West Japan Works, JFE Steel†

Abstract:

West Japan Works of JFE Steel was founded as a result of the merger of both Mizushima Works of Kawasaki Steel and Fukuyama Works of NKK, which are geographically proximate to each other. This one of the largest steel works in the world aims at achieving global competitiveness in quality and quantity of products by establishing optimum production systems. This paper describes several features of the West Japan Works.

1. Introduction

JFE Steel's West Japan Works was established on April 1, 2003 as part of the merger between Kawasaki Steel and NKK, and consists of Kurashiki District (formerly Mizushima Works of Kawasaki Steel) and Fukuyama District (formerly Fukuyama Works of NKK). The two districts have a combined annual crude steel production capacity of approximately 18 million tons and manufacture a diverse repertoire of products. Both sites have adjoining steel laboratories, giving West Japan Works world-class technical development capabilities in both new products and new processes.

2. Management Policy

The establishment of JFE Steel's West Japan Works in April 2003 created one of the world's largest steel works. The fundamental goal of West Japan Works is to establish a position as the world's No. 1 steel works in both quantity and quality by making full use of its advanced technical and implementation capabilities. To achieve this, it will be necessary to create a works which has the strength to withstand changes in the surrounding environment. Specifically, this will require the development of new processes which satisfy JFE Group's corporate vision as a company with the "world's most innovative technology," development of new products which cannot be matched by other makers, and management which improves profitability by maximizing the plant's working ratio. By meeting these objectives, the works will consistently improve its cash flow income, thus making a substantial contribution to the JFE Group as a whole.

3. Origins and History of West Japan Works

3.1 Kurashiki District

Construction of Kurashiki District (formerly Mizushima Works, Kawasaki Steel) began in 1961. In 1967, the No. 1 blast furnace (BF) was blown in and a steelmaking shop and a plate mill were started up, establishing an integrated iron and steel manufacturing system with an annual crude steel capacity of 2 million tons. In the following years, a series of new facilities were constructed, including a large section shape steel mill, a hot strip mill, a cold strip mill, a bar steel mill, and others. In 1973, the No. 4 BF was blown in and the No. 6 basic oxygen furnace (BOF) came on stream.

Beginning in the second half of the 1970s, the works carried out a variety of major modernization projects aimed at improving labor productivity. They included a fully-automated No. 2 plate mill, which was started up in 1976, construction of a new billet mill with an automatic hot slab carrier system and No. 1 continuous annealing line (CAL) in 1984. The manufacturing facilities for coated steel sheets and electrical sheets were also put in place subsequently. Today, Kurashiki District has an annual crude steel capacity of 8 million tons (with a three BFs production system) and boasts the world's highest level of production efficiency **(Fig. 1)**.

3.2 Fukuyama District

Fukuyama District (formerly Fukuyama Works, NKK) was established in 1965. Blast furnaces were constructed and started up in rapid succession with the blow-in of the No. 1 BF in 1966 and No. 2 in 1968. By 1973, the site had grown to a five BFs and three steelmaking shops system. During the same period, a hot strip mill, a plate mill, and a large section shape

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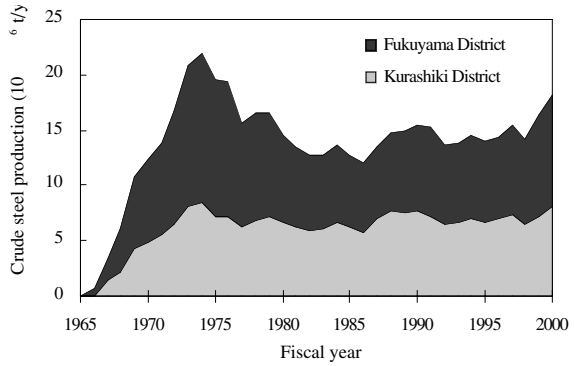

Fig. 1 Crude steel production at West Japan Works

steel mill were also started up. In 1974, the works set an annual crude steel production record of 13.4 million tons. In the harsh business climate following the 1st Oil Crisis in 1973, however, demand declined and Fukuyama District was obliged to scale down its production. Over the next decade, some BFs and steelmaking shops were shut down in succession until the production bottomed out at 6.4 million tons in 1986. Thereafter, Fukuyama District returned to growth by focusing on high quality products mainly in the area of steel sheets for automobiles, electrical appliances and containers, and constructed a full complement of production facilities for hot dip galvanized sheets, electrogalvanized sheets, and tin-free steel, as well as electrical sheets and other high end products. In October 2002, Fukuyama District became the first steel works in Japan to reach the important milestone of 300 million tons of cumulative pig-iron production. This was a great record achieved in the remarkably short time of 36 years after the startup of the No. 1 BF. Fukuyama District has now reactivated the No. 2 BF, establishing a four BFs production system with an annual crude steel production capacity of 10 million tons.

4. Outline of Facilities

An outline of the main production facilities at West Japan Works is presented in **Table 1**.

5. Kurashiki District

5.1 Products and Production Volume

Kurashiki District manufactures plates, hot rolled strips, cold rolled and coated products, electrical sheets, various types of long products, semi-finished products, and others. The annual crude steel production in fiscal year 2002 was 8.55 million tons. The annual shipments of products were 1.83 million tons of plate, 2.39 million tons of hot rolled strip, 2.34 million tons of cold rolled strip, coated strip and electrical sheets, 1.19 million tons of long products and 470 thousand tons of semi-finished products.

5.2 Features of Kurashiki District

Kurashiki District produces a wide range of products from basic materials to high value-added products, and also plays an important role in JFE Steel's overall business strategy as a supplier of materials to downstream steel product makers in the Asian region. It has established an extremely efficient production system through process continuation and synchronization, making it possible to ship a variety of products within tight lead times. Distinctive features of Kurashiki District include the following:

(1) Ironmaking

Kurashiki District has established an ironmaking plant which utilizes economical coking coal and is characterized by extremely stable operation, enabling production of low-cost hot metal. The No. 2 BF is currently extending its record as the longest operating BF in Japan, which now stands at 24 years.

(2) Steelmaking

Kurashiki District's steel making features multi-continuous tapping of low P and low S LF (ladle furnace) material and the continuous casting of slabs at the world's highest speed.

(3) Plate Rolling

The plates are produced efficiently in a high working ratio operation utilizing a simple 1 stand and 1 shear equipment configuration.

(4) Hot Rolling of Sheets

A slab sizing press with a capacity of large width reduction enables high efficiency production using a wide mill for heavy gauge products.

(5) Cold Rolling and Coating of Sheets

Continuous annealing is performed over a wide range of size (Thickness:0.25-3.0 mm, Width: 750-1 850 mm).

The sheets are transported without using cranes from the entry side of the pickling line to shipment from the warehouse.

(6) Electrical Steel Sheets

Grain oriented and non-grain oriented electrical sheets are exclusively produced.

(7) Long Products

Short lead-time production of H-shapes with fixed outer dimensions is carried out by a multi-chance pro-duction system.

Steel bars and wire rods are produced at a high dimensional accuracy by size-free rolling using a revolutionary 4-roll rolling method.

(8) Infrastructure

Table 1 Main production facilities at West Japan Works

Class	Equipment		Kurashiki District		Fukuyama District	
			No.	Outline	No.	Outline
Iron-making	Blast furnace	BF number (Inner volume)	3	No.1 : Shut down, No.2 : 2 857 m^3, No.3 : 4 359 m^3, No.4 : 5 005 m^3, Total : 12 221 m^3	4	No.2 : 2 828 m^3, No.3 : 3 223 m^3, No.4 : 4 288 m^3, No.5 : 4 664 m^3, Total : 15 003 m^3
	Sintering machine		3	No.2-4, DL type, Total : 1 005 m^2	2	No.4, 5, DL type, Total : 930 m^2
	Coke batteries		6	No.1-6, 464 ovens	3	No.3-5, 444 ovens
Steel-making	Converter		6	No.1 : 180 t/charge, 3 units No.2 : 320/290 t/charge, 3 units	5	No.2 : 250 t/charge, 3 units No.3 : 320 t/charge, 2 units
	Electric arc furnace		2	30 t/charge (Daido Lectrometal) 100 t/charge (Daiwa Steel)	—	
	Continuous casting machine	Slab CC	5	4 units (8 strands), Shut down : 1 unit	5	5 units (9 strands)
		Bloom CC	3	2 units (10 strands), Shut down : 1 unit	1	1 units (4 strands)
		Billet CC	—		1	1 units (6 strands)
	Slabbing mill	Number soaking pits, mills	5+1	Soaking pit : 5, Universal mill : 1	—	
	Degassing equipment	RH degasser	4		4	
Rolling	Hot rolling	Hot strip mill	1	(Width) 600-2 200 mm	2	(Width) 650-1 925 mm, 610-1 641 mm
		Skinpass mill	2	(Width) 600-2 200 mm, 700-2 200 mm	3	(Width) 610-1 880 mm, 610-1 550 mm, 450-1 630 mm
		Shear, Slitter	1	Shear : 1, Slitter : 1	1	Shear : 1, Slitter : 1
	Cold rolling	Pickling line	1	(Width/Thickness) 600-1 600 mm /1.0-6.5mm	1	(Width/Thickness) 600-1 290 mm/1.2-4.5 mm
		Continuous tandem mill	—		1	(Width/Thickness) 610-1 270 mm/0.15-1.6 mm
		Pickling-Tandem mill continuous line	1	(Width/Thickness) 600-1 600 mm /0.15-3.2 mm	2	(Width) 762-1 880 mm, 600-1 650 mm
		Continuous annealing line (CAL)	2	(Width) 600-1 600 mm, 750-1 850 mm	4	(Max. width) 1 067 mm, 1 270 mm, 1 650 mm, 1 880 mm
		Temper mill	1	(Width) 600-1 600 mm	3	(Width) 762-1 880 mm, 508-1 320 mm, 508-1 270 mm
	Coating	Electrogalvanizing line (EGL)	1	(Width) 700-1 830 mm	2	(Width) 900-1 880 mm, 600-1 650 mm
		Continuous galvanizing line (CGL)	1	(Width) 700-1 850 mm	3	(Width) 610-1 880 mm, 610-1 880 mm, 610-1 650 mm
		Electrolytic tinplating line (ETL)	—		1	(Width/Thickness) 457-1 067 mm/0.1-0.6 mm
		Tin-free steel line (TFS)	—		2	(Width) 600-1 067 mm, 600-1 260 mm
		Coating line	1	MCL	1	UCL
	Electrical steel	Tandem mill	1	2TA	—	
		Heat treatment equipment	2	Grain-oriented, non-grain oriented manufacturing equipment : 1 set	1	Non-grain oriented electrical steel continuous annealing line (EFL)
	Billet	Reheating furnace	11	Continuous type : 1, Batch type : 10	—	
		Roughing mill	2	Roughing : 1, Finishing (4 strands) : 1	—	
	Plate	Reheating furnace	4	Continuous type : 2, Batch type 2	4	Continuous type : 2, Batch type 2
		Roughing mill	—		1	5 000 kW
		Finishing mill	1	8 800 kW, (Width) 1 000-5 350 mm	1	6 500 kW, (Width) 1 000-4 500 mm
		Heat treatment furnace	2	Tempering furnace, Normalizing/Quenching furnace	3	Tempering furnace, Normalizing/Quenching furnace, SUS furnace
	Large section shape steel	Reheating furnace (Continuous type)	1	Continuous type: 1	2	(NKK BARS & SHAPES)
		Rolling mill	4	BD : 1, Roughing mill : 2, Finishing mill : 1	8	BD : 2, Roughing mill : 4, Finishing mill : 2
	Medium section shape steel	Reheating furnace (Continuous type)	1	(DAIWA Steel)	—	
		Rolling mill	7	BD : 2, Roughing mill : 2, Finishing mill : 3	—	
	Wire rod /bar	Roughing mill	8+6 +6	Roughing + Intermediate + Finishing (Final 2 stands: 4-roll mill)	—	
		Wire rod finishing mill	2	10 stands (block mill) + 3 stands (4-roll mill)	—	
Castings and forgings	Forging	Press	1	6 000 t press	—	
Pipes	UOE pipe	Press	—		3	C-press : 1, U-press : 1, O-press (45 000 t) : 1
		Welder	—		10	Inside : 6, Outside : 4
	Spiral pipe	Spiral pipe mill	—		1	(Thickness) 6-30 mm, (Outer diameter) 600-2 540 mm
Power plant	Power generating equipment	(Co-generation thermal) Thermal power plant	5	617 000 kW	6	844 000 kW

Kurashiki District has implemented a comprehensive production planning system and has promoted the effective use of slag from the BFs in the forms of water granulated slag and rock wool.

It has opened a golf course and ocean fishing park adjacent to the works for public use.

Examples of Kurashiki District's efficient production system are flexible steelmaking technology, size-free rolling technology for steel bars and wire rod material, and implementation of the comprehensive production planning system described below.

5.3 Development of Schedule-free Technologies

5.3.1 Development of flexible steelmaking technology

Flexible, or schedule-free steelmaking technologies have been developed to enable the production of steel of an exact amount at an exact time required by the down-stream processes. An ultra low S steel in a large lot is made by matching the continuous casting time at the LF and reducing the processing time in the sequential casting through the improvement of the desulfurization process. For a material in a small lot which used to be cast using a single tundish because the preparation of tundish or preheating governs the process, an optimum recycling technique has been developed to eliminate preheating of tundish. For high purity steels (e.g. electrical steel material), which had conventionally been refined by modifying the tapped pig-iron composition, a technology which eliminates this process has also been established by applying hot metal pretreatment under uniform hot metal conditions. As a result, Kurashiki District has established a chance-free steelmaking process using hot metal with a uniform chemical composition.

5.3.2 Size-free rolling technology for bars and wire rod material

Kurashiki District developed a 4-roll rolling method for the finishing sizing mill used in bar and wire rod rolling and applied this technology to actual production equipment before any other maker in the world.

This technology enables rolling over the widest size range that is theoretically possible, combined with a high dimensional accuracy. It is also a revolutionary technology that overturns the conventional view that caliber rolls must be changed whenever the product size is changed. This equipment was introduced at the bar mill in 1994 and at the wire rod mill in 1998.

Development of the 4-roll rolling method was established by solving the two major technical problems such as simplification of the mill structure and prevention of coarsening of micro structure of the material. They were solved by adopting a 2-roll drive method and microstructure control by roll axis offset.

Development of this technology has enabled rolling of products with excellent circular accuracy and high secondary working properties. As a size-free technology, the 4-roll method has also made it possible to consolidate pass schedules and reduce the frequency of roll exchanges, thereby reducing inventories of rolls/guides, saving labor, and shortening lead times. Moreover, by employing this technology in combination with low deformation resistance cold forging steel and as-rolled (quench and temper-free) steel materials, the need for initial processes in secondary working, including heat treatment, has been largely eliminated. In fiscal year 1998, this technology received the Technology Prize of Okochi Memorial Foundation, which is the most prestigious award of its kind in Japan.

5.3.3 Comprehensive production planning system

In order to respond quickly to the changes in business environment, Kurashiki District implemented a real-time scheduling system and line balancing system. Standardization of the tacit knowledge of experienced personnel accumulated through work practices has made it possible to perform production planning in real time and make judgments and corrections whenever required. To meet the mutually contradictory needs of delivery schedule assurance and maximum equipment utilization, a system which enables daily verification of the balance between orders received and maximize or the same time the total production capacity of the site has also been implemented.

The technologies described above have realized a short-time delivery by reducing production lead times.

6. Fukuyama District

6.1 Products and Production Volume

Fukuyama District produces numerous product types, including hot rolled strip, cold rolled strip, coated strip and sheets, electrical sheets, plate, UOE pipe, spiral pipe, shapes, rails, semi-finished products, and others. In fiscal year 2002, the annual crude steel production was 10.19 million tons, making it No. 1 in Japan for 5 consecutive years. Annual shipments by product type were hot rolled strip of 2.95 million tons, cold rolled strip of 1.25 million tons, coated strip and sheets of 1.94 million tons, plates of 1.08 million tons, welded pipes of 480 thousand tons, rails and shape of

840 thousand tons and semi-finished products of 1.25 million tons.

6.2 Features of Fukuyama District

Fukuyama District takes pride in being the world's largest-scale steel works. It is the only site in Japan with 4 operating blast furnaces and features a straight-line layout from raw material receiving through product shipment. With its extremely wide repertoire, Fukuyama District manufactures products which meet numerous and diverse customers requirements. As a distinctive feature of Fukuyama District, the percentage of sheet products is high, and it emphasizes high value-added products such as automotive sheets. Fukuyama District is also aggressively addressing the themes of environmental preservation and energy saving by adopting waste plastic injection at its blast furnaces, energy efficient regenerative burners, and other environmentally-responsible technologies. Features of the production processes at Fukuyama District include the following:

(1) Ironmaking

Fukuyama District has maintained Japan's No. 1 ranking in crude steel production for 5 consecutive years.

It produces low cost, high quality hot metal by using high-ratio PCI (pulverized coal injection) to cover raw material capacity shortfalls and low-Si operation.

(2) Steelmaking

Slag-free operation using the zero slag process is performed at converters.

Direct hot charging has been carried out in the continuous caster-breakdown mill operation using high quality and high speed casting.

(3) Hot Rolling

Products of high performance, high value-added and low cost can be made by an optimum operation of two hot mills, 1 HOT whose performance has been raised by various innovative technologies including *Super*-OLAC H (as described below) and 2 HOT which is placed in a straight line directly with a continuous caster.

(4) Cold Rolling

Fukuyama District has Japan's largest cold rolling capacity and manufactures high strength steels up to 1 470 N/mm^2 class including WQ HITEN and high carbon steels.

(5) Coating

Fukuyama District manufactures galvannealed (GA) sheets of high lubrication, environment-friendly chromate-free sheets, etc. which are destined for automotive use.

It has a production line for tin plates, one for tin-free steel sheets and one for laminated steel sheets to meet various needs for containers.

It also produces vibration-damping steel sheets with a steel sheet/resin sandwich structure.

(6) Steel Plate

A 2-stand mill efficiently produces TMCP plates by applying *Super*-OLAC.

It also produces high grade special steel plates such as stainless steel plate, clad steel plate, etc.

(7) Rails and Shapes

Numerous types of product from H-shapes to rails are produced.

The rails of high grade are produced in an on-line heat treatment facility.

(8) Welded Steel Pipes

As a pioneering mill of steel pipes in Japan, Fukuyama District produces high grade line pipes using its high level technologies leading the world in fields such as ironmaking, steelmaking and plate manufacturing.

(9) Others

A process for feeding waste plastics into blast furnaces has been realized as a major energy saving/recycling system.

The following paragraphs introduce *Super*-OLAC and laminated steel sheets as examples of JFE Steel's unique technology at Fukuyama District.

6.3 New On-Line Accelerated Cooling System "*Super*-OLAC"

6.3.1 Plate mill

OLAC (On-Line Accelerated Cooling) is a type of on-line accelerated cooling equipment for steel plates which was practically applied by the former NKK in 1980 before any other mill in the world. Since accelerated cooling can increase the strength of steel with low additive elements, it enables mass production of steel plates with excellent weldability. In 1998, the original version of OLAC was replaced by *Super*-OLAC. As features of *Super*-OLAC, the cooling rate can be increased to the theoretical limit, while also securing uniform material properties by maintaining uniform cooling and minimizing strain. Consequently, the stable production of plates with higher strength, higher toughness and better weldability than those produced by the original OLAC has become possible. The expansion of available thickness range has also been possible. The *Super*-OLAC has contributed to the development of innovative new products such as API X65 pipes for use as buckle arrestors in sour service. The *Super*-OLAC technology was introduced to the shape steel mill at Fukuyama District in 2000 and to the hot strip mill in 2002.

6.3.2 Shapes

Since an H-shape has a cross-section of H and its thickness varies in the product, the required cooling capacity is different depending on part, resulting in a significant increase in strain after water cooling. This has been overcome by establishing a technology for inner web cooling.

6.3.3 Hot rolling of sheets

In a hot rolling line where a strip runs at a speed exceeding 70 km/h, a new technology for driving table rolls was developed to ensure proper passing of strip and to realize uniform cooling and the world's highest cooling rate. A high carbon, hot rolled steel sheet with good formability was developed as a new product.

In recognition of this outstanding achievement, the *Super*-OLAC technology was awarded the Okochi Memorial Technology Prize for fiscal year 2002. The *Super*-OLAC equipment is also being introduced to the plate mill and also to the shape steel mill at Kurashiki District with a plan to start up in 2003 at both mills.

6.4 Laminated Steel Sheets

Using the No. 2 TFS line, which has the world's highest line speed (250 m/min) for a film lamination process, two types of environment-friendly, low cost product have been developed and put into mass production. The first is Universal Bright F for food can use, a low cost PET-laminated steel sheet which is compatible with food products and has the advantages of excellent formability and easy removability of the can contents. The second is Universal Bright E for 18ℓ pail cans. With this product, it is possible to select a high corrosion resistance olefin film which is suitable not only for food products, but also for various types of chemicals.

Customers who adopt these products can omit the painting process, saving the cost of treating organic effluents, and thus realize large cost savings while contributing to environmental preservation.

7. Summary

As one of the world's largest and strongest steel works, JFE Steel's West Japan Works plans to maximize the advantages offered by its production scale, and will also work to achieve further improvements in equipment, production, and distribution efficiency. West Japan Works comprises two districts, Kurashiki and Fukuyama, which are located in close proximity. These two districts are continuing to merge and unify their management in order to fulfill their responsibility as a profit base for JFE Steel from a global viewpoint.