

# Manufacturing Processes and Products of Bar and Wire Rod in JFE Steel Group<sup>†</sup>

OGAWA Takao<sup>\*1</sup> SHIRAGA Tetsuo<sup>\*2</sup>

## Abstract:

*JFE Steel and associated companies have been manufacturing and selling bar and wire rod and related products. JFE Steel Group has developed distinctive products and manufacturing processes to support a wide range of request by customers. This paper outlines the manufacturing processes and typical bar and wire rod products in JFE Steel Group.*

## 1. Introduction

The JFE Steel Group was launched in April 2003 as a result of a merger of the former Kawasaki Steel and former NKK. The group has production bases for special steel bars and wire rod at JFE Steel's West Japan Works (Kurashiki) and JFE Bars & Shapes's Sendai Works. Both of these plants manufacture products under an integrated control system which extends from receiving of raw materials to steelmaking, rolling, and product transportation. Kurashiki is a blast furnace steel works, while Sendai Works employs the electric furnace route. Taking advantage of these respective processes in a mutually complementary manner, the group as a whole produces a wide range of product types.

In FY2007, the JFE Steel Group's total production of bars and wire rods reached approximately 1.52 million tons/year, which was an increase of 30% compared with production before the merger.

The following introduces the distinctive features of the related technologies and products of the JFE Steel Group, focusing on recent trends.

## 2. Distinctive Features of Manufacturing Processes

### 2.1 West Japan Works (Kurashiki)

The most important feature of steelmaking at West Japan Works (Kurashiki) is that this works possesses both large-scale converter/continuous casting equipment and ingot casting equipment. By utilizing these facilities, it is possible to produce a wide range of steel types, from low carbon steel to high carbon steel and alloy steel. Kurashiki also manufactures high cleanliness steels, centering on bearing steel, by hot metal pretreatment and vacuum degassing with strong stirring, using mainly blast furnace hot metal (molten iron)<sup>1)</sup>. In December 2007, Kurashiki introduced ladle furnace (LF) equipment, enabling production of high cleanliness steels with a higher degree of freedom.

**Table 1** shows the available production range at each plant. The Kurashiki Billet Mill has the capability to manufacture the world's largest class of rolled large-diameter products, including round bars up to  $\phi 420$  mm and square bars up to  $\square 750$  mm. This was made possible by construction of a dedicated automated finishing line for large-diameter round bars and establishment of an integrated process. It is also possible to manufacture bars and wire rods which are free of surface defects/decarburization by surface fully-automated flaw detection for round billets and a billet peeling machine.

As a distinctive feature of the Kurashiki Plant, rolling of bars and wire rods is performed with a 4-roll mill developed by JFE Steel, using both square billets and round billets as materials. The 4-roll mill is a unique technology which received the prestigious Okochi Memorial Technology Prize and enables size-free rolling over a wide range. It is also capable of producing square

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<sup>\*1</sup> General Manager, Steel Bar & Wire Rod Business Planning Dept., JFE Steel



<sup>\*2</sup> Dr. Eng., Fellow, JFE Bars & Shapes

Table 1 Manufacturing facilities for bar and wire rod in JFE Steel Group

			(mm)
Mill	Product	West Japan Works (Kurashiki)	Sendai Works
Billet Mill	Round bars	$\phi 95-420$	$\phi 130-200$
	Square bars	$\square 250-750$	—
Bar Mill	Straight bars	$\phi 16-90$	$\phi 17-120$
	Bars-in-coils	$\phi 16-38$	$\phi 13-55$
Wire Rod Mill	Square wire rods	$\square 12.7-27$	—
	Wire rods	$\phi 4.2-19$	$\phi 5-16$

wire rod with excellent squareness and dimensional accuracy of the opposing sides. Precision rolling is possible by taking advantage of the minimal lateral spread which is a feature of the 4-roll rolling process, and it is also possible to manufacture products down to a minimum diameter of 4.2 mm, contributing to omission of wire drawing by secondary processors<sup>2)</sup>.

## 2.2 Sendai Works

Sendai Works introduced a 130 t environment-friendly high efficiency electric furnace (Eco-Arc Furnace) as part of a modernization project in 2008, and is also introducing other equipment which give full consideration to CO<sub>2</sub> reduction, such as use of liquefied natural gas (LNG) for all fuel in the works, including the site's power plant, reheating furnaces, and others. In the recent modernization project, the billet size at the Bar Mill and Wire Rod Mill was unified on  $\square 160$  mm in order to realize higher efficiency in manufacturing. A further evolution in measures against surface defects in wire rod was also realized by modernizing the wire rod reheating furnace and strengthening the rolling equipment. Construction aimed at realizing high quality in combination with high efficiency was completed by changing the former 3 strand line to a 2 strand line.

In order to respond to precision rolling of steel bars, Sendai Works possesses a 3-roll mill manufactured by Friedrich Kocks GmbH & Co KG, and produces a product line with distinctive features utilizing proprietary on-line cooling technologies. In the Bar Mill, a water cooling zone comprising water-filled tubes is installed following the roughing mill, intermediate rolling mill, and finishing mill. In this system, Sendai Works manufactures a line of self-tempering steel bar products in which direct quenching of the product surface layer is performed mainly using the product water-cooling device installed after the finishing mill, and the product is self-tempered by the heat retained in the interior of the bar after passing through the water-cooling device. The Wire Rod Mill features a mist-spraying device which enables direct tempering by mist cooling<sup>3)</sup>.

## 3.1 Main Products of JFE Steel and JFE Bars & Shapes

Both of these companies manufacture product lines which respond to the diverse applications of bars and wire rods by effectively utilizing the distinctive features of their production equipment, as described above, in a mutually complementary manner. Because Kurashiki uses blast furnace hot metal as its main raw material, this plant manufactures mainly bearing steel and carbon steel. Kurashiki also manufactures high strength shearing reinforcements in cooperation with JFE Technowire, which is a JFE Steel Group Company. On the other hand, because Sendai uses the electric furnace route, it possesses distinctive product lines in free cutting steel, alloy steel, and micro alloying steel (non-heat treated steel).

### 3.2 Bearing Steel

As mentioned above, Kurashiki manufactures high cleanliness bearing steel. In addition, by focusing on the mechanism responsible for microstructural defects under rolling contact environments, Kurashiki has developed and commercialized bearing steel with excellent rolling contact fatigue life in the normal-to-medium temperature range and medium carbon bearing steel based on a new design method. Kurashiki also manufactures wire rods for small diameter bearings down to  $\phi 4.2$  mm utilizing the aforementioned 4-roll mill.

### 3.3 Free Cutting Steel

Sendai Works has long possessed equipment that enables production of Pb-added steels, which it uses in the manufacture of free cutting steels. Sendai Works is now developing Pb-free free cutting steels which contain no lead, thereby responding to the global environmental problems of recent years. A number of Pb-free products are already in standard production. As a substitute for the Pb-added low carbon free cutting steel AISI12L14 (AISI: American Iron and Steel Institute), which is widely used in printer shafts and automotive parts, Sendai Works developed a Pb-free free cutting steel with improved machinability by using Cr addition and

S increase to control sulfide inclusions<sup>4</sup>). Sendai Works has also developed a steel containing crystallized BN as a Pb-free free cutting steel which is suitable for forging applications<sup>5</sup>). Kurashiki developed a Pb-free free cutting steel utilizing graphite precipitation with the aim of satisfying both cold forgeability and machinability.

### 3.4 Alloy Steel

Diverse properties are required in case hardening alloy steels. This report introduces two developed steels. In carburized dual-phase steel, the Ac<sub>3</sub> transformation point is increased by addition of Si and V in order to secure a dual-phase microstructure of ferrite and martensite in the internal microstructure after carburizing at the normal carburizing temperature (the carburized layer is a single phase of martensite). As a result, distortion due to quenching after carburizing is reduced, and improved pitting resistance under high Hertz contact stress is achieved simultaneously with low distortion.

As a steel for high frequency quenching use, a fine grained steel was developed from an early date with the aim of improving toughness and fatigue strength by refining the austenite grain size in the quenched part.

### 3.5 Micro Alloying Steel

As micro alloying steels which make it possible to omit heat treatment with carbon steels and alloy steels, JFE Steel Group has commercialized steels for hot forging use and direct cutting use. In the steel for hot forging use, toughness is secured by suppressing grain growth with addition of an appropriate amount of Ti, and strength is secured by adding V. Products include the THF series, which are ferrite-pearlite dual-phase type steels, and the TBH series, which has a bainite microstructure and improved toughness resulting from a low carbon composition. As steels for direct cutting use, the NH series utilizes the production equipment at Kurashiki in the manufacture of micro alloying steels in large-diameter round bars. At Sendai Works, on-line

quenching is performed with a water cooling device after finishing rolling of steel bars. The TQF steels have been commercialized using the self-tempering process, in which the surface layer forms a tempered martensite microstructure, and the interior forms a fine ferrite-pearlite microstructure.

### 3.6 Bars-in-Coils and Wire Rods

Kurashiki, in cooperation with JFE Techno-wire, has developed and commercialized a yield strength 1 275 MPa class shearing reinforcement with excellent ductility after welding, and a 785 MPa class shearing reinforcement which achieves alloy saving by controlling cooling. Sendai Works has commercialized TMP wire rods which make it possible to omit off-line lead patenting by applying its mist-cooling process.

## 4. Conclusion

JFE Steel Group possesses bar and wire rod products and manufacturing equipment which are capable of responding to the diverse requirements of customers. The company is continuing to devote great energy to various technical developments aiming at environment-friendly product manufacturing. This special issue focuses on recent achievements in technical development.

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