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Steelmaking Plant Technology for Steelmaking Operations

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Abstract

Steelmaking technology have been developed by some needs and environmental changes. Among them, in steelmaking plant, more technology have been preceded by production of high quality products, approach for global environmental affairs and application of information technology and computer technology. From these viewpoints, some aspects and results of recent steelmaking plant technology will be described in this paper.

1. Introduction

Eighteen years have passed since publication of the last "Special Issue on Steelmaking," which gave a detailed account of steelmaking plant technology with a focus on automation and saving labor.[1] During that period, the production of steel has fluctuated wildly: it plummeted in the wake of the collapse of the bubble economy, rebounded owing to the economic progress of East Asia, especially China, and then declined following the Lehman Shock.

In the field of steelmaking plant technology, the steel industry has met various challenges in response to contemporary demands. Among them, customer demand for steel products of higher quality, the social demand for environmental protection, and the effective utilization of peripheral technologies have had a profound influence on the progress of steelmaking plant technology.

① Response to demand for steel products of higher quality

In the past 18 years, the Nippon Steel Corporation has markedly increased the sophistication of its steel product mix. For steelmaking plants too, the company has developed various new technologies. In this report, we shall describe the RH process equipment for manufacturing extra-low-carbon steel, the electromagnetic stirrer (EMS), and the tundish heater.

② Response to demand for environmental protection

Since the Earth Summit held in 1992, protecting the global environment, especially reducing CO_2 emissions, has become a major issue. Under this condition, it is imperative that we pursue not only the conventional approaches to energy conservation but also that we press ahead with the so-called 3Rs (Reduce, Reuse, Recycle) and that we implement activities based on LCA (Life Cycle Assessment). In steelmaking operations, the use of scrap and the recycling of slag, dust, and other materials can be cited as effective measures. Looking at steelmaking equipment, prolonging equipment life has become important as a means of enhancing the LCA of the equipment itself. In this report, we shall describe efforts to prolong the life of steelmaking equipment taking the converter body and continuous casting (CC) rolls as examples.

③ Progress of information technology (IT), increase in speed and capacity of computers, and effective use thereof

The progress of IT has enabled the near ubiquitous transmission and reception of data. At manufacturing sites too, it has become possible to input and output various types of information on an on-line, on-site basis. In this report, we shall present a few examples of the application of IT to enhance the productivity and safety of steelmaking operations.

Additionally, the increase in speed and capacity of computers since the 1990s has made it possible perform sophisticated numerical simulations that could hardly be done before.[2] In this report, an example of the simulation of dust collection at a steelmaking plant shall be presented.

2. Response to Demand for Steel Products of Higher Quality

2.1 RH extra-low-carbon steel refining technology

Recent years have seen a rapid increase in demand for extra-low-carbon steels, such as interstitial free steel (IF), for automotive sheet. The widening of automotive steel sheet and an increasing CC speed has made it necessary to shorten the RH treatment time. Various measures have been taken to facilitate these changes such as to increase the decarburizing rate, to shorten the exhaust time of the

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RH process, and to prevent the contamination of molten steel with carbon. In the initial efforts to increase the decarburizing rate, molten steel circulation was enhanced by expanding the immersion nozzle diameter in the vacuum vessel and by increasing the circulating gas flow rate. Because of this enhancement of molten steel circulation, the No. 2 RH unit at Kimitsu Works is superior in decarburizing rate to the No. 1 RH unit, although they have identical exhaust capacities (**Fig. 1**).[3)]

In addition, with the aim of shortening the time necessary to attain the required degree of vacuum in the early stage of RH treatment, an evacuation technique was adopted that vacuum-exhausts the RH equipment (with the exception of the vacuum vessel) prior to the treatment (**Table 1**). As a result of this modification, the initial exhaust time for the No. 3 RH unit at Nagoya Works could be shortened by about one minute (**Fig. 2**).[4)] Furthermore, a powerful new vacuum exhaust system combining a high-efficiency booster ejector and a high-performance mechanical pump increased the exhaust rate while reducing the steam consumption. As a final example of the measures taken to shorten the RH treatment time, efforts have been made to prevent molten steel from being contaminated with carbon. To this end, a burner facility was provided, which is inserted into the vessel from above, to permit melting and removing the skull speedily, even during the treatment. Advanced RH facilities provided with the sophisticated features mentioned above have been installed in Kimitsu (No. 2/3 RH unit) and Nagoya (No. 3 RH unit). These advanced facilities permit the dependable production of extra-low-carbon steel of [C] < 10ppm in 15 minutes of decarburization (**Figs. 3** and **4**, **Table 2**).[3, 4)]

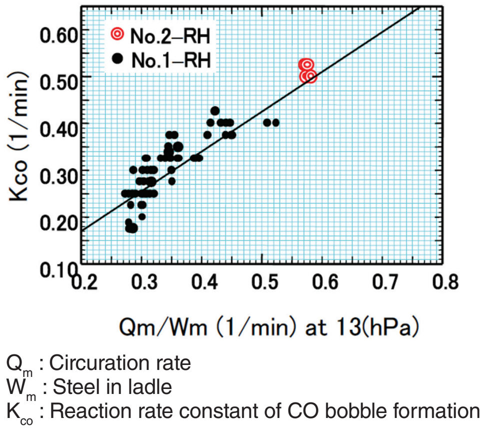


Fig. 1 Correlation between K_{co} and Q_m/W_m

Table 1 Specification of No.1RH and No.2RH at Kimitsu Works

		No.1 RH	No.2 RH
Ar gas injection rate (Nl/min)		Max.2500	Max.4000
Snorkel diameter (mm)		650 φ	750 φ
Lower vessel diameter (mm)		2288 φ	2420 φ
Evacuation capacity (kg/h)			
	at 0.7 hPa	1000	1000
	at 1.3 hPa	1500	1500
Steam consumption (t/h)		40	20

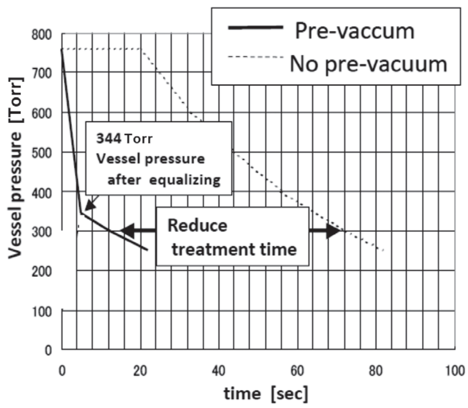


Fig. 2 Effect of pre-vaccum valve

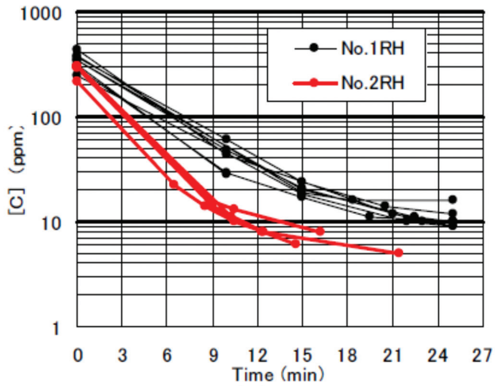


Fig. 3 Change of [C] in No.1RH and No.2RH at Kimitsu Works

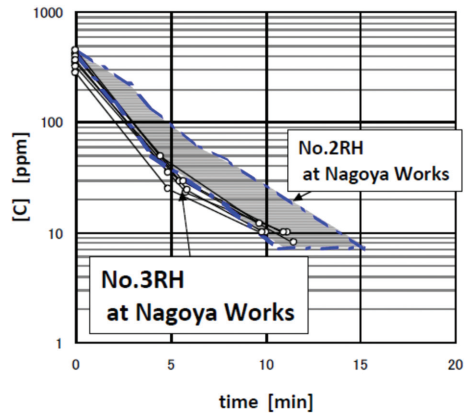


Fig. 4 Change of [C] in No.2RH and No.3RH at Nagoya Works

Table 2 Specification of No.3RH at Nagoya Works

	No.3 RH
Snorkle diameter (mm)	800 φ
Ar gas injection rate (Nm^3/h)	Max.200
Evacuation capacity (kg/h)	1350 (at 0.7 hPa)

2.2 Design and application of an electromagnetic apparatus for continuous casting

Applications of electromagnetic apparatuses play a major part in improving the quality of slabs in casting process. A conventional one of the apparatuses, a linear motor-driven electromagnetic stirrer

(EMS) is often installed in pairs along the two wide faces of the mold as shown in **Fig. 5**. This device stirs the molten steel horizontally below the meniscus of the molten steel in the mold, which prevents the sticking of inclusions into the solidified shell and ensures uniform heat distribution in the initial solidification. Nippon Steel Corporation successfully put EMS into practical use in 1980s and began designing EMS systems based on numerical analysis in the 1990s. At the turn of the century, we have further established the specified designing scheme of electromagnetic applications and carried out in-line and off-line performance tests. As a result, it has become possible to design equipment and process refinement with a higher degree of precision. It should be noted here that we have also developed electromagnetic casting as an entirely new approach for the control of molten steel solidification (see a separate article on the subject in this issue).

An EMS system having 3-phase AC magnetic poles arranged along the two wide faces of the mold is shown at the right-bottom in Fig. 5. An example of an EMS model having four poles is schematically drawn in **Fig. 6**. Top view **Fig. 7** illustrates the electromagnetic force distribution (Lorentz force) generated by an EMS system at the meniscus. Vortexes of the distribution are formed corresponding to the number of poles. The result of a molten steel flow analysis with the electromagnetic force is shown in **Fig. 8**. It can be seen that a strong flow from left to right is generated by the EMS.

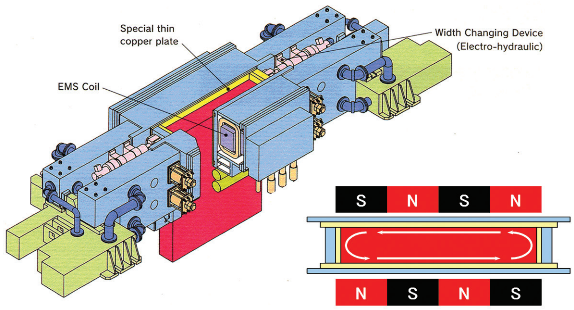


Fig. 5 Electromagnetioc stirrer in a CC mold

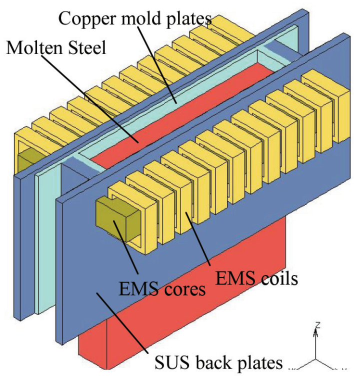


Fig. 6 Model of EMS

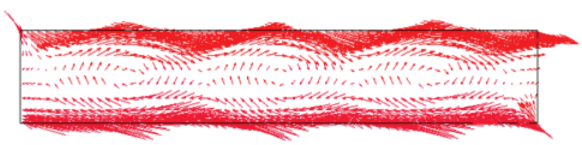


Fig. 7 Lorentz force distribution in the molten steel at middle-height of the EMS core

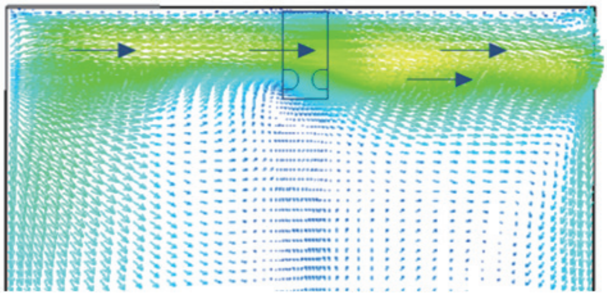


Fig. 8 Molten steel flow by the EMS force on the mold plate

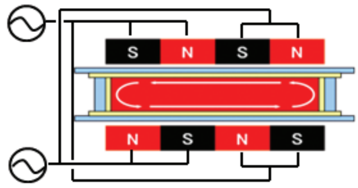


Fig. 9 Diagonal power configuration

At the conception stage, multiple EMS models are investigated, under various electrical and mechanical conditions, in order to obtain a design that provides a required molten steel flow rate that is as uniform and smooth as possible. Specifically, the width of the EMS apparatus must be set larger than the casting width. This requirement necessitates a modification of the mold structure because the EMS system will be built in it. However, this complication is essential in order to minimize the uncontrolled flow regions that occur around the corners. The occurrence of such an uncontrolled flow region can make the molten steel flow unstable and disordered. Depending on the mold size, therefore, the number of poles should be reconsidered at the early design stage.[5] In addition, the frequency of the EMS, for example, would be altered in accordance with the casting thickness to obtain a uniform stirring flow. There is another case in which, with consideration to the reverse ascending flow along the mold narrow face toward the nozzle at the meniscus, the distribution of the Lorentz force is appropriately varied by use of a diagonal power configuration, rather than a symmetric one, as shown in **Fig. 9**.

Owing to the real designing of the EMS application with magnetohydrodynamic analysis described above, defects in CC slabs have been diminished remarkably and have come to be extinguished (i.e., defect-free slabs) at a certain rate. Manufacturing sites, at present, are seeking to implement optimum operation conditions fitting for the different operating characteristics of the individual continuous casters so as to facilitate reliable mass production of defect-free slabs.

Numerical analysis technology, used in the design of electromagnetic apparatuses, made rapid progress throughout the 1990s. This progress was due largely to the enhanced performance and downsizing of computers that made it possible to execute numerous complicated calculations on a personal computer at low cost in practical time. Even so, only about 10 years have passed since elaborate EMS design with numerical analysis was started in earnest, and both production workers and researchers have been making concerted efforts to further improve the qualities of CC slabs.

2.3 Tundish heating

2.3.1 Nippon Steel Corporation-type tundish plasma heaters

In recent years, the Nippon Steel Corporation has installed tundish plasma heaters that control the molten steel temperature in the tundish in order to simultaneously help enhance product quality and productivity, save energy, and improve yields of high-grade steels in the CC process. As shown in **Fig. 10**, the temperature of molten steel in a tundish unavoidably declines in the final stage of casting and during the ladle change because of heat absorption by the ladle, the tundish refractory and heat radiation from the molten steel surface. The application of plasma heating permits compensation for the temperature loss of molten steel in the tundish, which in turn makes it possible to lower the tapping temperature at the converter, cut the cost of furnace and ladle refractories, and save the energy input for tapping. In addition, compensation for the described temperature loss helps improve the product quality and operational stability as it promotes the floating separation of nonmetallic inclusions and reduces the clogging of immersion nozzles.

For this purpose, the Nippon Steel Corporation has developed two types of tundish plasma heaters—the single-torch type ("NS-Plasma I")[6] and the twin-torch type ("NS-Plasma II").[7] These heaters play an important role in the CC systems where they have been introduced. **Table 3** compares the two types of tundish plasma heaters. The single-torch type consists of a cathode torch installed at the top of the tundish and an anode (steel plate) embedded in the tundish refractory. For plasma discharge, it uses a torch of hot cathode type emitting thermo-electrons. By contrast, the twin-torch type consists of a pair of torches installed at the top of the tundish, wherein one torch serves as the cathode and the other as the anode. The advantageous features of the twin-torch type are as follows: it produces a higher power output than the single-torch type, it does not require embedding an anode in the tundish refractory, and maintenance of the unit is easier than that for a single plasma unit.

For small- to medium-scale continuous casters, which do not require a large-capacity plasma heater, the single-torch type is preferable because it fits in a relatively small space, consumes a smaller amount of argon, and has fewer consumable parts. For large-scale continuous casters, which require a large-capacity plasma heater, however, the twin-torch type that produces higher power output with a single power supply unit is advantageous. Thus, both types of heaters have been introduced in continuous casters according to specific requirements.

2.3.2 Effect of molten steel temperature compensation by use of a tundish plasma heater

By compensating for the molten steel temperature by a plasma heater, it is possible to minimize not only the slowdown of casting speed required when the molten steel temperature is on the high side but also the interruption of casting operation owing to a clogging of nozzles when the molten steel temperature is on the low side. Thus, it helps to enhance the productivity of CC. On the other hand, as shown in **Fig. 11**, it is necessary to keep the molten steel temperature in the target range throughout the CC operation in order to secure the required slab quality (i.e., to minimize the centerline segregations and nonmetallic inclusions). Proper control of the molten steel temperature during the CC operation thus also improves the quality of cast slab. Finally, it also permits lowering the tapping temperature at the converter and electric furnace and thereby cuts the cost of refractories and reduces energy input.

2.3.3 Measures to assure reliable operation of tundish plasma heaters

In order to make the most effective use of plasma heaters, we have applied design techniques based on heat and flow analyses to design an optimum torch layout and heating chamber, to optimize the electrode shapes and materials from the standpoint of obtaining durable torches, to implement a method of cooling the torches according to the thermal load, and to improve the heat efficiency and response of the heater (**Fig. 12**). In addition, we have optimized the method of argon injection into the heating chamber and torches, made the heating chamber sufficiently airtight, and determined the

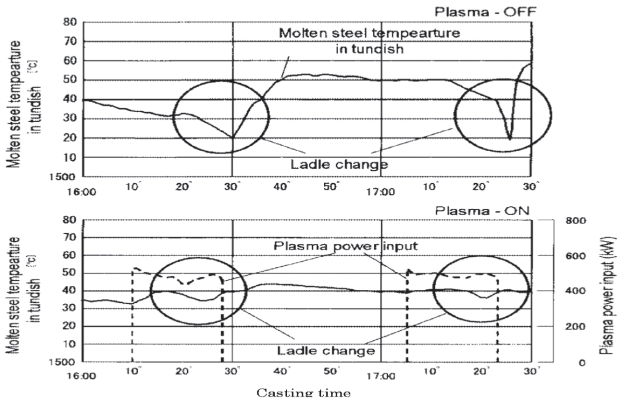
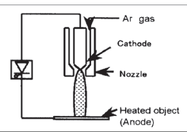
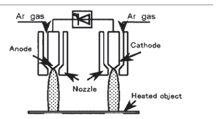


Fig. 10 Molten steel temperature control (example)

Table 3 Comparison of the plasma heating type

	NS-Plasma I		NS-Plasma II	
Plasma torch type	Single torch Cathode torch (Anode: TD)		Twin torch Cathode and Anode torch	
	DC			
Composition				
Maintainability of torch	○	An external diameter: 1.1 (Type of separated nozzle)	○	An external diameter: 1.0
Power	○	0.2〜0.7MW Recommend 0.5MW	◎	0.3〜0.8MW
Heating efficiency	○	60〜70%	○	60〜70%
Plasma gas → noise	◎	1.0 noise: Low	○	2.4 noise: a little low
Lifetime of torch	○	Cathode: 1.0 Anode: 1.0	◎	Cathode: 2.0 Anode: 2.0 Nozzle: 2.0
Electric noise	△	Generated noise: a little	○	Generated noise: little
Revamp	△	Heating chamber Anode plate in tundish	○	Heating chamber
Maintainability of refractory in tundish	△	Need to maintain anode plate in tundish Adapted TD heat recycle: difficult	○	Only general maintenance Adapted TD heat recycle: possible
Equipment layout	◎	Small (Because of one torch)	○	Middle (Because of two torches)

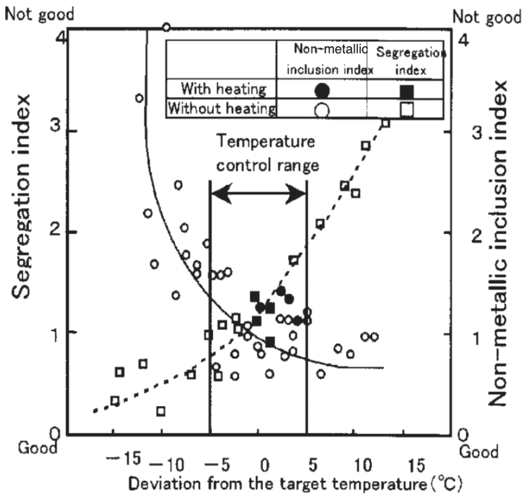


Fig. 11 Improved cast strand quality by the molten steel temperature

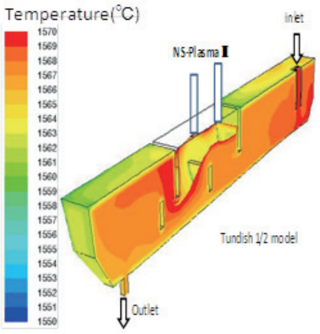


Fig. 12 Temperature distribution in tundish by NS-plasma II (example)

optimum distance between the torch and the molten steel surface. Furthermore, the use of a torch construction that is easy to maintain has made it possible to shorten the time required for torch replacement. Thanks to the comprehensive efforts mentioned above, tundish plasma heaters have been routinely employed towards producing the intended effects as have been described above.

3. Prolonging Equipment Life

3.1 Technology for prolonging the life of the converter body

Since its introduction, the converter has been increased in scale with the expansion of steel output. This, together with the increase in oxygen supply rate, the rise of end-point temperature, and the adoption of new refractory materials, has caused the thermal load on the converter body shell to increase. As a result, the incidences of deformation and cracking of the converter body and trunnion ring have become increasingly conspicuous and have led to a corresponding increase in maintenance and repair costs. Under such conditions, it is necessary to make on-site repairs of cracked parts, control and adjust the clearance between the converter body and the trunnion ring, and renew the converter body as necessary. Therefore, substantial efforts have been made to restrain the deformation and cracking of converter bodies and trunnion rings through optimization of the converter body/trunnion cooling system, improvement on the converter body supporting system, and other measures.

In addition, a new material (sev295mod.), having superior hot strength and creep resistance, has been employed for the converter shell in order to minimize thermal deformation and restrain cracking of the converter body. As an example of the benefits of the new material, **Fig. 13** compares the amount of converter body deformation (initial value 0 mm for the circumference of the straight section of the body) between a straight section made from the conventional material (SM400C) and a straight section made from the new material, measured after a certain period of use. Thus, the application of this new material dramatically reduces the aging deformation of the

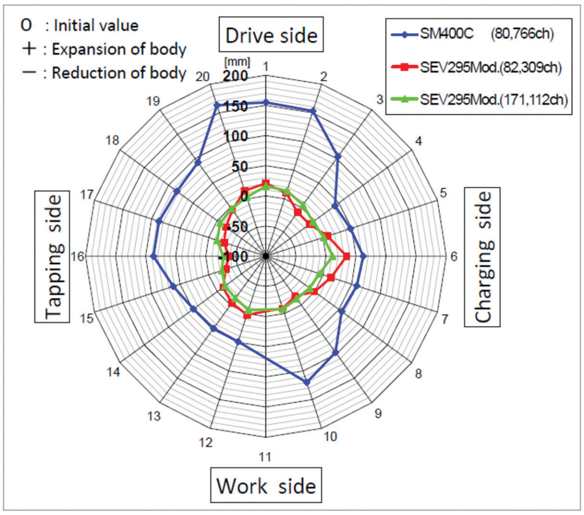


Fig. 13 Comparison of the converter body deformation

converter body, thereby eliminating the need for adjustment of the belly. In addition, the new material discussed deteriorates so slowly that the converter body requires scheduled replacement much less frequently.

3.2 CC rolls

The main factors governing replacement of the CC roll segments is the degree of damage or deterioration of roll barrels caused by oxidation, corrosion, wear or thermal cracking and the degree of damage of the roll bearings. Various measures have been taken to prolong the service life of CC rolls against various deteriorating factors and under changing casting conditions.

(1) Improving roll materials

Ordinarily, used rolls are stripped of their deteriorated parts and repaired by means of padding before they are reused. For many years after the introduction of the CC process, a 13Cr-based padding material, having good resistance to corrosion, oxidation, wear, and cracking under high temperatures, was used for the rolls, especially their outermost layers that make direct contact with the slab (**Fig. 14**). Later, in response to a change in powder materials and other factors, a high-alloy-based padding material having superior hot corrosion resistance owing to a suitable adjustment of its alloying elements (Ni, etc.) came to be used, especially for the upper rolls that are located closer to the mold.

Although high-alloy-based materials, like the one mentioned above, are quite robust, an increase in the proportion of their alloying element causes a corresponding increase in their thermal expansion coefficient. This translates into an increase in thermal stress. As a result, rolls constructed of this material are susceptible to thermal

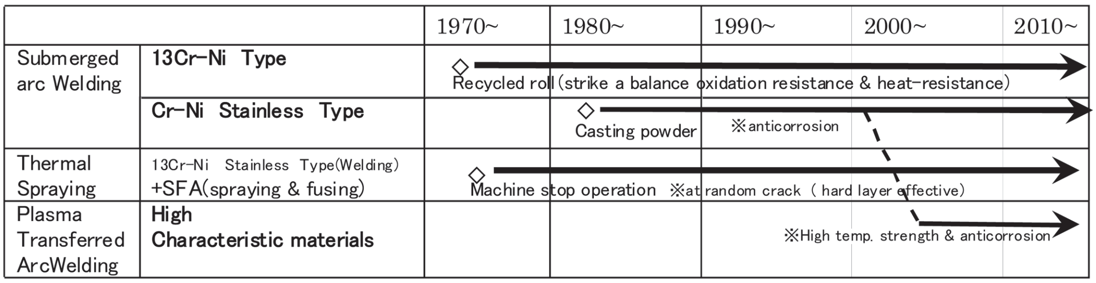


Fig. 14 Trends for CCroll with hardfacing

cracking. Therefore, in designing a roll material, it is imperative to consider the thermal conditions under which the rolls are to be used.

(2) Optimizing the roll surface groove shape (relieving thermal stress)

The operation conditions for continuous casters that are required to handle many different steel grades demand frequent machine shutdowns, causing the thermal stress of the rolls to increase. As a result, thermal cracking has become the major factor determining roll life.

In order to reduce the occurrence and propagation of thermal cracks in rolls, the following measures have been taken: a) application (by spraying) of a self-fluxing, Ni-based alloy designed to resist the propagation of existing thermal cracks, and b) providing a groove in the roll surface to reduce thermal stresses near the roll surface. Recently, in particular, emphasis has been placed on optimizing the surface groove shape in an effort to maximize thermal stress relief. Specifically, numerical analysis techniques have been established for evaluation of thermal stress near the roll surface and for prediction of the roll life-span prior to crack initiation on the basis of the thermal expansion properties of the roll materials used and the operational conditions of the continuous caster. As a result, it has become possible to design an optimum roll material and surface groove shape for each of the segment locations (vertical, curved, horizontal, etc.).

Employing the techniques described above, a special surface groove shape was developed that maintains rolls in a condition that is free from thermal cracking for several years even under those operation conditions that are subject to frequent machine shutdowns. At the same time, a technique was developed to fabricate rolls with the above special surface groove.

(3) Prolonging roll bearing life

Since the CC rolls turn very slowly and are subject to large loads, a lubricant film does not form well on the roll bearings. In addition, dust and water enter the bearings relatively easily. Thus, the bearings operate under an extremely austere lubrication condition. In order to improve the condition of lubrication and prolong the life of bearings, various measures have been taken, such as reinforcing the bearing seal to prevent entry of foreign matter and using high-performance lubricant. Recently, an oil-air lubrication system has also been employed. In this system, the bearing internal pressure is always kept higher than atmospheric pressure to prevent the entry of foreign matter into the bearings.

Ordinarily, self-aligning roller bearings are used with CC rolls. In this case, even a slight difference in peripheral speed between the roller and the inner/outer rolling contact face can cause two-groove wear, which tends to cause an early flaking defect, etc. If the defective bearing continues to be used, it can lead to a crack in the bearing or some other serious trouble. Therefore, efforts have been made to improve not only the bearing lubrication system but also the bearing materials and construction in order to prolong the life of bearings. They include the use of a bearing material having superior wear resistance and the development of a self-aligning roller bearing free from two-groove wear.

Prolonging the life of CC rolls and implementing optimum planning and management of segment changes will provide for further reduction of production costs and increases in the activity rate of continuous casters. As a result, there is much to be gained by developing new roll technology and making continuous improvements on CC rolls.

4. Safety, Security, and the Environment

4.1 Introduction of IT in CC

Nippon Steel Corporation's automatic control technology for its steelmaking lines is considered among the most advanced in the industry. Nevertheless, the stable manufacturing of steel products enjoyed continues to owe much to the skill possessed by plant operators and maintenance engineers. On the other hand, because of the ongoing saving of labor and the mass retirement of skilled personnel (the so-called 2007 problem), the number of production works has been decreasing and the proportion of less experienced operators has been increasing. In order to cope with various problems that are expected to arise from the foregoing conditions, the company has been engaged in the development and practical use of operational support techniques based on IT[8]. Incidentally, this project won the "Nikkei Monozukuri Grand Prix" for 2007. Of the technological elements shown in **Fig. 15**, this section shall describe the operation navigation system and the IT-based field memo system, together with a few examples of their applications in the steelmaking process.

(1) Operation navigation system

The salient feature of this system is that it permits skilled workers to register in a database their explicit knowledge about important points to be heeded and rules to be followed in judging specific manufacturing conditions and monitoring results and this information is cast for the purpose of operational guidance (**Fig. 16**). During the CC operation, this system selects appropriate actions to take, according to specific manufacturing conditions and monitoring results, and communicates them to the operator via a display screen or voice

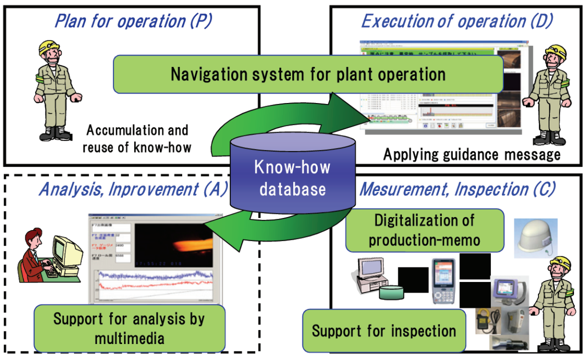


Fig. 15 Concept of IT-based operational support technology

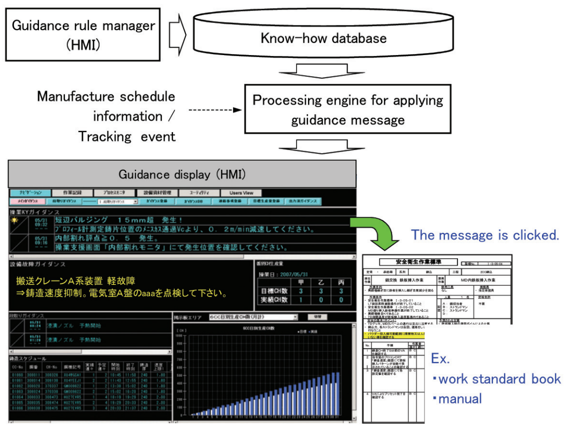


Fig. 16 Outline of navigation system for plant operation

Fig. 17 Examples of user interface by PDA

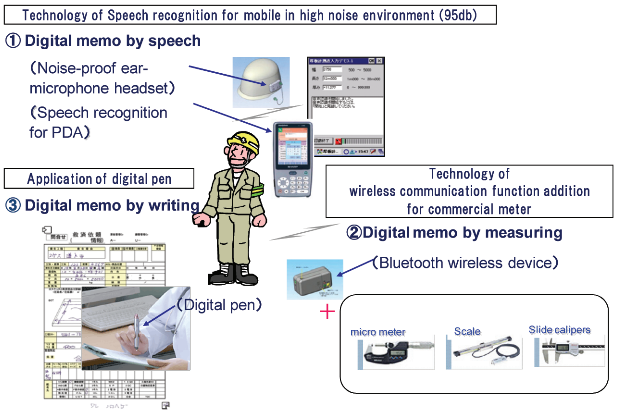


Fig. 18 Technology for digitalization of production-memo information

as required. For addition and or modification of guidance rules, the system is provided with a screen for registration that can easily be manipulated even by unskilled programmers, allowing not only the text messages but also the related electronic files to be linked to the screen. At the plants that have introduced this operation navigation system, operators use the system as a tool for improving their day-to-day operations. As a result, disruptions in manufacturing, ascribable to miscommunication of operational guidance, have decreased appreciably.

(2) IT-based field memo system

Recent years have seen the improvement and maintenance of the system environment developed to permit operator outside the control room to monitor the operating condition of the plant on the screen of a portable information terminal (PDA, tablet). Examples of PDA screen displays are given in **Fig. 17**. In addition, as part of its effort to apply portable information terminals to support various operations at the manufacturing site, the company has been pressing ahead with the development and practical use of what it calls an "IT-based field memo system." **Fig. 18** illustrates the key technologies that underlie the system. They are: ① noise-proof mobile voice recognition, ② wireless instrumentation, and ③ use of an electronic pen. By selecting one or more of these technologies for a specific job or purpose, it is possible to develop a system that supports inventory checking, work logging, defects recording, dimension measurement, and tolerance checking.

The Nippon Steel Corporation has been promoting the practical use of IT-based operation support techniques, like those described above, at many of its plants, including the No. 6 CC of Kimitsu Works, and has continued developing more advanced operational supports.[9)]

4.2 Steelmaking plant dust collection utilizing environmental simulation technology

The necessity to collect dust in a steelmaking plant shall be discussed in a separate report.[10, 11)] In this section, the characteristics of the environmental simulation technology owned by the Nippon Steel Corporation and the dust control engineering that utilizes it are discussed.

4.2.1 Characteristics of Nippon Steel Corporation's environmental simulation technology

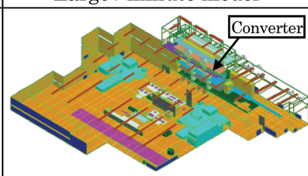
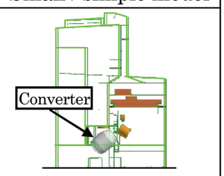
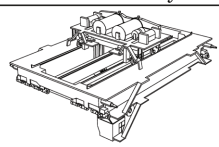
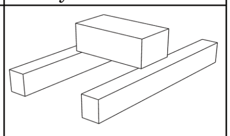
The steelmaking converter generates smoke, which is diffused within the converter building and eventually causes gravity settling of particulates entrained within the smoke. This particular phenomenon can be numerically analyzed by computational fluid dynamics (CFD). However, the air flow to be evaluated exists within the context of a huge, complicated steelmaking plant. Additionally, the condition of smoke generation undergoes drastic changes during the converter operation cycle and this leads to rapid temperature and velocity changes in the air flow. Furthermore, the flow in question is multiphase and consists of air, generated gases, and particulates of varying particle size. Therefore, the described analysis involves a large computational load that must be balanced with the need for accuracy, which itself depends much on the appropriateness of the shapes input into the model and the mesh division used.

In order to ensure timely performance of the difficult calculations described above with sufficient accuracy, the Nippon Steel Corporation has, over a more than 10 year period, accumulated specialized knowledge about planning for on-site measurement, modeling techniques, and setting of boundary conditions. Representative examples are given below.

(1) Modeling techniques (**Table 4**)

If the entire plant is taken as the target space, the computational load for the calculations will become excessively burdensome. On the other hand, if only a part of the plant is modeled, it will become difficult to obtain calculation results of the desired accuracy. Therefore, it is necessary to consider a target space that will assure both reasonable computational load and accuracy in addition to providing a suitable measure at the boundary between target and non target spaces. The mode of shape input serves as another dilemma between computational load and accuracy. For example, inputting the complicated shape of an overhead crane precisely is impractical; however, if the input shape is excessively rough, the calculated direction of the diffusion of gas generated may be drastically different from the actual direction. Thus, it is necessary that the shape of objects be in-

Table 4 Difficulty to combine calculation precision and calculation load

	Large / minute model	Small / simple model
Target space	 Whole factory	 Only converter bld.
Input shape (ex. Overhead crane)	 Minute	 Box shape
Calc. precision	◎	×
Calc. load	×	◎

put in an optimum manner.

(2) Setting boundary conditions

In the immediate vicinity of the converter nose from which the flames emanate, the concentrations of gasses and particulates generated cannot readily be measured. Therefore, it is necessary to set suitable boundary conditions on the basis of measurement results obtained at a location some distance away from the converter nose. To that end, the company has accumulated relevant data concerning boundary conditions through measurements and analyses at many of its steelmaking plants.

Together with the development of the technical factors mentioned above, the computing environment has been continually improved to enhance the performance of the company's environmental simulation technology. This technology is, in turn, effectively utilized in the study of measures to collect dust at the company's steelworks and affiliated manufacturing plants.

4.2.2 An example of the implementation of dust control engineering

For the steelmaking converter shown in **Fig. 19**, calculations based upon the company's environmental simulation technology were utilized to develop measures to manage the dust concentration at the operating floor at appropriate levels.

As shown in **Fig. 20**, the analysis concluded that the primary stream of dust rising straight up from the converter was predominantly drawn in by the flue suction port, but that the rightward side stream branching portion, after contacting the bottom of the overhead crane, was not sufficiently drawn in by the suction port and was causing an increase of the dust concentration at the operating floor. Therefore, the distribution of dust was analyzed, with a focus on the ceiling suction port, and it was proposed that the dust-collecting hood be expanded to increase the suction rate to as high a value as 22,000 m^3/min without causing a long-time stoppage of the converter operation (**Fig. 21**). From the calculations performed, the proposed measure was expected to reduce the dust concentration at the operating floor by 89% (**Fig. 22**). The actual reduction of dust concentration measured after completion of the hood expansion work was found to be 87%, very close to the expectation.

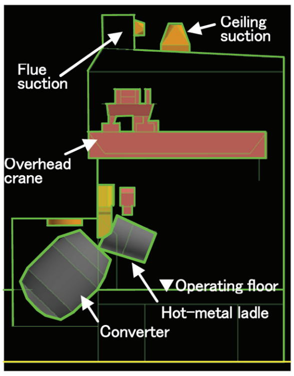


Fig. 19 Cross section of converter building

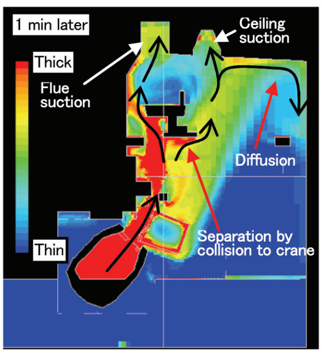
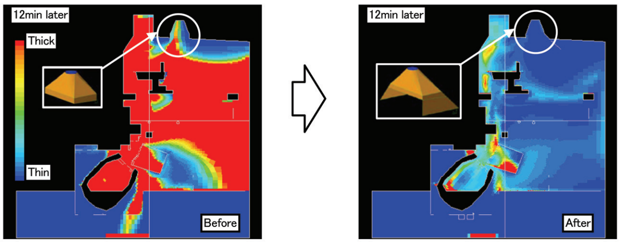


Fig. 20 Dust distribution (non-measure)



a) Non-measure b) After measure

Fig. 21 Improvement of effect of dust distribution

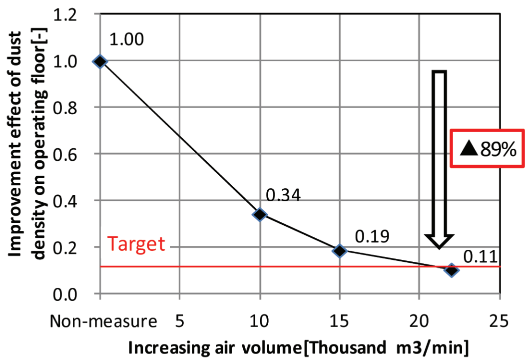


Fig. 22 Improvement effect of work environment by increasing air volume

4.2.3 Summary

Nippon Steel Corporation's environmental simulation technology is used to study measures to control dust at many of its steelmaking and electric furnace plants, and dust control measures based on that technology have already been implemented at eight of those plants. The technology is also used widely in the study of measures to prevent heat disorder in operating floor employees, the condensation of dew at rolling mills, the leak of poisonous gases, and other undesirable situations.

5. Conclusion

Concerning the progress of steelmaking plant technology that has been made since publication of the last "Special Issue on Steelmaking," we have described characteristic plant technologies that have been pursed for the purposes of quality improvement, equipment life prolongation, safety, security, and the environment. Compared with the active plant and equipment investment currently undertaken in East Asia, the Nippon Steel Corporation presently focuses its steelmaking plant technology on improvement and modification of existing equipment. Therefore, it is subject to many limitations. Nevertheless, the company has continually developed new plant technologies that are more compact and more economical. From the standpoint of strengthening the company's international competitiveness, it continues to be essential to accurately grasp the needs of customers and surrounding conditions and to develop technologies for meeting those needs through activities like those that have been described in this report.

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