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Development and Application of Advanced IT Technology Systems for Steel Factories

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Abstract

We introduce IT technology applications in steel factories to address tough operational and environmental needs.

1. Introduction

To satisfy the ever-growing customer demands for stable supply of high quality products, it is crucial for the Nippon Steel & Sumitomo Metal Corporation to establish highly profitable and stable operation of equipment with excellent operational efficiency and the ability to respond customers' claims promptly.

This article introduces an operation support system utilizing IT technology, which was developed to address problems in responding to customer needs promptly while securing stable operation.

2. Present State and Issues of Production Field

In the iron and steel industry, sophisticated operation technology is required to realize the stable supply of high quality products and improvement of yield.

Since the start of automation in the 1970s, automatic tracking and automatic control have spread in production lines; however, the stable production of products and improvement of yield owe much to the plant operators' expertise even today. Furthermore, in the finishing line where work such as forming same-sized shipment lots to meet customer demand is performed, works such as identification of each product and reliable performance of measuring dimensions are difficult to automate and still rely on workers. Furthermore, through recurring rationalization programs, the operation floors are being manned less and the number of inexperienced plant operators has increased. This has led to the following issues: (1) Expansion of the area of responsibility of experienced supervisors with expertise, as well as the increasing difficulty of their instructions being thoroughly communicated; (2) Erroneous operation by inexperienced plant operators in situations where high-level operation skill is required; (3) Complicated operation analysis work based on various data in the production of high quality products; and (4) Increased work load of workers on the finishing line where they have to multitask such as tracking-follow-up and dimension measurement.

To improve this situation, utilization of the expertise of experienced operators as guidance, automation of setting and realization of observation and controlling of operation from remote out-of-pulpit production floors are required. Furthermore, tracking support and the automation of measurement, as well as analysis work support are also required. To address these issues, the Nippon Steel & Sumitomo Metal company group has developed the following: navigation systems for operation and analysis, dimension-inputting support systems by portable digital dimension measuring apparatus, exclusively developed ID code reading apparatus and portable marking apparatus as tracking support technology. These support systems and apparatuses are introduced hereunder.

3. Operation Navigation and Operation Analysis Support

A navigation system and operation analysis support system, the current flow of work instruction to operators and the system configuration of a manufacturing plant in Nippon Steel & Sumitomo Metal are shown in **Fig. 1**.

The business computer of production management executes operation management, quality control and process management. The process computer displays the operation status to operators and outputs instructions to production equipment based on operation control information such as production specifications to execute optimum control and automated operation, and thus conducts plant operation. Electrical and instrumentation systems are built into respective specific equipment and execute equipment control with respect to the subject equipment.

In automatic operation, the business computer informs the process computer of the production schedule. The process computer determines the setting values based on a detailed description of the production schedule (e.g. sheet thickness, sheet width, steel grade, etc.), issues a control instruction to electrical and instrumentation

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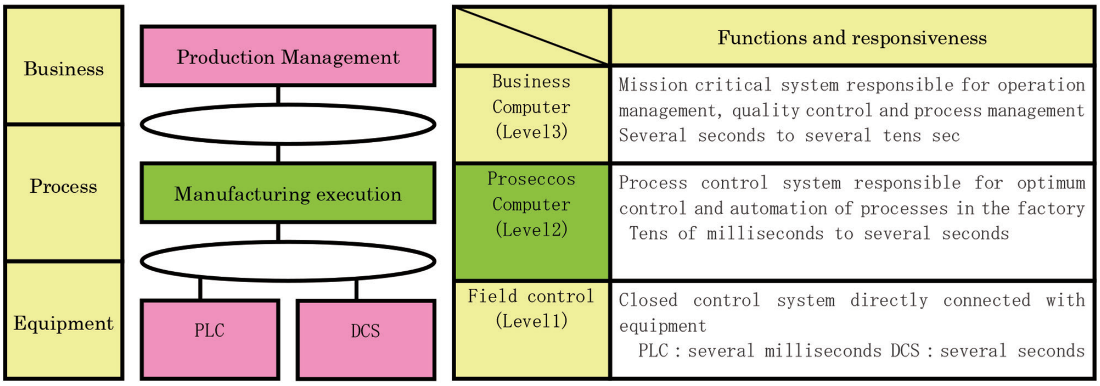

Fig. 1 System structure on steel works

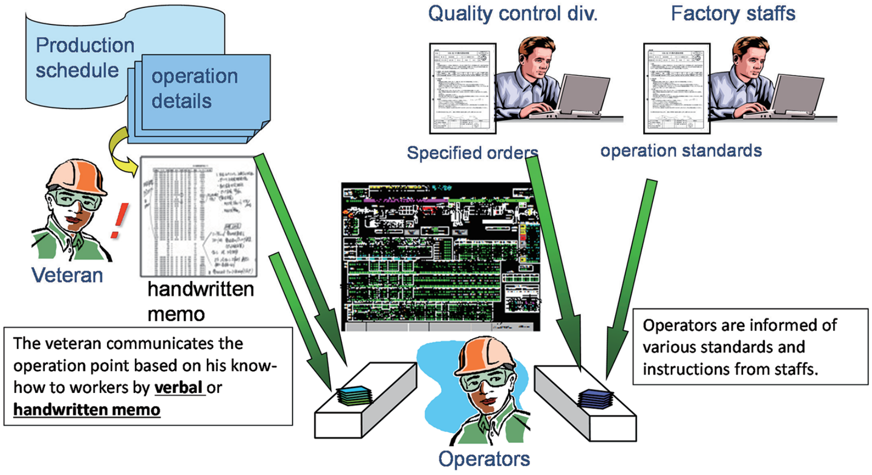

Fig. 2 Work instruction to operators

systems, and thus conducts plant operation. However, to realize the stable production of high quality products and to improve yield, the expertise of plant operators, especially that of experienced supervisors, is important. Instructions from technical staff or the quality control department are distributed in a written form such as an instruction sheet or communication sheet in a meeting before the start of operation. Additionally, experienced supervisors deliver their expertise pertaining to the production schedule to operators, handwritten on the printed production schedule sheet.

Operators enter the pertinent information provided by the experienced supervisors in the detailed production sheet (a document that specifies the production condition such as steel grade and size on a product-by-product basis) already made available at the manufacturing site and begin production according to the production schedule. As shown in **Fig. 2**, operators keep the instruction sheet and the detailed production sheet at the manufacturing site and conduct operation by referring to the production schedule and the information in the production description sheet. This enables a certain level of operation.

However, once a problem occurs, the operator becomes preoccupied with visiting the site of the problem and frequently intervening in the operation, and the fine details of the production sheet become less of a concern. Therefore, oversight or failure to notify the problem due to inability to confirm the content may occur. The more stringent the content of the production specification becomes, the smaller the range of margin in production capability in production, and intervention in operation to normalize the situation that requires detailed information and expertise becomes necessary. However, unless the information is broken down into detailed specific work and operation procedures, inexperienced operators may cause operation mistakes.

Shift operators submit a shift report at the end of their work day (or night). Information such as operational issues and results, issues to be transferred to the next shift plant operators and, equipment problem information to be transferred to the maintenance section are entered in the report.

The contents of the shift report and the day report are reported in a daily plant meeting at which plant managers, staff engineers and equipment maintenance personnel are informed of pertinent matters and the status of the production line. This information is important for staff engineers to analyze the operation status and study improvement measures. The shift report and the day report are now in the process of conversion to electronic form but the linkage between plant matters and the various plant data is insufficient. Therefore, this information gap means that staff engineers and maintenance personnel are required to pursue the causes of problems based on numerous information from various sources. Troubleshooting involves regular or non-regular analysis, which is based on trial and error. In regular analysis the necessary data are selected and collated, causes are pursued and countermeasures are studied. In trial and error based analysis, various data need to be examined and collated under various combinations.

As operators conduct operation based on various expertise, incorporating various requirements from a number of departments, appropriate just-in-time support is required. This means "Whenever, wherever needed, appropriate information is obtainable and appropriate instruction is provided." Furthermore, the staff department in charge of promoting improvements analyzes various data of daily operation matters, proposes improvement measures and verifies the result in operation. As such work needs to be executed effectively, the, "acquisition of appropriate information that matches the objective of the work" is required (**Fig. 3**).[1]

To extend support to the operation site, two operation support systems utilizing IT technology are promoted: (1) Operation navigation system, and (2) Operation analysis support system.

3.1 Operation navigation system

Navigation for operation used to refer to voice announcement systems (VAS) or alarms in conventional control systems; now, however, operation navigation systems are not so rigid in their definitions but are capable of dealing with improvement or alteration in daily operation.

Experienced operators are fully cognizant of where attention should be focused in the production schedule and deliver such expertise to operators via the production schedule sheet. Furthermore, various instructions concerning improvements or alterations for daily operation are issued by the departments concerned in the form of instruction sheets. The operation navigation system provides appropriate instruction and executes setting at an appropriate time based on the expertise and the instruction information associated with the control system.

Figure 4 shows the outline of an operation navigation system that produces shift production schedules by combining the instructions issued by the departments concerned with the production schedule, and issuing the said instruction at the requisite timing.[2] Staff engineers of the department concerned prepare the instructions from the department and upload them to the operation navigation database. The shift production schedule is produced by referring to the production schedule provided by the business computer. The staff engineers' instruction is linked to the shift production schedule

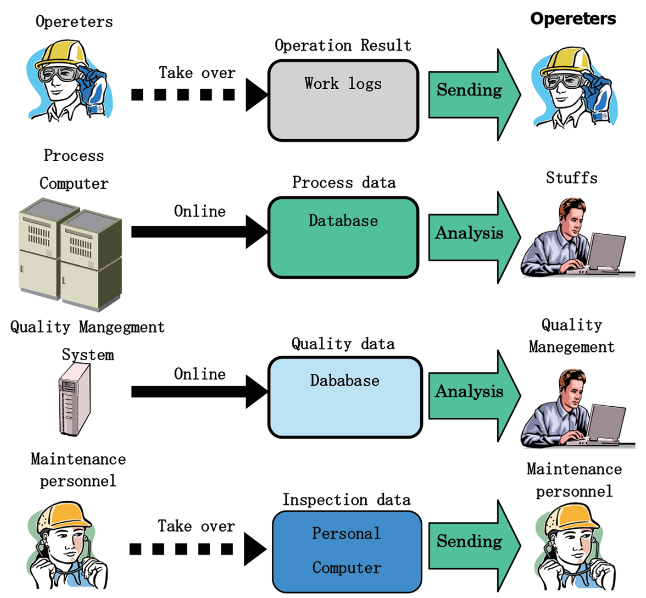

Fig. 3 Data flow of plant data for management departments or their staffs

by a time key for instance, and the operation guidance of the text data is provided through voice-synthesized VAS or display on the operation screen at the requisite time.

By collating the staff instruction content with the shift production schedules using a key such as a job number and by linking the event (e.g. tracking) issued by the control system with the content of the instruction, guidance at the requisite predetermined time is enabled. Staff engineers of the respective departments or the manager of the production department can upload the content of their desired work instructions to the database by simply entering the instruction and the contents are transferred to operators. Using an operation event as a trigger, the control system assesses whether the job number agrees with the key job number, and only when both job numbers agree, the process computer issues the notification to operators or executes setting. Thus, just-in-time notification or setting are realized, providing guidance to inexperienced operators and preventing the occurrence of mistakes.

Furthermore, even when an operator leaves a pulpit for inspection or to attend to a problem on site, by carrying a portable terminal, he can receive guidance just-in-time via wireless LAN. The operator who received the guidance instruction can confirm the instruction immediately at the site by referring to process data. Thus, the volume of information the operator can obtain outside the pulpit increases as compared to the previous situation. Accordingly, the operator can take appropriate measures. For example, when the time for setting of a welding condition approaches and is instructed while the operator is out of the pulpit due to work, he can execute setting through the portable terminal. Or, he can ask other plant operators who remain in the pulpit to set the condition through a communication means. Thus failure of setting up can be prevented.

3.2 Operation analysis support system

The operation navigation system was implemented selectively with respect to planning and execution in operation. Operation analysis support is required at the stage of extracting and solving problems from the actual operation result.

Operation analysis is a complex process using operation log information, quality information, monitoring camera video images and so forth. However, as such data are scattered mostly in various databases, staff engineers have to start by acquiring the necessary data for analysis from the numerous databases. Furthermore, practically, data are stored in the respective databases of each system independently; therefore, due to timewise discordance for instance, staff engineers need to adjust the positions of data to match the positions of process data in a timewise manner and according to the equipment position so that they can determine appropriate positions for analysis. In the database shown on the left side of **Fig. 5**, data-

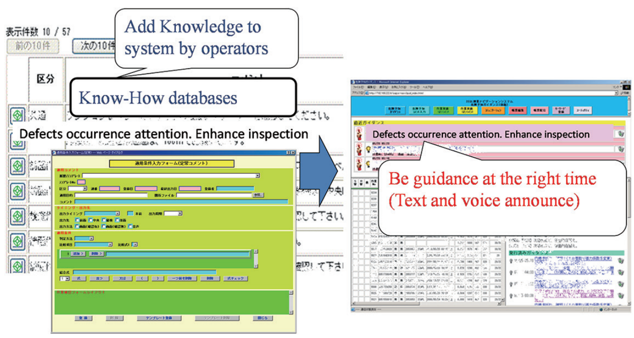

Fig. 4 Navigation system for factory operation

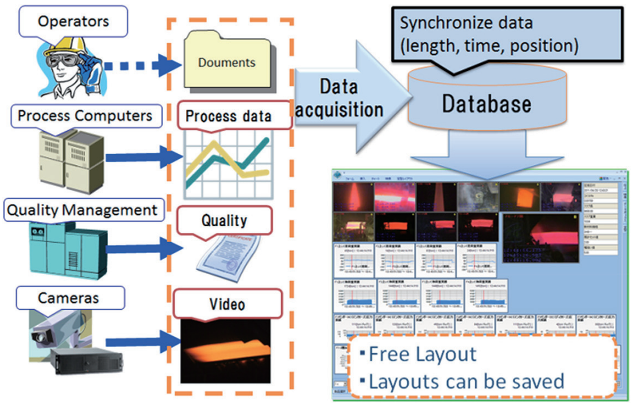

Fig. 5 Sample image for integrated analysis

base matching work such as time synchronization and equipment-position matching of pluralities of systems is automated so that staff engineers in charge of analysis can use data from such databases without being concerned about any timewise and equipment-position discordance.[1)]

Furthermore, shown in the right side of Fig. 5 is an example of a screen displaying data for integrated analysis. On the screen, with drag & drop operation, the display of data, charts and images is possible. Furthermore, the arrangement of these data is determined freely by users, and also the layout according to analysis type is also possible. With predetermined key information, e.g. time key information or product length key information, data are sorted according to the attribute defined by the key information, e.g. timewise or product-length-wise, and displayed. Thus, by utilizing the structure that automatically arranges the necessary data for analysis in the required form and displays it in a simplified form, efficiency of the operation analysis work is improved.

4. Developments of Measurement Result Input Support and Identification-related Technology

In the finishing line, confirmation of product identity (ID), measurement and input of dimensions rely on basic manual work in many cases. Therefore, problems due to misidentification or erroneous input occur, the countermeasures of which are review of the job manual or training on error-free implementation. From the viewpoint of human error, these countermeasures are insufficient. To this end, efforts, introduced hereunder, have been made to automate product-identity confirmation and measurement data input.

4.1 Measurement result input support

Various digital measuring apparatus are available in the market such as that for thickness measurement. However, they are mostly of the type that outputs the measurement result to a printer dedicated to printouts. Therefore, even if such measurement apparatus is used, there still exists a risk of erroneous input as the measurement results have to be input into the business computer manually. Then, for measurement apparatus that is designed to be connected to the external I/F of a system, a data transmission device using Bluetooth was developed and direct input to the upper system was realized.

For length measurement, there is an apparatus that could measure and display length within a 5 m range. However, in this method, usability was poor and the same risk of human error existed. Therefore, an apparatus which reads the scale of a JIS 1st level measuring instrument and measures the length thereby was developed, and direct input of the measurement result to a system was realized (**Fig. 6**).[3)]

4.2 Development of identification-related technology

For identity (ID) control, the bar code system or QR code system is employed for the final products of coiled forms because such products are at an ambient open air temperature, and the rate of stained or damaged labels is low. On the other hand, for most of the semi-finished products such as slabs and billets, ID alphanumeric characters are directly marked on the products. These ID markings tend to suffer from erosion of characters caused by rust or scale during the storage period.

In the case of erosion of characters, at the time of shipment and reception for transfer to other steel works for inter-steel works sales, the characters are rewritten manually, which can lead to mistakes due to human error. Also, such work carries the risk of misidentification when the original ID marking is misread by workers. Then, hereunder, the application of IT technology to ID control for semi-finished products is discussed; specifically, identification work using the voice recognition method, versatile marking apparatus and TEX code.

4.2.1 Application of IT for identification utilizing vocal recognition

In the major production lines of iron and steel, steel materials and products are basically controlled by tracking in lines. However, in material stock yards and finishing lines where automatic tracking by a process computer is not applied, there is a risk of misidentifica-

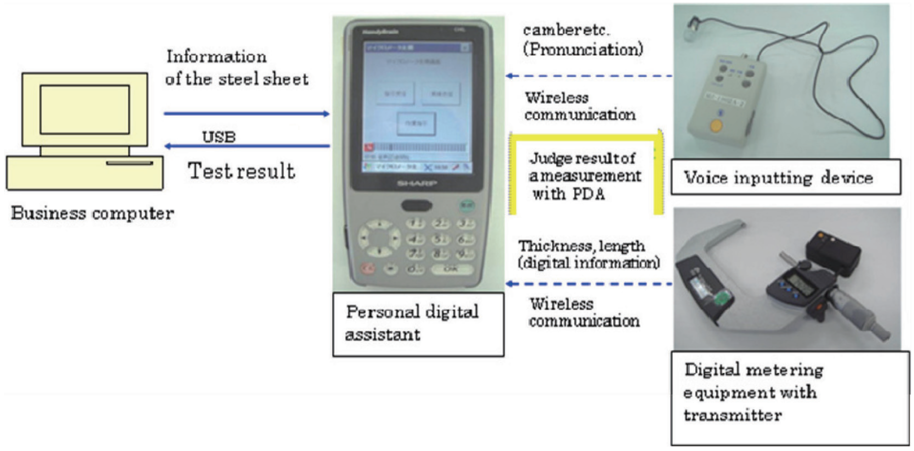

Fig. 6 System configuration of measuring sizes

tion.

Conventionally, although identity is double checked by two workers using a different method, misidentification cannot be eliminated completely. Then, instead of visual identification, identification by a voice-reading system was introduced. To execute identification with a voice-reading method, slab-stock pile number information, a voice inputting device for use at the site and a voice recognition tool are required. Therefore, a portable terminal was equipped with voice recognition software and slab identity was checked by a system that compares the voice-recognition identity information of a slab with that of a slab in a slab-stock pile stored in the business computer.

4.2.2 Application of IT to replace manual identification marking

Conventionally, when the marked characters became worn, illegible, or deteriorated during long-term storage in a yard, manual identification marking work was executed. In the slab yard, tracking of slabs is controlled by the business computer. A worker downloads to his form the slab information of a stock pile with a number in the system. In the yard, by comparing the slab identity information obtained on-site with the one on the form, he marks the slab number manually when necessary. There still exists the possibility of erroneous marking.

Furthermore, for hand-written characters in marking, although there are certain rules, e.g. in style or size, they vary widely, leaving the risk of misreading in subsequent processes. Furthermore, when reading is automated in future, this variation will prompt deterioration in the successful reading rate. Then, a marking apparatus to replace the handwritten marking work was developed (**Figs. 7, 8**).[4] The apparatus was designed for works in a slab yard and the printing head was mechanically-configured to be portable so characters can be marked on each of the piled slabs. The marking apparatus is designed to be linked to the slab information of a slab-stock pile number in the system.

4.2.3 Application of IT for identification utilizing TEX code

After the merger of Nippon Steel Corporation and Sumitomo Metal Industries, Ltd. in 2012, reform of the production structure was promoted to obtain synergistic effects and increase in the flow of inter-steel-works materials such as semi-finished products is predicted. Therefore, further countermeasures in this field are indispensable.

Voice recognition and marking are technologies that support code (ID) identification work and enhance the quality of identity both of which required a worker for each slab. To identify an article, the well-known bar code system and QR system are widely used in Nippon Steel & Sumitomo Metal. However, they are used only for reading identification marking on a one-by-one basis and are unable to grasp the entire arrangement (order of arrangement of each piece). In addition, these codes for identification are widely used in the delivery business and are used mainly for automatic reading or reading with a portable reading device for unsoiled codes under sufficient lighting conditions, to which none environmental worthiness is required.

For articles that are difficult to mark or those stored outside buildings, there are still a number of factors that hinder automatic reading and necessitate workers' involvement such as varying lighting conditions, rain, staining, rust and so forth. Therefore, Nippon Steel & Sumitomo Metal focused on the TEX code developed by Nippon Steel & Sumikin Texeng. Co., Ltd. and started development to strengthen article identification. The Code is characterized not only by the pattern finder, which locates articles quickly and automatically assesses the arrangement, but also by various devices such as the automatic recovery function in reading (**Fig. 9**). Such features enable the identification of rusty and soiled articles temporarily stored outside despite the differences in light and shade during the day and night, as well as varying lighting conditions due to changes in weather during the around-the-clock operation of steel works.

To date, the following tests have been conducted: automatic reading during an outdoor tour where the light and shade difference is large, simultaneous reading of a mass of articles and test for legibility of characters on articles with rust developed by exposure to the open air and to artificial rainfall (**Figs. 10–13**). Characters shown in red indicate those that were read successfully, showing good results in the respective conditions.

By taking advantage of these features, application is being promoted to: identification, arrangement control and lot-formation of

Fig. 7 Marking sample drawn by portable marker device

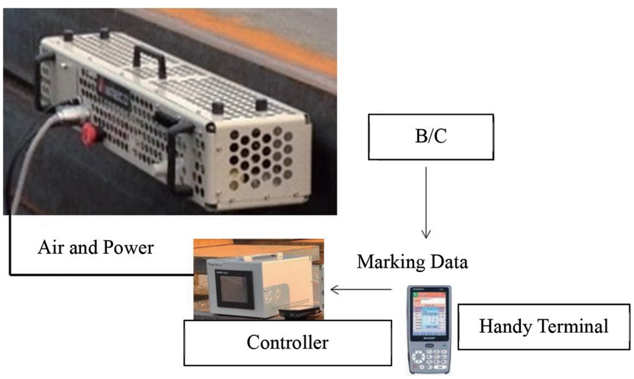

Fig. 8 Sample of marking system configuration

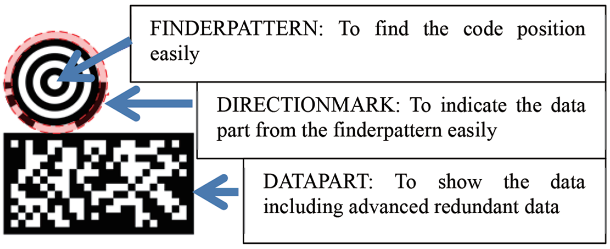

Fig. 9 Structure of TEX Code

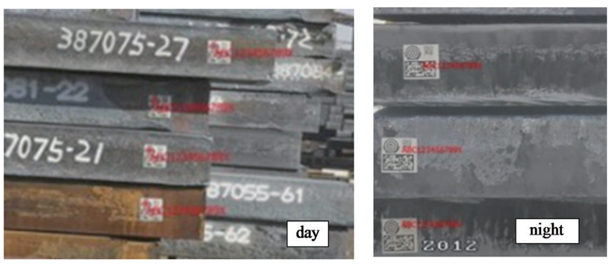

Fig. 10 Sample of recognition in day and night

Fig. 11 Sample of simultaneous multi recognition

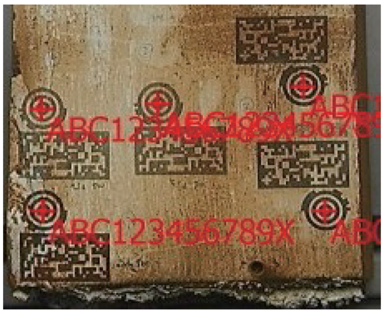

Fig. 12 Sample of recognition with rust

Fig. 13 Sample of recognition in rain

articles, for instance, in temporary storage, shipping and unloading for inter-steel-works sales.

Some of the applications have already been put into practical operation, and we are determined to solve the various issues of automatic marking and automatic labelling to expand the area of application.

5. Conclusion

To satisfy customer needs quickly while securing stabilized operation, an operation support system by utilizing IT is presented. We are further determined to enhance the level of the operation support system along with the progress of IoT technology.

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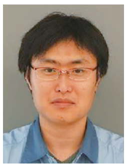

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