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Technological Knowledge Management Systems in Large-Scale Facility-Intensive Steelworks*

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< 요　약 >

본 연구에서는 일관제철 공정의 철강산업과 같은 대규모 기계설비 집약적 산업 환경에 적합한 기술지식 경영시스템에 대해 고려하고자 한다. 기술경쟁력 확보를 위한 철강업체의 전략적 기술경영은 핵심기술에 대한 지식경영 활동과 연계될 때 비로소 시너지효과를 극대화할 수 있다. 또한 철강업체의 지식경영은 암묵적 혹은 형식적 제철공정 기술지식의 창출, 획득 및 공유 등의 활동을 통해 활성화되어야 한다. 본 연구에서는 먼저 철강산업 현장의 기술지식 관리대상으로 조업설비 프로세스 및 무형 지식자산의 범위를 정의하고, 일관제철 공정의 핵심기술 로드맵에 따라 기술지식 경영활동에 적합한 계층적 지식경영 조직구조를 구축하고자 한다. 또한 제철공정 노하우 등과 같이 암묵적 기술지식을 획득하고 이를 공유할 수 있는 형태로 변환하기 위한 기술지식 획득 방법론을 수립하고 이를 기초로 인터넷에 기반을 둔 제철공정 기술지식 경영시스템을 구축하고자 한다.

Key Words : technological knowledge, large-scale, mechanical facility, know-how, steel industry, technology management, knowledge management system

주제어 : 기술지식, 대규모, 기계설비, 기술, 노하우, 철강산업, 기술경영, 지식경영시스템

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I. INTRODUCTION

An integrated steel mill is composed of large-scale mechanical facilities in terms of its main processes such as iron making, steel making, hot rolling and cold rolling. Its production lines run successively throughout the year unless a periodical inspection is scheduled. According to the automation of control systems in facility operation, very few operators are required in contrast with the scale of a steelworks facility. The main tasks of each operator are to monitor production systems for the maintenance of normal operations, and to take precautionary measures for the prevention of any trouble or malfunctions. Since steelworks are a series of consecutive lines, any error may cause a fatal degree of damage such as a whole system breakdown. The performance of steelworks operations is evaluated by the measure of how smoothly processed production lines continue without stoppage or trouble, and how consistently low the variance of qualified product output is.

According to an advanced industrial structure and the increase of national income, end-user customers prefer high performance products that feature various advanced functions. The suppliers of raw materials in the iron ore and coking coal and steel consumption industries, such as automakers, have strong bargaining power coupled with a high level of concentration. Thus, the steel industry is like a nut being cracked between the supplier and customer industries, threatened with the pressure of lower costs and the responsibility for innovative technology. Globally leading steel mills are adopting a customization strategy in order to maintain a certain level of market growth and profitability in fierce competition. To ensure a proactive response to various customers and the improvement of productivity, production systems have become knowledge-based, rather than labor- or capital-based as in the past.

The steel industry deploys strategic technology management in pursuit of cost competitiveness and differentiated products such as high strength steel for lightweight properties, hot-dip galvanizing for anti-corrosion, and high formability for pressing. Technology management refers to the managerial activities of planning, acquiring and exploiting technological capabilities in order to achieve a corporate vision. It includes various activities such as in-house R&D, outsourcing, and technology collaboration with competitors. Investment costs become lower according to the progress of steel facility technology, and technology barriers are lowered according to the diffusion of technological knowledge. These factors result in the entrance of more newcomers into the global steel industry.

When technology management in steelworks is interconnected with the activities of knowledge management, the revolution in innovative technology is enhanced by improving performance through the process of systematically searching, collecting and sharing technological knowledge within an organization. The purposes of knowledge management are to improve job efficiency and acquire intellectual property. Technological knowledge acquired through the activities of technology management is also accumulated in the knowledge management system. Therefore, technology management is activated with the integration of knowledge management and vice versa. In 4th-generation R&D theory (Miller 2001), the exploitation of various channels in physical and virtual spaces is effected in order to achieve the innovation of discontinuous technology alongside successful implementation.

This study considers the nature of technological knowledge management systems in large-scale mechanical-facility-intensive steelworks. Firstly, it is emphasized that strategic technology management should be integrated with the activities of knowledge management in order to improve the efficiency and effectiveness of revolutions in technology. Furthermore, the technological knowledge management in steelworks is considered along with the operations management of processing lines and the scope of intangible intellectual assets of steelworks as knowledge objects. The hierarchical organization structure of technological knowledge management is shown according to the roadmap of core technology in steelworks. Finally, an Internet-based technological knowledge management system is developed according to the methodology of knowledge acquisition.

II. INTERCONNECTION OF TECHNOLOGY MANAGEMENT WITH KNOWLEDGE MANAGEMENT IN STEELWORKS

Traditional manufacturing industries such as the steel industry are composed of large-scale mechanical facilities. They pursue the economy of scale and the creation of high added value through the reduction of production costs, the improvement of quality, and the differentiation of product so that profitability and market growth are achieved. As the major consumer of steel products, the automotive industry has been consolidated into 6~8 mega-mergers through M&A and strategic alliances among global automakers. OEMs have a stronger bargaining power against supplier industries such as materials and component parts. They adopt long-term concentrated contracts with a few suppliers and pursue world-wide purchasing for cost competitiveness, and impose more responsibility on suppliers for innovations in technology to create high performance and additional functions. According to rapid changes in customer taste and requirements, the traditional industry has coped with the most appropriate management strategies in order to survive in a climate of fierce competition. Figure 1 shows the trend variation of business strategies with corresponding production strategies as the managerial environment changes.

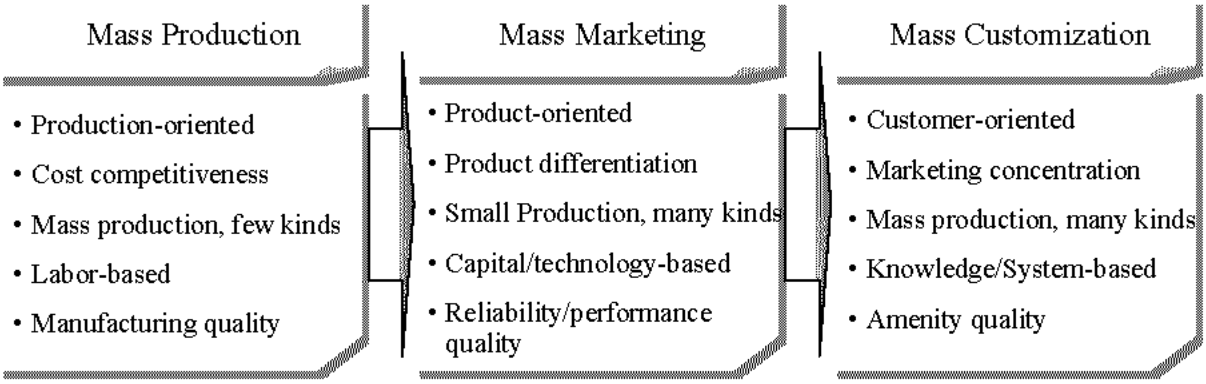


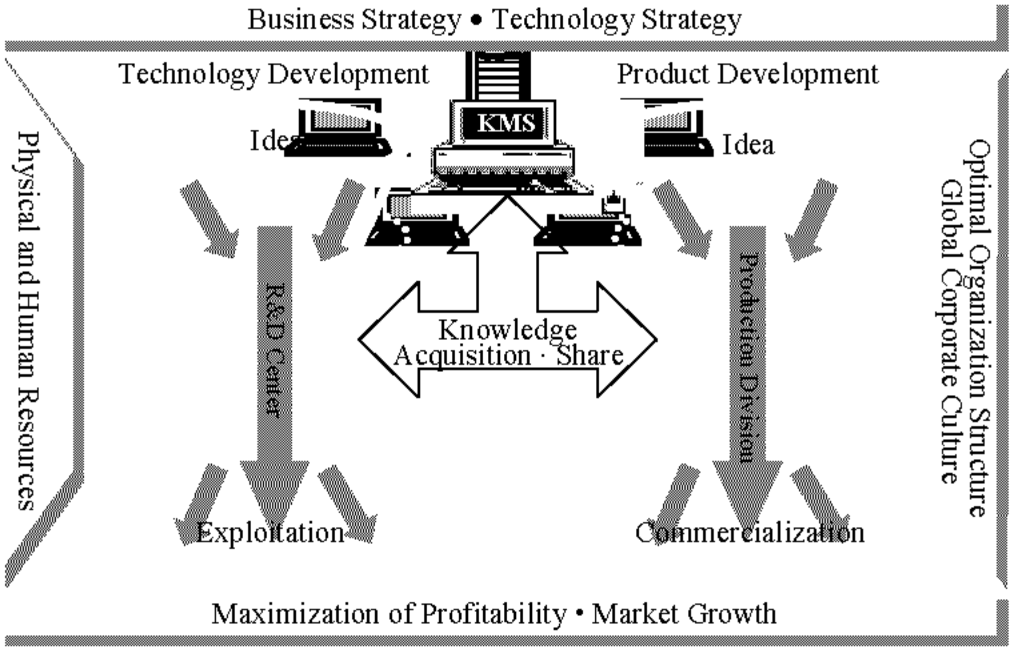
Figure 1. Trend Variation of Business Strategies

Among the five competitive forces noted by Porter(1998), competitors and new entrants with their own core competence always threaten market dominance in an environment of lower investment costs and technology barriers. From the view of the customer, according to an advanced industrial structure and the increase of national income, end-users prefer the quality of amenities brought by the advent of an intelligent consumption era in pursuit of both low cost and high quality.

Now, manufacturers such as steel mills are adopting a mass customization strategy to maintain or even acquire a certain level of market share and profitability through the mass production of various customer-oriented products. For a proactive and quick response to a wide range of customers, production systems have become knowledge-based and no longer labor- or capital-based according to mass production or mass marketing strategies. The steel industry focuses on process technology to improve quality and reduce production costs, and product technology for the creation of high added value in order to expand market volume and the range of customers.

Technology management comprises the management activities of a company in the processes of planning, acquiring and exploiting technological capabilities by combining the principles of science, engineering and management in order to achieve corporate goals and strategy (Betz 1993). It contains various activities of technology acquisition such as in-house R&D, the imitation of external technology, and strategic technology collaboration. Then, the CTO(Chief Technology Officer) in a steel mill plays a leading role in the performance of strategic technology management activities.

Figure 2 represents the context of technology management, which is interconnected with the knowledge management system(KMS) in order to improve the efficiency and effectiveness of technology and product developments. The knowledge management system is a management system to maximize corporate value by improving performance



Frame Source : A. D. Little in Boghani & Brown, Jr. 2000

Figure 2. Technology Management Integrated With Knowledge Management System

through the processes of systematically searching, collecting and sharing knowledge in an organization. The objectives of knowledge management are designed to improve job efficiency and to acquire intellectual property in a firm. Both scientific and empirical knowledge acquired or created through the activities of technology management are also accumulated in the knowledge management system. Therefore, technology management is activated by the interconnection of knowledge management and vice versa.

III. TECHNOLOGICAL KNOWLEDGE MANAGEMENT IN STEELWORKS

1. Operations Management of Large-Scale Facility-Intensive Steelworks

Steelworks are composed of large-scale mechanical facilities and the process and product technology in the steel sector is facility-oriented. Processing lines run successively throughout the year unless a periodical inspection is scheduled. When a production line is temporarily interrupted by trouble or equipment malfunction, it may cause fatal damage to the entire plant as steel mills are linked with a series of consecutive processes. The performance of operations in steelworks is evaluated by the measure of how smoothly processed production lines are executed without stoppage or error, and how qualified are the products output along with a consistently low variance.

The operations management in large-scale facility-intensive manufacturing plants is performed differently according to a consequence, progress, or prevention based structure. Firstly, consequence-based management is desirable for plants with a manufacturing quality problem, where manufacturing systems just start the test run or commercialization. First of all, the quality problem should be solved through the improvement of operational skills. Secondly, progress-based management is desirable for plants with a reliability quality problem of low-grade products from the perspective of percentage or frequent malfunctions. The number of low-grade products should be reduced through total quality management. Thirdly, the prevention-based management is appropriate for plants with a performance quality problem at a level of ppm, where problem-solving capability within abnormal conditions is guaranteed. It seems that domestic steel mills are at the phase of moving from a progress-based to a prevention-based model.

Processing operations in steelworks have radically changed according to the revolution of innovative technology in the field of mechanical facilities, and therefore operators have become knowledge workers rather then physical laborers. The main areas concerned in facility technology are automation to reduce man-hours and man-power, flexible systems to be satisfied with various customer needs, integration of components for quick problem-solving, environmentally friendly design for human beings, interface with external systems, substitute energy for the reduction of emissions, and artificially intelligent systems cognizant of internal troubles and causes.

2. Intellectual Property of Steelworks

By defining the scope of knowledge objects to be considered, the conceptual model of a knowledge management system can be designed. It also prohibits any limitation on the ownership of intellectual property to a few people or small groups, and therefore knowledge management activities are energetically executed with a maximum efficiency of acquisition and utilization.

This study focuses on the manufacturing processes of steelworks, rather than the whole spectrum of business processes in the steel industry. The intangible intellectual assets of steelworks can be classified into six knowledge objects as shown in Figure 3. That is, the regulations and laws of a company and its steelworks, the historic data and operation/maintenance manual of mechanical facilities, knowledge or information data of raw materials and resources such

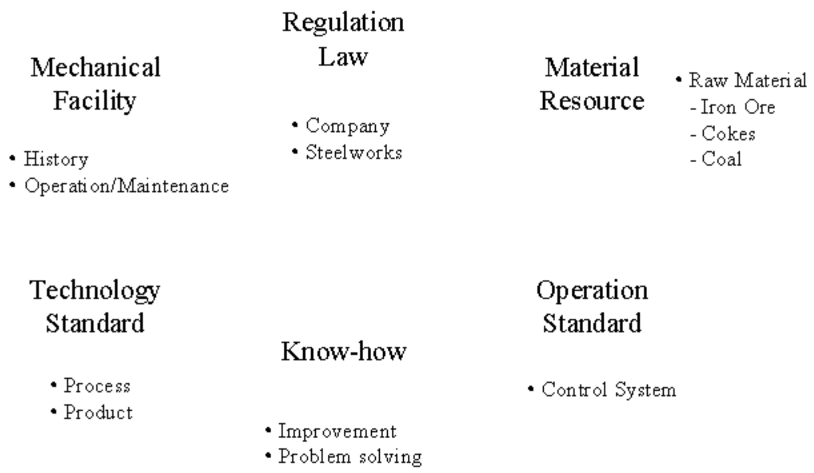


Figure 3. Classification of Knowledge Objects in Steelworks

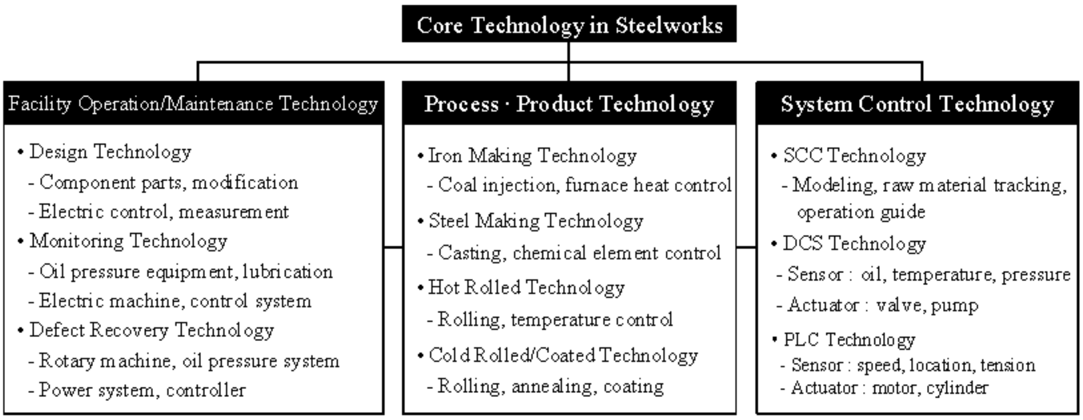
as iron ore and coking coal, product/process technology standards, operation standards, and empirical knowledge obtained in problem solving and improvements.

Among the six knowledge objects in Figure 3, three can be continuously added or modified through operational findings and a revolution in technological innovation: technology standards, operation standards and know-how. We shall assume that these factors are the primary elements of technological knowledge required in large-scale facility-intensive steelworks.

3. Technological Knowledge Management in Steelworks

Technology means to create a product or provide a service by utilizing scientific or engineering knowledge. As a wide-ranging concept, it includes process, invention, experience, function, know-how, etc. Here, know-how means knowing how to do something as a practical concept. It is often used with the know-why of knowing why to do and know-where of knowing where, who and what to do. There are several kinds of know-how, which are easily transferable and simple information, a high level of scientific knowledge-based know-how, and the operational know-how of mechanical facilities. In manufacturing, know-how is represented through improvement and problem-solving, and therefore, it should be widespread in the learning organization.

The core technology in the manufacturing processes of steelworks can be categorized into three areas as shown in Figure 4: process and product technology, facility operation and maintenance technology, and system control technology. Steel products such as cold rolled or hot rolled sheets are produced by passing

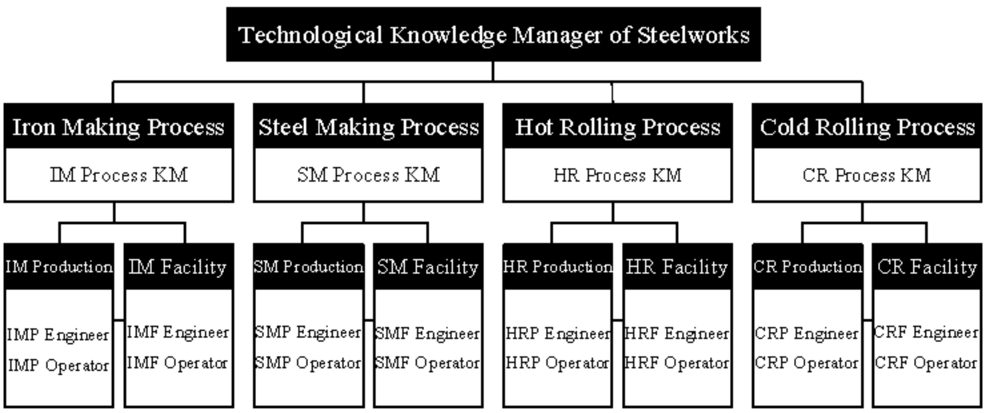


※SCC : Supervisory Control Computer, PLC : Programmable Logic Controller, DCS : Distributed Control System

Figure 4. Technology Roadmap in Steelworks

through the four main processes of iron making, steel making, hot rolling and cold rolling in steelworks. The basis of steel technology is oriented from the facility because the steel industry itself is facility-intensive.

With such a technology roadmap in steelworks, the hierarchical organization structure for technological knowledge management can be represented as in Figure 5. Knowledge workers such as engineers and operators acquire scientific and empirical technologies through the activities of R&D and operation/maintenance. Then, process knowledge managers in each processing division collect and screen the technological knowledge acquired by engineers and operators, in the role of a gatekeeper enforcing the channel of communication among other processing divisions. The knowledge manager of steelworks coordinates four process knowledge managers with decision-making skills, and these knowledge managers develop the goal or mission of knowledge management and execute action plans



KM : knowledge management, IM : iron making, SM : steel making, HR : hot rolling, CR : cold rolling, P : production, F : facility

Figure 5. Hierarchical Structure of Technological Knowledge Management in Steelworks

including training and promotion activities.

IV. DEVELOPMENT OF TECHNOLOGICAL KNOWLEDGE MANAGEMENT SYSTEM IN STEELWORKS

Knowledge can be classified according to sequential phases (Wiig 1993). The first phase of knowledge is idealistic knowledge, or knowledge-why, and is explicitly represented or tacitly shared in the organization. It is utilized in the establishment of corporate goals. The second phase of knowledge is related with system, schema, and methodology, and is utilized in the analysis of new methodologies and alternatives. The third phase of knowledge is the knowledge-how, which is utilized in decision-making and job operation. This knowledge is directly connected with operational know-how. The fourth phase of knowledge is automated knowledge, which is utilized in automatic job execution by embodying conventional knowledge into automated systems. Sometimes, operational know-how in the third phase of knowledge is converted into the fourth phase. In this study, the technological knowledge management system is developed on the basis of sequential knowledge.

This knowledge management system is developed through main activities as shown in Figure 6; that is, the extraction of technological knowledge to be managed, the conversion of technological knowledge to a documented form, the finding of user requirements, and the computerization of technological knowledge management systems. Actually, the extraction and conversion of knowledge belongs to the knowledge acquisition process, and therefore, knowledge acquisition and computerized system development will be considered in detail in the following sections.

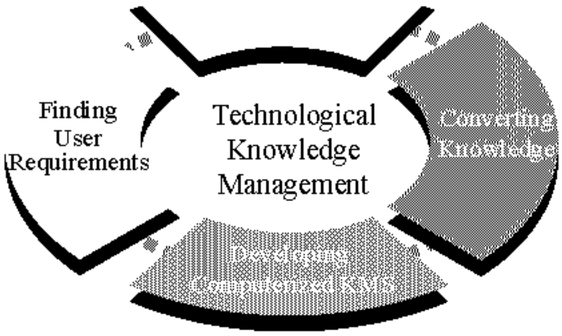
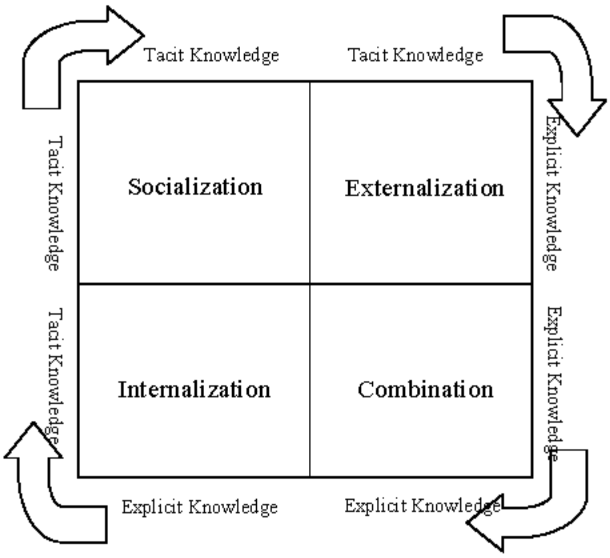


Figure 6. Main Activities in Knowledge Management System Development

1. Acquisition of Technological Knowledge

The technological knowledge utilized in steel processing operation can be classified according to the knowledge source. The first is the manual of operations and maintenance provided by equipment makers, which is basic knowledge. The second is the empirical knowledge experienced in fatal situations, which are not described in the manual. The third is the theoretical or scientific knowledge obtained through RA&D (research, acquisition and development). However, empirical knowledge is basically originated from scientific knowledge, and obtained in the process of utilizing various analytical tools.

Nonaka(1998) classifies knowledge into two patterns: tacit knowledge and explicit knowledge. Tacit knowledge is realized in the form of pattern, physical sense, common sense, image, etc., while explicit knowledge is manifested in the form of language, code, reason, etc. As the mechanism of knowledge acquisition, knowledge conversion is performed through the mutual reaction of tacit knowledge and explicit knowledge. Figure 7 shows knowledge conversion processes such as socialization, externalization, combination and internalization.



Source : Nonaka et. al. 1998

Figure 7. Knowledge Conversion Processes

The main processes in the business value chain of the steel industry are technology and product development, production, and marketing & sales. For these business processes, the knowledge conversion processes are shown in Table 1. In regard to the production process, engineers and operators share their experiences with each other in the process of socialization, and some experiences are converted into explicit know-how through the process of externalization. In order to acquire intangible knowledge there are manual methods such as an interview or questionnaire, and advanced methods such as rule induction and machine learning in computer systems. In order to systematically extract know-how from knowledge workers and experts, the method most commonly used by professional knowledge engineers is the interview. However, only a part of operational know-how in a tacit form can be documented as explicit knowledge.

Next, explicit know-how is combined with existing technology and operational standards in the process of combination. Finally, engineers and operators acquire explicit knowledge through updated standards and improve their technical skills in the internalization process.

2. Structure and Development of Technological Knowledge Management System

The structure of each knowledge management system in a company is different according to its end-users, such as chief executives, middle class managers, and actual workers with the appropriate

Table 1. Knowledge Conversion Processes for Main Business Processes

Business process / Conversion process	Technology Development	Product Development	Production	Marketing · Sales
Socialization	Share of Company Vision and Mission	Communication With Customers, Experts, and Marketing Division	Share of Experience Among Engineers and Operators	Contact and Communication With Customers
Externalization	Innovation	Product Concept	Know-how	Embodiment of Customer Needs
Combination	Patent Applied	Design, Specification	Technology & Operation Standards	Receiving Orders
Internalization	Share of Performance	Understanding Marketing Division	Improving Technical Skills	Training, Simulation

Source : Nonaka et. al. 1998

information. The technological knowledge management system in steelworks is mainly utilized by knowledge workers such as engineers and operators.

The computerization of technological knowledge management systems is composed of three phases as shown in Figure 8; that is, prototype system development, improvement of the system through trial operation, and the final development of a knowledge management system.

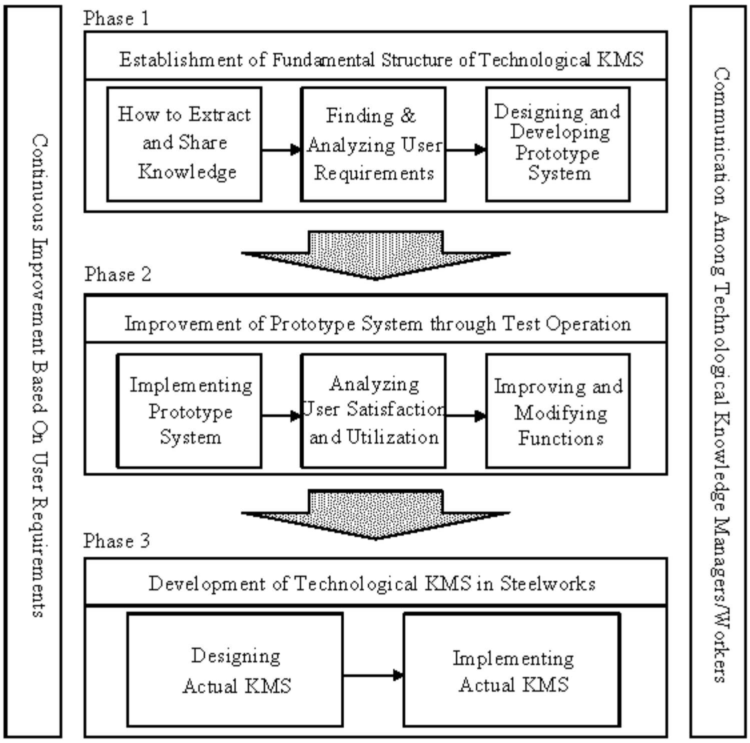


Figure 8. Procedure of Technological Knowledge Management System Development

In the first phase, user requirements can be found via the questionnaire and interview as the most common methods. Through interviews with engineers and operators it has been found that there are two kinds of know-how; that is, know-how about how to continuously maintain a normal condition, and how to cope with serious quality problems. Each knowledge worker keeps a technology pocketbook and records their experiences with related data and information. A technology pocketbook is useful for a quick search during operation, and each year the explicit knowledge in a pocketbook is updated by eliminating the knowledge memorized in his or her brain. This is the process of converting explicit knowledge into tacit knowledge. In most cases, the operators use only a small amount of retained mental knowledge although they acquire advanced knowledge through on-the-job training or learning programs. Because it is not easy to access such a knowledge management system in large-scale facility-intensive steelworks, it is required that information be stored in ultra-mini equipment such as PDA for more active exploitation. All user requirements may not be reflected due to a limitation of system capacity. Regarding the selection of critical constraints, they are prioritized by using the method of analytic hierarchy process (AHP).

The structural design of the knowledge management system is most important since user requirements and system implementation should be simultaneously considered in the relationship of a trade-off. The integration with external systems is also considered in this phase, otherwise it may cause some critical modification or design changes. Figure 9 shows the structure of the technological knowledge management system considered in this study. Tacit knowledge such as know-how acquired from the field experience and explicit knowledge such as technology and operation standards and external documents/reports are stored in the knowledge base. Especially, the problems with their main causes and appropriate treatments are included in the empirical knowledge. Furthermore, daily checking points and precautionary measures for the confirmation and examination are added. The activities of knowledge acquisition and utilization are performed by all constituents in steelworks.

In the implementation phase, system quality such as processing speed, reliability and stability is improved with a verification of the result. No critical problems

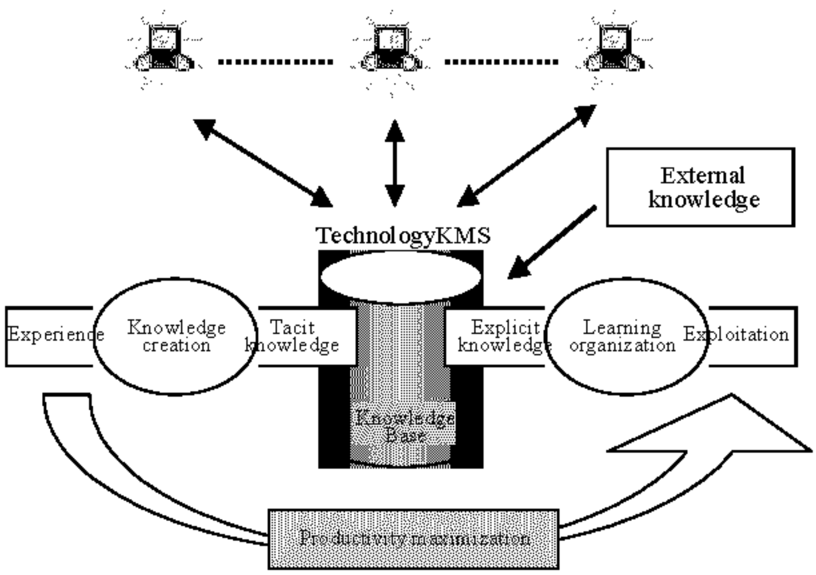


Figure 9. Structure of Technological Knowledge Management System

will occur during implementation if the design phase is sufficiently well performed. A prototype system developed here has been implemented for a certain time, and then inquired into the internal-customer satisfaction. As a result, it has been found that system utilization and user convenience need to be replenished. Technological knowledge management is developed in an Internet-based environment, including search functions so that the accessability, maintenance and interface with other systems can be easily executed. The languages used in this knowledge management system are PHP and MySQL database engines in the Linux environment.

According to the roadmap to search for the technological knowledge of steelworks, core knowledge data is stored in four modules as shown in Figure 5: iron making, steel making, hot rolling and cold rolling. A menu to share the technological knowledge among different processes is also added. For continuous improvements and changes according to a rating of importance, the hierarchical structure with an updated roadmap can be easily modified including the addition or elimination of modules. Figure 10 shows the initial and knowledge search screens in the technological knowledge management system of steelworks, which is known as the TechnologyKMS.

The processes of knowledge registration and exploitation have been improved. By updating the knowledge list in the main screen, the status of knowledge registration is easily confirmed. In order to improve the accessability to the TechnologyKMS, besides the acquisition of technological knowledge, there are some supplementary functions such as daily documentation, reservation for meeting rooms, and linkage with news or related websites. System users can directly access these functions on the initial screen of a TechnologyKMS web browser. For voluntary experts united by a common concern, knowledge base and information, a support community is also provided.

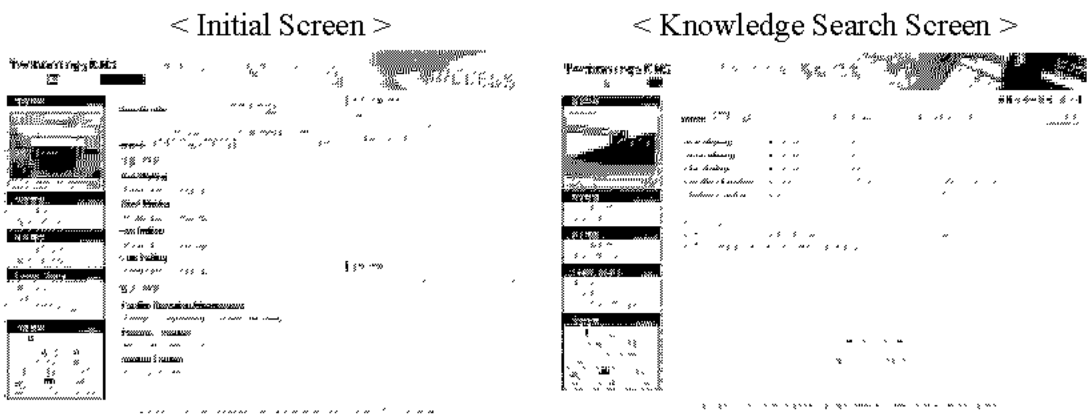


Figure 10. Initial and Knowledge Search Screens in TechnologyKMS

V. CONCLUSIONS

Currently, the steel industry is focusing on strategic technology management in order to achieve cost competitiveness and product differentiation through high value-added activities. Technology management comprises all managerial activities of a company in the process of planning, acquiring and exploiting technological capabilities, as based on the pursuit of a corporate vision and goals. When the activities of technology management are interconnected with the knowledge management system, it is expected to maximize synergy effects. Furthermore, technology management accelerates knowledge management through the acquisition of technological knowledge in the former. According to the progress of information technology, the speed of knowledge transfer is rapidly improved and this activates knowledge management as the source of corporate competitiveness.

This study considers technological knowledge management systems in large-scale mechanical-facility-intensive steelworks. A knowledge management system is not simply designed to register acquired knowledge in computerized systems, but should be leveraged to exploit and diffuse this knowledge within the entire organization for the improvement of job efficiency. In order to stabilize and accelerate knowledge management activities, user convenience as well as functional improvement has to be considered. For the successful development of knowledge management systems, all constituents in a company must join in the process of acquiring, sharing and exploiting knowledge with a precise understanding about their knowledge management system. In addition, knowledge management activities should be periodically evaluated by using a questionnaire or interview methods.

By developing the technological knowledge management system of steelworks, improvements in technical skills and job efficiency are expected through the pursuit of systematic learning. It is also possible to create new business via the commercialization of technological intellectual assets in the role of a technology enabler. However, there still exist some obstacles to knowledge management activities; insufficient time for knowledge activity due to the heavy load of employees' main job, cultural difference such as a passive attitude in debate or discussion, and deficiencies of enthusiasm and proactiveness. As success factors, the systematic support of chief executive officers, voluntary and positive attendance, and leader initiative are necessary.

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