UDC669.14/15-462+621.774

Progress in Pipe and Tube Technology and It's Future Prospect – Applications and Manufacturing –

Shosuke Sone*1

Abstract:

Pipe is applied in all fields of industry and manufactured through processes with a wide variation. Further, not like a simple material, pipes provide many functions, and therefore the supplier is often required to be involved in engineering problems at customers. Through a review of technical issues on the pipe application in several fields and the technical progress of its manufacturing processes, this paper introduces the contribution of Nippon Steel Pipe Division to the industry up till now, and clarifies its future prospects of both the technology on pipe and tube and the strategy of enterprise.

1. Introduction

Our steel pipe division supplies products to almost every field of industry. It is closely involved not only in a wide range of industries, including automobiles, machinery, plant, construction and civil engineering, but also in the electronics industry[1]. It is also an exceptional division that handles product types directly associated with energy production industry which is quite small in Japan, and the engineering fields involved therefore inevitably cover a broad spectrum.

In addition, steel pipes are a product with features that go beyond those of a mere raw material. When pipes, boiler steel pipes with pressure-holding functions, large-diameter steel pipes serving as structural semi-finished products, or oil country tubular goods and line pipes, etc. that are shipped to users as finished products, are sold, more intensive involvement in the technical planning of the engineering task by the customer is required than when raw materials are being supplied.

Nippon Steel has supported the progress of each industrial field by developing and supplying steel pipes at the highest technological level. Future prospects in this area are described here, in addition to a look back at the progress in each application area and pipe manufacturing technology.

From the point of view of manufacturing technology, basic technological improvements in steel production have been seen, including high purity refining, process metallurgy through hot rolling, and welding control, as well as the progress that has been made in pipe manufacturing technology in each area.

The outstanding feature of technological developments carried out by the Nippon Steel Pipe Division is the fact that development has also been pursued systematically by enhancing FEA (finite element analysis) application technology, in combination with experiments in response to rapid progress in computers in recent years. Pipe manufacturing as a business is a strongly labor-intensive industry, and its profits depend largely on labor-saving technologies. Production depends to a great extent on the world energy situation, in addition to business fluctuations. It is therefore important to optimize flexibly the operational formation in production lines , and each mill has managed to implement this.

2. Prospects by Application

2.1 Automobile steel pipes

Safety and environmental problems present a significant challenge in the field of automobiles at present. Although an increase in car body weight is required in order to achieve accident safety, improved fuel consumption is also being sought after in order to

*1 Head Office

reduce running costs, so that weight reduction is also becoming a major trend.

In these circumstances, Nippon Steel developed ultrahigh-strength steel pipes in the 1,470 to 1,570 N/mm^2 class quenching by high frequency induction heating, for use in protection against side collision by door beam, requiring a high level of energy absorption. This safety measure resulted in weight and cost reductions. The technology has also begun to be adopted in trucks for protection against head-on collisions.

For propeller shafts, the high-tensile steel with less softening property against welding on heat affected zone was developed by reducing the softening of the zone affected by welding heat (HAZ) from 690 to 780 N/mm^2, in addition to producing conventional steel pipes in the 440 to 540 N/mm^2 class to meet the need for weight reductions to prevent weld fatigue characteristics. This technique also allows thin walls to be constructed with four-roll sizer technology, enhancing roundness characteristics[2].

For important parts based on this type of propeller, automobile steel pipes are highly valued by manufacturers, and the market share has exceeded the greater part. There have been cases in which weight reductions of as much as 15% were achieved by manufacturing suspension elements in pipe form.

On the other hand, the need to reduce environmental pollution and enhance durability in the steel used for exhaust pipes has led to the development of various types of stainless steel pipe, ranging from exhaust manifolds to tailpipes behind mufflers that are heat-resistant, corrosion-resistant, formable, and low-cost, etc. In exhaust pipes, the achievement of low thermal capacity is required in order to purify exhaust gases, and making thin walls will be furthered by using double pipes as measures against transmission noise. Nippon Steel can address these problems by low-strain pipe forming technology.

2.2 Plant steel pipes

In recent years, the domestic plant manufacturing industry has been facing severe competition from foreign manufacturers due to the appreciation of the yen and reduced investment in domestic plant and equipment, leading to falling profits. To remedy this situation, the industry is actively implementing reductions in plant construction costs, expanding materials procurement from abroad in order to shorten construction periods, transferring design divisions abroad, and adopting new engineering methods and new materials, and these trends will continue.

In the meantime, it has become possible for domestic petroleum plants to carry out continuous operations for more than two years, due to amendments in the relevant safety regulations. As a result, these plants requiring extended continuous operations are increasing, and long-life materials are required in order to ensure stable and continuous operations.

Specific requirements expected of steel pipes for plant include adoption of pipe in coil (PIC) capable of quality assurance by greatly reducing numbers of welds and shortening construction periods, the application and expansion of high-frequency bending methods, expansion of automatic girth welding at site by narrow-range control, including outside diameters, roundness, thickness, groove dimensions of LNG piping stainless steel pipes, adoption of high purity ferritic stainless steel pipes to extend the life of heat exchangers in petroleum plants, application and expansion of HIC (hydrogen induced cracking resistive steel pipes in carbon steel piping portions.

Nippon Steel provides new products tailored to every need, and the adoption of new engineering methods and new materials will be encouraged in order to reduce plant construction costs and operating costs.

2.3 Boiler steel pipes

In the field of thermal power boilers, generating efficiency has recently been improved through the introduction of high-temperature, high-pressure steam conditions to reduce costs and control CO_2 emission for environmental reasons. In addition, the construction of ultra super critical boilers with a steam temperature of 600°C/610°C and steam pressure of 25 MPa is also planned. At the same time, more economical materials are being demanded in order to reduce electricity generating cost.

Manufacturing high-efficiency power boilers requires the use of ferritic heat-resistant steel pipes with a high creep strength in headers and main steam pipes. The developments in this area have been remarkable in recent years, and Cr steel (9Cr-1.8W steel, NF616, etc.) containing W with a high creep strength has also been developed in Japan, following the Mod. 9 Cr-1Mo steel (ASME P91) developed in the USA[3].

These high creep strength materials make it possible to keep the walls of steel pipes thin, allowing weight reduction, and they are suitable for the above requirements, reducing transport costs and construction costs in addition to the reduction in material costs.

For example, the NF616 developed by Nippon Steel has a permissible stress over 30% higher than that of P91, allowing material cost reductions of as much as 20%. The NF616 is already standardized in ASME, and it will also be standardized in Japan in time to be adopted in actual power plant. The development of high W steel is also progressing toward higher creep strengths in order to allow high temperatures and high pressures in thermal power plants in the future. Electric resistance welding (ERW) boiler tubes are increasingly being used in commercial boilers in order to achieve cost reductions. ERW boiler tubes have not been adopted domestically in semi-public commercial boilers, due to the accidents that occurred with foreign ERW boiler tubes in the 1960s. However, in order to achieve increased reliability and reduce costs, they have recently begun to be adopted for commercial use by many electric power companies[4]. Portions and steel types adopted range from water wall tubes and reheater tubes to superheater tubes, and from carbon steel pipes to low alloy steel pipes (STBA22).

With regard to austenitic boiler steel pipes, high creep strength steel has been developed for 20-25% Cr, using the precipitation strengthening of the carbon nitrides of Nb and Ti. In particular, the NF709 (20Cr-25Ni-1.5Mo-NbTiN) developed by Nippon Steel has the highest creep strength in this class. Steam conditions in the field of waste incineration boilers were in the range of 300-30 kg/cm^2, and generating efficiency was as low as 10-15%. High-temperature and high-pressure steam conditions have been achieved in order to improve generating efficiency, since power prices have recently been supported by the power market situation change, and plant operations exceeding an efficiency of 20% have already been seen in the class of 400°C-40 kg/cm^2.

Furnaces currently going into operation, such as stoker furnaces, cause heavy corrosion when they run at 300°C or more, requiring the use of highly corrosion-resistant steel pipes, such as austenitic stainless steel of 20 to 25Cr (formerly NF709) or Ni base alloy.

Low alloyed steel types are also being developed to enhance economies, but guidelines for the selection of materials are difficult to standardize at present, in view of the fact that the corrosive environment depends on the quality of the garbage being incinerated, which varys according to the situation.

In the meantime, for the next generation of furnaces such as gasification conbustion furnaces, there have been some reports of test results in which attack to the material has been reduced, and in which carbon steel is acceptable even at a steam temperature of 500°C. New alloy materials will continue to be developed, in addition to reinforcing basic research, including the elucidation of the combustion ash corrosion mechanism.

2.4 Structural steel pipes

New products and technologies have been developed in the field of steel pipes for transmission steel towers, railway stringing poles, circular steel pipe poles for construction purposes, internally or externally ribbed steel piles, concrete-filled steel pipe piles, and warp streak steel pipe poles, meeting the requirements for diversified steel pipe performance, including corrosion resistant treatment by galvanizing and aluminizing in the field of structural pipes, as well as in civil engineering and construction. Other new aspects include optimizing the weldability according to the application, adhesion of composite steel pipes to concrete, reduction of workpiece weight and volume by high strength steel pipes, steel pipes conforming to seismic design standards, and steel pipes matching scenic conditions.

Future prospects include comprehensive technological developments, including effeciency of field work and raw materials cost to meet the need to cut working costs. Specifically, these measures need to be linked to applied working technologies, such as shortening working time using new steel pipe joining technology, and proposals for steel structures that take advantage of the rigidity of steel pipes themselves, as well as the whole range of applied working technologies and raw materials technologies, including selecting raw materials with a view to maintenance costs after completion. Technological cooperation with users will therefore become increasingly important.

2.5 Steel pipes for piping and coating

Steel pipes appropriate to a wide range of different conditions have to be supplied, both with regard to the fluid passing inside them (gas, petroleum, water, etc.) and with regard to the external environment (indoors, seashore, tropical zones, frigid zones, etc.). Consequently, keeping ahead of its competitors, Nippon Steel has developed a variety of steel pipes, as shown in **Table 1**, to respond to market needs.

As can be seen from **Table 1**, various coatings can be applied to the inside and outside of steel pipes in order to suit market requirements. As a result, the original standard for pipe includes three types, while the standard for coating steel pipes includes as many as nine types, indicating the typical small lot with wide variation production pattern.

Market requirements are expected to move toward coping with harsher environments in the future (high accuracy, high temperature, high reliability, etc.). The manufacturing technology required to produce a wide variety of products efficiently has to be developed, in addition to the technological developments needed to respond to these extreme demands. Since most of the steel pipes described above are used at ordinary temperatures, technological developments for coating at high temperatures may be required[5].

On the other hand, domestic small-diameter steel pipes are being replaced by resin pipes, which are easy to carry because they are lightweight and can be coiled. New types of steel pipe capable of competing with resin pipes will have to be developed in the future[6].

2.6 Pipelines

During the past 25 years, pipelines have made tremendous progress as a means of long-distance transport for natural gas and crude oil. Large-diameter steel pipes of API standard X65 were manufactured in large quantities for TAPS in Alaska in the late 1960s. This ushered in a new era of long-distance pipelines. As the exploitation of natural energy resources moves into more severe conditions in the extreme north and offshore, requirements for pipelines have become more diversified and advanced, and the manufacturing technology has made great progress.

In terms of strength and toughness, the technologies established in the field of line pipes (large-diameter pipes in particular) now include basic ingredients such as low C-Nb-Mo and Nb-B, grain-refining technologies adding Ti in trace amounts, high strength and high toughness technologies with low-temperature heating and control rolling, and high strength and high toughness technologies with excellent welding characteristics through accelerated cooling[7].

Improving the low-temperature resistance of the seam welds of UO steel pipes includes the achieving increased toughness through the adoption of Ti-B based alloy design and decreasing oxygen level in steel, HAZ toughness improvement by adding Ti in trace amounts, and HAZ improvement by oxide metallurgy (TiO). Improvements in the seam welding process for ERW pipe include welding stabilization by dynamic control of welding con-

Table 1 Steel piping manufactured by Nippon Steel

Item	Standard and name	Range capable of manufacture	Item	Standard and name	Range capable of manufacture
Carbon steel pipe	JIS G3452 · SGP	15A～500A	Polyethylene-coated steel pipe	JIS G3469 · HI-PL	15A～1,600A
Carbon steel pipe for pressure piping	JIS 3454 · STPG	15A～600A	Polyethylene powder lining steel pipe for water supply	JWWA K132 · FLP	15A～100A
Arc-welding carbon steel pipe	JIS G3457 · STPY	400A～2,000A	Hard vinyl chloride lining steel pipe for water supply	JWWA K116 · VLP	15A～150A
Galvanizing steel pipe for water supply	JIS G3442 · SGPW	15A～300A	Tar epoxy inner coating steel pipe	WSP 032 · ELP	32A～350A
Coating steel pipe for water supply	JIS G3443 · STW	80A～3,000A	Mortar lining steel pipe	WSP 001	200A～2,000A
PIC for piping	Example SGP-P	6A～32A	Alumer steel pipe	ALM	15A～900A
Steel pipe for cable protection	APS,ASC,AS	25A～150A	Corrosion-resistant channel seam-welded steel pipe	SUPER SEAM	15A～600A SGP125A up

ditions and the achievement of high toughness by adding on-line heat treatment. Measures to provide steel with sour environment resistivity include preliminary treatment of pig-iron, and the achievement of high-purity steel, through secondary smelting, the application of light sizing in continuous casting, reducing the central segregation by applying accelerated cooling after controlled rolling, and hardness reduction of field welding of T cross-sections. In the field of corrosion-resistant high-alloy pipelines, improvements have been made in 0.5% Cr line pipes, high Cr stainless steel (9 to 13% Cr) line pipes[8], and clad steel pipe manufacturing technology.

The supply of natural gas as an energy resource will certainly continue to increase rapidly in especially Europe and Asia, and large-scale pipelines are planned. However, since natural gas has to be transported over long distances, substantial reductions in production and transport costs will be required as a result of competition with other energy sources. Consequently, high-strength line pipes of X80 to X100 or more will be required. Similarly, the demand for corrosion-resistant steel pipes will increase to reduce production and transport costs. This may lead to the expansion of new systems, such as the FPSO (floating production storage off-loading). In this method, untreated gas has to be transported, since sulfur removal equipment cannot be used due to the limitations of vessels. The same applies in the deep sea area and ice floe area, where jackets cannot be installed. Accordingly, 13% Cr line pipes will be applied, and their sizes may be expanded. Steel pipes with excellent external SCC (stress corrosion cracking) characteristics, which present problems with land pipelines, may also be applied and expanded.

With regard to high-strength characteristics, points for future technological development will involve optimizing the control of fracture toughness values, developing field welding materials, establishing design standards, and improving the manufacturing system for fittings. For high corrosion resistance material, it will be required establishing application of CC process for seamless pipes, cost reduction including the application of ERW tubes, increase of sizes by UO application, and material development responding to reeling (coiled line pipes). External SCC resistance will involve elucidating the generating system of both types of cracks (low and high pH) and developing line pipes excelling in external SCC resistance.

2.7 Oil country tubular goods

The demand for natural gas and crude oil is still increasing, due to the slow progress of alternative energy technologies, and the areas requiring development now involve harsh environments, such as deep sea regions, polar regions, and highly corrosive environments. Consequently, high-strength and highly corrosion-resistant characteristics are needed for oil country tubular goods, and safer, highly functional joints have to be used. In the field of low-alloy steel oil country tubular goods, the high-strength, sour environment resistant oil country tubular goods C90 and T95 have been standardized in API, and C110 grade products are also being put to practical use. In addition, the application of premium joints providing a high sealing performance, as well as resistivity against high tension, compression, bending and make up torque, is increasing. Nippon Steel has met these challenges with NS-CC, which is a screw originated by Nippon Steel, in addition to developing high-strength, acid-resistant oil country tubular goods ahead the competition.

Oil well development costs are still increasing in environments that are becoming more and more harsh, and various technological developments have taken place in order to reduce development costs. One of these is a horizontal or high-angle drilling method. This engineering method permits increasing productivity per well, while at the same time reducing the number of platforms required in offshore drilling. In this application, casing pipes are subject to various types of severe stress, and it is therefore essential to implement design of casing string with the service conditions and steel pipe characteristics (including joints) in consideration. On the basis of its past research results, Nippon Steel was commissioned by the Japan National Oil Corporation to develop software to achieve an optimum casing design at high speeds in various conditions, and completed this task[9].

The use of 13% Cr steel oil country tubular goods has been rapidly increasing in recent years. This indicates that the use of 13% Cr provides substantial cost advantages in conventional carbon steel + inhibitor operations. As a result, development in environment including carbon dioxide will be furthered. High-performance 13% Cr steel far exceeding the corrosion resistance and sour environment resistance of API-defined 13% Cr steel is also progressing toward practical use. Nippon Steel has developed highly corrosion-resistant 13% Cr with sour environment resistance in which a high alloy such as duplex steel has been used, and this is being put to practical use[10].

Harsher environments and higher quality requirements will probably continue. Nippon Steel will therefore press forward in developing materials selection and stress evaluation technologies, in addition to developing even more highly functional steel pipes and joints. In recent years, with the growing interest in environmental and safety issues, it has become necessary to make protectors and packing system suitable for recycling and re-use, and to keep the compound grease environmentally friendly. Nippon Steel will be addressing these technological problems, including the development of dope-free threaded joints.

3. Prospects for the Pipe Manufacturing Process

3.1 UO steel pipes

Pipe manufacturing equipment has repeatedly been improved for response to making wall thicknesses heavy and labor productivity enhancement. For line pipes, which have constituted the main use for UO steel pipes in recent years, the trend toward making steel pipes stronger and making the walls thicker are based on improvements in transport efficiency in high-pressure processes and strength problems associated with deep-sea pipe laying.

Problems involved in the manufacture of UO steel pipes include the insufficient forming capacity of presses or expanders, reduced accuracy in spring-back and butt angles after the pressing of high-strength materials, and reduced roundness. It is therefore important to solve these problems in order to maintain and increase the share of Nippon Steel in the line pipe market.

For line pipes, domestic mills are aiming to expand the market for new domestic applications of steel pipes in construction, drilling propelling pipes and other types in order to gain profits during a slump caused by a sharp change in demand. Since the market of this application is characterized by small lots, the time in which the mold change in presses or expanders can be completed, and the number of times of these change over by which total productivity can be increased are key factors for production capacity and cost competitiveness.

3.2 Spiral steel pipes

The most serious problems in the market for steel pipe piles and steel pipe sheet piles for civil engineering purposes, which include most of the applications for spiral steel pipes, are the keen competition with concrete piles and the market penetration of imported steel. In both cases, cost competitiveness is a key factor, rather than quality competitiveness. Increasing cost competitiveness requires improvements in labor productivity, and Nippon Steel has succeeded in speeding up pipe manufacturing welding in order to achieve top speed in Japan of 5 m/min. However, further acceleration of production will be essential for the future. Combined welding with lasers and the development of new welding technology will be important ways of achieving this.

Since secondary working includes reinforcement bands, sheet piles, pad eyes and heavily anticorrosive coating, each mill is running behind with mechanization. The extent to which labor savings can be achieved will be decisive for future cost competitiveness. As specific measures, automatic high-speed sheet pile welding and robot-operated coating equipment are already being implemented in practice.

3.3 Medium-diameter seam-welded mill

Medium-diameter seam-welded steel pipes are mostly used as line pipes, oil country tubular goods and structural steel pipes, such as seamless/UO. The most important target in the seam-welded steel pipe manufacturing process in relation to the line pipe and oil well pipe market is to ensure a welding quality that is capable of competing with seamless/UO, and to establish a corrosion-resistant high-alloy steel pipe manufacturing technology. It will be necessary to establish atmospheric control technology in addition to the current method of heat input constant welding control, and also to develop a combined welding method based on present ERW.

The efficiency of production in small lots has to be enhanced in the structural steel pipe market. It is necessary to promote the use of cage rolls as a size-independent technology in the production process, or the application of FF (flexible forming) mills to medium diameter pipes. At the same time, it is essential to manufacture products (secondary working) suited for use in specific environments, and to improve the technology, adding various workings at low cost. For high-strength seam-welded steel pipes (mostly oil country tubular goods) of the 690 MPa class or higher, which required heat-treatment (quenching and tempering), a combination of TMCP technology in hot stripmill during coil manufacturing and strong cold-working forming technology made it possible to manufacture the pipes without heat treatment. As a result of the reduced manufacturing costs and improved quality, including collapse characteristics, seam-welded steel pipes have entered the market for high-strength, high-grade pipes, in which seamless pipes have been predominant.

Integrated technology and product development, including raw materials manufacturing processes as well as seam-welded steel pipe manufacturing processes, will in the future become more and more important in responding quickly to diversified markets with severe competition (high dimensional accuracy, extremely thick walls/extremely thin walls, high corrosion resistance, low costs, etc.).

3.4 Small-diameter seam-welded mill

Nippon Steel has small-diameter seam-welded mills in its Nagoya Steel Mill and Kimitsu Steel Mill, which are in charge of this range of products. The Kimitsu 4-inch mill, featuring extremely thick walls and low-alloy and high-carbon steels, took advantage of aspects of the cold manufacturing method to exploit the field of its own high-grade pipes, including boiler tubes and stainless steel pipes, and through gaining customers' confidence by entering the market for public power plant for electric-power companies. It is currently aiming to extend the market for this type.

The Nagoya small-diameter seam-welded mill is mostly involved in automobile steel pipes and steel pipes for materials, and it offers characteristic products for high-tension propeller shafts, door impact beams, etc. Even in small-diameter seam-welded mills, exchanging and adjusting a roll during size changes is the greatest factor for productivity. The flexible forming mill adopted in Nagoya may be a solution to this problem. Nippon Steel has pressed forward with the development of high-precision pipe manufacturing technology adaptable to small lots, varieties of products, and high quality, and has completed its installation in Kimitsu [11].

In order to meet customers' requirements for low costs, it is necessary to carry out "dimensional accuracy improvements," aiming at the "elimination of cold-drawing," and "workability improvements," aiming at the "elimination of heat treatment." One of the causes for reduced dimensional accuracy is the deformation of the end of a pipe occurring due to pipe circumferential forces and residual stress distribution. The roll sizing technology developed by Nippon Steel is effective in achieving these improvements. Low-strain pipe manufacturing, minimizing forming strain during the manufacturing process, allowed improvements in workability. In the future, a seam-welded steel pipe manufacturing technology capable of controlling forming strain in a positive way will become even more important than technologies for the mere formation of shapes.

3.5 SR-PIC steel pipes

"SR-PIC" is an original Nippon Steel product, in which a specific external diameter pipe size is manufactured by the seam-welding method, and forming a variety of external diameter sizes using the hot SR (stretch reducer) process reaching 1,000 m in product length, by combining a garret reel coiling system used in wire rod mill with them. With the ERW + SR process, Nippon Steel has established a technology for constant temperature control to enhance weld reliability, and a technology for optimizing edge bending R (radius), allowing the efficient manufacture of a wide range of high-grade products, from pipes with extremely thin walls to pipes with very thick walls, while optimizing the SR reduction. In coiling processes, pre-deformation coiling technology was made practical with the product being formed into an ellipse beforehand, making it possible to achieve roundness after coiling and to develop the SR-PIC, with high grades and a wide range of sizes, which is used widely in automobile pipes and road snow melt pipes, etc. [6].

From now on, it will be necessary to promote further quality enhancement in seam welding and to extend the manufacturing of thick-walled pipes, taking advantage of the superiority of the ERW + SR process.

3.6 Continuous butt welded (CW) pipes

The continuous butt welded steel pipe mill, featuring high productivity and low costs, is a mass production-type mill mainly involving small-diameter piping. Its production volume is decreasing due to the entry into the market of ERW and other competitive materials in recent years, but quality requirements are being further advanced and diversified. Responding to these will require improvements in both cost competitiveness and quality competitiveness. Nippon Steel has pressed forward with measures to improve productivity, such as expansion of workers responsibility on job coverage. In addition, it has installed a high-precision wall thickness control system in order to achieve high dimensional accuracy in original pipes for coated steel pipes, responding to the need to reduce the amount of processing required by customers. Nippon Steel has also responded quickly to market changes, including meeting the requirement for shorter steel pipes to facilitate the workability of piping. It will be also important to produce thin pipe walls in response to the demand for weight reduction to improve workability, to enhance the quality of fitting portions, with the widespread use of mechanical joints, and to achieve high-efficiency pipe manufacturing processes to ensure high productivity and enhance cost competitiveness.

3.7 Hot extrusion

The hot extrusion method makes it possible to manufacture shaped steel and steel pipes of various shapes by changing the dies, and this method is suitable for small lots since die costs are far lower than roll costs. Nippon Steel is currently manufacturing 500 types of shaped steel monthly. By the continuous effort with the expansion of manufacturing ranges and menus and implementing complex shapes, thin walls, and large sections, improving die design technology and optimizing the die material, the number of shapes could be increased to more than 5,000.

Responding to the demand for more varied applications requires the production of thin walls, sharpening the corner radius and improving dimensional accuracy. Nippon Steel pursues with improvements in hole die design technology, using extrusion analysis technology with plastic dynamic techniques and further expanding the range capable of being manufactured by optimizing the die material. Most steel pipes consist of stainless steel, and the improvement in die shapes and development of lubricants suitable for extrusion materials have provided various types and sizes of steel. Nippon Steel won the Ohkouchi Commemorative Production Award in this field for the development of direct extrusion technology with continuous cast material, eliminating ingot rolling. Improvement of the internal lubrication method provided a maximum reduction rate of up to 99% for SUS304, allowing the elimination of some cold working processes. It will be necessary to develop a long-life die material or to improve dimensional accuracy by developing lubricants capable of replacing glass, and improving the internal and external surface quality.

3.8 Seamless steel pipes (small-diameter plug mill)

Nippon Steel has a small-diameter plug mill in its Tokyo Mill, and manufactures various types of seamless steel pipe for the domestic market. The very compact mill can handle small lots, and it has met various user requirements quickly, such as an increase in manufacturing size with a small diameter, very thick steel pipes, deformed steel pipes, etc. Nippon Steel Tokyo plug mill will aim for high-productivity mills that can take advantage of these features in the future. To do this, it is important to meet strict standards, strengthening adaptability to diversified requirements for quality and delivery time, and achieving productivity improvements through labor savings. Technological problems include improving rolling control accuracy, improving the hot lubrication method, and optimizing manufacturing schedule systems in terms of quality and construction period, as well as expanding the automatic operation range of rolling and utilizing robots for tool change work.

3.9 Seamless steel pipes (medium-diameter plug mill)

It is some twenty years since Nippon Steel's medium-diameter plug mill (Yawata) started operations in 1977, and competitive features of this highly automated mill are still being maintained. The unique processes, using square pipe material, offer advantages in sharing materials processing with other types of product in the integrated steel mill. The adoption of fully automatic warehousing achieved fundamental improvements in labor productivity, and at the same time established a complete computerized piece-tracking system for products, meeting the need for quality assurance and maintenance of strict standards. Nippon Steel has completed the integration of its pipe material sizes to form a mill that can adapt flexibly even to small lots, and it is aiming to achieve an all-round high-quality mill and achieve productivity improvements by expanding the automatic operating range of the mill further, streamlining through the installation of robots and shortening setup times.

3.10 Seamless steel pipes (small mandrel mill)

The small-diameter mandrel mill in Yahata, which started operation in 1983, has the same features as the medium-diameter mill constructed earlier. The automatic warehousing and piece-tracking system created a flexible manufacturing system in addition to the above advantages. To improve rolling control accuracy, Nippon Steel introduced the semi-floating mandrel mill, and the control of mandrel bar realizes a high level of quality.

The use of high alloys in oil country tubular goods and line pipes has been increasing in recent years, and measures to improve production capacity have been taken. Tool life and the occurrence of flaws, which are problems in high-alloy rolling, will be solved by the development of new material tools and constituent designs, as well as new rolling lubrication technology.

4. Conclusion

In the field of steel pipes, demand trends depend on the world energy and political situations, and technological developments have therefore tended to address the current market problems correspondingly.

Since there is now a global over capacity of steel pipe supply, and cost reductions are becoming a matter of concern for the whole manufacturing industry, competition in terms of technology and cost in the field of steel pipes will become increasingly acute. Pipe & Tube Division of Nippon Steel Corporation commits itself to maintain its current technological superiority in the supply of steel pipes in every field of industry. To do this, it is necessary to establish highly advanced product types and enhance profits, and an orientation toward strategic technological development will become increasingly important.

References

1) Doi, M.: Shinnittetsu Giho. 362, 11 (1997)
2) Itami, A. et al.: Shinittetsu Giho. 362, 66 (1997)
3) Ohgami, M. et al.: Shinittetsu Giho. 362, 49 (1997)
4) Sumimoto, D. et al.: Shinittetsu Giho. 362, 54 (1997)
5) Funatsu, S. et al.: Shinittetsu Giho. 362, 62 (1997)
6) Watanabe, Y. et al.: Shinittetsu Giho. 362, 17 (1997)
7) Terada, Y. et al.: Shinittetsu Giho. 362, 38 (1997)
8) Asahi, H. et al.: Shinittetsu Giho. 362, 43 (1997)
9) Maruyama, K. et al.: Shinittetsu Giho. 362, 24 (1997)
10) Asahi, H. et al.: Shinittetsu Giho. 362, 6 (1997)
11) Hada, K. et al.: Shinittetsu Giho. 362, 31 (1997)