Development of Control Maintenance Support System

ETO Ayaka[*1]　MOROOKA Nobuyuki[*2]　TOMINAGA Futoshi[*3]

Abstract:

JFE Steel has been working on improving the efficiency of maintenance work using ICT. As part of this effort, we promoted the construction of a system that allows maintenance personnel to browse necessary materials on site using a tablet terminal during failure recovery work. As part of these activities, we built the first control equipment failure recovery support system ("J-mAIster™") using AI technology in domestic steel industry and introduced it to all steel works and other works in September 2018. In this report, J-mAIster™ is introduced along with examples of effects.

1. Introduction

JFE Steel Corporation is one of the world's largest steel makers in terms of production scale. Its main production bases, as shown in **Fig. 1**, include two large integrated steel works, East Japan Works (Chiba District, Keihin District) and West Japan Works (Kurashiki District, Fukuyama District), with processes from the blast furnace through rolling, Chita Works, a specialty mill that produces steel pipes and tubular products, and Sendai Works, which mainly produces bars and wire rod material. All of these bases operate under a 24 hour-a-day, 365 day-a-year production system, and stable equipment operation is indispensable for ensuring a stable supply of these products to customers. Because quick failure recovery is extremely important when an equipment failure occurs, we successfully completed the construction of a failure recovery support tool that allows maintenance personnel to efficiently utilize information necessary in failure recovery at the site when failures occur at production lines. This paper reports the effects of the tool, including shortening of the recovery time and work time.

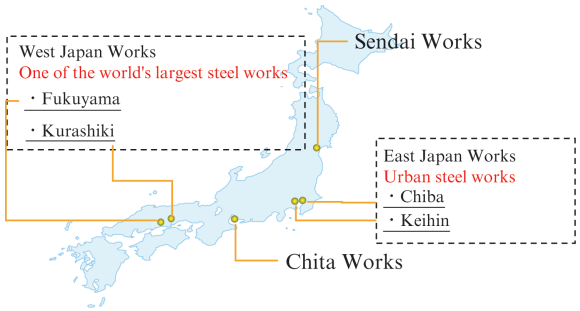

Fig. 1　Main steel works

2. Equipment Maintenance Work in Steel Industry

2.1 Role of Equipment Maintenance Work in Steel Industry

In comparison with other industries, the steel industry is an equipment industry with a high equipment investment rate as a ratio of sales, as shown in **Fig. 2** [2]. In equipment industries, stable equipment operation is essential for the production of products. Equipment maintenance work can be divided into two types, preventive maintenance to prevent failure in advance and failure recovery work for quick recovery after failures occur. This paper mainly discusses failure recovery work.

Failure recovery requires not only a specialized

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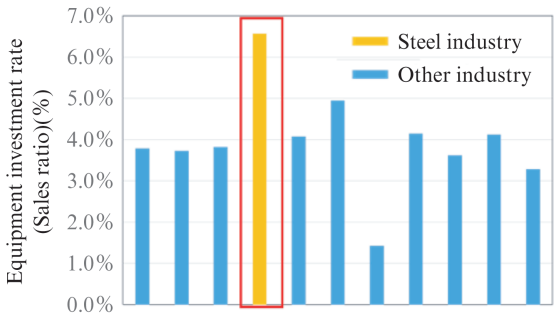
*1 Plant Control Technology Sec.,
Plant Control Dept.,
West Japan Works (Kurashiki),
JFE Steel

*2 Staff Deputy Manager,
Plant Control Technology Sec.,
(currently, Manager, Cold Rolling Plant Control Sec.)
Plant Control Dept.,
West Japan Works (Fukuyama),
JFE Steel

*3 General Manager,
Plant Control Dept.,
West Japan Works (Kurashiki),
JFE Steel,
(currently, General Manager, Kurashiki Construction Center, JFE Plant Engineering)



Source: Ministry of finance corporate statistics survey (2016)

Target: Companies with capital of 1 billion yen or more, excluding finance and insurance

Fig. 2 Equipment investment rate

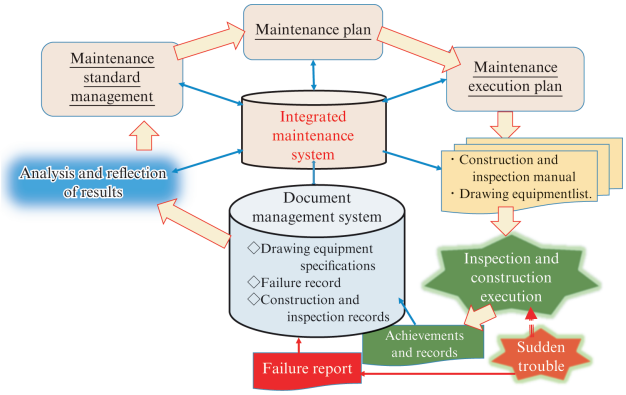


Fig. 3 Maintenance system in JFE Steel

knowledge of control and machinery, but also a wide range of knowledge that includes the operation procedures of steel manufacturing equipment, etc. Therefore, differences in the experience and knowledge of individual maintenance workers become evident in the time required for failure recovery.

2.2 Efforts and Issues in Equipment Maintenance Work

For stable equipment operation, JFE Steel has constructed and operates the JFE maintenance management system as a company-wide integrated system with the aim of achieving higher efficiency in maintenance work. In this system, it is possible to create maintenance standards, establish maintenance plans and manage budget and repair results. The PDCA cycle in maintenance work has been developed efficiently by utilizing this system, as illustrated in **Fig. 3**.

However, one issue in failure recovery work is the long periods of time required for control failure recovery. The background of this problem includes an increase in the necessary knowledge accompanying the introduction of diverse kinds of equipment and devices, including some manufactured in other countries, and a lack of knowledge and experience due to the retirement of skilled veterans. As can be seen in **Fig. 4**, the time required for failure recovery at Kurashiki District increased remarkably from 2008 to 2015.

As a countermeasure for this problem, the Kurashiki Plant Control Department began failure recovery support utilizing tablet terminals like that shown in **Fig. 5**. In this support system, data in the form of the past history of failures, information on spare parts and the operating procedure manuals necessary in failure recovery, which are stored in multiple servers, is periodically transferred to tablet terminals by manual operation, making it possible to browse the data on the tablet terminal screen.

Although it was found that this effort made it possible to shorten the failure recovery time by browsing the

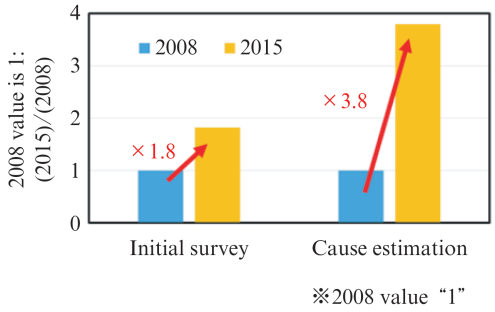


Fig. 4 Time taken for failure recovery (Kurashiki)

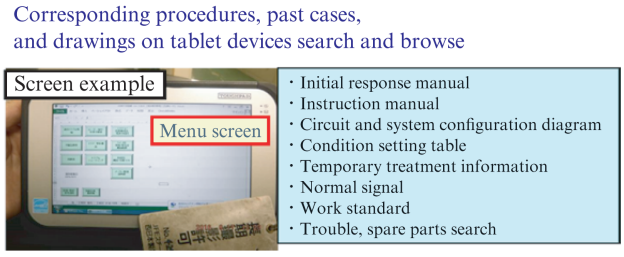


Fig. 5 Utilization of tablet terminal in maintenance work

necessary materials at the site using a tablet terminal, the data accumulated in the past was so-called unstructured data, consisting of accident reports, manuals and standards which were not compiled in a uniform format. Therefore, the extraction accuracy of words in texts by general search systems was poor, and excessive time was required when searching for documents from all data. In addition to these problems, maintenance workers also presented new requests for a search function for past examples of failures with a low frequency of occurrence, a function for linkage with synonyms and automation of linkage with recent data.

To address these needs, the authors began a study on the introduction of a system utilizing AI technology in the control division, which is responsible for a part of equipment maintenance work, to further shorten the failure recovery time by improving the level of the fail-

ure recovery support system. For searches, we adopted a text mining technology with excellent performance in extraction and analysis of words from unstructured documents.

3. Overview and Introduction of Functions of J-mAIster™

3.1 Introduction of J-mAIster™

AI technology generally refers to technologies in which a computer simulates the functions of the human brain. Among the various types of AI technology, in this system, we adopted "IBM Watson," a product of the American company IBM Corporation, as this technology prioritizes the concept of cognitive technology for support of human decision-making and also includes a powerful text mining technology.

JFE Steel named the new system J-mAIster™ and conducted initial operation at key steel processing lines at Fukuyama and Kurashiki. After confirming the operation of the basic functions and verifying the effects of the system, J-mAIster was deployed at all of the company's plants beginning in September 2018. J-mAIster is an abbreviation for "JFE Maintenance AI of Smart TPM for Electric Repairs."

The flow of failure recovery work can be divided roughly into the following 8 processes, as shown in **Fig. 6**.

First, when a failure occurs in a plant, the operator in the plant contacts the maintenance personnel by telephone. At this time, the maintenance personnel stand by at an office separated from the actual site, and conduct an interview on the detailed circumstances of the failure with the operator. After organizing the content of the interview and checking some related materials which are kept in the office, maintenance workers are dispatched to the plant where the actual site is located. On arriving at the site, they confirm the location of the failed equipment and conduct an investigation of the failure. In concrete terms, the maintenance workers conduct a specialized investigation of the equipment error status and electrical signals, a check of the program and so on. Based on the results of this investigation, a cause estimation is made and action is taken. Failure recovery is finally achieved through this series of steps. However, if the cause estimation is incorrect, these processes must be repeated from the investigation step, and as mentioned above in section 2.1, differences in the experience and knowledge of the individual maintenance workers affect the time required for failure recovery.

The assumed range of application of J-mAIster is shown by the red frame in Fig. 6. A work-time shortening effect can be expected in this range of processes by browsing and utilizing the materials necessary in failure recovery.

3.2 System Configuration

As shown in **Fig. 7**, the J-mAIster system was constructed to enable use in all of the company's plants by implementing the server on J-OS, which is a dedicated private cloud in JFE Steel. By linking the system with "IBM Cloud," which is a public cloud, and "box," which had already been introduced in JFE Steel and is also a public cloud, it was possible to introduce state-of-the-art technologies like "IBM Watson" while maintaining the required security conditions. Moreover, linkage with the integrated JFE maintenance management system enabled effective utilization of the data accumulated in JFE Steel over many years.

3.3 Basic Functions of J-mAIster™

J-mAIster, as shown in **Fig. 8**, is linked with the history of past failures and troubleshooting and operational procedures, spare part information and other data stored in the JFE maintenance management system, and these data can be browsed by anyone in the company. Furthermore, it is also possible to browse the

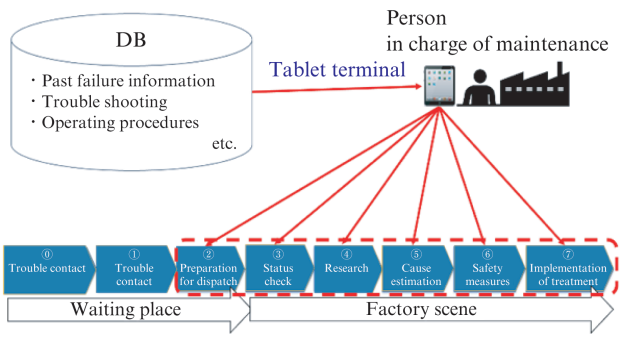


Fig. 6 Use case of J-mAIster™

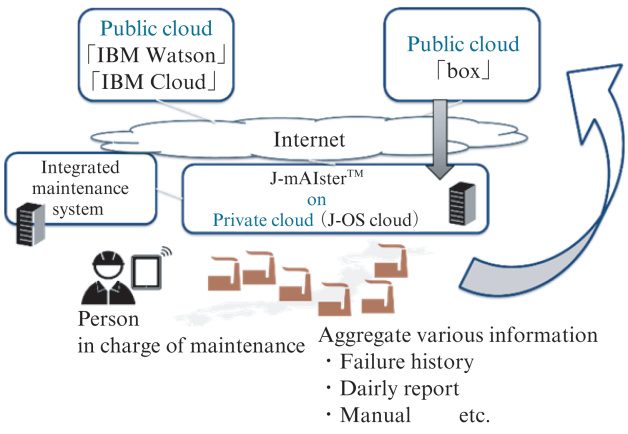


Fig. 7 System configuration of J-mAIster™ [3]

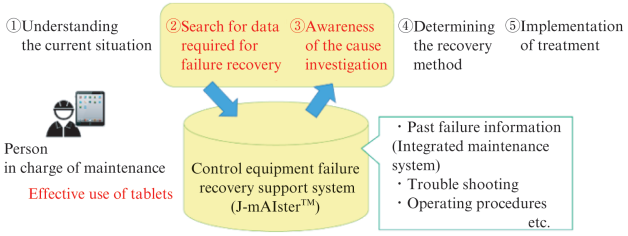


Fig. 8 Outline of J-mAIster™

necessary data anywhere within the vast area of the steel works by connecting from tablet terminals.

As distinctive features of J-mAIster, based on voice input or text input from the keyboard, the system identifies the optimum data source for the condition of the equipment in which a failure has occurred from the enormous volume of possible data, and presents the results of a search and analysis of information with high similarity on the screen in real time. Using this function, the history of past failures can be displayed on the screen so that maintenance workers will gain an awareness of cause investigation, even for failures which they have not actually experienced. Because similar equipment exists and similar failures occur in all of the company's plants, the system was designed to enable use of data across all sites. This increases the volume of data on similar failures that can be browsed, and thus is a more effective system for maintenance personnel.

One point that was particularly important in the implementation of this system was high search accuracy. However, many technical terms and abbreviated expressions are used in a steel works, and in many cases, these cannot be recognized as words. To solve this problem, a dedicated dictionary of keywords was created, and tens of thousands of synonyms and abbreviated terms were registered. As a result, J-mAIster can also recognize these terms as single words.

3.4 Analysis Functions of J-mAIster™

In addition to the basic functions described above, J-mAIster also has the functions of i) correlation analysis, ii) usefulness analysis and iii) advanced analysis. These are described in order in the following.

First, correlation analysis quantitatively expresses the relation between designated words and groups of documents that include the search conditions.

This value is called the correlation value, where larger values indicate a stronger relationship between designated words and groups of documents that include the search conditions. Thus, if the correlation value is large, it is possible to extract documents with a high frequency of appearance with the designated word, even for failures with a low frequency of occurrence relative to the total number of failures.

The second function, usefulness evaluation, quantitatively reflects the evaluation of the searched document by maintenance workers. This function was introduced to improve the accuracy of data, and makes it possible to display and check the usefulness of keywords based on evaluations input by maintenance workers. Since this makes it possible to select data in the database based on usefulness, it can be said that the system constructed in this project will also be useful into the future.

The third function, called advanced analysis, can be applied to preventive maintenance by visualizing the temporal trends and correlations of the equipment and numbers of parts related to failures, and analyzing the cycles and causes of failures.

4. Examples of Application

This chapter introduces examples of the results of application of J-mAIster in failure response at four districts, which are denoted as A district to D district.

Case of A district: An inspection device failed, resulting in an uninspected condition. As shown in **Fig. 9**, a search was conducted with J-mAIster using "device name and uninspected" as keywords, and a similar case from two years earlier was found. Although the maintenance worker was inexperienced in similar failures, the failure recovery time was shortened by 30 minutes by referring to the action in the past case.

Case of B district: A certain device failed and the cause was identified, but for failure recovery, it was necessary to change the parameters in the device. Therefore, a search was carried out with J-mAIster using "type of equipment and parameters" as keywords, and the failure recovery time was shortened by 30 minutes because the related operational procedure could be browsed at the site.

Case of C district: A certain device failed, and an error code was displayed on the screen. A J-mAIster search was conducted using "device name and error

Fig. 9 Effect example (A district)

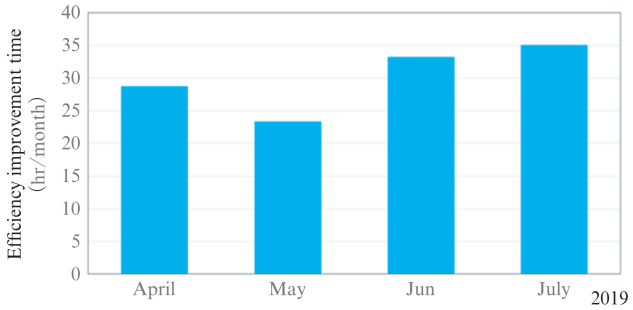


Fig. 10 Work efficiency improvement time in all district (2019/4 – 2019/7)

code" as keywords, and the failure recovery time was shortened by 1 hour by taking action referring to a similar case from 15 years before.

Case of D district: A conveyor failed and charging became impossible. A J-mAIster search using "device name and charging impossible" as keywords discovered a similar case from 20 years earlier. Although the person in charge of maintenance this time was also inexperienced in similar failures, the failure recovery time was shortened by 40 minutes by referring to the action taken 20 years before.

In these examples of results, the failure recovery time was shortened by referring to past cases, and the failure recovery was carried out by only a maintenance worker with no experience related to similar failures, without depending on a highly skilled veteran. The effect of J-mAIster in shortening work time in all districts from April 2019 to July 2019 totaled more than 120 hours, as shown in **Fig. 10**.

5. Conclusion

Persons in charge of maintenance have voiced the opinion that J-mAIster "makes it possible to gain an awareness at the site plant from past cases, and has improved work efficiency," and its effect in shortening failure recovery time was also confirmed.

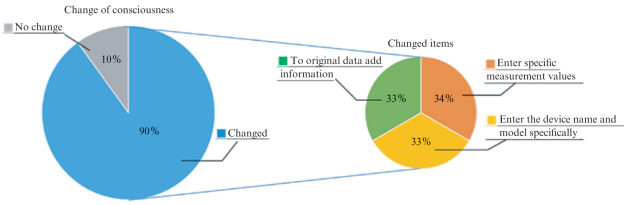


Fig. 11 Awareness improvement questionnaire results (Kurashiki)

In addition to these benefits, the following effects were also achieved. Conventionally, in records of the response to failures, persons in charge of maintenance had focused on the causes of failures and the actions taken until failure recovery. In contrast, the introduction of J-mAIster has greatly increased the consciousness of persons in charge of maintenance of the importance of accumulating data as a useful tool for future maintenance. The Kurashiki District conducted a questionnaire survey of key persons selected from each maintenance group in each area, and found that the consciousness of 90% of these key persons was changed by the introduction of J-mAIster. This change of consciousness led to increase inputting of concrete and quantitative data into the JFE maintenance management system in comparison with the past, including the names and models of the target equipment, measured values and measurement points, etc.

Tasks for the future include incorporation of undigitized information and application to preventive maintenance. By solving these problems, we hope to improve J-mAIster to a more effective system.

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