Review

Strategy on Research & Development of Nippon Steel & Sumitomo Metal Corporation

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1. Introduction

On October 1, 2012 the former establishments Nippon Steel Corporation and Sumitomo Metal Industries, Ltd. merged to form Nippon Steel & Sumitomo Metal Corporation. For more than a year and half after the announcement of talks about integration of the two companies at the beginning of 2011, the R&D staff of both companies at all levels had continued lively preliminary consultations, which led to the inauguration of the new Technical Research & Development Bureau.

Soon after the preparations for the integration were started, the Great East Japan Earthquake and the Fukushima No. 1 Nuclear Power Plant accident occurred. The scars left by the disasters remain. In the meantime, the conditions surrounding the Japanese steel industry and Nippon Steel & Sumitomo Metal changed dramatically, namely the aggravation of the European debt crisis and the sudden deceleration of the world economy both triggered by the Greek financial crisis and the downturn of the steel industry, which is ascribable to a widening gap between supply and demand of steel materials.

In the early stages of preliminary talks about the integration, the manifested idea underlying the planned merger was "aiming to become the world's largest steelmaker by producing 60 to 70 million tons of steel a year." (As described later, this idea is still an unequivocal indication of the future image of the new company.) However, when the new company was established under the unfavorable economic conditions that are expected to continue for several years to come, the emphasis shifted from expanding the scale of production and seeking an absolute advantage to enhancing the competitiveness through improvement of the earning power and cost structure or establishing a relative advantage early in order to struggle through the global competition.

On the other hand, in light of its role the R&D department as an organization should be managed on the basis of the universal behavioral principles as long as it can respond flexibly and dynamically to the economic changes mentioned above (changes in economic trends, business indexes, etc.). Namely, the author considers that it is ideal even for the R&D organization of a company to set the goal of continually bringing about desirable results and changes in mankind by deeply understanding natural phenomena and presenting general solutions to various problems in diverse application fields, which is the universal role of science and technology in society. Needless to say, this does not mean that the R&D at Nippon Steel & Sumitomo Metal is purely intended to contribute to society. In fact, as far as possible, even a business enterprise should carry on its R&D activities with the support of key technologies in accordance with appropriate rules and principles. By doing so, it would be able to materialize its R&D results early and increase its earnings and thereby contribute to the industry and society.

"Since integration, the R&D organization of Nippon Steel & Sumitomo Metal has significantly increased in responsibility and presence in terms of scale, products, and technologies." This is a very pleasing comment received by the new company from many of its customers and business partners. However, the company has just taken the first step toward its aimed ideal by implementing R&D from various new viewpoints, marshaling the staff in various fields of research to develop advanced new technologies, and such other steps. The activities that were impracticable before the integration need to be tackled in future.

Frankly, the author must admit that the R&D strategy of Nippon Steel & Sumitomo Metal described here involved even imperfect measures that need to be brushed up in future. They are fanciful dreams of the individual research sections, and inexperienced challenges that do not necessarily promise any tangible result. This is partly due to the fact that the strategy was formulated not long after the start of Nippon Steel & Sumitomo Metal. Now, the author shall outline the R&D strategy of Nippon Steel & Sumitomo Metal, including the R&D policies, R&D organization, R&D management, industry-academy cooperation, and intellectual property strategy with focus on technology development at Nippon Steel & Sumitomo Metal.

2. Roles of the Technical Research & Development Bureau of the Nippon Steel & Sumitomo Metal Group

When Nippon Steel & Sumitomo Metal was newly established, the company announced that it would aim to become the world's largest steelmaker. To this end, Nippon Steel & Sumitomo Metal formulated four measures. They are as follows: 1) displaying technological innovativeness, 2) enhancing cost competitiveness, 3) expanding steel business on a global basis, and 4) reinforcing business foundations for non-steel segments.

Under the first objective "displaying the technological innovativeness," the company declares that it will strive to attain the world's highest levels of technology through integration of the R&D

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departments of the former establishments Nippon Steel and Sumitomo Metal Industries. It is undoubtedly the most important role of the new Technical Research & Development Bureau. Needless to say, the term "technological innovativeness" indicates a concept that is common not only to R&D but also to operation, equipment, and all other technical aspects. In this review, the author first describes the management of R&D and related measures and then goes into details about how the Technical Research & Development Bureau intends to display its technological innovativeness.

Under the second objective "enhancing cost competitiveness," the company plans to achieve cost cuttings amounting to ¥150 billion (larger amounts of reductions are under consideration) as the synergy of integration of all operations of the two companies. As for technology and R&D, the company intends to enhance the speed and quality of development and promote best practices of operating and manufacturing technologies through fusion of technology and R&D. For the integration of the R&D departments, in addition to the abovementioned cost cuttings, the company aims to step up the number of R&D projects that had been carried on separately by its predecessors and shorten the period and enhance the efficiency of development through consolidation of similar or close related projects.

Under the third objective "expanding steel business on a global basis," the company plans to increase its steel output to 60 to 70 million tons a year within 5 to 10 years and expand its capacity to supply growth fields such as automobiles, the environment, and energy. It is considered that under the present conditions, the emphasis will be placed on the transfer of the company's equipment/operation technology and know-how accumulated in the domestic steel business and fostering of personnel required for speedy, efficient expansion of production of steel products. In any case, the R&D departments are determined to provide sufficient backing to those activities. In addition, as part of the activity to reinforce the network with overseas customers and research institutes, the R&D departments intend to promote technological interchange on a global basis.

Under the fourth objective "reinforcing business foundations for non-steel segments," the company plans to promote joint research/contract research with business enterprises in non-steel segments while placing emphasis on augmenting the synergy of steelmaking operations. Nippon Steel & Sumitomo Metal has become a business entity that comprises five business segments; that is, steelmaking, engineering, chemicals, new materials, and system solutions with the steelmaking business at the core. Even so, the corporate concept of deepening the interchange between segments has remained unchanged so as to enhance the corporate value of the Nippon Steel & Sumitomo Metal Group. Therefore, the Technical Research & Development Bureau shoulders the R&D functions not only for the steelmaking business but also for the entire Nippon Steel & Sumitomo Metal Group (**Fig. 1**). As a matter of fact, the bureau is tackling many research themes in the form of contract research or joint research with companies in non-steel segments.

So far, the author has briefly described the measures that Nippon Steel & Sumitomo Metal plans to implement in the years ahead. The roles the Technical Research & Development Bureau is supposed to play will largely determine the success or failure of these measures.

3. R&D Organization of Nippon Steel & Sumitomo Metal

The three core R&D centers, namely R&E Center (at Futtsu), Amagasaki R&D Center, and Hasaki R&D Center, and local technical research departments and groups present in the steelworks of Nippon Steel & Sumitomo Metal (Muroran, Kamaishi, Naoetsu, Kashima, Kimitsu, Nagoya, Sakai, Hirohata, Hikari, Yawata, Oita) (**Fig. 2**) are the R&D bases of the Technical Research & Development Bureau. The research functions of the three core bases and individual steelworks developed when the company was newly established were basically the same as those of the research organizations of the two companies before the merger. In managing the R&D bases of the new company, the bureau intends to accelerate its efforts to review the differences in the way the individual bases have been established and share R&D with the steelworks and to optimize the cooperation between those bases, specifically in the development of software.

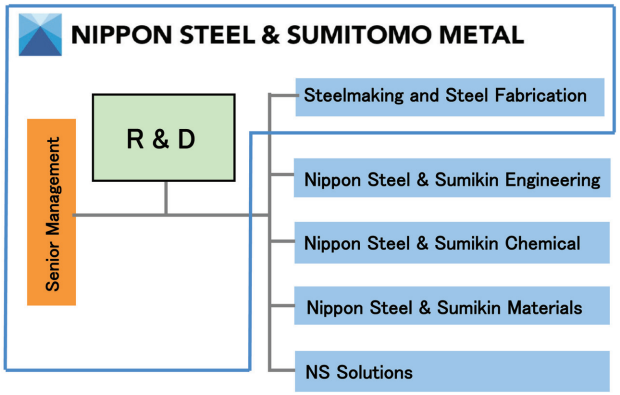

Fig. 1 Position of R&D in Nippon Steel & Sumitomo Metal

Basically, the existing R&D bases share the infrastructures of the two predecessors of the new company. However, they shall be managed as a solid organization by the Technical Research & Development Bureau. As shown in **Fig. 3**, the bureau consists of the three core research laboratories; that is, Steel Research Labs., Advanced Technology Research Labs., and Process Research Labs., and the technical research departments of the individual steelworks. Thus, in the new organization, the three central research laboratories of the former establishment Nippon Steel at Kimitsu Works are maintained and the individual research institutes and departments are horizontally linked to the central research functions of Amagasaki and Hasaki of the former Sumitomo Metal Industries.

The Steel Research Labs. engages in R&D on steel materials/products and application technologies/solutions. It has comparative-

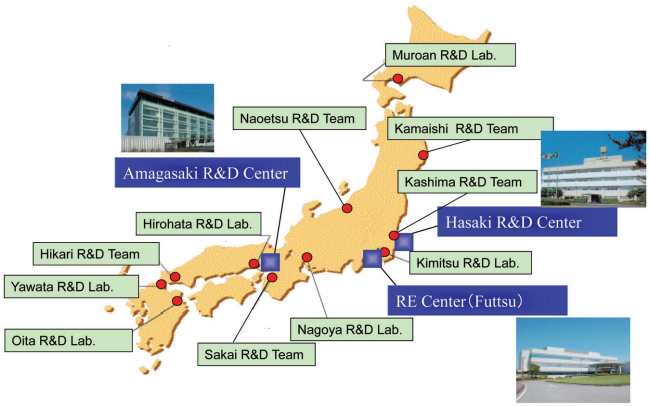

Fig. 2 Location of each part of Technical Development bureau of Nippon Steel & Sumitomo Metal

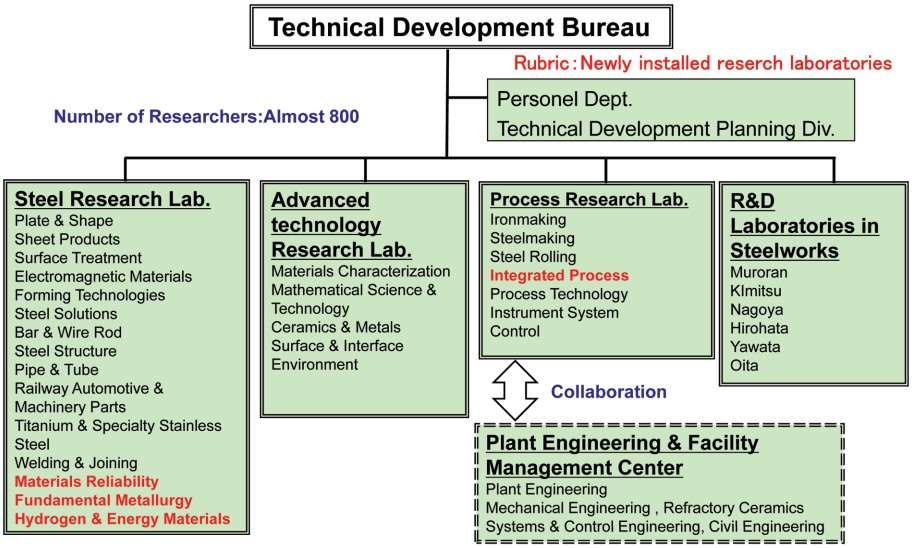

Fig. 3 Organization chart of Technical Development Bureau

ly the same scale of research activity at Futtsu and Amagasaki, respectively. In addition, several research departments have their bases at Hasaki.

The Advanced Technology Research Labs. is in charge of R&D on common key technologies and new materials to support businesses in non-steel segments. Its bases are concentrated at Futtsu and Amagasaki.

The Process Research Labs. takes care of extensive R&D on steelmaking processes. With Futtsu as its base, the laboratories also have important research functions, mainly for upstream processes, at Hasaki. In close cooperation with the Equipment & Maintenance Technology Center (based at Futtsu), which is mainly engaged in equipment engineering and development of equipment and maintenance technology, the laboratories strive to develop R&D results into commercial production equipment as early as possible and propose new technologies to the appropriate engineering departments.

Next, the research laboratories and functions introduced by Nippon Steel & Sumitomo Metal shall be described below.

There are four newly installed research laboratories; that is, Materials Reliability, Fundamental Metallurgy, Hydrogen & Energy, and Integrated Processes. They were installed when the company was newly established with the aim of pressing ahead with R&D from new standpoints.

The Materials Reliability Research Lab. is responsible mainly for common, elemental, and fundamental studies from the standpoint of reliability common to steel products. Specifically, it is engaged in R&D on mechanical phenomena; that is, fatigue, fracture, corrosion, and combinations thereof to improve the reliability and safety of steel products and structures.

The Fundamental Metallurgy Research Lab. studies the metallurgy of steel materials, structural control, etc. It engages itself in elemental studies of steel products (sheet, plate, pipe, wire rod, etc.) from a unified standpoint in order to deepen and systematize the fundamental metallurgy of steel products and develop new innovative metallurgy.

The Hydrogen & Energy Research Lab. is responsible for R&D on the storage, transportation, etc. of various types of energy, especially hydrogen, which is expected to play an important role as energy of the future.

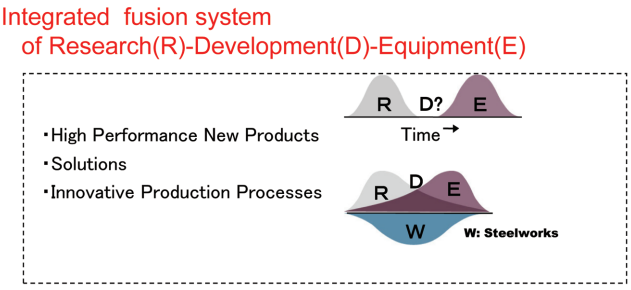

Fig. 4 Fusion of R, D&E

The Integrated Process Research Lab. develops new integrated processes in place of independent processes like steelmaking and rolling to optimize each individual process. By doing so, it studies integrated process metallurgy and develops innovative new processes with the aim of enhancing the functions and cost competitiveness of steel products drastically.

The Equipment & Maintenance Technology Center that formerly belonged to the Technical Research & Development Bureau of the former Nippon Steel and transferred to the Headquarters in 2011 is in charge of operations related mainly to equipment technology and equipment maintenance technology in close cooperation with the Technical Research & Development Bureau as in the past. It is positioned as a base, handling the same equipment technology as the central research bases. The aim of fusion of R-D-E that had been fostered by the former Nippon Steel for the early and smooth development of R&D results into commercial production equipment has been maintained and strengthened ever since the integration (**Fig. 4**).

The departments that support R&D, including Planning, General Affairs, Accounting & Purchasing, and Personnel are functional ones responsible for managing the technical research departments of individual bases and steelworks across the corporate organization.

Now, the Fellow System of Nippon Steel & Sumitomo Metal shall be briefly described below. The Fellow of Nippon Steel & Sumitomo Metal is the highest-ranking position (treated as executive officer or managing director) afforded to the company's researchers who have made remarkable achievements in research and provide guidance/training in their specialized fields or technology

development in general. The purpose of the Fellow System is to engage the fellows and technical advisors in R&D on a routine basis for technical training/education in projects executed by the Technical Research & Development Bureau and thereby help in managing the bureau from the companywide standpoint in joint activities with academies/associations and joint research studies with universities, research institutes, etc.

4. R&D Strategy for Displaying Technological Innovativeness

Taking advantage of the strengths of the former establishments Nippon Steel and Sumitomo Metal Industries and making the most effective use of the R&D organization described above, the new company (Nippon Steel & Sumitomo Metal) presses ahead with its R&D activities from the following four standpoints. In doing so, Nippon Steel & Sumitomo Metal executes its strategic tasks through utilization of outside knowledge; that is, tie-ups with universities/societies/associations and involvement in national projects. In addition, the company attaches importance to R&D projects and executes them on the basis of rules and principles, which are considered as behavioral principles.[1-3)]

4.1 R&D themes

As for the areas and themes of R&D, Nippon Steel & Sumitomo Metal executes its strategies from the following four standpoints in order to display its superb technological innovativeness by taking advantage of the strengths of the former establishments Nippon Steel and Sumitomo Metal Industries.

1) Meeting customer needs: Development of products that meet customer needs, proposal of advanced new application technology, and reinforcement of tie-ups with customers
2) Coping with hikes in prices of raw materials: Enhancement of cost competitiveness that helps in putting low-grade materials/fuels into practical use
3) Dealing with environmental problems: Proposal of solutions to environmental problems through promotion of "three ecos" (eco-process, eco-product, eco-solution) and reinforcement of tie up with affiliated companies
4) Implementing R&D on global basis: Joint research with overseas alliance companies, universities, and customers

Under the objective "meeting customer needs," one salient characteristic is that the company implements co-development/cooperation with client manufacturers during or prior to product design for customers and thereby develops and proposes new materials fully reflecting customer needs (**Fig. 5**). In the development of products at client manufacturers, it is expected to increase the freedom of design of materials, permit adding new product functions, widen the choice of manufacturing technology, etc. In addition, the company presses ahead with the development activity using the abovementioned R-D-E organization in order to isolate problems in planned mass production of new products and propose improvements in materials, etc. on a timely basis. In relation to the above responses to customer needs, the Steel Research Labs., specifically the newly installed Solution Development Lab., and the Processing Technology Lab., which studies the basics and applications of processing of steel materials, powerfully promote joint development with the customers from the standpoint of application technology/applied design of steel materials.

The second item "coping with hikes in price of raw materials" continues to be among the most important issues in view of the global change in the structure of raw materials procurement, the rising cost of steel manufacturing, the aggravation of environmental problems, the need to save energy, etc., although the hikes in prices of raw materials seem to have stopped temporarily. Even for raw materials that are procured on a long-term contract basis (i.e., iron ores and coals), it is necessary to apply a technology that is appropriate to their compositions and characteristic values. In addition, it is necessary to develop a new technology that permits the use of inferior raw materials that could hardly be used with the conventional technology. Therefore, the Process Research Lab. presses ahead with the technology development adapted to the ongoing global changes in the medium to long run.

Under the objective "dealing with environmental problems," the company is accumulating suitable technologies through verification tests of eco-towns/hydrogen towns around its steelworks in addition to the conventional environmentally friendly products (light, high-strength steel, high-performance electrical sheet, etc.) and processes that help reduce environmental pollutants, save energy and CO_2 emissions (maximum utilization of by-product gases, recovery of waste heat, effective use of waste, etc.). For the steelmaking process, the company continues to deal with technology development as an important field in addition to the existing technologies for converting inferior natural resources into useful ones by using large amounts of inferior coals in coke ovens, recycling dust, permitting effective utilization of by-product in steelmaking, slag, etc.

Under the objective "implementing R&D on a global basis," through establishment of a global three-pole organization having bases in Japan/Asia, Americas, and Europe, the company's R&D departments propel joint research/joint development with overseas research institutes and universities in order to expand steel production around the world (**Fig. 6**). In addition to acquiring appropriate technologies and deepening research themes, the company wishes to execute a multifaceted R&D activity, including start-up of overseas production bases, improvement of operations, joint development with overseas customers, and proposal of new products in the global market.

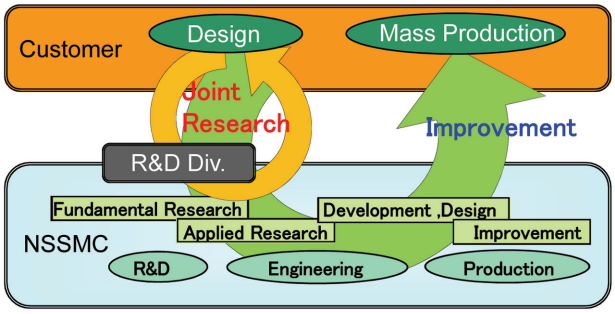

Fig. 5 Joint research method with customers

Fig. 6 Global network of research & development

4.2 Activities related to industry–academy cooperation

The purpose of industry–academy cooperation implemented by the technical development departments of Nippon Steel & Sumitomo Metal is to solve important technical problems speedily through reinforcement of the company's foundations for R&D by positively promoting collaborative research and development with universities and public research institutes at home and abroad.

In the cases of steel materials and processes of academic societies and universities, it is often said that the presence of the academic field has been decreasing. One probable reason for this is that the academic courses related to steelmaking are considered outdated and thus leave little room for research and development. However, as described later, the properties derived by present steel products from their materials only represent very small proportions of theoretical potential of the materials. For the superiority of Japanese materials technology to continue being foremost in future, it will become more important than ever before to let the individual enterprises continue promoting technology development and cooperating with academic societies in basic studies. In this context, the company wishes to continue its joint activities with other steelmakers in Japan to support the academic societies conducting R&D on steel materials and metallic materials; this involves organizing intercollegiate/endowment lectures and fostering talented personnel in related fields through university lectures, etc. by researchers of Nippon Steel & Sumitomo Metal.

Since FY 2007, Nippon Steel had been conducting joint research on strategic, large-scale themes in several different fields through a theme-oriented tie up with multiple research laboratories and universities. In addition, in FY 2010, it started up a young teachers' contract system to implement not only conventional contract researches in individual technical fields but also industry–academy joint research activities from a broader perspective. The new company also intends to review the insights provided by previous studies and widen the research perspective so that it will be able to make the future government-academy-industry cooperation more significant.

As examples of the national projects in which the former establishment Nippon Steel has participated, Next-Generation Coke Manufacturing Technology (SCOPE 21) and the Development of Environment-Friendly Steelmaking Processes & Technologies (COURSE 50) have been established by the New Energy and Industrial Technology Development Organization (NEDO) since FY 2008. The new company intends to positively propose and execute large-scale national projects, including not only innovative new steelmaking processes and measures to curb global warming but also R&D projects on energy and environment that require the fusion of most advanced technologies and large-scale experimental equipment, pioneering R&D projects paving the way for next-generation R&D, and development of technology relating to standardization of materials evaluation and construction systems.

4.3 Intellectual property

In relation to the keyword "technological innovativeness," the company presses ahead with its intellectual property strategy, whose main purpose is to protect its advanced new technologies as an intellectual property right and utilize them in the execution of its business strategy. In terms of the number of patents held in the world steel industry, Nippon Steel & Sumitomo Metal is the leader in Japan. Through measures to promote the application for foreign patents in future, the company intends to firmly secure its intellectual property in Japan, Asia, Americas, Europe, and the pan-Pacific region.

From the standpoint of intellectual property strategies, consideration should also be given to securing competitiveness or implementing differentiation not only by the acquisition of right through patent application (making the intellectual property open) but also by the acquisition of know-how (making the intellectual property closed). Namely, concerning intellectual property that should be protected from the standpoint of unique technical information, the company strictly manages it in accordance with its guidelines on management of business secrets.

In pressing ahead with a more comprehensive strategy on intellectual property on the abovementioned premises, the Technical Research & Development Bureau, which supervises most of the patent applications of the entire company, is supposed to play the leading role. In the future intellectual property activity as part of the company's R&D strategy, the research, sales, manufacturing, and intellectual property departments will work in close cooperation.

4.4 Viewpoint of management of research and development: Mastering rules and principles

As the common key technologies that support the development of new products and processes, it is important to employ metallurgy, analytical technology, mathematical science, and phenomenon analysis technology. For example, in the field of metallurgy, for the purpose of controlling a microstructure, the change in the microstructure of the material in each of the processes of heating, processing, and cooling is analyzed or an approach combining quantitative prediction based on numerical calculations is adopted to obtain basic understanding of the phenomenon involved. In the behavioral analysis of steelmaking processes also, mathematical science and technology, including numerical calculations, mathematics, etc., are widely applied. In addition, with respect to the technology for analyzing various phenomena that is indispensable for the development of new products and solutions, efforts have been made to develop techniques for evaluating hydrogen embrittlement, improve the delayed fracture characteristic, analyze the metal fatigue for improving the reliability of welds, clarify the mechanisms of corrosion, etc.

Figure 7 shows an example of R&D based on fundamental studies together with the progress of atomic-level status control/steel material structure control made possible by the sophistication of analytical technology. To implement atomic-level material control, the refinement of resolution and detection sensitivity of the technology for observing the material is indispensable. These achievements are based on the sophistication of materials observation technology at the Analytical Science Department of the Advanced Technology Research Labs. Basically, materials researchers, mainly those at the

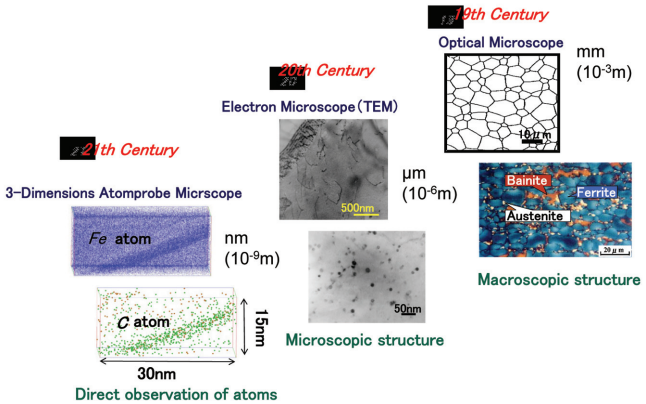

Fig. 7 Material structure control technology based on the sophistication of analytical technology

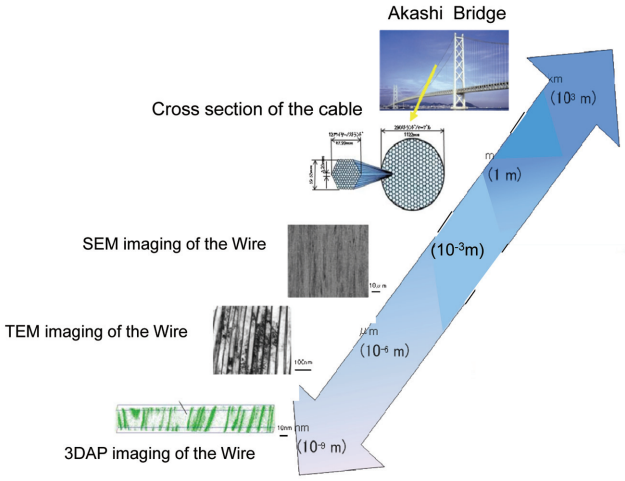

Fig. 8 Steel structure control of nano- to kilometer level

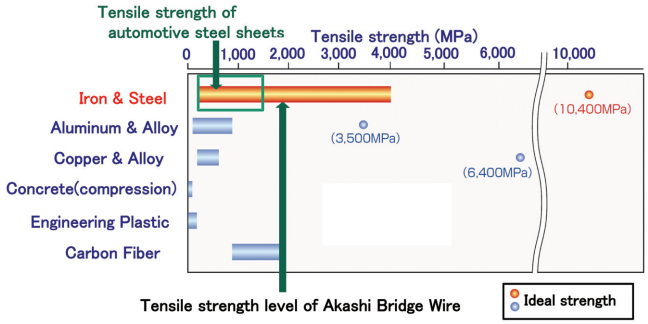

Fig. 9 Potentials of each material and practical use level [4)]

Steel Research Labs., tackle the common goals of technology development. Namely, rather than simply waiting for the progress of analytical devices from the standpoint of materials research, the researchers present the technical problems and new targets to the department engaged in elemental studies and perform the task in cooperation with that department. By doing so, the application of a new analytical technology to actual materials becomes sophisticated, which in turn helps in refining the analytical technology.

Figure 8 shows the relationship between the observation scale of analytical technology and the viewpoint of materials control; that is, the relationship between various analytical techniques (resolution, detection sensitivity) from nanometer to kilometer level and process quality assurance of actual materials (viewpoint of controlling the scale and material of structure/function manifestation factors). With a bridge cable bundled to support the prescribed load, for the millimeter-order steel cord to manifest the prescribed strength as a single wire, it is necessary to control a steel material to a size of tens of microns in diameter. This is attained by detailed observation of nano-level molecular segregations and interactions.

In addition, the evolution and progress of fundamental technologies, such as materials/process design based on computational science, become increasingly important for the development of new materials and sophisticated processes. Nippon Steel & Sumitomo Metal plans to refine those basic and fundamental technologies.

5. Conclusion

It is generally understood that the steel industry is a mature industry. Then, has the steel product technology reached a level at which no major breakthroughs can be hoped for? Also, has the research and development of steel materials become a "low-tech" field directly as opposed to "high-tech" fields such as electronic materials and bio-materials? Is the present steel manufacturing process the ultimate one leaving little room for any major improvement?

The author opines that the answers to all above questions are "No."

Figure 9 shows the theoretical strength and behavior of various materials when they are put into industrial use. Admitting the presence of design margin, variance in materials, and limitations from the manufacturing process, there is a wide gap between the potential of steel materials and the actual property of a steel product. The implication is that there is still much room for improvement of the characteristics of steel materials. It seems that the above fact provides Nippon Steel & Sumitomo Metal with a power source by which it can seek to tilt its technological superiority in the steel industry. Needless to say, since the current levels of steelmaking technology have been attained after many years of strenuous efforts of our predecessors, the hurdles for further technical improvements will increase. The technology development departments of Nippon Steel & Sumitomo Metal make concerted efforts to clear the hurdle.

So far, the author has briefly described the R&D strategy of Nippon Steel & Sumitomo Metal. He hopes that the contents of this review will be of help to the readers. In conclusion, the author wishes to remind the reader of the fact that this review contains items that have been omitted owing to space constraints and strategic measures that are still under consideration. The author intends to give a detailed account of them on a separate occasion.

References

1) 80-Year History of Yawata Works; With Flames; 10-Year History of Nippon Steel; etc.
2) Centennial Anniversary Issue of Shinnittetsu Giho
3) Sumitomo Metal Industries, Ltd.: 50-Year History of Technical Research Labs.
4) Nippon Steel Corporation: Publication on Iron Sheet & Plate. Nippon Jitsugyo Publishing, p. 138. Fig. 1 "Strength Levels of Various Types of Industrial Materials" Revised in Part.

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