance that has been conducted. IHI calls these records the ‘Boiler Maintenance Plan & Record.’ An example is shown in **Fig. 4**.

If the above information can be mutually confirmed by the customer and us (the manufacturer), formulating an inspection or renewal plan for periodic inspection becomes more efficient and effective. Therefore, we decided to share this information with customers.

Figure 5 shows an example of a Boiler Maintenance Plan & Record, into which customer information has been consolidated as data. The shared information has been systematically classified and computerized so as to construct a history management database. This has provided improved browsability through searches and narrowing down of information, and contributed to enhanced efficiency, because drawings, work records, and various reports are electronically linked to each other. In addition, measurement results are also stored as data, making it easy to understand aging and other trends.

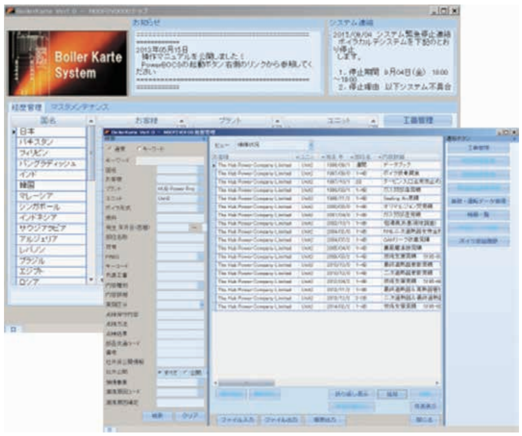

Fig. 4 Example of main screen in Boiler Maintenance Plan & Record

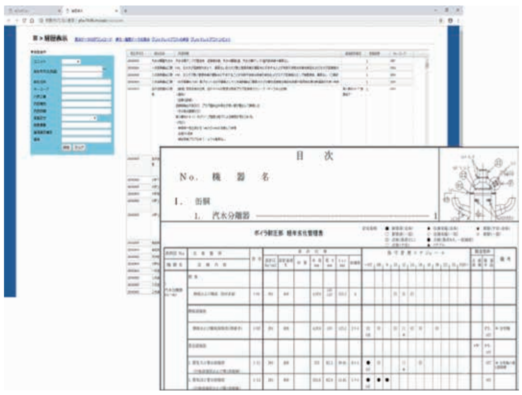

Fig. 5 Example of detailed customer data in Boiler Maintenance Plan & Record

3.3 3D maintenance history management system

Figure 6 shows the structure of a boiler. A boiler has a bundle of tubes that form each path. For example, the red area is a final superheater, which consists of approximately 500 heat transfer tubes suspended from the ceiling. Other paths are configured in a similar same way, and the walls shown in the figure also consist of heat transfer tubes. The total number of heat transfer tubes is approximately 8 000, and the total length would be approximately 700 km if all the tubes were connected together. Nevertheless, the boiler must be shut down if any one of the tubes is damaged.

With regard to such heat transfer tubes, it is extremely important for history management to have accurate positional information relating to maintenance history, such as where the damage occurred and what part was renewed due to aging or other reasons.

However, confirming positions in an actual boiler is surprisingly difficult when using the 2D drawings that remain as records. Representing such positions within the boiler using a 3D model makes them easy to confirm. In addition, color-coding the timing of renewal allows easy understanding of deterioration trends. **Figure 7** shows an example of 3D representation. In this way, if renewal history can be confirmed using a 3D model, it becomes easy to understand the scope of the next renewal, raising expectation that all necessary actions during periodic inspection can be planned without omission.

3.4 Life management system

When examining the scope of renewal of a boiler, various causes of damage are taken into consideration, and the scope of renewal is determined after confirming damage status through inspection and measurement. For example, for welds and tubes, corrosion, wear, deformation, remaining thickness, cracks, and creep life are taken into consideration. During periodic inspection, IHI provides support through non-destructive testing, etc., but it is difficult to inspect everything in a short time. It is therefore common for the scope of inspection to be narrowed down, and IHI has developed a life management system as part of its support for examining the scope of renewal.

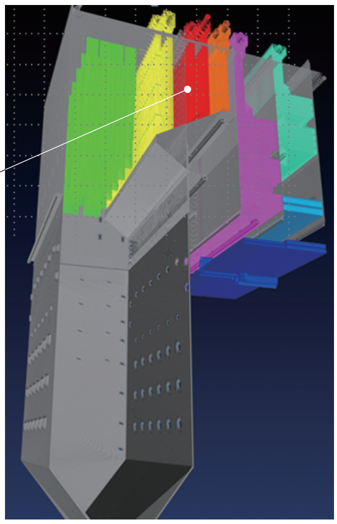

Fig. 6 Boiler structure

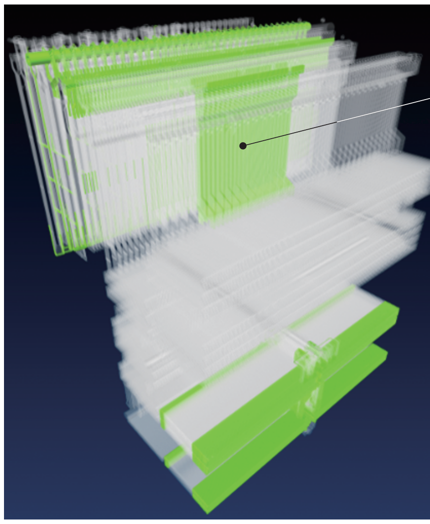

Fig. 7 Visualization of repair history with 3D model

The aim of the life management system is to evaluate the life of individual boiler heat transfer tubes based on the operation data. This is because, as previously described, if even one tube is damaged, the boiler is forced to shut down, resulting in an unplanned shutdown of the entire power station. Estimating the accurate life requires measuring the temperature of each tube, but it is difficult to measure all the tubes with thermocouples because there are too many of them and the ambient temperature around the heated areas is extremely high. Therefore, we installed a sufficient number of sensors in the unheated area of each path outlet to accurately estimate the temperature distribution in the path. **Figure 8** shows an example of sensor (thermocouple) installation. This is for a reheater. When the life management system was built, thermocouples were added to those that had been installed at the time of and after construction of the power station, so that approximately one-ninth of all tubes had a thermocouple, allowing efficient representation of the temperature distribution in each path. **Figure 9** shows the temperature distribution.

In addition, by analyzing the correlation between the temperature distribution and operation data obtained after the addition of the thermocouples, and by applying analytical techniques used in the design stage, it has become possible to estimate the temperature distribution before the addition of the thermocouples in the same manner as after they were added.

The main causes of damage, including creep life, steam oxidation, and high temperature oxidation, are mainly related to the metal temperature. The accurately estimated steam and metal temperatures of each tube shown in **Fig. 9** are extremely useful for evaluating tube life. In addition, if wear caused by coal ash in the area where the soot blower is installed and other thickness reduction are observed, the life of each tube is evaluated with the thickness reduction of the tube taken into consideration.

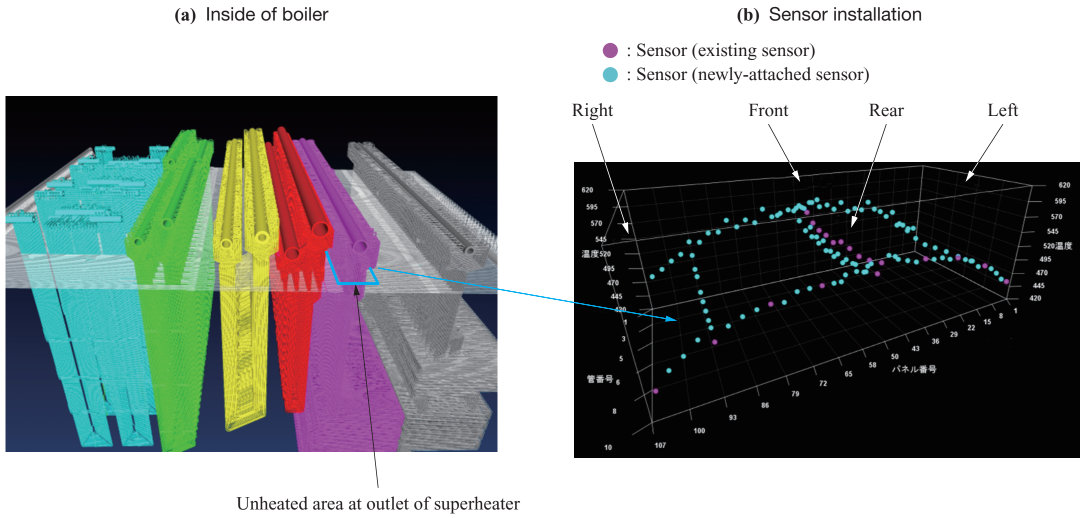

Fig. 8 Example of sensor installation

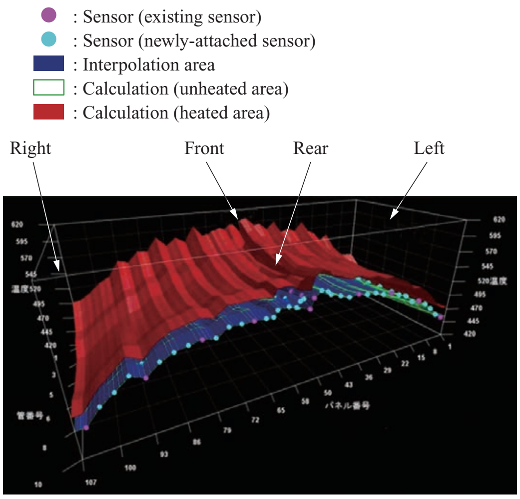

Fig. 9 Distribution of metal temperature at heated and unheated area

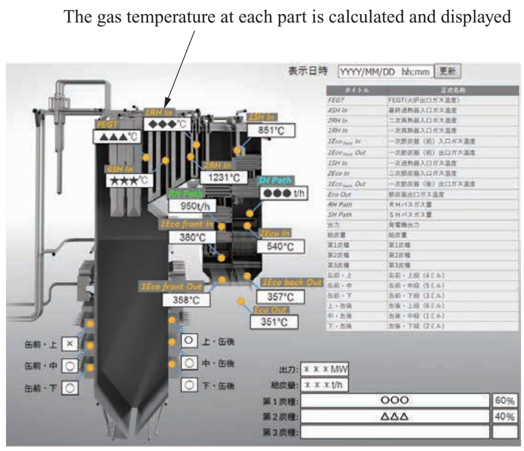

Fig. 10 Sample of boiler model calculations

In the above-mentioned life analysis, almost all operation parameters affect the life of each tube, and we therefore quantified all the internal conditions of the boiler, such as the heat flux and gas temperature of each part, and amount of gas distributed to the heat transfer area at the rear[(3)]. IHI calls this 'boiler model.' The model automatically determines the stable state of boiler operation, calculates the current internal conditions in a nearly real-time manner, and updates relevant graphics. An example is shown in **Fig. 10**. In this figure, the gas temperature information is considered useful for monitoring slagging and fouling with different coal types. Corresponding judgments have conventionally been made based on furnace observation results, amount of gas sprayed, gas distribution damper opening, etc., but it is expected that the gas temperatures at the outlet of the furnace and outlet of each path will offer new knowledge on ash attachment and accumulation, and provide new guidance regarding boiler operation.

4. Future prospects

4.1 Operation support

When a boiler is in an abnormal condition, it is extremely difficult to determine whether to shut it down. With a guidance that considers operation conditions and unit characteristics in order to help determine the necessity of shutting down the boiler, the spread of damage can be prevented and renewal work needed for restoration minimized. To achieve this, we intend to investigate how we can provide more accurate and reliable guidance.

4.2 Periodic inspection support

In order to eliminate unplanned shutdowns of boilers, it is important to conduct all necessary inspections and repairs during periodic inspection. To achieve this, detailed monitoring of the condition of the boiler — which consists of heat transfer tubes — must be performed. We have already created a digital boiler model based on the results of measurement and operation condition analysis, and believe that life can be evaluated with relatively high accuracy.

Currently, this analysis is supported by the use of large numbers of thermocouples and sensors, but the required equipment represents a large capital investment for large thermal power stations. Therefore, we believe it necessary to investigate means of achieving greater simplification.

5. Conclusion

This paper has described the operation and periodic inspection support systems that we have developed as a boiler manufacturer with the aim of contributing to the stable operation with high utilization rate of thermal power stations. We believe that we can make these systems more useful and reliable by increasing accuracy through the accumulation of experience, and by incorporating the candid opinions of customers who actually operate power stations. We, as a boiler manufacturer, will continue devoting ourselves to achieving this goal. In addition, we hope that this paper will be helpful to thermal power station personnel and other interested parties.

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