

Advanced TPS for Global Production Strategy: V-MICS-VM for Intelligence Operators

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Abstract— To achieve simultaneous, worldwide high quality assurance and other global production developments, today's task is to maintain high reliability in production facilities. In response to the increasing expansion of overseas plants, it is necessary to improve and maintain highly accurate production equipment through the development of intelligence operators.

The authors clarify in this paper *Advanced TPS* as a global production technology and management model designed to realize high quality assurance in global production. Furthermore, the authors propose *V-MICS-VM* (*Virtual - Maintenance Innovated Computer System – utilizing Visual Manual*) that contributes to *Advanced TPS* utilizing a visual manual that consists of three elements, (i) fundamental skill acquisition (*-FSA*), (ii) equipment knowledge acquisition (*-EKA*) and (iii) preventive maintenance acquisition (*-PMA*).

Specifically, the authors developed a visual manual that can be simultaneously distributed and used throughout the world. The effectiveness of this system has been verified in the domestic and overseas Toyota plants.

Keywords—Global Production, Intelligence Operator, Advanced TPS, V-MICS-VM, Visual Manual, Toyota

I. INTRODUCTION

Recent Japanese enterprises have been promoting global production in order to realize uniform quality worldwide and production at optimal locations for survival through severe competition [1]. To achieve simultaneous, worldwide high quality assurance that accompanies simultaneous production startup and other developments of global production, an important task is to establish a new production control system. This system would allow the production department to develop a new, highly reliable production system that enables global production. In response to the increasing expansion of overseas plants, it is necessary to improve and maintain highly accurate production equipment through the development of intelligence operators.

The authors have clarified *Advanced TPS* as the global production technology and management model designed to realize high quality assurance in global production. Particularly, in order to accomplish a new, highly reliable production system, intelligence operators are expected to have a deep knowledge of facilities (manufacturing).

Furthermore, the authors propose *V-MICS-VM* (*Virtual - Maintenance Innovated Computer System – utilizing Visual Manual*) as a new people-centered principle that contributes to *Advanced TPS* that consists of three elements, (i) fundamental skill acquisition (*-FSA*), (ii) equipment knowledge acquisition (*-EKA*) and (iii) preventive maintenance acquisition (*-PMA*). Specifically, the authors have developed a visual manual that can be simultaneously distributed and used throughout the world. The effectiveness of this system was verified in domestic and overseas Toyota plants.

II. BACKGROUND- NECESSITY OF NEW MANAGEMENT TECHNOLOGIES

It is generally perceived that the Japanese style production system represented by the Toyota production system (TPS) was the management technology that Japan contributed to the world in the latter half of the 20th century [2]-[4]. However, conventional TPS, specifically kaizen and genchi-genbutsu, has not caught up with the speed of globalization. Amidst severe global competition for survival among manufacturers in Japan and abroad, and through the rapid expansion of global production, the most important mission in developing highly reliable new products ahead of competitors is the simultaneous attainment of QCD requirements.

In order to accomplish these requirements, an important task is to establish a new production control system. This system would allow the production department to develop a new, highly reliable production system that enables global production. In moving towards applying this new system all over the world, it is necessary to improve and maintain highly accurate production equipment through the development of intelligence operators. Consequently, a production technology and management model that involves the systematization of production management methodology for the next generation of global production control must be rapidly established.

III. STRATEGIC DEVELOPMENT OF THE GLOBAL PRODUCTION SYSTEM ADVANCED TPS

After the globalization of production resulted in the rapid expansion of overseas production, several cases of failure to achieve output targets occurred at overseas production sites. These failures were due to productivity underperformance resulting from the accumulation of kaizen and other efforts. This indicates that the traditional production system relied on the kaizen awareness of operators, or personal quality, and that the system was not effective for foreign people with different cultural backgrounds.

Therefore, the authors considered the necessity of including and organically integrating four elements (quality, cost, productivity and workability) with the strategic application of conventional TPS in view of global production. We have clarified Advanced TPS as a global production technology and management model as shown in Figure 1 [5]-[7].

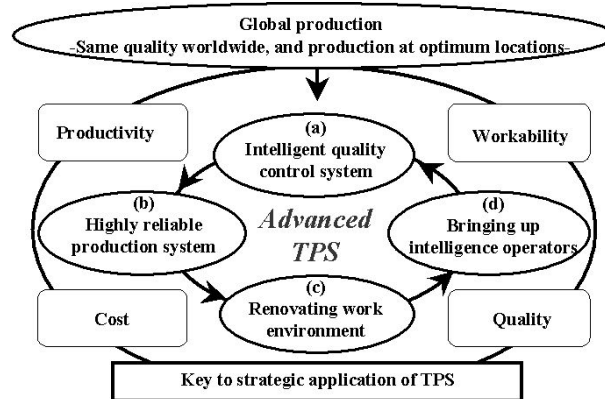


Fig. 1 Advanced TPS, global production technology

The aim of globally deploying Advanced TPS is to realize high quality assurance in global production. In implementing Advanced TPS for uniform quality worldwide and production at optimal locations, the fundamental requirements are renewal of production management systems appropriate for digitized production and creating attractive workshop environments tailored to the increasing number of older and female workers. In more definite terms, implementing Advanced TPS requires (a) strengthening the maintenance and improvement of process capabilities by establishing an intelligence quality control system; (b) establishing a high-reliability production system for high quality assurance; (c) reforming work environments in order to enhance intelligence productivity; and (d) developing intelligence operators (skill level improvement) and establishing an intelligence production operating system.

Particularly, in accomplishing a new, highly reliable production system appropriate for digitized production, intelligence operators are expected to have a deep knowledge of facilities (manufacturing). In other words, to realize simultaneous QCD attainment, it is necessary to improve and maintain these facilities by developing the skills of intelligence operators.

IV. PROPOSAL OF V-MICS-VM

A. Necessity of developing high quality assurance for global production

The foundation of conventional maintenance activities can be summarized as trouble detection and improvement. In the past, cost reduction was mainly conducted through repeated kaizen. Recent globalization involving increased overseas production has sometimes resulted in production quantity targets not being achieved due to low productivity at overseas locations. The authors [8] therefore perceive developing intelligence operators as the key to success in global production with high quality assurance. In order to achieve high quality assurance, it is necessary to ensure a consistent level of manufacturing skills (especially fundamental skills) for all intelligence operators. In addition, it has been indicated that non-remedied deterioration accounts for 70 to 80% of equipment failures [9] [10]. Actual status surveys suggest the possibility of solving these problems through preventive maintenance. It is considered possible in the future to improve problem detection and the skills of production operators by making them find and repair any minor equipment defects on their own, before the defects develop into actual failures.

B. Details Effectiveness of proposed V-MICS for integrated equipment

The authors have proposed V-MICS (Virtual - Maintenance Innovated Computer System) [5], which focuses on visually representing integrated equipment maintenance skills in preparation for global production. This system works to support innovation in maintenance skills and techniques, such as administering equipment availability, defect analysis [11] [12], and other intelligence-based functions. The authors saw the latest digital engineering technologies, such as computer graphics (CG) and databases (DB), as a new means for transferring intuition and knack for skill at a globally applicable level.

However, it is difficult to maintain the required QCD level amidst rapidly developing global production using only V-MICS.

In addition, the authors propose a new principle as a way of practically achieving intelligence productivity, recognizing the need for the creation of a new, people-centered production system that incorporates rich creativity and the motivation of those involved. Concretely, they should strengthen human resources development for production operators, meaning that intelligence operators carry out some maintenance work such as uncovering minor defects of facilities in addition to manufacturing. This involves developing more highly capable production operators at overseas companies as well as in Japan.

C. Requirement of intelligence operators for global production

Thus far, the authors have achieved given results in improving the maintenance skills. Presently, however, the development of more complex and advanced facilities has subsequently caused a stalemate in the development of production efficiency (maximizing the performance and functionality of a production system), regardless of maintenance skill improvement. It has thus become urgently necessary to effectively transfer maintenance skills to the intelligence operators in order to promptly and precisely improve their knowledge and skill levels. This is achieved by incorporating IT-based educational methods, without adhering to conventional on-the-job training (OJT)-based education that calls for the accumulation of direct experience [13].

For strategic implementation of such activities, it is necessary to develop technicians' intelligence through acquisition and mastery of the following:

- (i) Complete fundamental skills for manufacturing,
- (ii) Knowledge and skills regarding equipment, and
- (iii) Ability to find and repair minor defects.

A device is necessary to train novices so that they acquire a level of skill equals to that of skilled technicians within a short period of time. To do this, it is necessary to get rid of the thick and difficult-to-understand operating manuals, and create and provide novices with intelligence and user-friendly operating manuals to enable them to fully understand the structure of the facilities [14].

Conventional text-only instructions exhibit problems, as they can be difficult to understand as well as search when a certain section is needed.

D. Concept of the V-MICS-VM model as an educational management system

The authors propose the V-MICS-VM (Virtual - Maintenance Innovated Computer System – utilizing Visual Manual) as a new people-centered principle that contributes to Advanced TPS that consists of the three elements, elements (i) to (iii) as shown in Figure 2. This would allow the addition of fundamental requirements, such as the renewal of production management systems appropriate for digitized production, the establishment of high-reliability production systems, the creation of attractive workshop environments tailored to the increasing number of older and female workers, reformation of the work environment in order to enhance intelligence productivity, the development of intelligence operators (skill level improvement), and the establishment of an intelligence production operating system.

Figure 2 shows the V-MICS-VM model utilizing a visual manual, which will be mentioned later, for the establishment of Advanced TPS. The authors have successfully achieved a three-core system consisting of (i) fundamental skill acquisition (-FSA), (ii) equipment knowledge acquisition (-EKA) and (iii) preventive maintenance acquisition (-PMA). The three-core system is explained below.

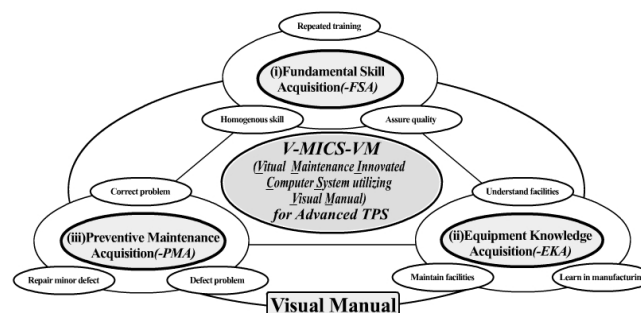


Fig. 2 V-MICS-VM model utilizing visual manual

1) Fundamental skill acquisition (-FSA)

Operators may catch sight of functional defects in a product in the course of performing operational skills such as tightening and inserting. That is why standardized work must be ensured in order to maintain the necessary level of quality. In other words, lack of fundamental skills is the cause of failure to reach target levels. Lack of quality and product defects result from inadequate skills applied to manufacturing.

The authors have therefore developed the fundamental skill acquisition (-FSA) system in response. Specifically, it was

developed in order for operators involved in manufacturing to attain a complete set of fundamental skills. The fundamental skills set is selected according to each production process, as skill level determines whether quality can be assured. All members are trained constantly by reviewing the visual manual mentioned below.

2) Equipment knowledge acquisition (-EKA)

Traditionally, production operators are in charge of manufacturing and maintenance staff in charge of repairing failed facilities. The division of labor among them has been effective in terms of productivity; however, its availability is approaching its limit.

The authors are promoting preventive maintenance, meaning that production operators are expected to have a deep knowledge of facilities and manufacturing as well as detailed information regarding the defective mechanism and equipment structure. As a result, operators would be able to physically detect signs of a defect. This would involve developing more highly capable production operators at overseas companies as well as in Japan.

As a system of equipment knowledge acquisition (-EKA), it is intended that intelligence operators enable production operators to understand facilities and maintain them using visual manuals. For that purpose, production operators are sent to maintenance departments to study off-line construction and other features of facilities. This is done by combining visual manuals and para-equipment, as well as through on-the-job training (OJT) by accompanying maintenance staff to the site when problems occur. By employing these methods, production operators will understand the working of facilities and gain a sound knowledge of manufacturing.

3) Preventive maintenance acquisition (-PMA)

Intelligence operators can find problems and minor defects in facilities and make simple corrections where feasible. Thus, the authors believe that it is possible to enhance their abilities to detect problems and improve the processes and facilities by themselves.

This system of preventive maintenance acquisition (-PMA) is designed with the goal of correcting problems and minor defects. Maintenance staff joins manufacturing departments in order to enable the departments to carry out minor repairs. To this end, intelligence operators are made to experience virtual-reality simulations using visual manuals, and maintenance staff makes use of idle facilities to provide production operators with on-the-job training (OJT). They would also be able to carry out some maintenance work such as uncovering minor facility defects in addition to manufacturing work.

E. Visual manuals, key V-MICS-VM technology

The V-MICS was constructed by integrating CG and DB. This allows maintenance engineering to keep up with recent advanced facilities that have become more complicated due to automation. However, as the globalization of production makes it important that operator with different cultural and linguistic backgrounds share the same level of work expertise, it is necessary to develop, implement, and utilize a user-friendly method that can be used around the world.

Therefore, the authors have invented a new digital communication tool that we call a visual manual. This manual is a key technology that supports the above-mentioned three-core system as well as the V-MICS-VM. The three points listed below are the visual manual requirements.

(1) Easy to create and modify

It is necessary to get rid of thick and difficult-to-understand operating manuals and instead create and provide novices with intelligence and user-friendly operating manuals that allow a full understanding of the topics covered. Manual contents must be modified to reflect clearer thinking.

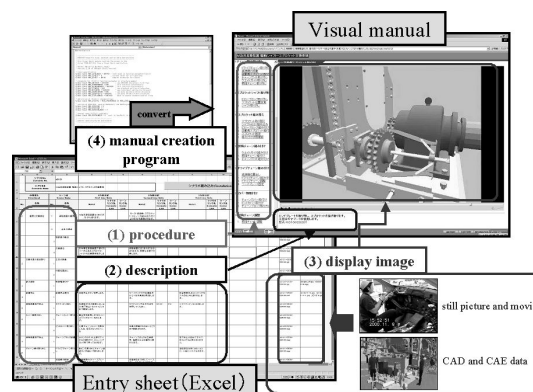


Fig. 3 Schematic visual manual outline

Figure 3 shows the structure of the visual manual creation. The entry sheet was developed using Microsoft Excel, a world

standard. Using this sheet, the operator enters the procedure (1), description (2), and display image (3), followed by running a manual creation program (4) that converts the entered information to a visual manual.

Using this system, anyone can easily improve the manual by correcting images and descriptions whenever necessary. Through these creation methods, manuals, which have traditionally been used solely for obtaining knowledge, evolve through the accumulation of expertise.

(2) Easy searching and accumulation of know-how

It is necessary for intelligence operators to be able to immediately look for and use the necessary contents of visual manuals, at the actual work site and worldwide. In addition, accumulation and delivery of updated data concerning modifications and additions to the manual must occur simultaneously.

Figure 4 shows the system for selecting a visual manual. Selection methods allow a choice of screens according to various topics. Method 1 displays selections in a list and searches for the necessary content from the elements in order. Method 2 is the selection program that uses keywords to display search result and locate the necessary content.

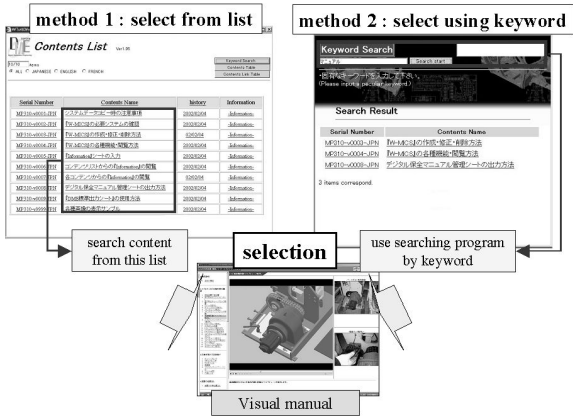


Fig. 4 Visual manual retrieval method

The visual manual data is handled using a general-purpose application in HTML format to make it operable anywhere in the world. Data can be sent both locally and globally via the Internet. Regarding the hardware system configuration, a plant server is installed at each production plant to establish a server and client system form. Intelligence operators read the data via network on the client system (PC) at each office or the actual work site as needed. The intelligence operators then write down any special remarks if necessary. Each plant server is controlled synchronously with the central server. If the content is changed, the system implements the entry and distribution at the same time.

This way, intelligence operators at both domestic and overseas plants can experience data on each process virtually and share knowledge and information on the same process for common understanding.

(3) Visual manuals using CAD and CAE data

Text-only instructions present problems such as lack of clarity or difficulty in searching for the necessary sections. In constant, visual instructions describe a scene perfectly so that members who function in different languages can achieve a unified understanding of the material. Because skill level and training methods can be different according to the trainer, the visual manual allows a higher level of consistency through the use of still pictures and movies.

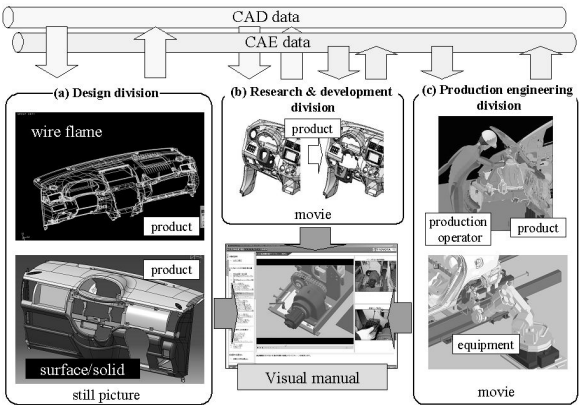


Fig. 5 Using CAD and CAE data

Figure 5 shows data flow using CAD or CAE data. Product data can be easily used by (a) design divisions as a still picture; it can also be converted for use by (b) research and development and (c) production engineering divisions. At the same time, the visual manual can be used at the manufacturing site.

V. V-MICS-VM APPLICATION AT TOYOTA

A. Result of V-MICS-VM application utilizing visual manual

An examination based on the actual results of V-MICS-VM applications proved the efficiency of intelligence operator training in both domestic plant and overseas plants.

1) Example of fundamental skill acquisition (V-MICS-VM-FSA)

Figures 6 and 7 show an applied example of the practical utilization of a visual manual for fundamental skill acquisition (V-MICS-VM-FSA). First, operational procedure is broken down into smaller operational movements. Figure 6 shows the standardized form of the visual manual. The screen consists of a procedure block, description block, and a display image block that has main and sub-screen. This manual is to be read by turning the page using the forwarding button according to the procedure. Particularly, in the description block, key points representing the know-how of each intelligence operator are written and visual information not indicated on the main screen is shown in detail in the sub-screen. This figure displays a movie showing the nut feeding procedure for assembling product parts on the main center screen. The sub-screen on the right side displays a still picture showing a key point of good posture maintaining a right angle between the arm and the fingers. On the other hand, Figure 7 shows an example of a practical training application using the visual manual by an overseas intelligence operator. He watches the visual manual in front of his table while practicing using actual equipment.



Fig. 6 Application example of V-MICS-VM-FSA (bolt tightening)



Fig. 7 Practical training scene using visual manual (bolt tightening)

Intelligence operators all over the world can learn using homogeneous training methods rather than the inconsistent styles of individual trainers. This maintains a high and consistent skill level, while reducing the time required for training by half.

2) Example of equipment knowledge acquisition (V-MICS-VM-EKA)

Second, Figure 8 shows an example of applying visually enhanced description of welding work for equipment knowledge

acquisition (V-MICS-VM-EKA). These materials are designed for off-line learning to assist intelligence operators in understanding how facilities work. The material is about resistance welding, the most common welding work. The principles of welding, welding processes, quality problems, and other information are described in a visually enhanced manner. In particular, the mechanism of occurrence and organization of welding processes and quality problems are revealed.

Each intelligence operator is expected to use this data for increasing the usefulness of the visual manual. Operators can incorporate video images of actual work as well as their own background knowledge to increase the accuracy, thoroughness, and comprehensibility of the visual manual.

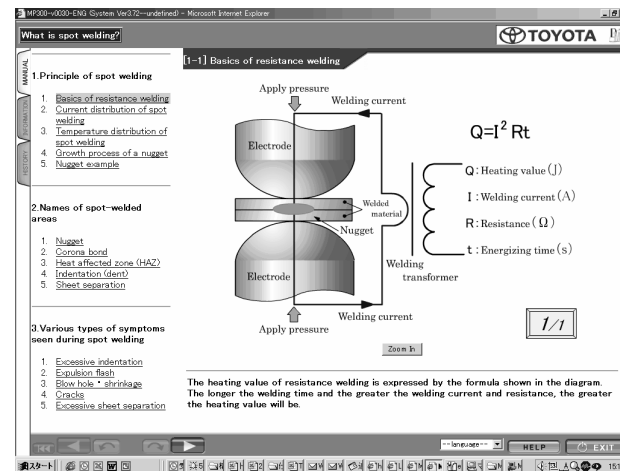


Fig. 8 Application example for V-MICS-VM-EKA (welding knowledge)

3) Example of preventive maintenance acquisition (V-MICS-VM-PMA)

Thirdly, Figure 9 shows an application example using a visually enhanced description of the disassembly of a die-casting pressure cylinder for preventive maintenance acquisition (V-MICS-VM-PMA). These are off-line learning materials showing a method of disassembling facilities to detect faulty conditions (minor defects).



Fig. 9 Application example for V-MICS-VM-PMA (disassemble procedure for die-casting)

The most frequent process among die-casting processes is pressure cylinder replacement. Traditionally, maintenance staff carry out this task after the occurrence of an equipment failure. This example shows the manual enabling intelligence operators to disassemble the facilities in advance, detect any faulty (or slightly defective) section, and correct the defect. The visual data shown in the main screen is animated work procedure data and exemplifies a form of sharing CAD and CAE data (facility design data) in the production group as well as in the design departments of the production engineering group. Each intelligence operator adds their notes on a work procedure sheet regarding points that they become aware of during actual work. Furthermore, they take a video image of the actual work that they redo at a later date and incorporate it into the procedure for ease of understanding.

B. Effectiveness of V-MICS-VM application

As a result of using V-MICS-VM, the target of zero failures was attained in domestic plants two years after the start of the activity in fiscal 2000, thereby establishing a new autonomous production line.

The change in the availability of the line is shown in Figure 10. As another success, it indicates that the target level for the line availability, 95%, has been achieved at an early period after starting the line operation. The data therefore indicates that the deployment to production lines both in Japan and abroad has been carried out with satisfactory results.

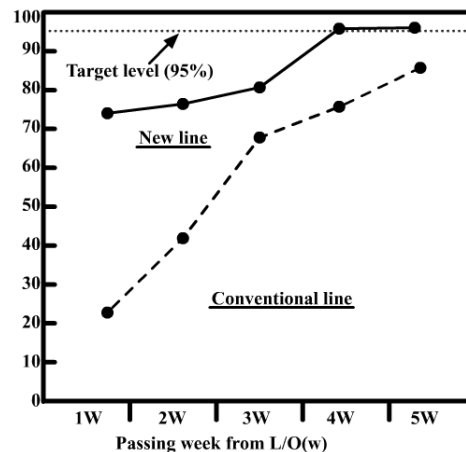


Fig. 10 Transition of availability after startup of the line

VI. CONCLUSION

In an environment of worldwide productivity and quality competition, establishing a new management technology that contributes to success in global production is an urgent goal being sought in the manufacturing industry worldwide. The authors see a need to develop Advanced TPS as the key to the development of Toyota's strategic global production. They also see the need for helping train production operators with different cultural and linguistic backgrounds to be intelligence operators, providing them with a resource to pool their knowledge with the aim of globalizing production and improving the quality of their work. In the course of the implementation of these methods, the authors also created the V-MICS-VM in order to develop the intelligence operators, consisting of (1) V-MICS-VM-FSA, as a fundamental skill acquisition, (2) V-MICS-VM-EKA, as an equipment knowledge acquisition and (3) V-MICS-VM-PMA, as a preventive maintenance acquisition. Specifically, the authors have developed a visual manual that can be simultaneously used and distributed around the world. The effectiveness of this system was verified at domestic and overseas Toyota plants.

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