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Outline of Stainless Steel Business in JFE Steel

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Abstract:

JFE Steel has a 59 year-old history of cold rolled stainless steel production that started at Nishinomiya Works and concentrated on ferritic and martensitic stainless steels, as a unique stainless steel maker in the world. Our products are produced by distinctive state of the art facilities, such as smelting reduction process of chromium ore, strongly stirred vacuum oxygen decarburization (VOD) system, tandem cold rolling and continuous annealing (CAL) processes that produce cold rolled products efficiently. Our products have unique properties and wide variety: "JFE443 Family" series including "JFE443CT", "JFE443MT" and "JFE445NT" have excellent corrosion resistance, "JFE-TF1" has high heat resistance for automotive exhaust manifold materials without Mo addition, and "JFE 20-5 HS" has high strength and excellent oxidation resistance for metal honeycomb materials.

1. Introduction

JFE Steel Corporation produces approximately 350 000 tons/year of thin stainless steel sheets and is the world's only stainless steel maker specializing in ferritic and martensitic stainless steels.

This paper presents an outline of the history and technology development of the stainless steel business in JFE Steel, together with the features of the company's production equipment and technologies and the features of its stainless steel products.

2. Outline of History and Technology Development of Stainless Steel Business

Table 1 shows the history of the stainless steel business in JFE Steel.

As of 2021, the company's stainless steel business[1–3] has a history of 59 years since the start of production of wide-width cold-rolled stainless steel at Nishinomiya Works in 1962.

Large-scale refining of stainless steel began in earnest with the ingot casting (IC) process using a 40 t electric furnace (EF) at Nishinomiya Works in 1966, and succeeded in continuous casting production in 1973 by a process utilizing the converter (LD)-outgassing (RH)-continuous casting (CC) at No. 1 Steelmaking Shop at East Japan Works (Chiba District).

In 1991, the company started up the stainless steel plant with cold rolling and finish annealing facilities at East Japan Works (Chiba District), which completed an integrated production system from steelmaking to finish annealing following cold rolling. Subsequently, No. 4 Steelmaking Shop was constructed at the Chiba West Plant in 1994, and a large number of state-of-the-art technologies were introduced, beginning with direct smelting reduction of chromium ore. In 1995, No. 3 Hot Strip Mill began operation with hot rolling equipment that is proud of the world's largest reduction capacity and enables high speed and high reduction hot rolling of stainless steel sheets, thereby realizing a system for production of ferritic and martensitic stainless steels with excellent quality and properties.

In cold rolling process, the company has established a system for bright products (2B finish) by the 12-high cluster type reversing cold rolling mill (SCM: Stainless Cold Mill) and CAP (Continuous Annealing and Pickling line) at East Japan Works (Chiba District), functional products by the process using a tandem cold rolling mill and CAL (Continuous Annealing Line), which is a multi-purpose plant used with ordinary carbon steel, also at East Japan Works (Chiba District), and bright products (BA finish) and foils by the 20-high Sendzimir type reversing cold rolling mill (ZR) and BA (Bright Annealing) process at East Japan Works (Chiba District) Nishinomiya plant. Throughout the history described above, JFE Steel has continu-

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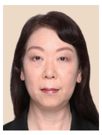

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Table 1 The history of stainless steel business in JFE Steel

Year	Main facility installed	Developed stainless steel	Note
1954			Start of production of stainless steels using facilities for specialty carbon steels (Castings and hot bands)
1955			Start of cold rolled flat products
1956		Tri-ply clad steel	
1962	(N) No.1 ZR, CB, CGR, BAF, No.1 AP (Cold)		Start of mass production of stainless steels at Nishinomiya Plant Start of hot rolling with hot strip mill at Chiba Works
1964	(N) No.2 AP (Cold)		
1966	(N) No.1 EF		
1967	(N) No.3 AP (Hot and cold)		
1968	(N) No.2 EF, PC, No.2 CB, No.1 BA, No.2 ZR		
1971	(N) VOD, ASEA-SKF		
1972		R430LT (18Cr-Ti)	Registration of trade mark as “River Lite”
1973	(N) No.3 ZR		Start of stainless steel making at Chiba Works (LD/RH/IC, CC)
1975	(N) No.4 AP (Hot and cold), No.3 CB		
1976		9 new River Lite series developed	Establishment of SS-VOD technology
1977		R304UD, R301L	
1978		R30-2	
1981	(C) MF, KBOP, VOD (Transferred from Nishinomiya Plant)		Shut down of Nishinomiya EF, and stainless steel making transferred to Chiba Works in full production: (MF)-KBOP-RH (or VOD)-CC
1982	(C) HAP, CB (Transferred from Nishinomiya Plant)	R409L, R410DH	Start of type 409 production by tandem cold mill rolling
1983		R410DB	
1984	(C) No.1 CGR (Transferred from Nishinomiya Plant)		
1985	(C) Coil box		Commercial production of R409L by tandem cold mill rolling
1986	(N) No.2 BA	R20-5SR	Start of smelting reduction of Cr-ore pellet: SR-KBOP-RH-CC Start of foil rolling with ZR mill
1988	(C) CAL/Pic		
1990	(C) SCM		
1991	(C) CAP, No.2 CGR	R315CX	
1992	(C) Finishing facilities	R445MT, R304S	Establishment of production process for bright grade at Chiba Works
1993		R429EX, R20-5USR, R436LT, R432LTM, R439	
1994	(C) No.4 stainless steel making facilities (SR, DC, VOD, CC) Dust smelting reduction furnace	R430UD, RSX-1, R430XT	Start of smelting reduction of Cr-ore sand Start of dust smelting furnace/STAR Furnace
1995	(C) No.3 Hot strip mill		
1996			(N) Revamping of No.1 ZR for foil rolling
1999			(N) Stop of No.3 AP
2000		RMH-1	(N) Stop of No.2 AP
2001	(N) NCR mill		
2003			JFE Steel established
2004	(C) Hot metal reservoir		Establishment of scrap melting and hot metal reservoir/J-FIRST
2005		JFE443CT, JFE18-3USR, JFE410RW	
2006			Concentrated on ferritic and martensitic stainless steel
2007		JFE445M	Shipment records of JFE443CT as over 50,000 t established
2008	(C) Revamping of No.4 CC for extension of metallurgical length		
2009	(C) Waste water treatment system with biological de-nitrification		
2010	(C) Burner lance for chromium ore heating and feeding in SR	JFE-TF1	
2011			(C) Production records of HAP as over 10 million t established
2017		JFE445NT	
2018		JFE443MT	
2019		JFE20-5HS	(N) 80^{th} Anniversary Nishinomiya Plant established

(N): Nishinomiya Plant, (C): Chiba Works, (Cold): For cold band, (Hot): For hot band, ZR: Sendzimir mill, CB: Coil build-up, CGR: Coil grinder, BAF: Batch annealing furnace, AP: Annealing and pickling line, EF: Electric arc-furnace, PC: Pressure caster, BA: Bright annealing line, VOD: Vacuum oxygen decarburization, IC: Ingot casting, CC: Continuous caster, SS-VOD: Strongly stirred VOD, MF: Electric arc melting furnace, KBOP: Kawatetsu blowing oxygen process, HAP: Hot band AP, CAL/Pic: Continuous annealing line with pickling facility, SCM: Stainless cold mill, CAP: Cold band AP, SR: Smelting reduction, DC: De-carburization, NCR: Nishinomiya cluster mill ously developed unique technologies and steadily continued to improve all aspects of its stainless steel business, including production capacity, quality and properties.

In addition to this technical background, in April of 2005, the company concentrated all of its thin stainless steel products on ferritic and martensitic stainless steels, foreseeing excess stainless steel production capacity, mainly by Chinese stainless steel makers.

JFE Steel, which specializes in ferritic and martensitic stainless steels, commercialized a high corrosion resistant Ni-, Mo-free ferritic stainless steel "JFE443CT" as a substitute for SUS304 in August 2005. Thereafter, the company continued to develop ferritic stainless steels with higher corrosion resistance, and added "JFE445NT" and "JFE443MT" to the "JFE443 Family"[4].

As automotive stainless steels, in the development of exhaust manifold materials, which are positioned at the leading edge of technology development of automotive stainless steels, JFE developed the high heat resistant ferritic stainless steel "JFE-MH1" for exhaust manifolds, which has higher formability than SUS444. This was followed by the Cu-, Al-added, Mo-saving "JFE-TF1" which possesses comparable corrosion resistance equal to that of SUS444 and comparable formability equal to that of the 15Cr-Nb type "JFE429EX"[5].

As a high Al, high heat resistant ferritic stainless steel foil for use in the metal honeycomb of exhaust gas converters, in addition to "JFE20-5USR," the company has also developed "JFE20-5HS" in order to meet the needs for even higher strength and higher heat resistance[6].

3. Features of Production Equipment and Technology

3.1 Steelmaking Process

One key feature[7, 8] of stainless steel production at JFE Steel is direct reduction of Cr ore by the SRF (Smelting Reduction Furnace) using molten iron from the blast furnace as the main raw material. In the SRF, direct injection of Cr ore from the lance is made possible by adoption of a large capacity furnace. This stainless steel production process also includes a Hot Metal Reservoir, which is used to hold the high-Cr molten steel refined by the SRF and to melt scrap. Fe-Cr alloy and scrap are subsequently added to reserved hot metal in the DCF (Decarburization Furnace), high speed decarburization of the molten steel held in the reservoir is performed by dilute gas blowing, and ultra-low C, N steel is finished by VOD (Vacuum Oxygen Decarburization). In both smelting reduction and decarburization, oxygen is blown from the top-blowing lances in the top- and bottom-blowing converter. However, in the bottom blowing tuyeres, oxygen diluted with argon and nitrogen is blown from the inner tube of a double-walled pipe, while propane gas is injected through the outer tube, and a strong stirring force is realized by blowing at a high flow rate. The ladle capacity of the VOD is 185 t. High speed decarburization and denitrification are possible in the VOD by strong stirring by bottom blowing using a large flow rate slit plug and control of the process to a high degree of vacuum during decarburization treatment by the powerful exhaust capacity provided by two-stage boosters and two-stage parallel ejectors. To enhance productivity, a two-tank method was adopted by separating vacuum treatment and atmosphere treatment.

3.2 Hot Rolling, Annealing and Pickling Process

No. 3 Hot Strip Mill (HSM) comprises 3 reheating furnaces, a width reduction press (Sizing Press), a 3-stand roughing mill, a 7-stand finishing mill, cooling equipment and 2 coilers. As features of this facility, the degree of freedom in width setting is increased and width accuracy is enhanced by the Sizing Press and hydraulic edger, heavy reduction is possible by powerful motors, and the thickness profile is improved by adopting pair cross rolls in the finishing stands.

Complete automation and unmanned operation have been achieved in each section from the slab yard to coiling, and only 3 operators are required for operation in the central control room.

Optimization of the slab heating temperature, the roughing and finishing reduction ratios and the coiling temperature were made much easier, and material design of base materials to realize excellent formability in products after finish rolling in the cold rolling process has become possible.

In 2013, No. 3 HSM began production of thick ferritic stainless steel strips with thicknesses exceeding 8 mm, and produces products with a maximum thickness of up to 13 mm. These thick ferritic stainless steel strips are used in many fields, such as parts for automobiles and manufacturing equipment.

Hot-rolled steel strips are annealed and descaled at the HAP (Hot band Annealing and Pickling line), while SUS410, 420 and 430 are processed by batch annealing. This HAP equipment is based on the No. 4 AP at Nishinomiya Works, which was relocated to East Japan Works (Chiba District) in 1982, and originally was a multi-purpose line that was used together with hot-rolled and cold-rolled steel strips. Later, however, it was revamped as a dedicated line for hot strip, and its capacity was upgraded by strengthening the descaling equipment (pickling tanks, scale breakers, brush equipment) and adding improvements such as reduction of cycle time on the entry and delivery sides. The HAP achieved cumulative production of 10 million tons in 2011, and currently are proud of one of the largest production capacities in Japan. A high speed acid concentration analysis device utilizing near-infrared spectroscopy was developed and installed to enable high speed pickling[9)], and a sensor which is capable of detecting fine remaining scale with a size on the order of 0.1 mm[10)] was also developed and installed, supporting the production of materials for high quality bright stainless steel products.

3.3 Cold Rolling, Annealing and Finishing Process

3.3.1 Bright products

Bright products (2B and BA finish) are rolled using the 12-high cluster type reversing cold rolling mill (SCM) and the 20-high Sendzimir type reversing cold rolling mill (ZR).

Production of bright products at East Japan Works (Chiba District) dates from the installation of the SCM and the continuous annealing and pickling line (CAP) in 1991. The SCM has a maximum product width of 1 600 mm and a high line speed capacity of 800 m/min. A control technology which greatly reduces strip thickness variations during acceleration and deceleration and an optimum shape setup model for ensuring flatness of the shape at the head end of steel strips were developed, making it possible to obtain a uniform strip thickness and shape over the full length of strips. Furthermore, high reduction, high speed rolling has been achieved by complex buckling shape control using the e-end tapered work roll shifting method. High speed operation was made possible by adopting neutral electrolytic pickling, nitric-hydrofluoric acid and nitric electrolytic pickling for descaling by the CAP, and in order to improve productivity and enable process omission, finishing facilities were incorporated in the line by adopting an inline skinpass mill and tension leveler with trimmer. Because the CAP is an atmospheric direct flame type annealing furnace, a thin oxidation film is formed on the strip surface after annealing. However, the inability to measure the strip temperature accurately with a conventional radiation thermometer was a problem since the thickness of the oxidation film changes and its emissivity fluctuates depending on the annealing temperature, atmosphere and steel composition. Therefore, a radiation thermometer which is relatively unaffected by emissivity fluctuations was developed and installed[11)] by applying principal component analysis utilizing data science, and a high level of quality stabilization was achieved by installing the developed thermometer.

3.3.2 Functional products

Functional products are mainly produced by the tandem cold rolling mill and continuous annealing line (CAL), which are multi-purpose facilities for the production of stainless steel and ordinary carbon steel and are proud of high productivity in comparison with the SCM-CAP process used for bright products.

Because nitric acid is used in the pickling processes of the HAP, CAP and CAL at Chiba District, the acid waste liquid and wash-water contain nitrate nitrogen. In response to regulation of nitrogen in wastewater to prevent eutrophication of sea areas, waste acid recovery systems were introduced at each of these lines in 1998. Later, a wastewater treatment plant with a treatment capacity of 3 000 m^3/d using the biological denitrification method (flotation method) was introduced in 2009, realizing a high quality, high efficiency and environment-friendly production process.

3.3.3 Ultra-thin foils

To meet expanding demand for stainless steel foils as a carrier material for exhaust gas purification catalysts in automobiles, JFE Steel began production of stainless steel foil in 1986. The largest technical challenge in the production of foils was prevention of wrinkles and strip breakage during rolling. In 1996, the No. 1 ZR mill at Nishinomiya Works was revamped for production of ultra-thin foil, and it became possible to roll foils with a width of 1 000 mm and thicknesses down to 30 μm. A 12-high cluster type reversing cold rolling mill (NCR: Nishinomiya Cluster Mill) as installed in 2001, and is capable of rolling foils with a width of 500 mm down to the thickness of 15 μm, responding to demand for ultra-thin foil products. With the strengthening of exhaust gas regulations worldwide, use of metal honeycomb catalyst carriers has expanded, centering on motorcycles, and use of thinner materials for weight reduction and higher performance is also progressing.

4. Features of Stainless Steel Products of JFE Steel

4.1 Stainless Steel Product Families of JFE Steel

Production of stainless steels at JFE Steel is concentrated on ferritic and martensitic stainless steels. **Table 2** shows this company's representative stainless steels.

As described in Chapter 3, JFE Steel is working to improve the properties of stainless steels by applying high speed decarburization technology in the refining process and microstructure control by the high speed and heavy reduction hot rolling mill. These technologies have made an important contribution to improving the formability of all types of general-purpose stainless steels and automotive stainless steels. The following presents an overview of JFE Steel's stainless steels by applications and features.

4.2 Features of High Corrosion Resistant Stainless Steels

The corrosion resistance of stainless steel depends mainly on its contents of Cr and Mo. The Pitting Index (P.I.) is used as an index of corrosion resistance, and Cr%+3.3×Mo% is used as the P.I. of ferritic and martensitic stainless steels. **Figure 1** shows JFE Steel's stainless steels arranged with the above-mentioned P.I. on the horizontal axis and the pitting potential (JIS G 0577) on the vertical axis. JFE Steel offers a complete lineup of stainless steels with various levels of corrosion resistance corresponding to the customer's use environment.

The ferritic stainless steel "JFE30-2," which has corrosion resistance comparable to that of titanium, has extremely high rusting resistance and is the optimum building exterior material for coastal environments. "JFE30-2" was adopted as the roof material for the Kansai International Airport, which was constructed on an artificial island and opened in 1993. This product has been adopted as a building exterior material for various coastal environments based on that record.

As a high corrosion resistant material second only to "JFE30-2," JFE Steel developed "JFE445M" with corrosion resistance equal or superior to that of SUS316. Because "JFE445M" has excellent corrosion resistance in the welding temper color zone and an alloy design which is not susceptible to stress corrosion cracking, it is suitable for the drum material of electric hot water heaters. Moreover, "JFE445M" also has excellent rusting resistance, and thus can be applied as a building exterior material even in coastal environments located around 100 m from the coast.

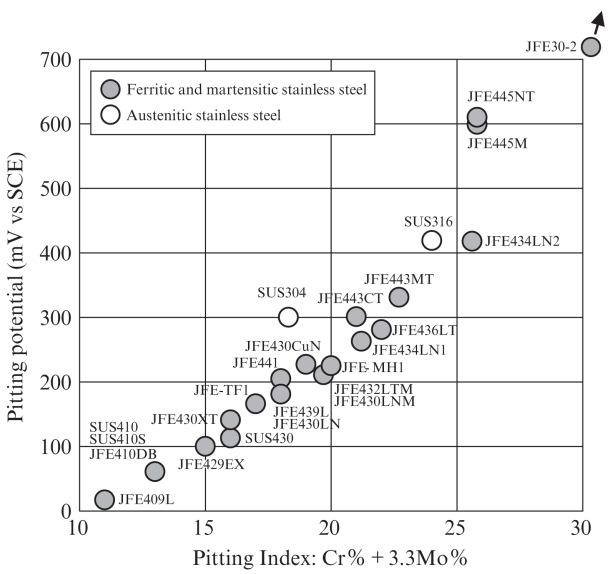

Fig. 1 Pitting potential of JFE Steel's stainless steels

Although addition of Mo is effective for improving the corrosion resistance of stainless steel, stainless steels which display the same corrosion resistance as SUS304 without addition of expensive Mo and Ni had been demanded. Responding to that need, JFE Steel developed the world's first product of this type, "JFE443CT" (21% Cr-0.4% Cu-Ti steel). "JFE443CT" has been applied as a low cost substitute for SUS304 in all applications, including kitchen equipment, industrial machinery, electrical machinery materials, building materials and automotive materials, among others. Furthermore, JFE Steel subsequently continued to develop ferritic stainless steels with even higher corrosion resistance, and has already added "JFE445NT" (22% Cr-1.0% Mo-Ti) and "JFE443MT" (21% Cr-0.5% Mo-Ti) to the "JFE443 Family"[4].

4.3 Features of Stainless Steels for Automotive and Motorcycle Use

Many automotive stainless steels are used as exhaust system materials, and other applications include exterior use in automobile moldings, scuff plates and the like. Exhaust system materials are broadly divided into materials used near the engine, which are called "hot end" materials, and materials used at some distance from the engine, called "cold end" materials.

Hot end applications include materials for the exhaust manifold and catalytic converter. Because the exhaust gas temperature is tending to increase due to its relationship with regulatory requirements for exhaust gas, enhanced heat resistance is demanded in exhaust manifold materials. However, a high alloy design is necessary to achieve higher heat resistance in materials, and this invites a decrease in formability. Although "JFE429EX" (15% Cr-1% Si-Nb) is a steel grade with a heat resistance temperature of around 750 to 800°C, its formability (r value) was improved by utilizing manufacturing technology. "JFE-MH1" (15% Cr-1.6% Mo-Nb) has heat resistance at 800 to 850°C, which is similar to that of SUS444 (19Cr-2Mo-Nb), together with excellent formability, and is also an outstanding steel grade in terms of cost performance, as the content of Mo is held to the minimum[5]. In recent years, "JFE-MH1" has been adopted as a material for

Table 2 Stainless steel products of JFE Steel

Classification	JFE Standard	Basic Composition	Characteristics	Major Application
Ferritic	SUS430	16Cr	Typical Cr-based stainless steels	Daily-use durable goods, kitchen equipment, architectural trimming, etc.
	JFE430UD	16Cr	Deep drawability and anti-ridging property are improved over those of SUS430	Daily-use durable goods, kitchen equipment, architectural trimming, etc.
	JFE430XT	16Cr-Ti-UL (C)	Workability and weldability are improved over those of SUS430	Household appliance pads, kitchen equipment, architectural trimming, electric appliance, etc.
	JFE430LN	18Cr-Nb-L (C,N)	Workability and weldability are improved over those of SUS430	Bicycle rims, electric appliance, etc.
	JFE430CuN	19Cr-0.5Cu-Nb-L (C,N)	Corrosion resistance is improved over that of SUS430	Automobile trim, kitchen equipment, electric appliance, etc.
	JFE430LNM	18Cr-0.5Mo-Nb-L (C,N)	Good corrosion resistance to water environment	Hot water storage tanks, water boilers, thermo pots, etc.
	JFE434LN1	18Cr-1Mo-Nb-UL (C,N)	Workability and weldability are improved over those of SUS434	Hot water tanks, tanks for water coolers, etc.
	JFE434LN2	19Cr-2Mo-Nb-UL (C,N)	Corrosion resistance is equivalent to that of 316	Hot water tanks, solar heat connector plates, etc.
	JFE443CT	21Cr-0.4Cu-Ti-L (C,N)	Corrosion resistance is equivalent to that of 304	Kitchen equipment, electric appliance, construction, etc. (Substitution of SUS304)
	JFE443MT	21Cr-0.5Mo-Ti-L (C,N)	Crevice corrosion resistance is improved over that of JFE443CT	Hot water tanks, etc.
	JFE445NT	22Cr-1Mo-Ti-L (C,N)	Dissimilar metal weldability is improved over that of JFE445M	Hot water tanks, roof materials, etc.
	JFE445M	22Cr-1Mo-Nb-UL (C,N)	Good corrosion resistance in the warm water environment	Hot water tanks, exterior parts of buildings, etc.
	JFE30-2	30Cr-2Mo-Nb-UL (C,N)	Excellent corrosion resistance even in coastal areas	Exterior parts of buildings, roof materials, etc.
	JFE409L	11Cr-Ti-L (C,N)	Good weldability and formability	Automobile exhaust system parts, etc.
	JFE409SR	11Cr-1.5Si-Ti-UL (C)	Good weldability and formability	Burning appliance, catalytic converter, etc.
	SUS410	13Cr	So called “13Cr stainless steels”	Tableware, machinery parts, valves, etc.
	JFE439L	18Cr-Ti-L (C,N)	Good weldability, corrosion resistance and formability	Automobile exhaust system parts, etc.
	JFE432LTM	18Cr-0.5Mo-Ti-L (C,N)	Good weldability, corrosion resistance and formability	Automobile exhaust system parts, etc.
	JFE436LT	18Cr-1.2Mo-Ti-L (C,N)	Extra-high resistance to automotive exhaust condensate	Automobile exhaust system parts, etc.
	JFE429EX	15Cr-0.8Si-0.5Nb-L (C,N)	Good oxidation resistance, thermal fatigue resistance and formability	Automobile exhaust system parts, etc.
	JFE-MH1	15Cr-1.5Mo-0.5Nb-UL (C,N)	Heat resistance property is improved over that of JFE429EX	Automobile exhaust system parts, etc.
	JFE-TF1	17Cr-1.2Cu-Nb-Al-L (C)	Heat resistance property improved without Mo	Automobile exhaust system parts, etc.
	JFE18-3USR	18Cr-3Al-La-Zr-UL (C)	Excellent oxidation resistance at high temperature	Catalytic converter for diesel cars, etc.
	JFE20-5USR	20Cr-5Al-La-Zr-UL (C)	Excellent oxidation resistance, with no deterioration even in very thin sheets	Catalytic converter for motorcycles and gasoline cars, etc.
	JFE20-5HS	20Cr-5Al-3Mo-La-Zr-UL (C)	High temperature strength is improved over that of JFE20-5USR	Catalytic converter for motorcycles and gasoline cars, etc.
Martensitic	SUS410S	13Cr-L (C)	Good formability	Tableware, house ware, etc.
	SUS420J1	13Cr-0.2C	Suitable for parts requiring wear resistance	Tableware, house ware, etc.
	SUS420J2	13Cr-0.3C	Higher quench hardness than SUS420J1	Cutlery
	EN1.4116	14Cr-0.5C	Higher quench hardness than SUS420J2	Cutlery
	JFE410DB	12Cr-1.5Mn-0.05C	Wide range of quenching temperatures can be used to obtain required hardness by quenching	Disk brakes for motorcycles and bicycles
	JFE410DB-ER	12Cr-1.5Mn-Nb-0.05C	Heat resistance property improved over that of JFE410DB	Disk brakes for motorcycles with excellent heat resistance
	JFE410RW	12Cr-1.7Mn-Ti-L (C)	Good weld joint performance and corrosion resistance	Coal wagons

L: Low, UL: Ultra-low

the converter and exhaust manifold of engines that use the spark controlled compression ignition (SCCI) method. A Cu-, Al-added Mo-saving steel "JFE-TF1" (17% Cr-1.2% Cu-Nb-Al) was also developed. In "JFE-TF1," in addition to precipitation strengthening by Cu, solute strengthening by Al is also used, achieving heat resistance equal or superior to that of the Mo-added high heat resistant steel SUS444 without adding Mo. Sales of "JFE-TF1" began in 2010, and this material has been adopted to conserve the Mo used in SUS444 or as a thin gauge, lightweight alternative to Type 429[12].

In catalytic converters, a precious metal catalyst is supported on the surface of a honeycomb-shaped carrier. Although both ceramic and metal carriers are used as catalyst carriers, metal carriers consist of a thin metal foil with a thickness of approximately 30 μm, and thus have the features of low exhaust pressure resistance, which is advantageous for engine performance, and a small thermal capacity, which contributes to excellent exhaust gas purification during cold engine start-up. A high Cr-high Al material is necessary because oxidation resistance is required in the condition of a thin metallic foil. To meet this need, JFE Steel developed "JFE20-5USR" (20% Cr-5.5% Al-La-Zr) as a metallic catalyst carrier material for gasoline automobiles and "JFE18-3USR" (18% Cr-3% Al-La-Zr) for diesel vehicles. These high alloy materials are tapped at a scale of 150 tons/charge in steelmaking process, and JFE Steel is the only maker in the world that can manufacture 1 000 mm wide-width foils with a thickness of 30 μm. JFE Steel has also developed the Mo-added "JFE20-5HS" (20% Cr-5% Al-3% Mo-La-Zr) to respond to needs for even higher strength and higher heat resistance[6].

For cold end applications, in which corrosion caused by condensed water from exhaust gas becomes a problem, JFE offers "JFE436LT" (18% Cr-1.2% Mo-Ti), "JFE432LTM" (18% Cr-0.5% Mo-Ti) and "JFE439L" (18% Cr-Ti, no Mo addition), which are based on an 18% Cr-Ti composition and have different contents of Mo corresponding to the necessary corrosion resistance.

5. Conclusion

JFE Steel produces ferritic and martensitic stainless steels with excellent properties, including high corrosion resistance, high heat resistance, high oxidation resistance and high formability, by making the maximum use of production equipment with features that utilize the company's unique technologies, and supplies those products to customers. In the future, the company will continue to develop new stainless steels and provide products which fully satisfy customers.

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