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"Developed Machinery Maintenance Technology
in Steelmaking Plant"

Management System Supporting Reliability of Equipment

Kitamura, H.; Fukumoto, M.

Synopsis :

An equipment maintenance management system has been developed with the purpose of the evolution of a theoretical equipment management by data endorsed. The equipment maintenance management system realized reduction of maintenance costs and stable operation of equipment with an equipment diagnosis system. Furthermore, equipment reliability has been improved rapidly while realizing strict machine precision, and a staff support system has been developed to make quick decision making and immediate maintenance actions possible. And also, operational user-interfaces have been progressed, and consequently, the efficiency of equipment managing work loads has been improved.

The body can be viewed from the next page.

Management System Supporting Reliability of Equipment*

Hideki Kitamura
Staff Assistant Manager, Equipment Technology Sec., Equipment Technology Dept., Chiba Works

Masakazu Fukumoto
Staff Assistant Manager, Equipment Technology Sec., Equipment Technology Dept., Mizushima Works

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An equipment maintenance management system has been developed with the purpose of the evolution of a theoretical equipment management by data endorsed. The equipment maintenance management system realized reduction of maintenance costs and stable operation of equipment with an equipment diagnosis system. Furthermore, equipment reliability has been improved rapidly while realizing strict machine precision, and a staff support system has been developed to make quick decision making and immediate maintenance actions possible. And also, operational user-interfaces have been progressed, and consequently, the efficiency of equipment managing work loads has been improved.

1 Introduction

Iron and steel manufacturing plants are composed of complicated, large scale equipment. Consequently, a considerably long period of time is required to restore normal operation if trouble once occurs, reducing the productivity of the plants and causing quality-related troubles. Moreover, if trouble occurs repeatedly, the quality competitiveness of the product will also suffer. For these reasons, equipment management to prevent trouble before it occurs is extremely important.

The methods of maintenance employed in equipment management are categorized into breakdown maintenance (BM), in which equipment is replaced after breaking down, time-based maintenance (TBM), in which equipment is replaced after a set period of time, and condition-based maintenance (CBM), in which equipment maintenance work are carried out while monitoring the equipment condition. These methods are applied selectively, depending on the equipment deterioration pattern, the ease of predicting deterioration, and the importance of the equipment.

At Kawasaki Steel, the ratio of CBM has increased with progress in predictive technologies using equipment diagnosis technologies. However, this does not mean that heavy maintenance can be performed on any equipment whatsoever; rather, the most rational equipment management must be realized. Further, such equipment management must be superior in individual specialized technologies and systems so that the optimum maintenance can be executed. Along with sperior individual technology and system, maintenance as a whole must be performed systematically and efficiently.

Kawasaki Steel's equipment maintenance management system was constructed incorporating quantified data with the purpose of realizing the optimum maintenance. In the 1980s, this system supported improvement in control accuracy together with reductions in maintenance costs and stable equipment operation. However, maintenance has become increasingly important in process continuation and high speed operation and in higher accuracy equipment, all of which are exemplified by the continuous rolling process at the new No. 3 hot strip mill at Chiba Works, and it became impossible to cope with these requirements with the traditional equipment maintenance management system.

This report describes an overview of the equipment maintenance management system that supports the reliability of equipment, and describes the staff support system which has enabled judgment-making and action-taking based on quick analysis in that system and examples of development which have dramatically improved operability with the aim of realizing efficient equipment management.

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2 Trends in Equipment Management Technology

Reviewing the history of equipment management in Japan, the 1950s was a period of preventive maintenance, which was introduced from the United States. In the 1960s, productive maintenance was adopted, and TPM (total productive maintenance) began in the 1970s. Chronologically, so-called time based maintenance was practiced until the 1970s, and in the 1980s, predictive maintenance, namely, the concept of condition-based maintenance, took root.

The historical trend at Kawasaki Steel was basically similar to that in Japan described above. The productive maintenance method was introduced in the 1960s. In the 1970s, due to the intended orientation toward stabilization of equipment, quality assurance, and low cost, a drastic restructuring of the equipment control system was carried out in order to expand the equipment maintenance division and improve its efficiency. In addition, Kawasaki Steel promoted its own unique maintenance activities for product quality assurance, namely, quality maintenance.

Around this time, equipment diagnosis technologies were developed or introduced, and a study of the equipment maintenance management system was conducted.

In the 1980s, product quality requirements began to diversify, and the needs for higher grade products and short-time delivery increased. Consequently, as equipment became more complicated, attention turned to assurance of the production line as a whole, in other words, to assurance of the operating performance of the equipment and assurance of product quality performance. As for the former, efforts were put into elucidating failure mechanisms and developing technologies for forecasting abnormalities. For the latter, technical development was promoted with the aim of elucidating the causal mechanism in the relationship between product quality and equipment and enabling forecast of abnormalities in advance and early action-taking.

Equipment maintenance management systems were developed[1,2] to achieve stable operation of equipment, aiming at evolution toward theoretical equipment management supported by measured data. In the 1990s, a total equipment management system was constructed,[3–6] in which these systems were organically linked. More recently, analysis functions that can meet the requirements of advanced, quick-response equipment management systems have been developed, and improvement in the direction of user-friendly systems have been carried out.

There have also been remarkable changes in the OA (office automation) environment in the past several years, and as a result, the word processor as a special purpose machine for preparing documents and the exclusive-use terminals of a host computer system have been replaced by a single personal computer, and the dot printer has been replaced by a high-speed laser printer giving distinct hardcopies.

Under the circumstances, nowaday even operators at the work site use own personal computers, and it has become possible to perform all work from his or her own personal computer.

The equipment maintenance management system is no longer used only by a limited number of equipment engineers, but has now been transformed into a general purpose system that can be used by all engineers and persons with practical work responsibilities by way of a single personal computer.

3 Equipment Management System

3.1 Necessary Equipment Maintenance Functions

The functions that are required in equipment maintenance are classified into the two: one is the functions that assure stable operation by preventing equipment abnormalities and failures in advance, and functions that assure product quality by maintaining a high level of performance and functions of equipment. In order to conduct this type of maintenance effectively with a small number of personnel, the following conditions are necessary in equipment diagnosis technologies and in the peculiar technologies of the equipment, and in equipment management.

(1) A precise equipment monitoring function, making it possible to grasp the conditions of the equipment.
(2) Assurance of the performance and functions of the equipment in accordance with scientific and engineering methods.
(3) Clarification of failure mechanisms and the causal mechanism in the relationship between quality and equipment.
(4) Systematized data collection, analysis, decision-making, and evaluation functions for the information which is necessary for equipment management.
(5) Trained human resources capable of making high level decisions regarding the management of equipment.

3.2 Configuration of Equipment Management System

The configuration of the equipment management system is shown in **Fig. 1**, and roughly comprises (a) the equipment diagnosis system, (b) the periodic diagnosis data control system, and (c) the equipment maintenance management system. These are supported by (d) expert systems and (e) an image information processing system.

(a) The equipment diagnosis system[7–9] monitors all the time the conditions of equipment which has an important effect on quality or the operation. When an abnormal affair, this system automatically determines

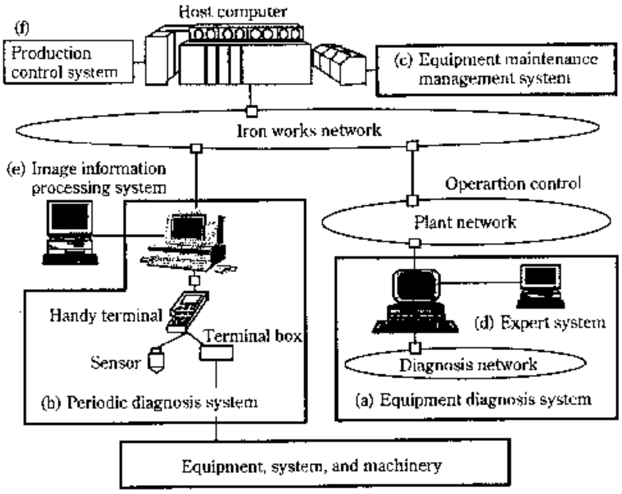

Fig. 1 The total equipment maintenance management system

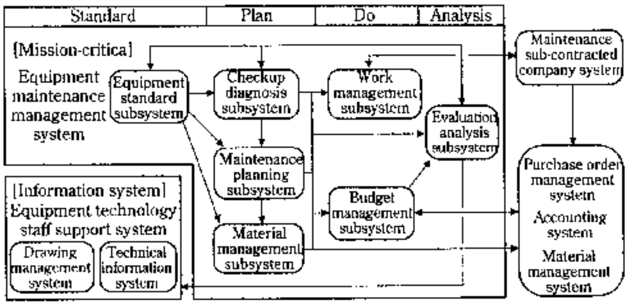

Fig. 2 The equipment maintenance management system

the root cause, based on the causal matrix for equipment and quality and the causal mechanism of failures, and gives guidance to the operator. Data which are not abnormal are transmitted to the upper level system by way of the plant operation control network as processed data for use in mid- and long-term equipment management and quality control.

(b) The periodic diagnosis data control system is used to improve efficiency in human diagnosis of symptoms of equipment deterioration. The necessary information is obtained in accordance with the inspection plan, and the results of inspections and diagnosis are recorded by a simple key operation and transmitted to the upper level system.

(c) The equipment maintenance management system is incorporated in the upper level host computer, and performs centralized control of planning, execution, collection of results, and evaluation and analysis, covering construction work, spare parts, budgets, and other items, based on the data transmitted from the equipment diagnosis system and the periodic diagnosis data control system. In addition, this system is organically linked to (f) the production control system, and can also review plans as required by production conditions.

3.3 Outline of Equipment Maintenance Management System

In equipment maintenance, the optimum maintenance method must be decided and the individual specialized technologies for executing maintenance must be superior. Along with this, it is also necessary to carry out such maintenance as a whole in a systematic and efficient manner. The equipment maintenance management system is responsible for this role. The configuration of the system is shown in **Fig. 2**.

The equipment maintenance management system that was developed by Kawasaki Steel comprises seven subsystems. The system automatically prepares a maintenance plan, which becomes the master plan, based on the production plan and equipment control standards, forecasts the life of the equipment from equipment deterioration information obtained by diagnosis and inspection, and then automatically corrects the master plan. The system also automatically orders the spare parts that are required for construction work and makes up budgets and performs other work.

With this system, it was possible to construct the foundation for the change from maintenance centered on time-based standards, to condition-based maintenance. After the system had been in operation for five years, equipment failures had been reduced by half, and an equipment maintenance system with a small number of top quality personnel became possible.

4 Development of High Function System

4.1 Changes in Equipment Maintenance Requirements

At the present time, when high-precision equipment has become the mainstream one. Extremely strict control of mechanical accuracy is required, and dramatic improvement in equipment reliability is demanded. In addition, shortening of the maintenance work period by developing more efficient maintenance execution techniques has also become an important task.

With conventional systems that used only a main frame computer, the information was limited to output in prefixed standard format, regardless of user's desire, and was not necessarily adequately suited to analysis needs which depend on the user's standpoint and purposes. Delay in taking-action is another problem for the reason that quick response analysis is impossible to grasp the conditions of equipment deterioration, clarify equipment that was a weak point in the process, or locate inventories of spare parts. Similarly, where the operability of the system was concerned, the main systems employed code inputting, which was difficult to use for personnel who were not thoroughly familiar with the system. In other words, not only the burden of inputting, but also the system itself was a basic obstacle to use.

To ensure that equipment demonstrates the required functions to the maximum possible extent during the equipment life cycle, a correct grasp of the condition of the equipment and appropriate improvements are more necessary now than ever. Overcoming the problems mentioned above is an urgent task for achieving this goal.

As countermeasures for the former problem, which concerned the analysis function, a staff support system that strengthens the analysis function and a search system for reducing inventories was developed. To solve the latter problem, concerning operability, dramatic improvements were made in system operability by adopting GUI (graphical user interface). Details are presented in the following.

4.2 Strengthening of Analysis Function (Staff Support System)

To reduce the burden of analysis and enable quick judgments and actions, a staff support system was developed as a system which makes it possible to limit analysis to the desired information and organize the results in a freely chosen format.[10,11] This system incorporates maintenance information in an RDB (relational data base), and was developed independently, mainly by personnel engaged in line work, using commercial spreadsheet software. As a system that supports the daily work of equipment engineers, it consists of six menus, including an explanation of system codes, paper supply in common formats, technical information search and a bulletin board, and inventory search, in addition to maintenance data analysis for clarifying weak point parts.

In maintenance data analysis, it is possible to clarify the condition of execution of inspections and construction work, clarify parts that are weak points, follow up on the condition of budgeting, and perform other quick analysis by specifying the analysis conditions, which enables the user to obtain the desired information immediately. Because the actual condition can be grasped easily and can be linked to immediate improvement activities, this system is being used practically as an important tool for supporting stable equipment operation.

Photo 1 shows an example of an equipment failure analysis. By simplifying data use in this manner, we can evaluate easily the status of various activities, such as improvement in the accuracy of life forecasts, support for determining the root cause when trouble occurs, inventory reductions.

4.3 Search System for Inventory Reduction

In response to calls for strengthening of the company's financial fundamentals, one important task is to reduce inventory assets in order to improve cash flow. In the equipment maintenance division, an inventory search system for the inventories of spare parts held in each maintenance department was developed in a form that anticipated this problem and has become a powerful tool for reducing inventories.

In addition to reducing equipment and material purchases by optimizing inventory levels and sharing inventories, this system enables quicker searches for spare parts when trouble occurs, and therefore has become indispensable for spare part control.

As an example of output of inventory information system, **Photo 2** shows the trend in the value of inventories. This screen shows the monthly change in the value of inventories, and allows the user to understand the increase and decrease in inventories due to purchases and consumption, respectively, in monthly units. In addition, as a function for following trends in the amounts of inventories in monthly units, lists are provided to show

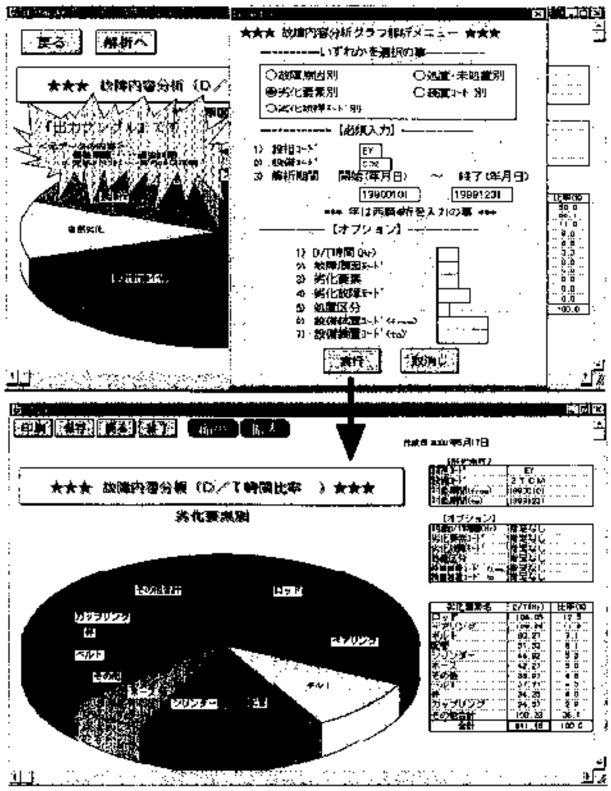

Photo 1 Example of analysis (equipment trouble)

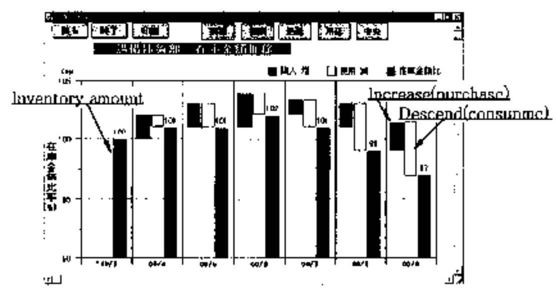

Photo 2 Inventory information system (trend of inventory ratio)

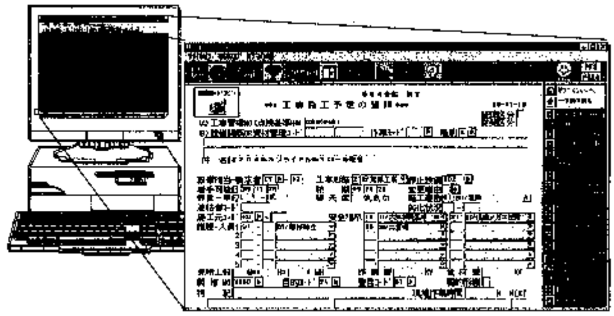

Photo 3 Image of GUI application program (GUI: graphical user interface)

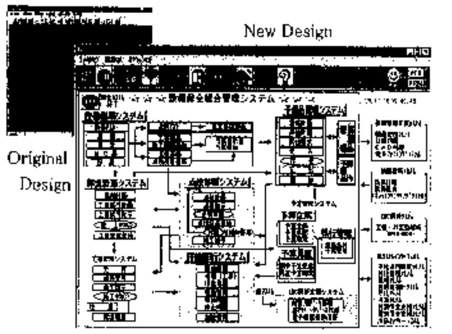

Photo 4 New equipment maintenance management system

increases and decreases by item base.

As a result, it has been possible to achieve an inventory reduction of approximately 13% during the latest two years by centralization of inventories and reductions in purchasing.

4.4 Improvement of System Operability (GUI: Graphical User Interface)

In recent years, the appearance of open systems (client-server systems) has called attention to problems with the operability of the main computer type systems (host systems) that had long been used. The client-server systems are based on the dialogue concept and give full consideration to easy viewing and operability by allowing the user to input selections with buttons and pull-down menus and providing 3-dimensional displays. In contrast, host type of system is difficult for the user understand and hard to use, although the host type offers excellent stability.

With regard to the operability of equipment maintenance management system, some improvements were carried out in the year 2000, based on the desires to reduce significantly the load to a system and upgrade the system aiming at easier understanding and operation by all the personal even at work site.

In doing these improvements, the system was converted to GUI screens with good operability, without revamping the existing host applications, by using personal computer software available in a usual market (GUI conversion tool).[12] The overall renewal was accomplished in a remarkably short period of 4 months.

Photo 3 shows the images of the GUI application program. The software that was used in this development employs a method to overlay a GUI display prepared on a personal computer system over the existing system screen. The new method can improve operability exactly as if the system would be converted to a client-server system.

A comparison in display design between before and after improvement is shown in **Photo 4**. Since the total configuration and data treatment flow of the system can be easily grasped at a glance, and the system can be understood in a very short time and operated simply by all the personel, even work site oprators. Selection and input from pull down menus has eliminated the need to know codes which were requested to be assigned, as in the past. Owing to attaining the enhanced reliability and quality of input data, analysis based on maintenance data of higher accuracy has been obtained easily, thus making this system a strategic tool of great impotance for stabilizing equipment. As an overall result, it has become possible to shift personnel to inspection and construction management jobs and allow much work force into monitoring the condition of equipment than in the past, contributing to stable operation of equipment.

4.5 Results

Based on the equipment maintenance management system, which was developed as the central function in equipment maintenance, a system environment for supporting the reliability of equipment was attained through newly developing a staff support system and dramatically improving operability.

Development of the staff support system has made it possible to obtain the desired information immediately, and has enabled quick decision-making and action-taking. Such information includes follow-up status of various activities such as the accuracy of life forecasts, investigations of the root cause once trouble occurs, and inventory reductions. Improvement of operability has made it possible to devote greater work force for monitoring the condition of equipment and thereby contributed to stable equipment operation.

5 Conclusion

From among various topics in the "maintenance revolution for the 21st century"[13] which is being promoted by Kawasaki Steel, this report described the equipment maintenance management system that supports the reliability of equipment, and discussed the necessary functions and configuration for an equipment management system that enables the most reasonable equipment management. The staff support system, which meets one of today's new needs by enabling quick analysis, and an inventory and spare part management system have been discussed as practical examples, and improved efficiency in operation by the introduction of GUI was also described.

In the future, in order to ensure stable operation of equipment, it seems that the role borne by technical capabilities in maintenance will be even more important, and development of theoretical equipment management backed by measured data will become indispensable.

Among these trends, the roles of maintenance experienced knowledge-free technology and engineer experts will become even more important.

The key tasks that should be taken up in the future are considered to be the followings: the development of a system that reports the conditions of equipment deterioration to the equipment management center in real time, a decision-making support system for skilled personnel that enables appropriate selection of actions, and a system for supporting high speed, concentration, and worldwide maintenance in equipment management, together with the training of engineer experts.

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