

Manufacturing Processes and Products of Steel Pipes and Tubes in JFE Steel[†]

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Abstract:

JFE Steel operates manufacturing facilities for seamless pipes and various types of welded pipes in order to respond to a wide range of customer requirements. Distinctive products and manufacturing processes include large diameter, heavy wall electric resistance welded (ERW) pipe for linepipes, UOE pipe for high strength, high performance linepipes, and high performance, high formability welded steel tubes used in automotive parts. This paper presents an outline of the distinctive features of the manufacturing processes at JFE Steel, together with representative steel pipe and tube products.

1. Introduction

As a result of the merger of the former Kawasaki Steel and former NKK in April 2003, the steel pipe and tube manufacturing system at the newly-created JFE Steel was expanded to include four districts, the Chiba District and Keihin District of East Japan Works, Fuku-yama District of West Japan Works, and Chita Works specialized in pipe mills. With a product line encompassing seamless pipe and welded pipes, including butt welded pipe, electric resistance welded (ERW) pipe, UOE pipe, and spiral welded pipe, JFE Steel supplies all major types of steel pipe and tube products and has established a system which is capable of responding to a wide range of customer requirements.

In fiscal year 2004, the company's annual production of all types of steel pipes and tubes was approximately 1.85 million tons.

2. Distinctive Features of Steel Pipes and Tubes at JFE Steel

2.1 Pipe and Tube Manufacturing System

JFE Steel operates manufacturing facilities for seamless pipe and welded pipe at its East Japan Works, West Japan Works, and Chita Works.

An outline of the pipe and tube manufacturing process is shown in **Fig. 1**. Depending on the manufacturing process, welded pipes can be divided into three classes by welding method, i.e., arc welding, electric resistance welding, and butt welding. Pipes manufactured by the arc welding method can be further divided into UOE pipe, bending press pipe, and spiral welded pipe, depending on differences in the forming method. Among welded pipes, hot rolled steel sheet is used as the material for electric resistance welding tube, butt welded tube, and spiral tube, while steel plates are used as material for UOE and bending press products.

JFE Steel's pipe and tube manufacturing facilities comprise one UOE line each at East Japan Works and West Japan Works, one ERW line at East Japan Works and four ERW lines at Chita Works, one spiral welded pipe line at West Japan Works, and two seamless pipe lines at Chita Works. **Table 1** shows the manufacturing facilities for pipe and tube production at JFE Steel.

The size range of the pipe and tube products in JFE Steel is shown in **Fig. 2**. The available size range differs due to differences in materials and processing and forming methods. Appropriate use of each product type corresponding to the application is important.

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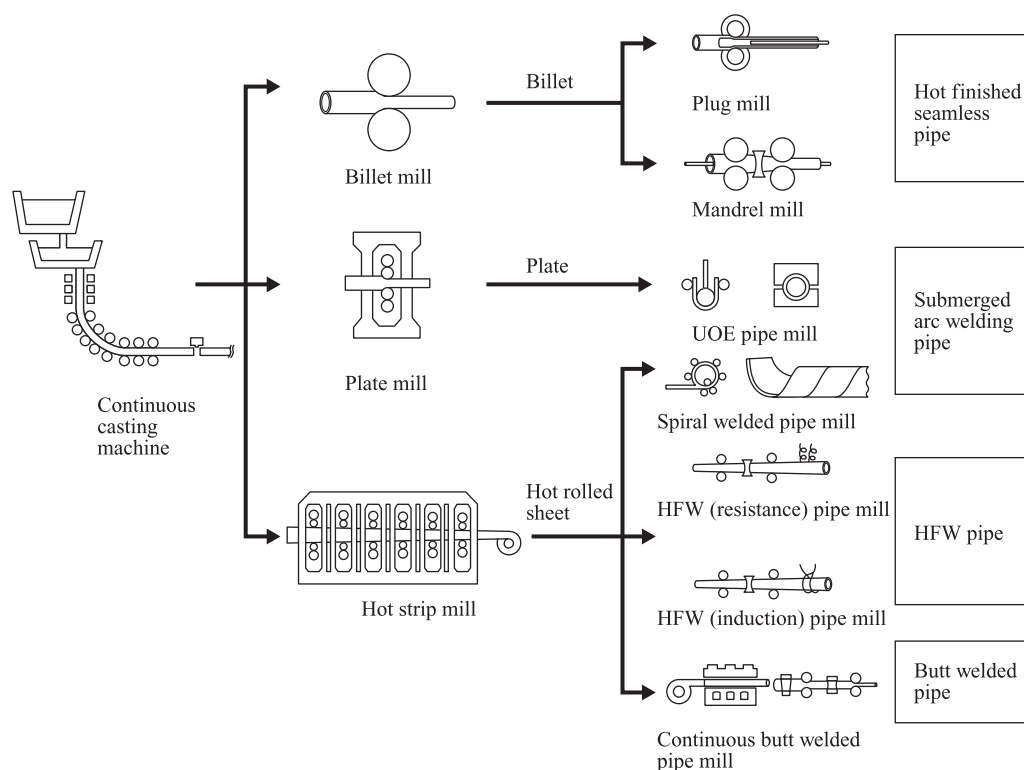


Fig. 1 Manufacturing procedure of pipes and tubes in JFE Steel

Table 1 Manufacturing facilities for pipe and tubes production in JFE Steel

Kind		Works	Line	Available size (mm)			Remarks
				OD	Wall thickness	Length	
Seamless pipe		Chita Works	Small diameter seamless pipe mill	25.4– 177.8	2.3–40.0	22 000	Mannesmann piercing/ Mandrel mill
		Chita Works	Medium diameter seamless pipe mill	177.8– 426.0	5.1–65.0	13 500	Mannesmann piercing/ Plug mill
Welded pipe	UOE	East Japan Works (Chiba)	Chiba UOE pipe mill	508.4–1 625.6	6.4–44.5	18 300	
		West Japan Works (Fukuyama)	Fukuyama UOE pipe mill	406.4–1 422.4	6.0–50.8	18 300	External and internal coating facility
	Spiral	West Japan Works (Fukuyama)	Spiral pipe	600 –2 540	6.0–30.0	35 000	
	Electric resistance welded pipe	Chita Works	Small diameter ERW pipe mill (3")	28.6– 76.4	0.6–10.0	18 000	
		Chita Works	Small diameter ERW pipe mill (6")	60.5– 168.3	0.6–10.0	18 000	
		Chita Works	Small diameter ERW pipe mill (4") HISTORY	21.3– 114.3	1.8–12.7	16 000	
		Chita Works	Large diameter ERW pipe mill (26")	318.5– 660.4	4.0–23.8	20 000	
				250 × 250	6.0–25.0	18 000	For square pipes
		East Japan Works (Keihin)	24" ERW mill	177.8– 609.6	3.2–19.1	18 500	External coating facility
				200 × 200	4.5–22.0	18 000	For square pipes
	Butt welded pipe	East Japan Works (Keihin)	Butt weld mill	21.7– 114.3	2.8– 4.5	7 000	Plastic lining facility

The distinctive features of JFE Steel's pipe and tube manufacturing technologies are outlined in the following.

2.2 Seamless Pipes and Tubes

JFE Steel has two seamless pipe manufacturing lines

at Chita Works, the small-diameter seamless pipe mill using the Mannesmann piercing/mandrel mill process and the medium-diameter seamless pipe mill using the Mannesmann piecing/plug mill process. The small-diameter mill produces pipes and tubes with outer diameters up to 177.8 mm (5"), while the medium-

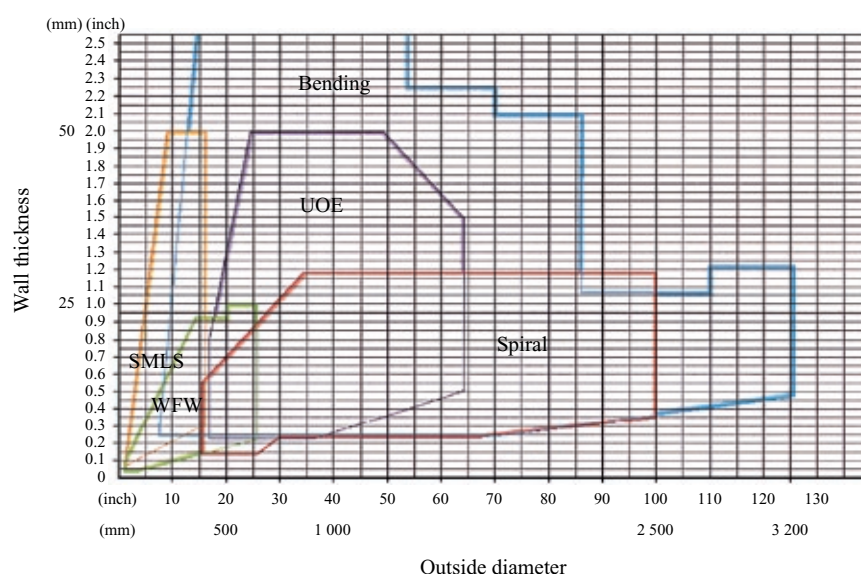


Fig.2 Size range of JFE Steel's pipe and tubes for products

diameter mill produces products with outer diameters from 177.8 mm (5") to 426.0 mm (16").

Among materials for seamless pipes and tubes, carbon steel and low alloy steel are melted and rolled at West Japan Works (Kurashiki District) and supplied to Chita Works. High alloy materials such as 13% Cr, etc. are melted and cast into slabs at East Japan Works (Chiba District); billet rolling is then performed at West Japan Works (Kurashiki District), and the materials are supplied to Chita in billet form.

High Cr seamless steel pipes used in oil country tubular goods (OCTG) and boiler tubes are one of JFE Steel's main product lines, and the company has a high level of know-how in rolling technology for these products. In the past, seamless pipes and tubes of high Cr alloy steel and stainless steel were generally produced by piercing using a hot extrusion process, followed by rolling. JFE Steel was the first steel maker in the world to succeed in obtaining stable product quality in these products in manufacturing by the Mannesmann piercing process. These products were realized for the first time as a result of improvement in the properties of the materials by heavy processing in the slab stage, in combination with the establishment of various pipe rolling technologies, including billet temperature control during pipe rolling, optimization of piercing conditions, optimization of the pass schedule in mandrel rolling, etc¹⁾.

The seamless pipe mill also has processing equipment for production of threaded joints for OCTG.

2.3 ERW Pipes and Tubes

As manufacturing facilities for ERW pipes and tubes, JFE Steel has a four ERW lines at Chita Works and a one ERW line at East Japan Works (Keihin District).

These facilities each have distinctive features, giving the company a system for manufacturing steel pipes

and tubes by the optimum process corresponding to the application.

2.3.1 Large diameter, heavy wall ERW pipes

The 26" line at Chita Works produces ERW pipes having the largest outer diameter in the world. With the manufacture of linepipe using this feature as one of its strong points, JFE Steel has commercialized extra-heavy wall ERW linepipes and conductor casings as substitutes for the conventional UOE products. To realize the same strength, toughness, and weldability as in UOE pipe, in these products, the composition design of the hot rolled steel sheet used in the ERW pipe was optimized and the cooling capacity of the hot rolling line was strengthened.

In parallel with this, Chita Works also strengthened the pipe manufacturing capacity of the 26" ERW pipe mill, developed an oxide control technique and weld seam heat treatment technology to improve the toughness of seam welds, and developed a weld seam quality assurance technology for heavy wall products.

2.3.2 HISTORY tube

The 4" HISTORY pipe mill at Chita Works is a unique JFE Steel manufacturing process which produces high strength, high ductility tubular products by applying warm reduction after electric resistance welding.

As a steel tube for machine structural use which satisfies both high strength and high ductility requirements, the HISTORY tube was developed for applications which assume high formability, such as automobile suspension parts²⁾. The HISTORY tube manufacturing process is shown in Fig. 3.

With this manufacturing process, strength and ductility are improved by performing warm reducing, in which the tube is heated after normal electric resistance welding; this results in texture formation simultaneously

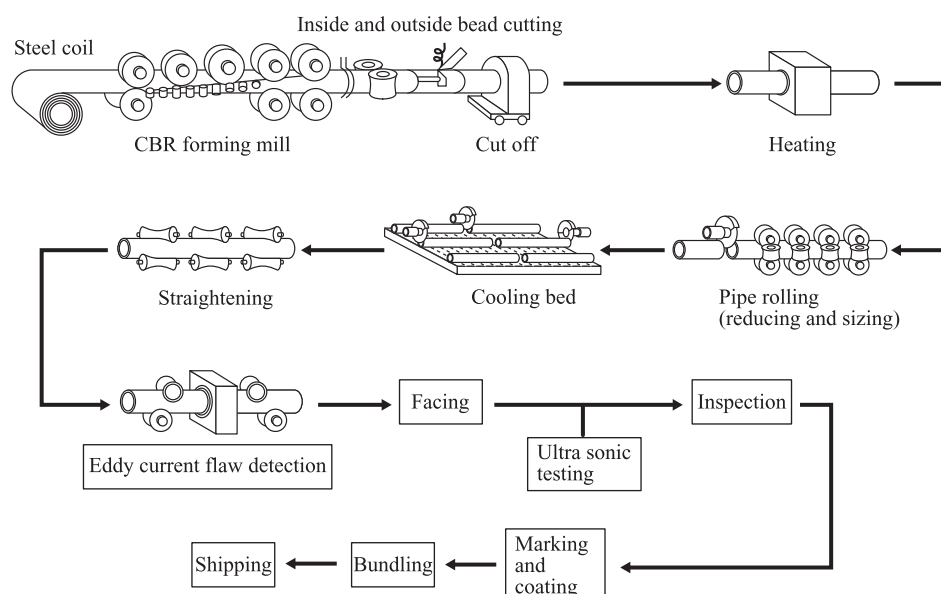


Fig.3 Schematic manufacturing procedure of HISTORY pipe

with refinement of the crystal grain size and refinement of carbides. These improved properties enable a 20–30% contribution to weight reduction in automotive parts. The problem of hardening of the weld seam is also eliminated by warm reducing.

2.3.3 Outside coated products

The 24" mill at East Japan Works (Keihin District) has outside coating equipment, making it possible to manufacture pipes which require outside coatings.

2.4 Butt Welded Steel Pipes and Tubes

The butt welded pipe mill at East Japan Works (Keihin District) mainly produces SGP as specified in the Japanese Industrial Standards (JIS)³⁾. This plant produces Zn galvanized steel pipes used in city gas and water piping and resin-coated corrosion-resistant steel pipes.

2.5 UOE Pipe

JFE Steel has one UOE mill each at West Japan

Works (Fukuyama District) and East Japan Works (Chiba District). These plants mainly produce high grade linepipes.

In manufacturing high quality linepipes, the properties and quality of the plates used as material are important. The majority of materials for UOE pipes at JFE Steel are supplied by Fukuyama District. The plate mill at Fukuyama District operates the state-of-the-art *Super-OLAC* (on-line accelerated cooling) thermo-mechanical heat treatment equipment and HOP (heat treatment on-line process), which is the world's only on-line heat treatment equipment for plates⁴⁾.

Utilizing these facilities, JFE manufactures as-rolled high grade steel plates with high strength and excellent weldability as material for UOE pipe.

3. Steel Pipe and Tube Products

Steel pipes and tubes are employed in a variety of applications, from linepipes and OCTG⁵⁾ used in the

Table 2 Major products of pipe and tubes and their manufacturing procedures in JFE Steel

Application	Manufacturing procedure	Description
General and building structure	UOE, SP, ERW	Marin structure, Pile, Square pipe
Piping	ERW, BW	Galvanized pipe, Inside lining pipe, Polyethelen coated pipe
Oil country tubular goods	SML, (ERW)	Tubing, Casing
		Drill pipe
Line pipe	SML, ERW, UOE	Transpotation of oil, gas, and water
Boiler and heat exchanger	SML, (ERW)	Heat exchanger pipe for heat recovery boiler
Machine structure	SML, ERW, HIS	Parts for automobile, Gas cylinder

SML: Seamless pipe, UOE: UOE pipe, SP: Spiral pipe,

ERW: Electric Resistance Welded Pipe, BW: Butt Welded pipe, HIS: HISTORY pipe

Table 3 Available grades of oil country tubular goods

Yield strength (ksi)	API Standard	Deep well service	High collapse	Sour service		Arctic service	Wet CO ₂ service	
				General/Special	High collapse		General	High temperature
40	H40							
55	J55, K55							
65	M65							
80	N80, L80/Type 1 L80/13Cr		JFE-80T	JFE-80S	JFE-80TS	JFE-80L	JFE-13Cr80	
85				JFE-85S JFE-85SS			JFE-13Cr85	
90	C90			JFE-90S JFE-90SS				
95	C95 T95		JFE-95T	JFE-95S JFE-95SS	JFE-95TS	JFE-95L	JFE-13Cr95	JFE-HP1-13Cr95 JFE-HP2-13Cr95
110	P110		JFE-110T	JFE-110S JFE-110SS		JFE-110L		JFE-HP1-13Cr110 JFE-HP2-13Cr110
125	Q125	JFE-125V				JFE-125L		JFE-UHP 15Cr125
140		JFE-140V						

Table 4 Chemical composition of corrosion resistance material for OCTG

(%)									
Grade	C	Si maximum	Mn	P maximum	S maximum	Cr	Ni	Mo	Cu maximum
JFE-13Cr	0.15–0.22	1.00	0.25–1.00	0.020	0.010	12.0–14.0	maximum 0.5		0.25
JFE-HP1-13Cr	maximum 0.04	0.50	maximum 0.06	0.02	0.01	12.0–14.0	3.50–4.50	0.80–1.50	
JFE-HP2-13Cr	maximum 0.04	0.05	maximum 0.06	0.02	0.01	12.0–14.0	4.50–5.50	1.80–2.50	

energy industry to steel tube columns and steel tube piles for construction and tubes used as materials for automobile parts. **Table 2** shows the main steel pipe and tube products at JFE Steel and their manufacturing processes by application. JFE Steel supplies various products for a wide range of applications by combining the optimum chemical composition and manufacturing process. Representative products are outlined in the following.

3.1 OCTG

Requirements for OCTG, used in oil and gas production include high strength and corrosion resistance against the hydrogen sulfide (H₂S) and carbon dioxide (CO₂) contained in wells. The grades of OCTG supplied by JFE Steel are shown in **Table 3**. In addition to the grades specified in American Petroleum Institute (API) standards, the company also produces various unique JFE Steel grades, which include high strength OCTG for deep wells, collapse-resistant steel pipes which resist collapse due to earth pressure, OCTG for sour service in corrosive environments, and 13% Cr alloy OCTG for CO₂ environments. In particular, from the early period when 13% Cr OCTG were applied practically, JFE Steel devoted great effort to establishing a mass production technology and improving corrosion resistance. As a

result, JFE Steel has now become the world's top maker of 13% Cr OCTG.

Table 4 shows the chemical composition of corrosion resistant OCTG at JFE Steel⁶⁾. In addition to 13% Cr, which is the standard product, JFE steel also produces HP1 and HP2, which provide improved corrosion resistance in high temperature environments. Because the service limit of HP2 is 160°C, JFE Steel is developing UP15Cr for higher temperature environments.

3.2 Linepipe

JFE Steel supplies a variety of steel pipes for use as linepipe, taking advantage of the company's abundant product line.

3.2.1 High strength, high performance linepipe (UOE)

Among UOE pipe, JFE Steel mainly produces large diameter, high strength linepipe and pipe for sour service. In recent years, linepipe design has shifted from strength-based design to strain-based design. Accompanying this, high deformability has also become a requirement in linepipe. JFE Steel developed the HIPER pipe as a product which meets to this requirement.

JFE Steel is also developing X100 and X120 grade high strength linepipe (UOE), which are expected to be

next-generation products. In particular, JFE was the first in the world to produce X100 at the mass production level and conduct construction tests of this product in linepipe.

One example of the application of JFE Steel's outstanding steelmaking technology is linepipe for sour service, which requires advanced inclusion control. This is a technology for preventing the phenomenon of hydrogen induced cracking (cracking due to hydrogen penetration in steel) in environments which contain H_2S , and thus is extremely important for securing the safety of linepipes⁷⁾.

3.2.2 Heavy wall, high strength, high toughness linepipe (ERW pipe)

With the aim of substituting ERW pipe for small diameter UOE pipe, which have the drawback of low productivity, JFE Steel developed high strength, heavy wall ERW linepipe using the 26" ERW mill at Chita Works, resulting in a large increase in orders.

3.2.3 Martensitic stainless steel (MSS) 12Cr high corrosion resistance linepipe (SML)⁸⁾

The linepipe called a flow line which is used between oil wells and the gas treatment facility is exposed to the same corrosion environment as OCTG. Because relatively small diameter pipe is used in this application, JFE Steel developed a corrosion resistant 12% Cr seamless linepipe. As this material has a low C, Ni- and Mo-added composition design, corrosion resistance is improved and welding is easy in comparison with the conventional 13% Cr steel.

3.3 Special Pipes and Tubes

Utilizing its high Cr alloy manufacturing technology, JFE Steel has developed and manufactures 9% Cr steel T91/P91 and W-added T23/P23 for thermal power plant boilers. In particular, JFE Steel has the capability to

manufacture boiler tubes with a maximum length up to 22 m.

3.4 Steel Tubes for Automotive Applications⁹⁾

Steel tubes are increasingly used in automobile suspension parts in order to reduce weight. In addition to material and product development, JFE Steel has also devoted much effort to cooperation with users in secondary forming technologies and performance evaluation technologies for steel tubes. The company's high formability ERW tubes¹⁰⁾ and HISTORY tubes are continuing to be adopted as materials for automobile suspension parts.

4. Conclusion

JFE Steel possesses products and manufacturing facilities which are capable of responding to diverse customer requirements. The company is also energetically engaged in various technical development efforts. This Special Issue of JFE Technical Reports introduces the results of recent technical development.

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