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Deployment of Solution Technologies in the Electronics Field

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Abstract

In the electronics field, information technology (IT) has been developing rapidly with sophisticated computer and network technologies in its core. In this paper, we outline our deployment of solution technologies which take consistent steps: identifying a problem, designing the solution systems and implementing them, while applying these evolving technologies to the various processes in the steel industry. Specifically our solutions consist of open systems solution, process control solution, magnetic fluid analysis solution, and instrumentation solution which all work drastically for cutting costs, improving productivities and qualities of the steel products.

1. Introduction

Competition in the steel industry continues to intensify due to factors like slack domestic demand and the development of a global market economy. This competition is evident in industry restructuring and integration of business departments both within and outside of Japan.

On the other hand, in surveying the electronics field, we notice the rapid development of information technology (IT) based on computer and network technology. As part of this trend, there has been an increasing shift toward open networks for control (exemplified by Device-net*1) and PROFIBUS*2)) and general-purpose, open systems in the area of basic software (i.e. operating systems (OS), exemplified by Windows*3), UNIX*4) and Linux*5)). Open technologies are being rapidly adopted in an ever wider range of general industrial systems. The development of computer technology has made it possible to process large amounts of diverse types of data in a short time, thus making new technologies practical - i.e. technologies for signal/information processing, numerical analysis and simulation to quantify and model at large-scale steel manufacturing process phenomena.

The steel industry is an equipment industry, the mission of engineers involved in the system control technology field is to reduce equipment investment and manufacturing costs, and to improve quality competitiveness. This is achieved via early adoption of state-of-the-art technologies in the electronics field, and by implementing so-called "solution technologies" wherein process issues are quantitatively analyzed, and a consistent approach is taken toward all phases of issue resolution - from problem solution proposal to implementation.

This report outlines the deployment of solution technologies from the electronics field, focusing on steel manufacturing equipment and systems.

2. The Role of Electronics Technology in the Steel Industry, and the Future Outlook

First, we shall discuss the role played by electronics technology in the steel manufacturing field. **Fig. 1** gives a conceptual diagram of the structure of the steel manufacturing process. In each steel process, products are manufactured by working and processing the appropriate materials. Process phenomena are observed using equipment like instrumentation and signal/information processing devices, and subsequently evaluated and elucidated (modeled) by applying

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*1) Device-net is a registered trademark of ODVA (Open DeviceNet Vendor Association).
*2) PROFIBUS is a field bus developed jointly by Siemens, Bosch, ABB and others in Germany.
*3) Windows is a registered trademark or trademark of the Microsoft Corporation (U.S.) in the U.S. and other countries.
*4) UNIX is a registered trademark in the U.S. and other countries, licensed exclusively by X/Open Company Limited.
*5) Linux is a registered trademark or trademark of Linus Torvalds in the U.S. and other countries.

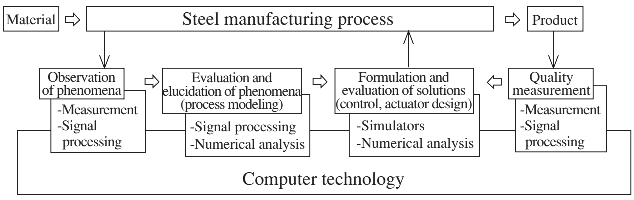

Fig. 1 Role played by electronics technology

various information processing and numerical analysis techniques to the obtained information and operations data. Each control system is designed using a simulator of the modeled process, and optimal control of the manufacturing process is achieved by using numerical analysis to design the various actuators (employing gas or electric power) which drive the process.

Products meeting the required quality are manufactured by using instrumentation to measure the material and form of the manufactured product in real-time, and by controlling the aforementioned actuators in response to the quality requirements of the product. In the manufacturing process for steel products, electronics technologies (for measurement, signal/information processing, numerical analysis and simulation) are key technologies for achieving a consistent approach to all phases of process design (from phenomena elucidation, to modeling and "building-in" quality). These technologies also help to ensure peak process performance, and achievement of process automation and labor-saving goals. Different technologies are integrated and controlled using computer technology. It is indisputable that progress in electronics technology contributes greatly to the development of the steel manufacturing process.

The following section discusses issues and the future outlook in the steel industry, from the standpoint of the electronics field.

Fig. 2 shows changes in the steel manufacturing process, and the corresponding changes in electronics technology. In the 1970s, when steel was called the "food of industry", the steel industry invested heavily in the latest equipment for mass production, and each piece of equipment employed the newest electronics technology of the time. Upon entering the 1980s, the industry had to respond to the need for rationalization and improved productivity. There was a tremendous improvement in the performance of computer technology based on progress in electronic micromachining technology. The steel industry incorporated the results of this progress and improved functionality, in order to achieve process automation and raise precision in product quality. In the 1990s, process control became even more sophisticated because of the need to produce an even more diverse range of products, while keeping up with the increasing diversification of user needs.

In this way, the steel industry has adopted the latest electronics technology in response to the needs of each era, and thereby achieved high-volume production, highly efficient manufacturing equipment, high quality and high functionality. On the other hand, 20 or 30 years has elapsed since the first operation of electrical, instrumentation and computing equipment installed subsequent to the mass production era, and the time is approaching when the industry must upgrade equipment because manufacturers have stopped manufacturing parts or providing maintenance, or because the function of the equipment has declined. Therefore, one issue for the future of the industry is the deployment of solution technologies for upgrade and function enhancement based on inexpensive, high-performance equipment. This work will be done by continuing to upgrade mass-production equipment, and by adopting open system technologies from the electronics field (described at the beginning of this paper) when improving equipment function.

There are also future issues relating to process control for reducing manufacturing costs, and improvement of production capacity and product quality. Previously the mainstream approach was classic control using PID, but in the 1980s, modern control theory (which analyzes process phenomena via numeric modeling) was introduced due to the improvement in computer performance, and the practical adoption of multi-variable control led to a drastic improvement in process control precision. However, these efforts were mainly directed at so-called product processes like rolling and surface treatment, whose phenomena are comparatively easy to model compared to other steel manufacturing processes.

In iron-making processes (raw materials, sintering, coke, blast furnace) and steel-making processes (converter, continuous casting) where solid or powdery materials and high-temperature fluids are handled, process phenomena are extremely complex and phenomena modeling is difficult, so the industry has introduced knowledge-based control methods like fuzzy logic or AI, which are based on human experience. However, these control systems are not always robust in the face of things like changes in the operator or operation conditions. Phenomena modeling is necessary to achieve optimal control, so there is a need here to deploy solution technologies from the electronics field, like instrumentation, signal/information processing, numerical analysis and simulators.

Fig. 3 shows issues and future deployment of solution technologies from the electronics field in steel manufacturing equipment and process control, as described above.

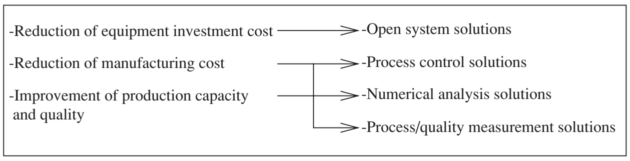

Fig. 3 Issues and solutions in the electronics field

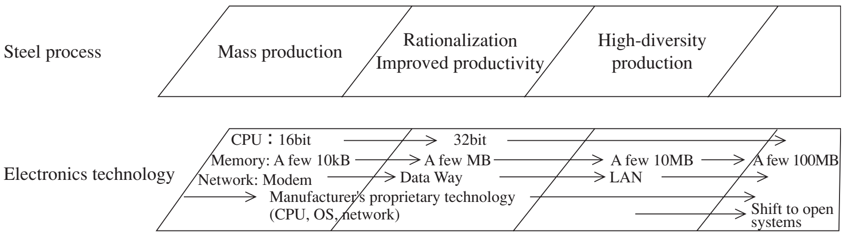

Fig. 2 Changes in steel manufacturing process and electronics technology

The next section outlines the authors' efforts to deploy each solution technology. In the area of numerical analysis solutions, we will focus primarily on electromagnetic fluid analysis solutions in the application of electromagnetic force to continuous casting equipment, because this is the primarily focus of our efforts at present. Deriving from efforts in the electronics field, progress is also being made with laser machining as process actuators, or a tool for developing new products. However, these are described in other reports in this issue, together with specific cases describing the detailed work involved in each solution, so please refer there.

3. Deployment of Solution Technologies from the Electronics Field

3.1 Open system solutions

The information/control systems in today's steel industry have a hierarchical structure, as shown in **Fig. 4**[1]. Management business computers for tasks like production planning, technology management and equipment management (batch processing) are placed at the uppermost level. Below that are business computers for tasks like operations management, quality management and process management (on-line processing); and, at the next level, process control computers which provide optimal process control and govern automation, electrical/instrumentation controllers (PLC, DCS) and electrical/instrumentation field devices are placed at the lowest level. The rapid development of computer technology in recent years has resulted in a tremendous improvement in the capabilities of EWS servers and personal computers (PC), and spurred the dissemination of general-purpose, open OS. In the steel industry, this has created an environment where conventional process control computers can be downsized from manufacturer's proprietary computers to general-purpose EWS and PC.

In switching to open system solutions, efforts are being made (as shown in **Fig. 5**) to escape from manufacturer dependence in hardware selection, and to radically reduce equipment investment costs by upgrading from existing systems to the latest systems with hardware upgrades only. This is being done by independently using common application software (AP software) for achieving goals like process optimal control and automation (so there is no dependence on manufacturers) and by using techniques which enable upgrading

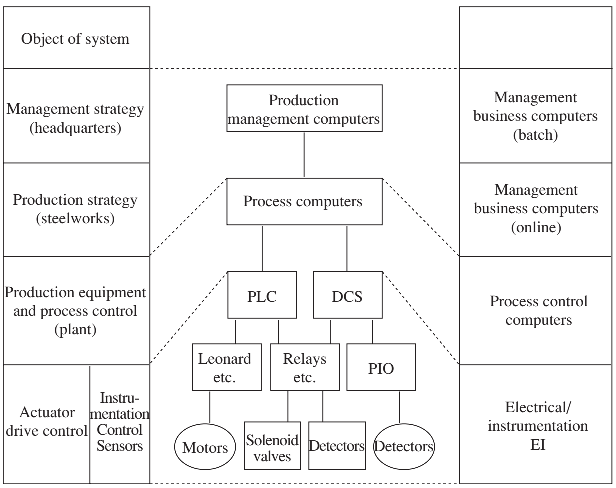

Fig. 4 Function hierarchy of steel information/control system

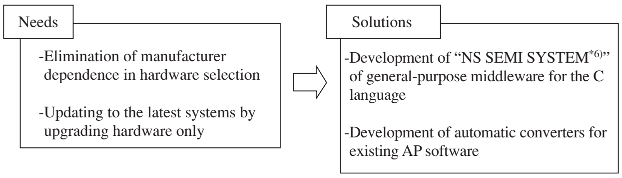

Fig. 5 Open system solutions

from existing systems to the latest systems without changing the content of AP software running under a manufacturer's proprietary OS.

More specifically, we have developed the "NS SEMI SYSTEM[*6)]", a type of general-purpose middleware for the C language which enables AP software to operate under any general-purpose open OS. This makes it possible to replace manufacturer's proprietary computers with EWS and PC. This system was applied first to the billet continuous casting equipment at the Kimitsu Works, and achieved a significant reduction in equipment investment costs[2]. In the process of using the "NS SEMI SYSTEM[*6)]" to develop AP software converter systems compatible with various manufacturer's proprietary OS, we have already verified the system in a number of example cases, and achieved our goal of realizing almost 100% automatic conversion in all of these cases.

In the future, our policy calls for packaging the above software, incorporating it into our steel manufacturing system, and having full-time staff deal with on-site fine-tuning and problem resolution. On the other hand, we are still dependent on manufacturer technology due to the strong need for high-speed processing in software for controlling electrical/instrumentation controllers like PLC and DCS. However, based on the shift of software production tools to general-purpose PC, we are developing tools to move toward software self-production, just as was done in the efforts for process control computers described above.

In the future, work will go beyond development of the above software, and will involve the construction of a seamless steel manufacturing system oriented toward general-purpose, open systems in the networks between process computers and electrical/instrumentation controllers, and between electrical/instrumentation controllers and field devices (see **Fig. 6**).

3.2 Process control solutions

The steel manufacturing process requires extremely complex, high-speed processing. It involves all the phenomena of gases, powders, liquids and solids, and various control techniques have been proposed and adopted previously.

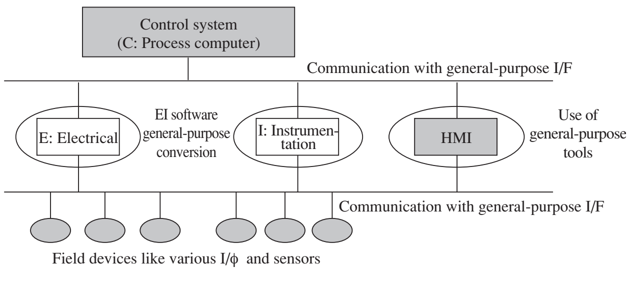

Fig. 6 Configuration-image of steel process control system after open conversion

*6) "NS SEMI SYSTEM" is a registered trademark in Japan of Nippon Steel Corporation.

Elucidation of process phenomena has previously focused on the rolling process, and mainly involved application of "linear control laws" where phenomena are linearly approximated, but in the future, efforts will have to focus on achieving control more closely integrated with product quality, and achieving new forms of process control which go beyond previous levels of performance.

In the area of process control, we are proposing new control rules and control systems, based on the ongoing improvement in performance and capabilities of PC and general-purpose simulators. As shown in **Fig. 7**, this is being done by realizing "non-stationary, non-linear process models" based on analysis of high volumes of diverse types of data, including quality data, and by self-producing dynamic process simulators (including detailed process models incorporating process dynamics). This makes it possible to quantitatively elucidate the various phenomena involved in the process.

As specific examples, we are making further efforts in the rolling process, directing our attention to iron-making and steel-making processes which handle powders and fluids (as described above), modeling process phenomena comprised of strict physical models, and making efforts to apply new control rules and control systems based on process simulator self-production. At present, our efforts include developing a system (Venus) for visualizing the operations status of a blast furnace from the standpoint of a skilled operator. The status is given as objective image information by converting instrument data from the many sensors installed in the blast furnace to graphical information. We are also constructing new mold level control rules by modeling molten steel flow phenomena in the mold of continuous casting equipment via 3-dimensional fluid analysis[3)].

Fig. 8 shows "non-stationary, non-linear process models and simulator tools" currently possessed by Nippon Steel. In the future, efforts will be made to drastically reduce costs, improve productivity and strengthen quality competitiveness, focusing on processes where there are remaining issues for improvement of control performance. This will be done by expanding the application of these models/simulators.

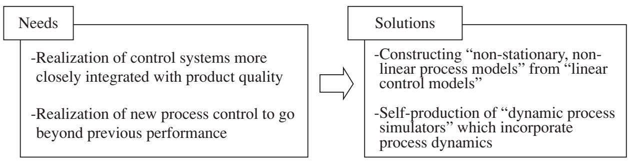

Fig. 7 Process control solutions

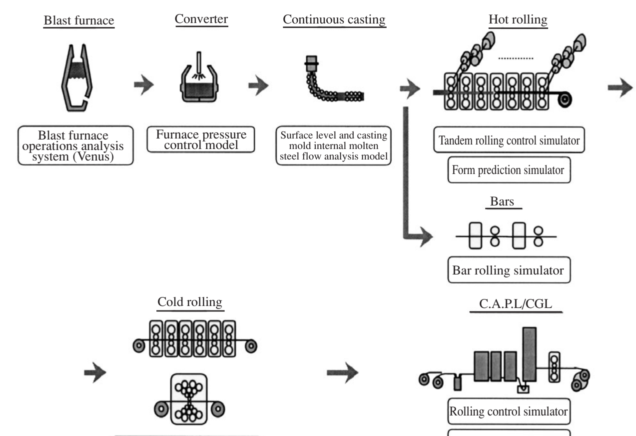

Fig. 8 Non-stationary, non-linear process models and simulator tools

3.3 Numerical analysis solutions

In equipment employing electromagnetic force, force or thermal energy can be applied without contact by applying an electromagnetic field to the object, so this technique has been previously adopted by the steel industry as a clean energy source with superior control performance, and the need to adopt it will continue to be high in the future. However, except in simple cases, it is extremely difficult to elucidate the relevant phenomena, so it is hard to verify effectiveness. In the future there will be a strong need for analysis and design techniques to elucidate phenomena and verify effectiveness in order to expand application to new processes.

In order to resolve the aforementioned issues with electromagnetic fluid analysis solutions, we are working to build a simulation environment as a tool for replacing online experiment equipment. This environment is based on the "FLEDY"[4)] general-purpose electromagnetic fluid analysis software developed independently by Nippon Steel (see **Fig. 9**).

As specific examples of work in this area, here we will describe our analysis and design tool of electromagnetic coil equipment for applying stirring force (M-EMS: In-Mold-Electro Magnetic Stirrer) and braking force (LMF: Linear DC Magnetic Field) to molten steel inside a continuous casting mold. **Fig. 10** shows a new electromagnetic fluid coupled analysis tool created by coupling electromagnetic field analysis based on the Maxwell equations (FLEDY[*7)]), with fluid analysis based on the Navier-Stokes equation, analysis of molten steel heat transfer and solidification, and analysis of heat transfer in the casting mold. Improvements in computer performance have made it possible to construct and analyze 3-dimensional detailed models, and verify these using data from actual equipment. It has

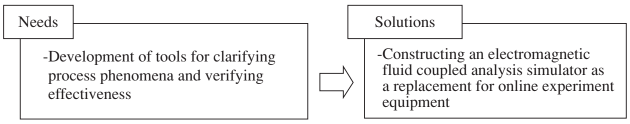

Fig. 9 Electromagnetic fluid analysis solutions

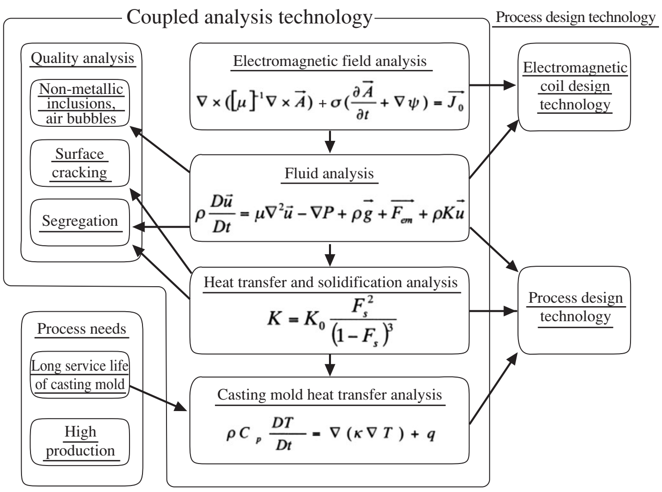

Fig. 10 Composition of coupled analysis tool for molten steel flow phenomena in continuous casting mold

*7) FLEDY is a registered trademark in Japan of Nippon Steel Corporation.

also enabled verification at the casting quality level by matching with actual casting quality data, and we are building a simulation environment to replace online experiment equipment in electromagnetic coil design for M-EMS and LMF.

At present, we have established various electromagnetic coil design techniques using this tool. We are conducting design (coil form, voltage, current, frequency, pole-numbers etc.) in order to fabricate the optimal electromagnetic coil for casting equipment specifications at our steelworks (mold size, casting speed etc.), and performance accords well with the original plan. We are also deploying the system for analysis of characteristics of steel materials via electromagnetic field analysis, based on technology developed in electromagnetic fluid analysis.

3.4 Process/quality measurement solutions

As shown in Fig. 1, instrumentation technology in the steel industry can be roughly divided into two types: "process measurement" for observing process phenomena (like temperature, element and form) with the aim of modeling the manufacturing process; and "quality measurement" which aims to measure factors relating to product quality like defects and materials qualities. The requirements in the former case are primarily: to accurately measure the modeling information necessary for optimal process control, and to establish inexpensive measurement systems. The requirements in the latter case are: to build in quality by detecting the cracking and defect situation in the previous process whenever possible, and to establish a system for high-precision measurement of microscopic cracks and defects as final quality assurance equipment for the user (see **Fig. 11**).

For process instrumentation solutions, steel process measurement requires measurement under conditions which are much more severe than other industries in terms of temperature, vibration and dust. Recent progress in memory and microchip sensor technology has made it possible to capture process information in image form using high-precision cameras. This can be done with high precision, high speed and low cost, and image processing devices for processing the captured images are attaining ever higher performance and lower price. Based on such image processing technology, we are developing sensor systems which enable new, previously impossible types of process measurement. We are also considering self-production of sensor systems by the user in this area.

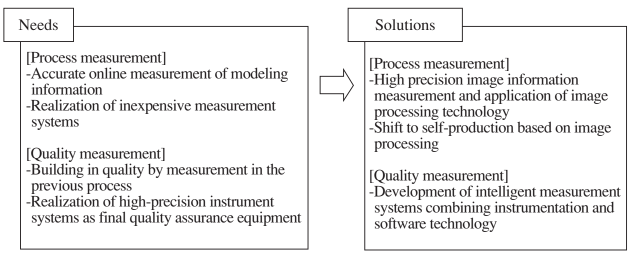

Fig. 11: Process/quality measurement solutions

In the area of quality instrumentation solutions, there has been progress in software technology, as exemplified by the development of various types of knowledge processing (like neural networks and wavelet transforms). As a result, the previous hardware sensor systems (based on approaches like electromagnetism and ultrasound) are shifting to software processing of measurement information obtained from sensors (i.e. to so-called intelligent systems). We are developing high-precision sensor systems which by establishing defect and material quality discrimination techniques employing various technologies.

4. Conclusion

Progress in computer technology provides various conveniences to society, and as the foundation of the global social system in the 21st century, its function and performance are expected to continue to improve in the future.

This report has outlined deployment of solution technologies, in which efforts are made to deal with issues arising in equipment and processes in a consistent fashion. The approach encompasses all phases of issue resolution — from quantitative evaluation to solution proposal and implementation, and problems are addressed through early adoption in the steel industry of new technologies from the electronics field (exemplified by the computer technology which has shown such remarkable progress, as mentioned above). We will continue to expand application within Nippon Steel of the results of these activities, and by packaging them, we intend to create a menu of products, with the option of supplying them more widely outside of our company.

We intend to actively deploy solution technologies, always keeping in mind that clever adoption of trends in new technology from the electronics field (exemplified by computer and network technology) by electronics engineers working in the steel industry (which is an equipment industry) contributes to the further development of the steel industry.

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