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Production Technology for Steel Bars and Wire Rods

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Abstract

This paper outlines the recent progress in production technology and the status of new product development at Nippon Steel Corporation Bar and Wire Rod Division. There has been progress in production technology for improvement in productivity, the saving of labor that is centered around automation and system engineering, and the reform in steel production brought about by continuous casting. There has been progress in new products that correspond to various customer needs and in evaluation methods to support product development. Total problem solving (con-current engineering) that includes designing and the technology in use and "seeds" creation based on fundamental research are important for future product development.

1. Introduction

Steel bars and wire rods are used for such elementary materials as bolts, nuts, cables and bearings that are the important safety parts of the drive train system of automobiles and as fundamental materials for industry. Nippon Steel Corporation bar and wire production trends are shown in **Fig. 1**. It is rare that hot rolled steel by steel manufacturers is used as it is. It is only after passing through several processes they become final products. Therefore, in the development of products, it is important to fully understand the forming processes. Also, in order to respond to the persistant requests for reducing costs from users in the ever increasingly severe international market such as in the automobile industry, there is an increase in the importance in the underlying processes including forming processes for parts being several times more expensive than hot rolled steel. In order to respond to these needs, besides adding to the rationalization of the manufacturing process, there have been progress in production technologies in the manufacturing process. This paper describes the current status of such technologies.

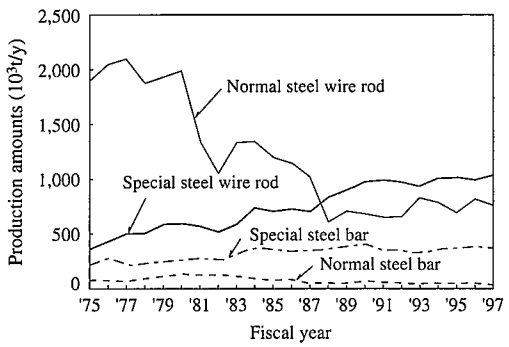

Fig. 1 Trends in production amounts of steel bars and wire rods

2. Progress of Bar and Wire Manufacturing Technology

2.1 Steel making technology

The technological development that should particularly be written about in the area of steel making is the revolution of the continuous casting process. Nippon Steel Corporation has led the industry since the 1970's in advancing continuous casting technology. In the 1980's, there was a dramatic improvement of the ratio of continuous casting with the combination of continuous casting of large cross-section casting and blooming. In 1992, 100% continuous casting was achieved (see **Fig. 2**). Also, from 1991, they undertook the direct casting of billet for bar and wire rod rolling and started continuous casting of 162 mm square steel first at Muroran Works, and in 1997 they started continuous casting of 122mm square steel at Kimitsu Works.

Direct-casted billet is intended to simplify and eliminate processes, but from the viewpoint of quality it was found to improve the uniformity of the composition in a cross sectional view, and is superior from the viewpoint of the control of precipitations. For its develop-

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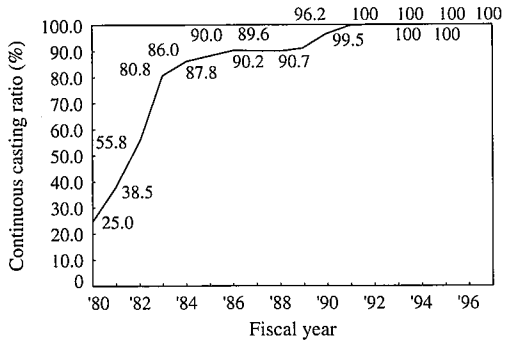

Fig. 2 Trends in continuous casting ratio

ment version, at the Muroran Works in 1998, they started a new process that combined a slight expansion of the cross section of casting with sizing having a larger diameter roll.

2.2 Rolling technology[1-3]

(1) Quality process technology

With regard to quality process technology in the rolling, there have been progress in precision rolling manufacturing of technology through AGC (Automatic Gauge Control) technology, process metallurgy that utilizes controlled rolling and controlled cooling, and planetary cross rolling that enables rolling of materials whose forming is difficult.

Up to now, Nippon Steel Corporation has used in-line heat treatment technologies such as EDC (Easy Drawing Conveyer), DLP (Direct Lead Patenting) and SCS (Slow Cooling System) in order to respond to the needs of users for simplifying processes. By combining the above technologies, it was possible to further reduce cost in an integrated manufacturing process and to provide new functions.

(2) Technology for improving productivity

At the wire rod mills of both Kimitsu and Kamaishi Works that have multiple strand rolling, a rolling of different steel grade and size wire rods at the same time was developed that rolls different wire rods among strands at the same time. It was possible to operate other strands that had been idling when operating DLP (Kimitsu Works) and SCS (Kamaishi Works) that were only setup for part of the strands, thus dramatically improving productivity (see **Fig. 3**).

(3) Technology for labor savings

Technology for labor savings has been applied not only to the main process of the hot rolling, but also widely in incidental processes, through the development of system and robot technologies. Particularly, in the incidental processes, manual labor has been greatly relied upon up till now. Automation has spilled over into many branche

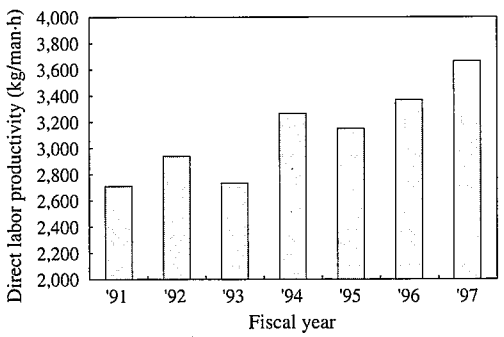

Fig. 3 Trends in direct labor productivity (total of 4 bar and wire rod mills)

such as "sampling of metal tags," "labeling," "packing on wire rods," "roll grinding," "pickling of samples for surface flaw inspections" and "cutting and grinding of samples for microscopic inspections."

2.3 Reforms of distribution[4]

For small lots of multiple bars and wire rods, there has been a lot of work in the materials distribution of products and semi-final products. However through the automated warehouse surrounded with such various solutions as all-weather direct shipping berths, AGV (Automatic Guidance Vehicles) and process management systems, labor productivity has been greatly reformed. These "solutions" not only reduce labor, but also improve quality (reduced handling damage) and shorten delivery lead-time.

3. Development of New Product Technology

3.1 Development of new products[5-7]

The characteristics of bar and wire rod products are:

(1) It is rare to use hot rolled steel as it is and various second and third processes right up to the completion of the final product are used and;

(2) There is a demand for strength, long fatigue-life and various product performances as represented by the important safety parts in the drive train system of automobiles, i.e. functional materials.

New products that answer these needs are being developed with the following aims.

(1) Those products that can simplify and omit the second and third processes, improve productivity and reduce manufacturing cost and;

(2) Those products that have superior product performance, longevity and can be lighter in weight.

For the former, there have been the wire rods that simplified and omitted heat treatment with Nippon Steel Corporation's original in-line heat treatment technologies of "EDC", "DLP" and "SCS". In addition, "super mild-alloyed steel", "in-line QT wire rods" and "bainitic wire rods" have been developed that tied together those technologies with process metallurgy.

For the latter, a 5 mmϕ/1,800 MPa class steel wire was developed. It was used as the main cable in the Akashi Kaikyou Ohashi Bridge which opened last year as the world's longest spanned bridge. Through high strength, it was possible to reduce the number of main cables by half, reduce construction costs and enable a longer span between the main pillars. Also, developments of even higher strengths (5 mmϕ/2,000 MPa class) were developed. Higher strengths in steel cords for tires have now advanced to 0.2 mmϕ/4,000 MPa. This is adding higher value to tires and is reducing the manufacturing costs. In addition, high strength bainitic steel for hot forging, steel for 1,300 MPa grade bolts, high strength shear reinforcement HIDEC 685H and 2,300 MPa PC strands have also been developed.

The item where the most attention must be done for achieving higher strength steel is the delayed fracture susceptibility of steel. The establishment of a method for evaluating the delayed fracture susceptibility of steel is indispensable to the development of higher strength steel. At Nippon Steel Corporation, the amounts of hydrogen in steel was found to be the cause of delayed fracture susceptibility. Nippon Steel Corporation developed a method that accurately evaluates the delayed fracture susceptibility of steel under the environment of actual use. It is expected that it will contribute to the development of higher strength steel and will become widely used.

3.2 Development of forming processes[8]

Manufacturing costs and product functions are greatly affected

by second and third process technologies for bar and wire rod products where various forming processes are done. In forging, there are increasing needs for optimum designs for processing, higher accuracy, and higher performance such as for complex shapes. At Nippon Steel Corporation, they developed a forging analysis simulation system to support to their large steel database. This database actively supports the speedy designing for the optimum process and reduces the resulting forging costs. Also in the wire drawing field, the development of wire drawing technology is advancing through the research of dies schedules, dies shapes and lubricants.

4. Future Prospects[9-10)]

Nippon Steel Corporation is using all its power from the viewpoints of materials, forming technology, evaluation technology in order to handle the high level and varying demands of each industry, beginning with the automotive industry. They have received high marks from users. However, in the future, development of new technologies from new viewpoints is indispensable because in the increasingly competitive international market there is no end to the demand for lower costs and higher level functions.

As a measure for reducing costs in the materials process, it is necessary to move forward the industrialization of multi-functions that reduce labor costs and introduce new viewpoints to study the radical reforms of manufacturing methods such as direct casting that omits blooming mill processes. It is necessary to use the knowledge of in-line heat treatment technology that is the leading manufacturing technology and to work on developing new heat treatment technology that can contribute to the further omission of processes and the creation of new functions.

There are many problems that cannot be solved by materials and forming technology alone because the demand for product development is complex and varied. With regard to these difficult issues, it is becoming more and more important to solve problems by studying concurrent engineering, including not only materials and forming, but also design and usage technologies. Also, with regard to the high strength represented by the steel cord of the 0.2 mmϕ/4,000 MPa class, it is a challenging level yet unseen in the world. It is important to create the "seeds" based on basic research using evaluation analysis technology. It is our duty in the future as a total steel manufacturer to use our expansive technological powers to continue creating products that contribute to society.

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