

# Production Technology of Bar and Wire Rod

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## Abstract

*Recent advances in bar and wire rod manufacturing technologies and the status of development of new products at Nippon Steel Corporation are described. There has been advanced in the production technology for productivity improvement, the progress in efficiency and capacity of billet inspection and conditioning, the introduction of highly functional block mill for bar and wire rod hot rolling process. There has been progress in new products through the final products, the support method and the evaluation method for product development. It is the mainly direction of development that is higher function, cost saving, contributing to environmental preservation.*

## 1. Introduction

Steel bars and wire rods are used as the material of gears, bolts, springs, bearings, cables and other basic components of safety-related parts typically such as automobile engines, drive train systems and chassis. Unlike cold-rolled sheets, heavy plates, pipes, sections and other steel products, bars and wire rods are seldom used as hot rolled for final products, but they are manufactured into machine parts after undergoing one or more stages of so-called post-processing such as heat treatment, forging and wire drawing at specialist plants. For this reason, every one of bar and wire-rod products is developed with due attention to its behavior at the post-processing stages. What is required for a steelmaker regarding these products is good processibility and fulfillment of required properties after the processing. Furthermore, since the costs of the post-processing is sometimes several times the price of the hot-rolled steel material, it is increasingly important to reduce the total integrated manufacturing cost from the steel material to final product.

Nippon Steel Corporation produces bars and wire rods at Muroran, Kamaishi and Kimitsu Works. Their production over the last decade has been as shown in Fig. 1; the production of special steel bars and wire rods has increased remarkably since 2001 in response mainly to the rapid increase in the demand for these products from the automobile and other industries of China.

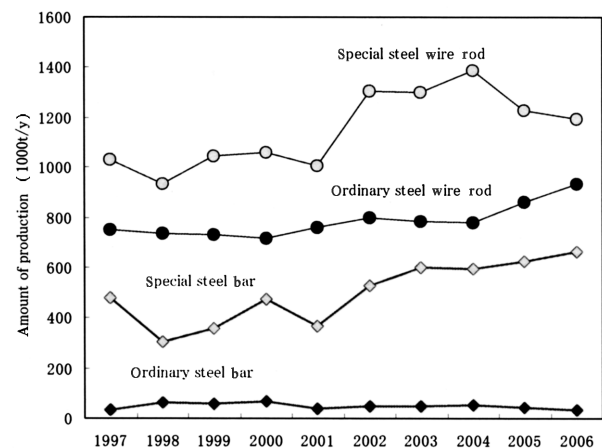


Fig. 1 Bar and wire rod production

Because of the present situation, in order to aim at offering high-value-added steel bars and wire rods to customers, Nippon Steel has concentrated efforts on significantly enhancing productivity and developing new products that can offer solutions to problems in post-processing and manufacturing stages. This paper outlines these activities.

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## 2. Advance in Bar and Wire Rod Production Technologies

### 2.1 Improved functions of rolling processes

To respond to the need for elimination or simplification of post-processing stages and increasingly severe quality requirements, the trend among the steelmakers that produce steel bars and wire rods over the last ten years has been to introduce compact, high-rigidity block mills to enhance dimensional accuracy and secure envisaged product quality by controlled rolling and cooling process.

To realize high dimensional accuracy by controlled rolling, Nippon Steel introduced the high-rigidity "Compact Rolling Mill (CRM)" made by Danieli and high-rigidity, high-accuracy, three-roll "Reducing and Sizing Block (RSB)" made by Kocks to the roughing and finishing stands, respectively, of the bar mill plant of Muroran Works, and the "Reduction Sizing Mill (RSM)" made by Morgan to the finishing stands of the wire rod mill of the same Works.

### 2.2 Productivity improvement

The productivity of wire rod mills of Kamaishi and Kimitsu Works, which are multi-strand mills, was improved through minimum capital investments for modification and renewal of obsolete equipment of bottleneck processes.

The Kamaishi wire rod mill was transformed into a low-cost, high efficiency mill as a result of the installation of a two-stand "Mini Block Mill (MBM)" of Morgan make at the exit from the finishing non-twist mill; this made it possible to increase the rolling speed from 61 to 95 m/s, and as a result, the number of strands was reduced from three to two.

At Kimitsu Works, on the other hand, the drive motor of the finishing mill train and the laying-cone-type winders (laying heads) were renewed after 30 years of use, and as a result, the restrictions on rolling speed were eased and it was raised from 54 to 74 m/s, significantly improving productivity. In addition, the already obsolete control system of the mill was replaced with a system based on the latest technology, which remarkably improved the functions of the mill such as the position control of wire rods on the cooling conveyers.

### 2.3 Enhancement of billet conditioning

Quality assurance throughout the whole length of bar and wire rod after rolling takes time and labor, and for this reason, quality control of billets, the materials before rolling, is of great importance. Nippon Steel has actively introduced laborsaving systems such as a product identification system consisting of a billet number-stamping machine and automatic number reader and automatic magnaflux inspection equipment to mechanize and automate the conditioning work of billets to minimize required labor.

In addition, in response to increasingly severer quality requirements of customers, the company has significantly enhanced the capacity and accuracy of product inspection systems and established the plan-do-check-action cycle in quality control through measures such as the feedback of billet defect information after breakdown rolling to the continuous casting process.

## 3. Development of Technologies for New Products

### 3.1 Development of new products

Steel bar and wire rod products are characterized by the following, though (iv) and (v) apply not only to bars and wire rods but also to all steel products.

- (i) Product grades are widely varied from standardized ordinary grades for general applications to high grades for high-end applications according to specifications individually defined for

each customer, mainly for the automobile and other manufacturing industries.

- (ii) The high-end products for safety-related applications typically such as automobile engines, drive train systems and chassis are used as functional materials and as such, are required to have highly demanding properties such as high strength and long fatigue life.
- (iii) These steel products are semi-finished products, which are seldom used as hot rolled, and they are manufactured into final products after secondary and even ternary processing such as forging, heat treatment and machining.
- (iv) The final industrial products for which they are used are subject to tough competition in the international market.
- (v) The industrial products for which they are used are required to minimize the load on global environment throughout the life cycle.

In developing a new steel product in consideration of the above, attention must be paid to the important issues such as the following.

- (1) Whether it is possible to eliminate or simplify one or more of the secondary and ternary processing to improve productivity and reduce manufacturing costs
- (2) Whether the new product improves the functionality, extends the service life, reduces the weight or brings about other advantages to the final product for which it is used
- (3) Whether it is possible to eliminate environmentally harmful substances

These requirements are not always mutually compatible, and it is important to proceed with development steps based on good understanding of the operation conditions at the processing stages, the use condition and characteristics of the final product for which the steel will be used and the like.

Examples of (1) above include conventional wire-rod products that allow simplification or elimination of heat treatment based on Nippon Steel's original in-line heat treatment methods such as the Easy Drawing Conveyer (EDC), Direct Lead Patenting (DLP) and Slow Cooling System (SCS) and more recent products such as Super Mild Alloy, In-line Quenched & Tempered Wire Rod and Bainite Wire Rod in which the above heat treatment methods are combined with metallurgical process control; these products have already been commercially used. In addition, the company has newly developed a soft wire rod having improved functionality for cold forging applications.

Increase in steel strength is typical contribution on the steel side to enhance the functional performance of the final product. For the main cables of the Akashi-Kaikyo Bridge, the longest suspension bridge in the world, Nippon Steel developed a wire rod product that exhibited a strength of 1800 MPa after drawing to a diameter of 5 mm, and further advancing the technology, has developed another that exhibits the same strength after drawing to a diameter of 7 mm. For somewhat different applications, 2300 MPa has been commercially implemented with prestressed concrete wires, and 4000 MPa with steel cords for tires 0.2 mm in diameter, and yet higher strengths are aimed at. Nippon Steel has also developed a new high-strength steel for valve spring use. All these wire rod products realize the world highest level of strength.

With respect to bars, the company commercialized new high-strength steel bars such as bainitic micro-alloyed steel and 1300-MPa-class steel for bolts some time ago, and more recently, extending these technologies, developed 1400-MPa-class high-strength steel for bolts for building construction. For automobile gears, which un-

dergo surface hardening treatment, a high-strength gear steel suitable for a new surface hardening method has been developed. High-corrosion-resistance coated steel wire developed recently is another example of improved functionality of steel.

The recently developed free-cutting steel not containing lead is a typical example of the elimination of environmentally harmful substances. Although neither the Directive 2000/53/EC of the European Parliament and of the Council on end-of life vehicles (ELV) nor the Directive 2002/95/EC of the same on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) does not demand to totally eliminate lead from steel, the new free-cutting steel is free of lead while satisfying the basic characteristics and good machinability required for the steel.

### **3.2 Development of post-processing technologies**

The technologies of the post-processing of steel bars and wire rods significantly affect the manufacturing costs and functions of the final products for which they are used. Improved functional performance requires higher dimensional accuracy and complex shape of parts, and as a result, the process design of forging becomes more and more delicate. Based on a rich database of steel materials, Nippon Steel has developed a simulation system for process analysis of forging to actively support quick and optimum process design and reduction of forging costs. The company has been active also in the filed of the research and development of die scheduling, die shape design and lubrication for wire drawing.

### **3.3 Development of analysis and evaluation technologies**

Sensitivity to delayed fracture is an important issue in increasing steel strength, and establishment of a method for evaluating the sensitivity is indispensable for the development of high-strength steels. Nippon Steel has focused attention on hydrogen content in steel as a principal cause of delayed fracture, and developed a method for accurately evaluating the resistance to delayed fracture in actual use environments.

As technical requirements for steel become more and more sophisticated, in-depth clarification of metallographic phenomena has become necessary for increasing steel strength. New techniques that Nippon Steel developed by means of transmission electron microscopy and atom probe microanalysis have made it possible to analyze atomic-sized phenomena that we could not handle in the past.

## **4. Future Prospects**

Nippon Steel has actively responded to increasingly sophisticated and widely varied requirements for steel from automotive and other industries in the aspects of material quality, processing technology, property analysis and evaluation, which has widely earned customer satisfaction. As the competitiveness of the international steel market intensifies, however, to meet ever-increasing requirements for lower costs and higher functionality, it is necessary to continue to develop new technologies and products from fundamentally new viewpoints.

It is important for steelmakers to reduce production costs through labor saving across organizational boundaries by fostering multi-disciplinary operators rather than through individual laborsaving measures and a fundamentally new standpoint to radically review and improve conventional production routes. Making the most of the technical lead in the in-line heat treatment processes, Nippon Steel is willing to tackle development of a new heat treatment technology capable of further simplifying post-processing and giving a new function to the steel material.

Increasingly sophisticated and widely varied requirements of the consumer industries pose many challenges to the development of steel products, challenges that cannot easily be met through approach only from the steel material or post-processing side. Such challenges would be effectively met by combining technologies of steel production and processing with those of the design and use of the final products for which the steels are used.