Advancement of Manufacturing and Quality Control by Shop Digitalization

YUSUKE SANO[*1] TADASHI YOSHINAGA[*1]
TSUYOSHI NISHIOKA[*2] TAKUMA TERAMAE[*2]
KENICHI NAGAO[*2] TAKASHI MIYAKE[*3]

For shops manufacturing high-quality nuclear components, manufacturing management and work record are essential to secure and assure product quality. In view of the recent circumstances in which the quality control requirements for nuclear components are becoming stricter, manufacturing shops are promoting a fine-tuned manufacturing management system by which high-mix, low-volume products used to enhance the functions of nuclear power plants can be manufactured according to the legal or standards. This report introduces a manufacturing management system that enables more accurate management of work instructions for various products and records of work history through digitalization using IT applications such as mobile terminals and electronic forms. Examples of quality record management in which human-involved work such as handwriting of quality records is minimized are also presented.

1. Introduction

For shops manufacturing nuclear components, both strict manufacturing management in ensuring high product quality and the quality of work records including work history to prove the appropriateness of work and product quality are very important. It is necessary to always perform the following:

(1) Execute a work according to the specified procedure and keep it as a quality record,
(2) Use the latest versions of drawings/specifications (e.g., drawings and work instructions) given for each work
(3) Create and retain reliable quality records essential for each work.

For these purposes, we have built a work management system that seamlessly connects the different stages ranging from design information to manufacturing management. Enabling each worker to utilize the work management system through a smartphone available for use on the premises has ensured that the works are always carried out according to the specified procedures and the latest versions of drawings/specifications. While records have been mostly handwritten, we are promoting the digitalization of work records using tablets, thereby minimizing the human involvement in record keeping in order to streamline the work and improve the quality of records. The following sections summarize these undertakings.

2. Work management system using smartphones

2.1 Work management system

At shops manufacturing nuclear components, fine-tuned manufacturing management is necessary to manufacture high-mix, low-volume products according to the product-specific legal or standards. We have built a work management system that seamlessly connects the different stages, from design information to manufacturing management and manufacturing is managed accordingly as shown in **Figure 1**.

At the stage of the production planning, the person in charge of manufacturing makes a flow

*1 Chief Staff Manager, Nuclear Energy Systems Nuclear Plant Manufacturing Department, Mitsubishi Heavy Industries, Ltd.
*2 Nuclear Energy Systems Nuclear Plant Manufacturing Department, Mitsubishi Heavy Industries, Ltd.
*3 Deputy Director, Nuclear Energy Systems Nuclear Plant Manufacturing Department, Mitsubishi Heavy Industries, Ltd.

chart of the fabrication process based on design information such as drawings made by the design engineer. Based on the manufacturing process flow chart, the person in charge of workflow then makes a schedule chart with the product manufacturing dates contained therein. Using work management system, based on the manufacturing process flow chart, work instructions (traveler) are created including the works listed in accordance with the work sequence. At the manufacturing stage, the work supervisor checks the schedule chart and the traveler regarding when a product should be manufactured and what work should be carried out and instructs workers accordingly. The workers in turn check the work procedure/details provided on the traveler and the relevant drawings/specifications, making sure that they can execute what must be carried out as per the specified procedure. After the completion of work, an input should be made in the work management system in this regard, which makes it possible to appropriately manage work progress and record the work history.

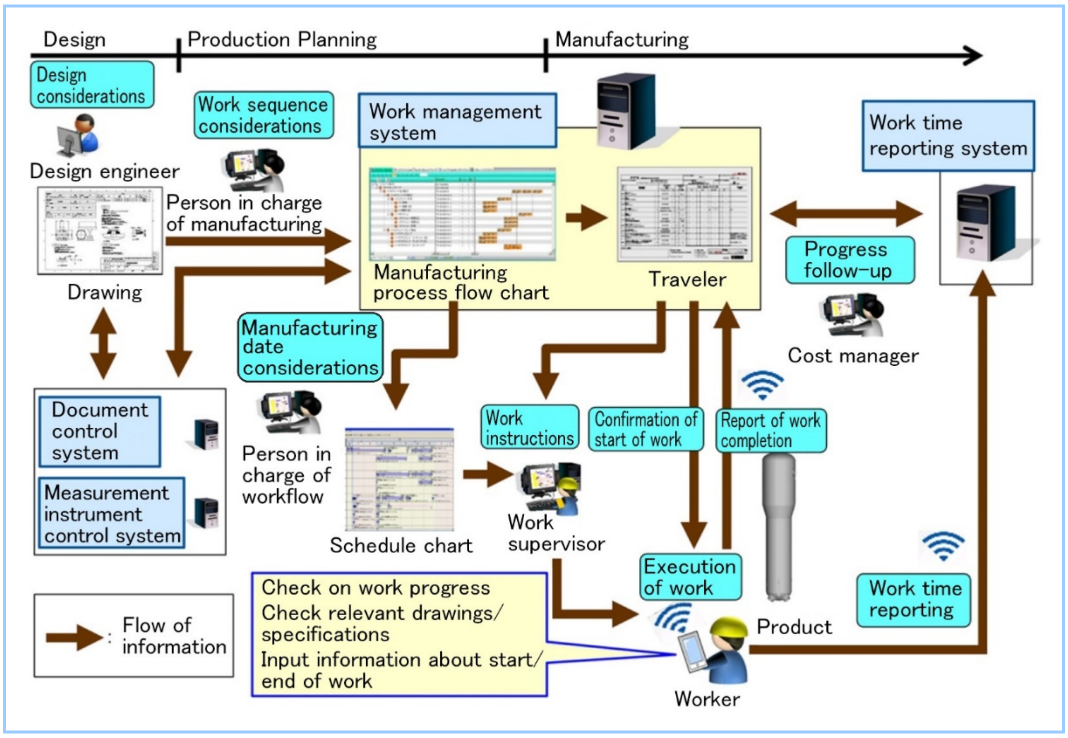

Figure 1 Overview of manufacturing management using work management system

2.2 Use of smartphones for real-time work management

To operate the work management system presented in Section 2.1, all workers are provided with smartphones for use on the premises and a highly-secure local mobile network has been built to cover the whole area of the shop. The workers use their smartphones to read the QR code attached to each product/component and access the work management system to check the traveler for work instructions and relevant drawings/specifications. Each worker can input the information about the start/end of their work. **Figure 2** shows the status of a typical QR code to read at the worksite. By allowing individual workers to use the work management system, strict real-time work management can be implemented to realize manufacturing that can meet the high quality requirements of nuclear components.

2.3 Coordinated operation with the measurement instrument control system

It is necessary to ensure that precision calibration is regularly performed on the measurement instruments used in manufacturing processes of nuclear components and keep records of their usage regarding which one was used for what work. The conventional handwritten records involve laborious effort to confirm the usage history. By enabling the work control system (shown in Section 2.1) and existing measurement instrument control system to operate in a coordinated manner, it has become possible to read a QR code attached to an instrument and automatically check the status regarding whether it has been properly calibrated before and whether it is still within the usable period. The capability of retrieving the usage history has been markedly improved by making the information about which instrument was used for what work available in the systems. **Figure 3** illustrates how instruments are managed in a coordinated manner with the measurement instrument control system.

Figure 2 Status of QR code to read at worksite

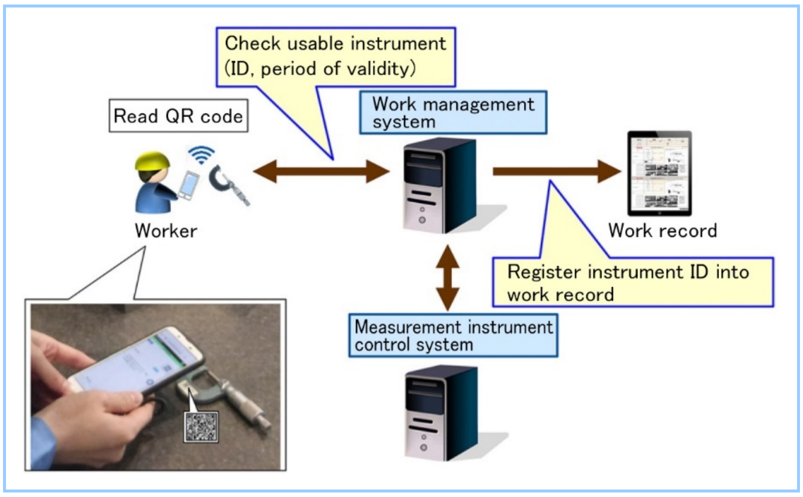

Figure 3 Management of instruments through coordinated operation with measurement instrument control system

2.4 Coordinated operation with the work time reporting system

The daily work time reported by each worker is an important piece of information, which, if summed and analyzed, can provide the exact number of hours actually required to complete a work and allow us to extract the aspects with room for improvement in the work. So far, work time has been reported by writing the hours required for each work in detail by hand, thus demanding a great deal of effort for summation. By enabling the work management system (shown in Section 2.1) to operate in a coordinated manner with the work time reporting system, we have built a system into which the hours for each work instructed by the work supervisor can be input, substantially reducing the time required for totaling work hours. Based on the obtained data, it becomes possible to improve work in an attentive manner.

3. The digitalization of quality records

Conventionally, when manufacturing nuclear components, quality records are handwritten and much effort is necessary to write and collate numerous records. To improve the situation, we have taken on the challenge to rationalize the work related to quality records by digitizing them and minimizing the human involvement in record keeping itself. The digitalization of records is effective in improving the reliability of quality records at the time of creation, making them available in real time and enhancing the capability of retrieving data at a later date. We are expanding the applicability of this technology using various IT applications.

Presented in Section 3.1 is a case of digitalization in which welding work is recorded using an electronic form and tablets for data input. The work records and welding conditions are automatically collated for efficient checking. Section 3.2 describes another case of digitalization in which the input to an electronic form is made possible by direct data transmission from the tools (machine to machine, or M2M) and digital record keeping applications such as voice recognition, in addition to the automatic assessment of work outcomes. Enhanced management of manufacturing processes and work rationalization have thus been achieved.

3.1 Digitalization of welding records

In the welding of nuclear components, qualified welders do the work using established welding procedures using controlled facilities, and once the work is carried out, it needs to be recorded. Welding records are conventionally written manually by the welders in the list of completed works at the time of welding. Much effort was spent to create and check more than 500 sheets of records per month. To improve the situation, we are digitizing welding records. **Figure 4** is a data flow diagram of digital welding records using an electronic form. Conventional handwriting on paper is replaced by electronic input from tablets using an electronic form. The filling in of forms and checking records are automated by enabling coordinated operation with existing systems such as the welding control system, which contains data related to the welding procedures and qualifications of welders and the measurement instrument control system, which contains information about the control of instruments. Information such as the work history of welders and the usage history of instruments can be easily searched and retrieved from the collected data.

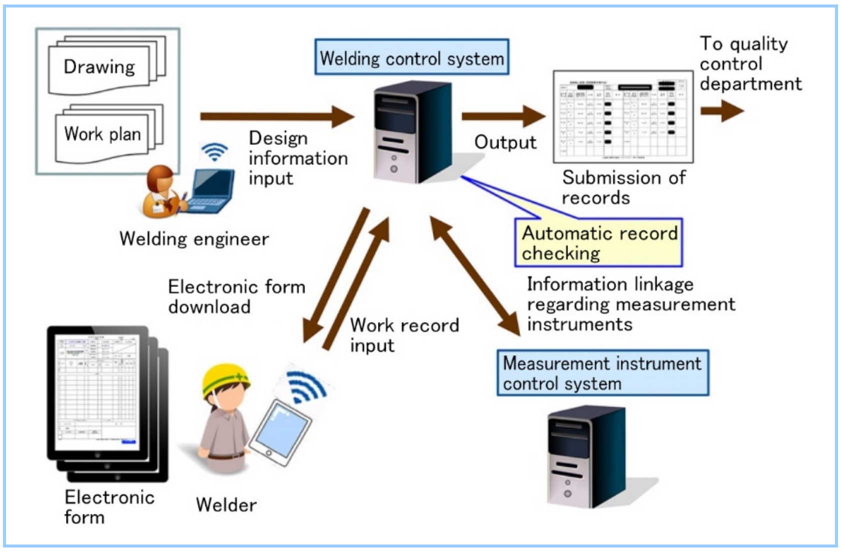

Figure 4 Data flow of digital welding records using electronic form

Figure 5 gives an actual status of welding records input from a tablet.

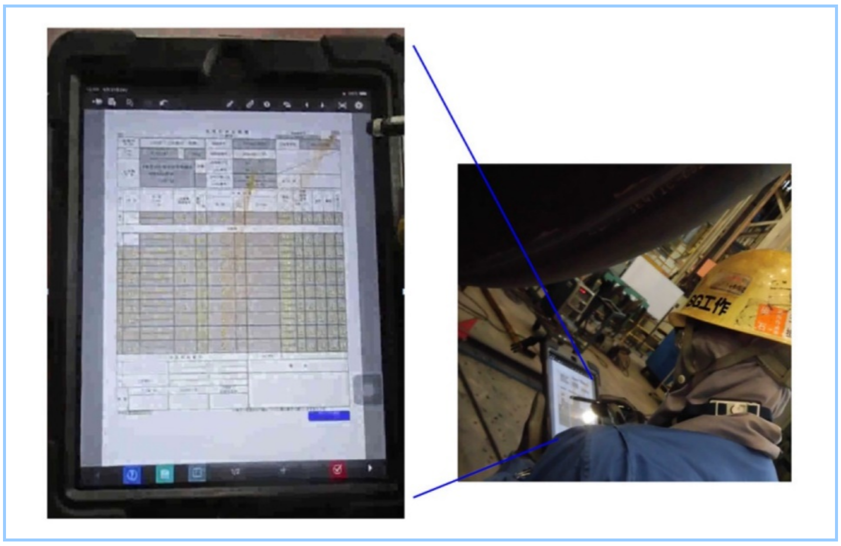

Figure 5 Status of welding records input from tablet

Through the aforementioned activities, we have successfully improved the quality of records and have rationalized the record check process and have also realized the rapid use of recorded data. We are currently expanding the applicability of this technology in order to complete the digitalization of welding records at the shop by the end of 2020.

3.2 Digitalization of other records

To further reduce human involvement in record keeping using an electronic form, rationalize work processes and improve the reliability of records, we are working on the digitalization of work records mainly by means of M2M record keeping or voice entry.

During the manufacture of control panels or electrical equipment for nuclear power plants, we inspect crimpers and measure the tightening torque for bolts to ensure that cables are crimped and that bolts are tightened. Such self-inspection data are usually recorded and kept in check sheets. Conventionally, the measured values were manually written on paper for record keeping. However, using the M2M system that we developed, the value measured by the measurement instrument can be automatically transmitted to fill in an electronic form. **Figure 6** presents the configuration diagram of M2M record keeping and management system. Automatic transmission of the value, which is enabled by making use of data transmission adapters for measurement instruments, tablets and electronic forms, is followed by automatic assessment of the value to ensure that it falls within the range of specifications. The recorded data are uploaded to the shared server so that they are available for search and use.

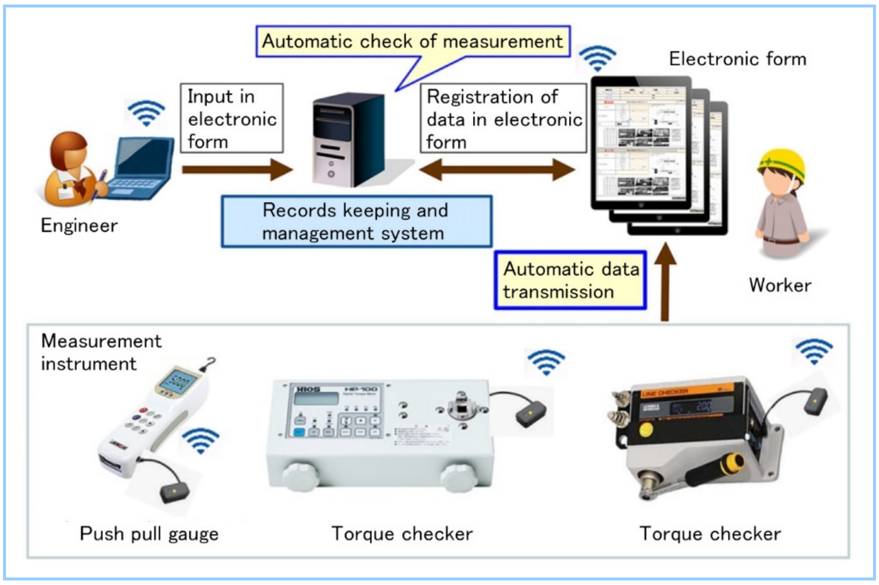

Figure 6 Configuration diagram of M2M record keeping and management system

In the case of work types unsuitable for M2M record keeping, such as tools being M2M incompatible, voice entry is used to reduce the workload. **Figure 7** is the status of such record keeping. For this purpose, headsets with a microphone for voice entry are used to realize hands-free record keeping and data checking. In addition, the system was able to carry out correct input more surely by enabling the system to repeat and confirm in the voice right after the worker inputs voice.

As described above, human involvement in record keeping is minimized by digitizing every type of record mainly by means of M2M record keeping and voice entry, in order to improve the quality of records, realize the strict management of manufacturing processes and enhance productivity. We will further expand the applicability of this technology.

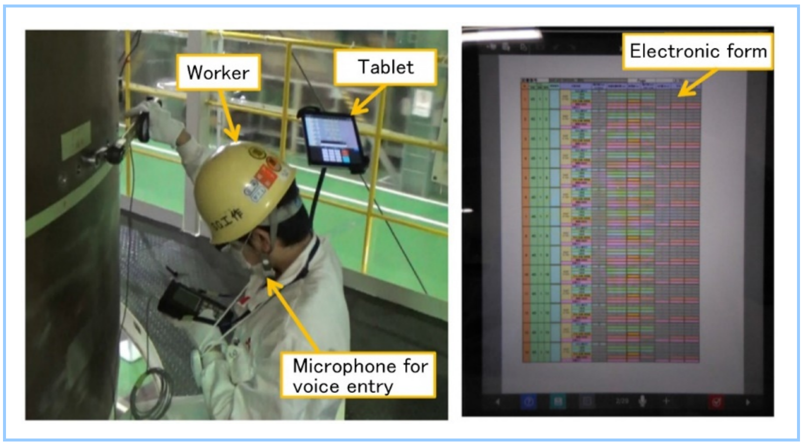

Figure 7 Status of record keeping by voice (bolt tightening)

4. Conclusion

As the main shop for manufacturing nuclear components, we are promoting the sophistication of manufacturing management and the digitalization of quality records in response to demand for advanced manufacturing management and quality control for nuclear components. The manufacturing management and quality of records for work management are the key functions in ensuring product quality. Continued improvement of such functions is essential to enhance the safety and reliability of the nuclear power plants in which these products are used.

As the most advanced shop to provide nuclear components that can be reliably used over a long period of time, we will further promote the sophistication of manufacturing management and quality control using IT and IoT, as well as the expansion of its applicability. We will also promote advanced activities so as to take a leadership role in the manufacturing premise of high-quality equipment.