Acquisition of skills on the shop-floor

— Visualization and substitution of skills in manufacturing —

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For the purpose of assisting skill transfer training in small and medium manufacturing industry, an acquisition method of judgment skills of experienced factory workers on shop-floors of metal processing such as forging, casting and plating is proposed. Several software applications based on the method that have been developed and evaluated in the manufacturing factories are also presented. The future vision of skills and skilled workers in the manufacturing industry is also discussed.

Keywords : Skill, tacit knowledge, skill acquisition, skilled worker

1 Introduction

The objective of this paper is to discuss the results of the research on the “Skill Acquisition Method” that was the subject of R&D in the “Project to Support the Transfer of Small Core Technology,” a project of the New Energy and Industrial Technology Development Organization (NEDO) conducted from 2006 to 2008, for the purpose of acquiring the skills of expert skilled workers of the small manufacturing factories and to smoothly transfer those skills to the successors. Changes in the research scenario will also be discussed. The content of the research described in this paper is the result of the effort of all who participated in the NEDO project, and the author, who was the project leader, shall outline the project as a representative.

In this research, the aspects of physics and engineering were considered for the expert skills in manufacturing technology, while the aspects of cognitive science and business management were eliminated as much as possible. Such a stance was not clearly defined in the initial research scenario. In the beginning, we did not consider the significance of clearly setting such a stance. However, as the research progressed, it became necessary to clarify the positioning of the skill research.

Since this project was supported by the Small and Medium Enterprise Agency, the purpose was to support the small companies. Therefore, the output of the project should be a skill transfer tool that could be used effectively by the small companies. Rather than being an innovative research, the development of an evaluation index which would be popularly used among the companies was important. The recent R&Ds through competitive funding have promoted the so-called outcome orientation where the contribution to the creation of a market after the completion of the project is emphasized. Many researchers in the basic fields feel this is a hindrance. In this paper, we shall also discuss how the demand, “develop a technology that can be used on site,” affected the R&D scenario.

2 Outline of the skills investigated

2.1 Skill and tacit knowledge

The *gino* or “skill” of manufacturing that will be investigated as the subject of this study is defined as “the ability to take actions and to make decisions that are useful in manufacturing, from design to production, although the exact reason why cannot be explained.” The opposing concept is the *gijutsu* or “technology.” Technology is defined as “something for which the rationale and the mechanism of actions taken and decisions made can be explained clearly to a third party, and the third party can reproduce the actions and decisions based on that explanation.” The *jukuren gino* or an “expert skill” is used in this paper to mean a skill that was learned through the long experience of working in manufacturing, and is generally highly advanced and highly useful. A worker who works for a manufacturing company and has this ability is a *jukuren ginosha* or an “expert skilled worker.” Therefore, the method for acquiring expert skills is the method for replacing the skill with technology. This is sometimes called “turning a skill into technology.” The method for acquiring expert skills in this research can be considered a method for turning the skill into technology.

Tacit knowledge is a term related to skills. Michael Polanyi, who was the first to propose tacit knowledge, discusses tacit knowledge in terms of the knowledge associated with physical action that cannot be described verbally, such as the knowledge of riding a bicycle[1]. On the other hand, tacit knowledge[2] in the SECI model of Ikujiro Nonaka is defined as “the knowledge based on experience and insight

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that cannot be expressed verbally." The difference between Nonaka's tacit knowledge and what is defined in this paper is how to address the action skills. Since action is influenced by knowledge, the boundary is not clear, but there is no discussion that encompasses the manual skills of an expert skilled worker in Nonaka's tacit knowledge. The skill discussed in this paper perhaps corresponds to the knowledge ability that combines the tacit knowledge of both Polanyi and Nonaka. On the other hand, Nonaka's formal knowledge overlaps to a great extent with the definition of technology. Therefore, excluding the action skills, the conversion of tacit knowledge into formal knowledge in the SECI model and the conversion of skills into technology are synonymous. Also, this paper will not discuss the tacit knowledge of a group that plays an important role in the SECI model.

By the way, is one person's tacit knowledge, tacit knowledge for other people also? There may be cases where a certain person is incapable of providing a verbal expression or cannot explain the reasons, but the subject might have been studied elsewhere and had already become formal knowledge. This is one assumption in this study. The knowledge of physics, chemistry, and engineering needed in materials and manufacturing is substantial, and we think that the assumption that a worker in a factory can be knowledgeable in everything is not practicable. It is more natural to think that an individual understands only part of the scientific and engineering findings made by humankind. As an assumption of this study, many of the tacit knowledge and the skills of the expert worker have already become formal knowledge (technology). Here, the phrase "does not understand" includes the nuance "has not solved the 'application' of how it affects the workings in the factory even though the principle is known." Although we did not conduct a survey that allows numerical expression, the company engineer who is a world leader in some specialty understands the formal knowledge of that specific narrow field while, in general, a worker at a family-run factory may not have a wide range of formal knowledge. Due to such an assumption, clarification of tacit knowledge that humankind does not yet know and the pursuit of the formal expression of such knowledge are not the subjects in the research for the expert skill acquisition method. This research does not investigate "tacit knowledge" in its true sense.

2.2 Traditional research of skills

The tacit knowledge of Polanyi and Nonaka discussed in the section is briefly explained. Michael Polanyi is a doctor of medicine, chemistry, and a philosopher. He thinks that there is a process in the human action where complex controls are conducted implicitly without explicit cognition, such as riding a bicycle. He calls this process tacit knowledge. If it cannot be essentially verbalized, Polanyi's tacit knowledge cannot be turned into formal knowledge or technology. Therefore, following Nonaka's definition, tacit knowledge will be re-defined as an "action based on experience and insight, and the verbal expression for its control mechanism is difficult," and this will be the subject of investigation in this research. In engineering, researches had been done on the automatic control of motorcycles, and the control system as an alternative to tacit knowledge for riding the bicycle has been realized. Considering this point, the tacit knowledge in Polanyi's sense will not be the subject of this research.

Nonaka, who is a scholar of business management, defines tacit knowledge as a keyword to analyze knowledge management in business, particularly in the Japanese manufacturing industry. He proposes the SECI model where the individual and group tacit knowledge and formal knowledge change and develop as a knowledge spiral. SECI is an acronym for socialization, externalization, combination, and internalization. What we are interested in is the content of the skill expressed as tacit knowledge. It is important to know the engineering meaning of the expert skill that works effectively in response to a new situation. In this sense, our standpoint for tacit knowledge differs from the one that covers business management.

In cognitive science, researches on the skill acquisition mechanism have been done. For example, Ericsson *et al.* point out the importance of training in acquiring expert skills[3]. While this is an extremely interesting topic, how a worker acquires a skill is not the subject of this research.

In engineering, there are proposals of skill transfer using virtual reality (VR)[4] and corporate attempts at digitizing and visualizing the skills for TIG welding[5]. Both researches are technologies to supplement and support on-the-job training (OJT).

Our stance is that it may be possible to express expert skills as formal knowledge, as described in the previous section. The basic policy for establishing the expert skill acquisition method in this research is to express the expert skill using the formal knowledge that has been already established.

2.3 Types of skills under investigation

In discussing expert skills, the mass media often portrays an expert craftsman of a family-run factory using exceptional manual skills to create beautiful parts, and transmits the message that this supports the Japanese manufacturing industry. This will be discussed later, but the skills investigated in this research are the skills related to various decision-makings rather than the skills of action.

The skills used at the processing factories are presented in Table 1. The subject of this research is mainly the skills related to preparations conducted before starting the work, such as the set-up. Particular attention is given to the skill of decision-making. The skill of decision-making is a skill for determining the specific figures, not just determining the right-wrong of a certain action. For example, in forging, such skills include the estimation of the necessary process pressure by looking at the plan and material of the ordered parts. The decision of whether a product can be manufactured by the machines available in the company factory is extremely important in the forging industry, and often depends on the expert skilled worker's assessment.

One of the reasons for looking at the skill of decision-making is because the output of this research is a skill transfer tool that can be used on site. To create the tool, it must be implementable on the computer, in such ways as entering some figures that will produce some figures or graphs. Therefore, it is necessary to look at skills that can be expressed in numbers, and the skills of decision-making became the main subjects of this research.

The goal of the NEDO project under which this research was conducted was to select four core processing technologies – casting, forging, plating, and heat treatment, to select 10 different skills for each processing methods, to extract individual skills, and to develop a skill transfer tool that can be used on site. This project was a joint project by AIST and RIKEN, and RIKEN conducted the research for metal cutting and metal stamping. These processing methods were selected among those set forth in the Act on Enhancement of Small and Medium Sized Enterprises' Core Manufacturing Technology, as enforced by the Small and Medium Enterprise Agency.

3 Research scenario

The development of the skill acquisition method of an expert skilled worker means that the acquired skill must function independently and autonomously from the skilled worker. It means to build a computer system that will be an alternative to the skilled worker, as shown in Fig. 1. Although we were aware of this concept only vaguely at the start, we became conscious of it when we actually executed the R&D. The construction of this alternative became the methodology for skill acquisition in this research. In this chapter, the path we followed is discussed in retrospect.

We started the research by learning how the expert skilled worker conducts decision-making. The case studies of decision-making done at companies were collected, and their importance and qualities were studied. This was the collection of the decision results or the output. Next, we considered the whole body of information that was used for that decision-making. This was the collection of the input for decision-making.

Although it is very interesting to recreate the thought process that takes place in the mind of an expert skilled worker, it is very difficult. Therefore, we built an algorithm that was established from the input and the output. This involved building a computer system using the known formal knowledge. The algorithm was inferred from the output, and the input to establish that algorithm was inferred. This was verified through interviews at the company, and then the algorithm and the input were reviewed. The creation of the alternative of decision-making by the expert skilled worker was the method for skill acquisition in this study.

Since the subjects were the input and output only, as a result, we decided not to consider the thought process of the expert skilled worker at all. Although the subject was skill acquisition, the expert worker was not the subject of analysis. We became clearly conscious of this at the late stages of the research. In this research, a device for observing the actions of the expert worker was developed, and we felt we were observing the expert worker at all times, but that was not the case. In the early phases of the research, consideration of the difference in methodologies for acquiring the different skills – decision-making and action control – was insufficient.

In contrast to the fact that the research for tacit knowledge and skills from the viewpoint of business management focuses on the role of the expert skilled worker and the process of knowledge creation, attention was given to the skill itself in our engineering research. However, neither the business management research and our method considered the thought process of the expert worker, and in that sense, the two were the same. The issue of the tacit knowledge in the brain is an issue for cognitive and brain sciences.

Table 1. Skills in processing.

Category of ability	Ability of expert skilled worker				
	Ability to set up		Ability during work (based on perceptivity)		Others
	Ability to plan	Ability to adjust	Ability to determine situations	Manual skills	Ability to respond to trouble, etc.
Example of on-site skills	・Processing method planning ・Riser arrangement planning	Adjustment of additives according to the day's weather	・Tapping timing: "Take it out now"	・Pouring ・Polishing ・Burr removal	Capable of responding quickly to new trouble
Difficulty of measurement	Easy	Relatively easy	Relatively difficult	Difficult	Difficult

Before work　　Immediately before work　　During work

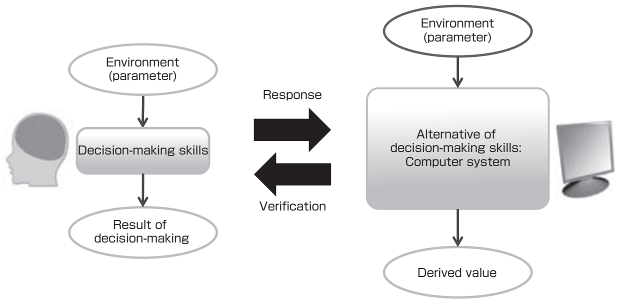

Fig. 1 Model for acquisition of the decision-making skills.

4 Research result

In this chapter, the skill acquisition method that was finally organized will be described. More accurately, the framework for acquisition is presented. This framework fails to propose the meta-structure for skill acquisition that allows acquisition of a desired skill with ease. However, it may provide a certain viewpoint when acquiring the skills and when considering the meaning of the expert skilled worker in future manufacturing.

4.1 Overall structure

The result of this research can be organized as shown in Fig. 2. The computer system as an alternative has a derived model for outputting the decision value. The derived model is composed of the derived algorithm that calculates the decision value by entering measurements or some derivable values from the work environment.

The excellence of an expert skilled worker that became clear by studying this derived model is the “ability to simplify the problem.” For example, in forging, the important role of the expert skilled worker is to calculate the pressure needed for manufacturing the product. Here, the expert worker seems to simplify and categorize the complex product shape to calculate the processing pressure. It is assumed that by doing so, the parameters to be considered can be greatly reduced and the sufficiently precise answer can be given for deciding whether a product can be forged using the machines at the company. The derived model as an alternative is quite different from an expert worker, yet there is a similarity that the complex phenomenon is simplified. As the research progressed, we thought that the greatest characteristic of an expert skilled worker was the ability to simplify the subject and to quickly come up with reasonably accurate answers. The ability to discern the simplification process is the true value of the expert skilled worker.

Simplification is important in the derived model for alternatives. The on-site environment is often complex, and it often becomes an extremely complex and unstable system if all the influences of the related factors are taken into account. It is necessary to build the derived model to enable decision-making by selecting the truly dominant factors. Also, obtaining useful results from simple input means that the operation on site is easy. The limitation of “developing a technology that can be used on site” actually played an important role in discovering the ways of simplification. In this research, the condition that it must be usable on site was effective in keeping the research activity sound.

Looking at the skill transfer tools created, they can be organized into several types. Following are the explanations of the types.

4.2 Derivation by theoretical formula

In the cold forging treatment, the desired part is shaped by stamping the metal at high pressure. It is known that the deformation resistance and restraint coefficient play important roles as shown in Fig. 3 in the process of metal deformation. From various experiences, it could be estimated that approximate value can be obtained by fitting the shapes of the part shape into some patterns for the purpose of considering the forging pressure, even though the shape of the parts are different. It was also found that by using iron as a standard for estimating the property values, this could be applied to other materials such as magnesium and aluminum.

The derived model for pressure values needed in cold forging was created from the companies’ experience and knowledge of metal plasticity, as well as the drawings and materials of the parts to be manufactured. Figure 4 shows the interface of the implemented computer system. We were also able to create a derived model for the temperature increase of the product during forging.

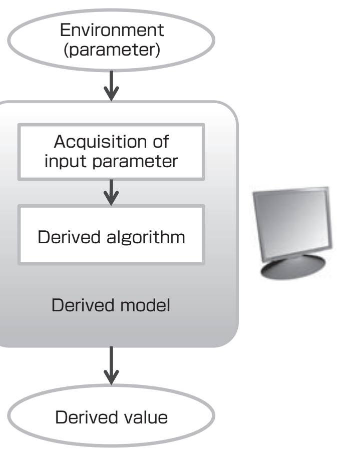

Fig. 2 Structure diagram of the counterpart to decision-making skills.

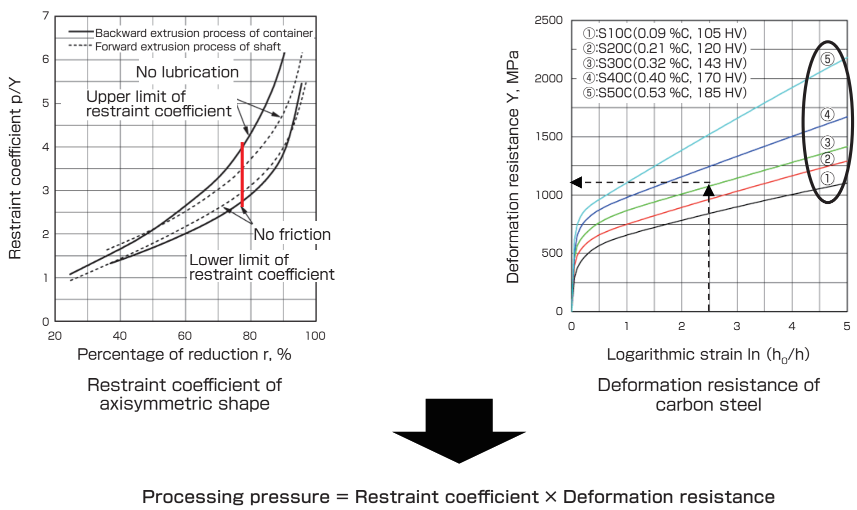

Fig. 3 Model for calculating the processing pressure in forging.

By fusing the theoretical model where the processing pressure is expressed as a product of the restraint coefficient and deformation resistance, and the model for simplifying the product shape based on experience, we created a computer system that serves as an alternative to the decision values that relied on the decision-making by an expert skilled worker. The measurement values of pressure used in actual processing can be entered and stored in this computer system. By doing so, the values dependent on the factory environment or the processing machine can be estimated.

This computer system is one type of simulation for cold forging. In skill transfer, this cold forging simulation can play the following role. First, it can be used as an alternative to the expert skilled worker. If the simulation is perfect, it will be finished there, but the materials and lubricants change with time. Good results may no longer be obtained using the same process if the situation changes. Therefore, the successor must understand the derived model and algorithm that are the basis of this simulation. By understanding the procedure and the principle of the computation, the successor will be able to respond to new situations. In the manufacturing industry that faces severe competition, the ability to do the same work constantly is not sufficient, and the ability to respond to new issues is demanded. In this sense, the simulation in which the principle and the processing procedure are clear can be considered one of the most effective ways to support skill transfer.

4.3 Derivation by experimental formula

In casting, the hardening process of metal plays an important role. The casting technology is a method where precise shapes are created by finely controlling the process of metal solidification. It is possible to an extent to conduct theoretical derivation by entering vast amounts of parameters such as detailed shape of the part, production condition and temperature environment, humidity and temperature of the mold, various properties of the molten metal, and others. However, measuring these figures on site, and entering them to conduct the simulation are very difficult. Also, in casting, the number of parts to be produced with one pour greatly influences the production efficiency and the resultant cost. Company cannot be managed by looking only at the product quality.

Considering the various conditions, we thought a mechanism for collecting and storing data that included the algorithm for experimental production based on estimates to some degree was more effective than the simulation format. The material deforms during the heat treatment. It is important to estimate the degree of this deformation. For this purpose, we conducted preliminary experiments at research institutes or companies, selected the degree of deformity and the main parameters that govern the process, and then created the experimental formula. We employed the derived model based on the experimental formula as an alternative to the expert skill of estimating the deformation in heat treatment (Fig. 5).

To handle new situations, successors have to employ new experimental formulas as derived models. Therefore, they need to learn the knowledge of physics pertaining to metal materials and to understand engineering to see how the simplification is done. We believe this is the skill turned into technology that the successor should inherit.

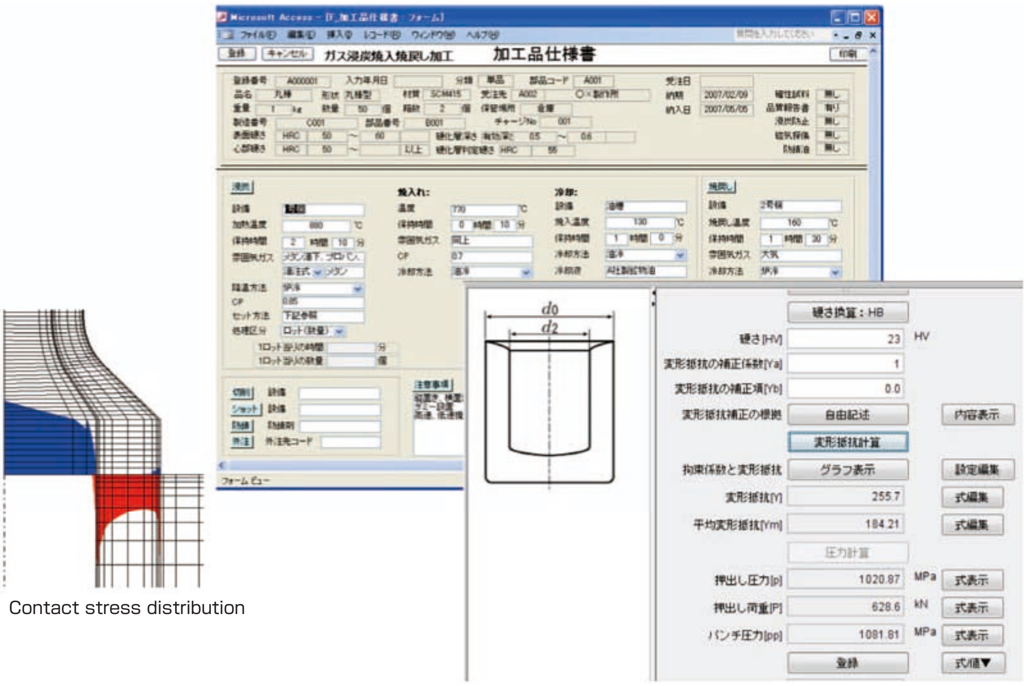

Fig. 4 Example of a system for decision-making skills.

4.4 Derivation by data mining

In manufacturing, responding to various troubles is an important skill. In plating, we built a mechanism for organizing the case studies of defects, to collect and to accumulate the relationships between the candidate causes of defects and the correctional procedures from the past data.

The troubles are categorized, and when a trouble actually happens, it is determined to which category a defect belongs. The past data are searched based on the situation where the defect occurred as additional parameter, and countermeasures are taken. This is a type of data mining. This is a method for obtaining the appropriate information from the past storehouse of data, for cases where the theoretical or experimental formulae cannot be estimated. Cluster analysis, neural network, and genetic algorithms may be effective, although these were not conducted in this research. In casting, we use a search method with an interface as shown in Fig. 6 to search the past case studies. This is a method called Eagle Search developed at the Center, and is characterized by the flexibly interchangeable search keys.

The fact that the derived model is based on data mining indicates that the derived model under investigation is not sufficiently clarified. If the cause can be theoretically pursued from the troubles that occur and the response can be clarified, a theoretical derived model can be built, rather than using data mining. However, in actual situations, theoretical pursuit may not be possible because the defect is not reproducible or the cost of reproduction is too great. Therefore, data mining where the past case studies and their solutions are accumulated and searched is effective as a skill for responding to trouble.

The three derived models were presented above. Comparing them, the method based on theoretical formula seems to be the most effective and reliable. That is because the derivative method can be explained theoretically. The method by experimental formula seems to be reliable following the theoretical formula method since the assumed parameters and their mutual relationships are clear. The method of data mining seems to be the least reliable since the cause-and-effect relationship is unknown. Therefore, the derived models should be reviewed constantly, and a method based on a theoretical formula must be investigated as much as possible.

However, the differences among these methods are not necessarily clear. The difference between the derivations by theoretical and experimental formulae is the difference of whether the theory is established or not. For data mining, as the range of the issues become clear and the data are accumulated, the estimation of an experimental formula may become possible. When using this research result, the derived model should be reviewed according to the changes in the situation and the method with higher reliability should be explored further.

4.5 Other derivative methods

For the decision-making skills, we believe the above three methods are typical. However, there are skills other than decision-making that must be transferred. In metal stamping that was studied by RIKEN, the processing methods are different according to the types of parts under investigation. This means that the most important skill is the skill of selecting the processing method according to the characteristic of the parts, and the skill of discerning the points that must be focused on in selecting the processing method. The selection of the processing method design is too complex to be called a simple chain of decisions. In this project, we worked on skill transfer by creating a meta-flow

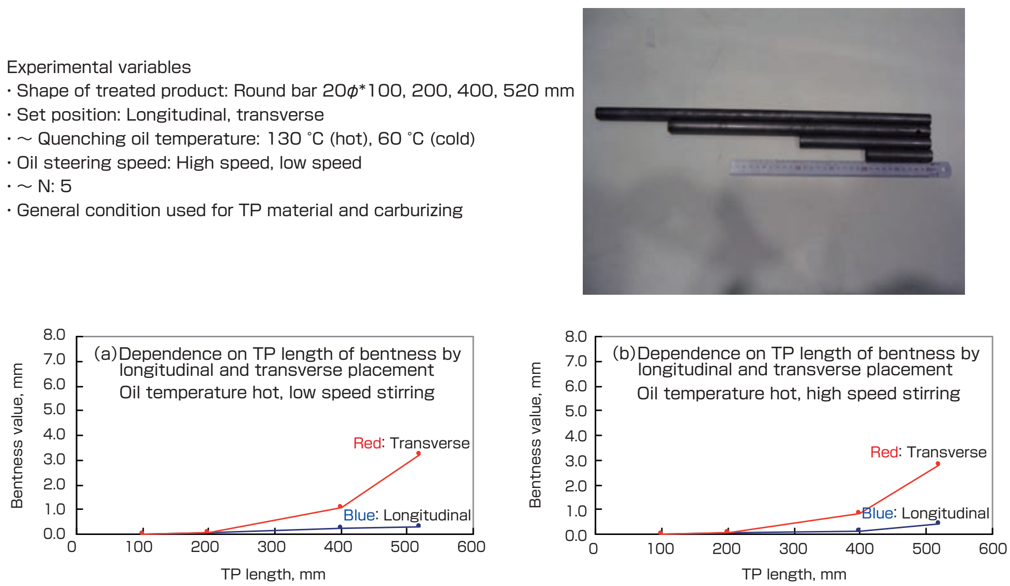

Fig. 5 Example of derivation of experimental formula in heat treatment.

model, but it is difficult to discuss this within the range of the above-mentioned three methodologies. This will be a topic of future research.

4.6 Measurement of the action of expert skilled worker

For the skill of action of the expert skilled worker, the following study was conducted in this study. One was the visualization of the pouring action in casting. As shown in Fig. 7, a device to measure the flow rate of the molten metal was developed by attaching a strain sensor to the neck of the ladle used in pouring. By doing so, we tried to visualize the expert skill of “fast in the beginning, slow in the middle, and push it in at the end!”

While visualization became possible, it is known that fine adjustments are done depending on the situation such as the number of parts produced and the form by which the parts were linked, and such control mechanism is not simple. To analyze the action, the meanings of the actions become apparent only by interviewing the expert skilled worker on how to control what, and then analyzing the relationship of the action and the flow rate and temperature of the molten metal. The analysis of the action skill requires the clarification of the meaning of the control, but that level has not been achieved in this research or in a similar research on welding.

5 Skills in future manufacturing industry

We discussed the research scenario and the result of acquiring the decision-making skills of the expert skilled workers, and described some examples of decision-making skills and the visualization of the action skills. Would expert workers in companies become unnecessary as such researches progress? We would like to discuss the training of future skilled workers and the positioning of expert skills.

The issue of expert skills is an issue for large corporations as well as small companies. For example, painting and welding are done almost entirely by robots in the automobile industry. The setting of the action is done by a method called “teaching,” and the actions of the robots are determined by the expert skilled worker. However, as the factories became automated and the skilled workers lost their workplace, the companies are now facing the problem where people who can determine the appropriate painting and welding conditions for new materials and new paints are no longer present. This also points to the problem that the companies do not fully understand the control mechanism of such actions.

As discussed in the section of the derivation by theoretical formulae, it is important that the successor who inherits the decision-making skills fully understands the physical and engineering meaning of the actions. It is necessary for the skilled worker of the future to engage in decision-making and action with sufficient engineering knowledge, at least in related fields. The worker must observe the actions objectively, and play the role of creating new skills by adapting to the new environment as an expert skilled worker. The future image of the expert skilled worker is to be an advanced engineer on site at the factory.

The fully analyzed skill is converted to technology, and automation will be realized by robots. The worker himself will then go on to study the next topic. The author believes that the future skilled worker should take on the role as an engineer. The companies and the society must favor such human resources in terms of status and income, or else the future of Japanese manufacturing, which is currently considered to be the top in the world, will be in question.

The skills of the current expert skilled worker are the results of long, hard efforts by excellent human resources who were the young people called the “Golden Eggs” who came from

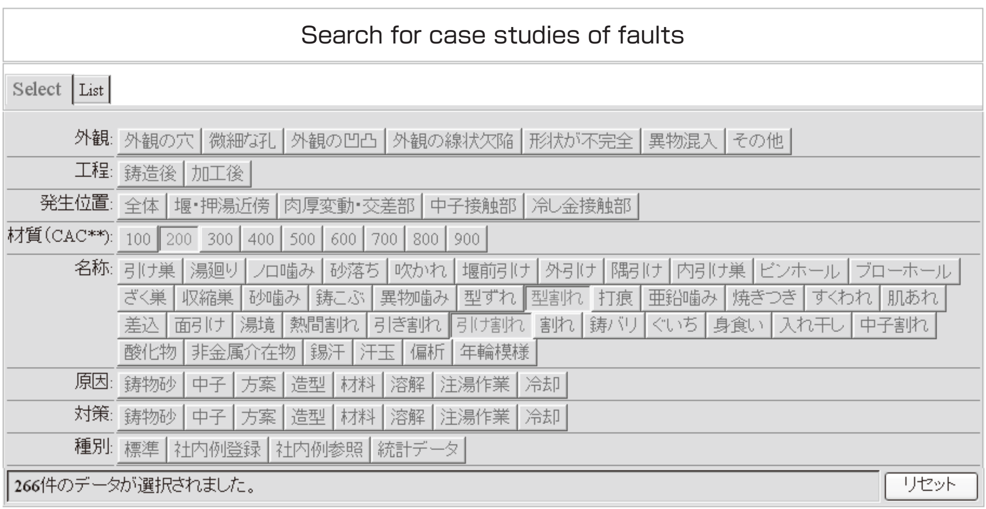

Fig. 6 Example of screen for data mining.

the rural areas to work in the large cities. I think we have come to the end of the age of manufacturing where high school graduates are called skilled workers while the college and graduate school graduates are called engineers. At the same time, the mass media message saying that the expert artisans of the family-run factories support the Japanese manufacturing industry must be corrected. While their role is not small in terms of required precision and cost, the future cannot be warranted by exaggerating the image of the artisans.

Finally, I shall discuss to whom the expert skills belong. Discussion on the possession of invention by the corporate researcher started with the blue diode incident, but the possession of the skills of the expert skilled worker is hardly discussed. When the skills for processing that was cultivated carefully over time is converted to technology, is the skilled worker left with nothing? Recently, the problem has been raised on the outflow of skills when the corporate retirees are invited by foreign companies to provide local training overseas. However, we must first discuss the subject of the possession of skills. I think there must be serious discussion by various parties involved.

6 Conclusion

The outline of the research scenario for the acquisition of expert skills and the results of the research were described. The results obtained in this research are as follows:

(1) The method by computer system construction as an alternative of the expert skilled worker was proposed for skill acquisition; and

(2) The alternative computer systems including the ones based on theoretical formula, experimental formula, and data mining were described.

We also discussed the position of expert skills in the future manufacturing industry.

The Digital Manufacturing Research Center has conducted research with the objective of "studying manufacturing scientifically." I think the R&D for the acquisition and the visualization of expert skills has clarified the relationship between expert skills and manufacturing better than ever before.

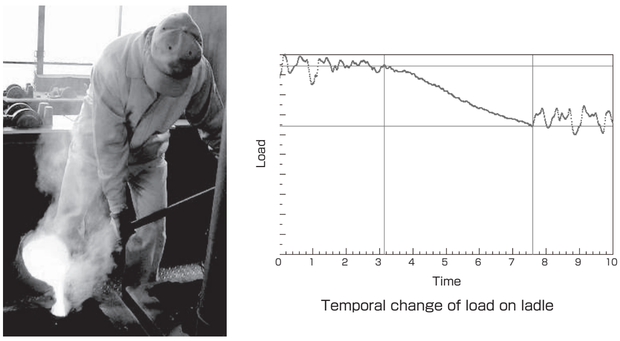

Fig. 7 Expert skill in casting and its visualization.

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Discussions with Reviewers

1 Structure of the paper

Question (Kanji Ueda, AIST)

It is unclear whether the title, objective, method, result, and discussion of the paper are exactly the same as the NEDO project "Skill Acquisition Method." Is the first section a part of the latter section, or is it reconsideration from a different point of view?

Answer (Norio Matsuki)

This paper is intended to be a description of the NEDO project "Skill Acquisition Method" from the viewpoint of the twists and turns in the research scenario. It was unclear at what point this view was taken, and the paper was revised to clarify that point.

2 Changes in setting of the scenario to match the actual situation

Question (Kazuo Igarashi, Measurement Solution Research Center, AIST)

You wrote that the direction was shifted to create an effective tool and allowed the use of methods outside the initial scenario because the initially set scenario could not be executed by ignoring the demands on site. However, estimating from the content of the factors that prompted the change, I think the items described here are important subjects that should have been studied and discussed in the beginning when the project was proposed.

Answer (Norio Matsuki)

As you indicated, they should have been studied beforehand. However, the actual situation of skills at the companies is complex, and there were many things that we would have never known until we started the project. I think this research could have resulted in a tool that could be utilized effectively on site even with the initial assumptions only, but we believe better results were obtained by changing the scenario according to the situation.

3 Clarity of the components

Question (Kanji Ueda)

For the derived model, is the content of “as derived model, theoretical formula… experimental formula… data mining…” related to Fig. 7 (Expert skills in casting and its visualization) or does it refer to the hypothesis or the obviosity?

Answer (Norio Matsuki)

These are the hypotheses of this research. If possible, we would like to continue our research of skills and continue investigating these hypotheses.

4 Future of expert skilled worker

Question (Kazuo Igarashi)

You say: as a result, it is necessary to have sufficient engineering knowledge to be a successor of an expert skilled worker in decision-making and action. You also say: the future image of the expert skilled worker is an advanced engineer on site. Certainly, this conclusion is in one direction, and while it may be applicable to large corporations, I don’t think this is feasible in middle and small businesses that were the subject of this research, due to the resource recruiting problem. Is it appropriate to draw such definitive conclusions in this paper?

Answer (Norio Matsuki)

The manufacturing industry faces severe global competition regardless of the size of the company. While this may sound like an extreme conclusion, I think even the small and minute companies can no longer afford to employ unskilled laborers in a traditional manner, and must move in this direction.