Applications of JFE443CT Steel Developed as a Substitute for SUS304†

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Abstract:

High corrosion resistant ferritic stainless steel JFE443CT has been developed as the substitute for SUS304. Its corrosion resistance is equivalent to that of SUS304, and without the addition of Ni and Mo its price is not affected by the change of the Ni or Mo price. JFE443CT has been applied for many use such as kitchenware, building materials, electrical appliances, machines, automobile and so on as the substitution for SUS304. This paper describes the properties of JFE443CT and its applications.

1. Introduction

Stainless steel used for general applications is austenitic stainless steel (also called nickel-based stainless steels typified by SUS304 (18mass%Cr-8mass%Ni (hereafter, "mass%" is abbreviated to "%")) or ferritic stainless steel such as SUS430 (16% Cr).

In the field of household utensils and electrical appliances, SUS430 is frequently used for its economic efficiency. Steel of many new types suitable for applications for automobiles has been developed and the majority used is ferrite-based stainless steel. By contrast, for construction materials, industrial machines and so forth, mainly SUS304 has been used for its excellent corrosion resistance, workability, weldability and further, high versatility and application results accumulated in many years.

Though SUS304 has excellent features, Ni, the principal raw material used to make it, is a rare metal with a sharply fluctuating price. Thus, the price of SUS304 itself is unstable. To solve this problem, JFE Steel has developed JFE443CT (21%Cr-0.4%Cu-0.3%Ti), a ferritic stainless steel as a replacement for SUS304[2)]. JFE443CT has the following features:

(1) Excellent corrosion resistance equal to that of SUS 304.
(2) No Ni and Mo are added. This saves resources and eliminates dependency on the price fluctuations of Ni and Mo.
(3) Formability equal or superior to that of conventional ferritic stainless steels.

Because the properties of JFE443CT differ from those of SUS304, in use of JFE443CT, it is important to select, on the knowledge of its characteristics, suitable applications and utilization technique.

Steep rises in the prices of Ni and SUS304 have already prompted manufacturers to adopt JFE443CT for many applications. This paper describes the features and typical applications of JFE443CT.

2. Features of JFE443CT

2.1 Basic Properties

Table 1 exhibits chemical composition of JFE443CT. Corrosion resistance equivalent to that of SUS304 is

Table 1 Chemical composition of JFE443CT

(Typical values, mass%)

Steel grade	C	Cr	Ni	Cu	Ti	Nb	N
JFE443CT	0.01	21	—	0.4	0.3	—	0.01
SUS430	0.04	16	—	—	—	—	0.04
SUS304	0.05	18	8	—	—	—	0.03

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Table 3 Physical properties of JFE443CT

Steel grade	Magnetism	Specific heat at 25°C (J/kg·°C)	Thermal conductivity at 100°C (W/m·°C)	Thermal expansion coefficient (10^{-6}/°C)	
				20–100°C	20–600°C
JFE443CT	Magnetic	440	22.5	10.5	11.6
SUS430	Magnetic	460	26.1	10.4	12.0
SUS304	Non-magnetic	500	16.2	17.3	18.7

Table 2 Mechanical properties of JFE443CT

(Typical values, Specimen thickness: 0.8 mm)

Steel grade	0.2% proof strength (MPa)	Tesile strength (MPa)	Elongation (%)	Mean *r*-value
JFE443CT	305	483	31	1.3
SUS430	320	490	29	1.0
SUS304	260	645	60	1.0

ensured by raising the Cr content to 21%, and besides, an addition of 0.4% Cu.

By adding 0.3% Ti as a stabilizing element, the C and N remaining in the steel are changed into harmless Ti-carbides and Ti-nitrides. This ensures good corrosion resistance of the weld zones and improved formability.

Table 2 indicates the mechanical properties of JFE443CT.

The *r*-value (Lankford value) is the ratio between the width-direction logarithmic strain and thickness-direction logarithmic strain produced when strain is imposed on a steel sheet: the higher this ratio, the better the deep drawability of the sheet. Compared with SUS430 steel, JFE443CT is soft and highly formable, with higher ductility (elongation) and a higher *r*-value. Compared with SUS304 steel, JFE443CT has a lower ductility, which results in inferior stretch-formability. Its *r*-value, on the other hand, is higher than that of SUS304, which results in better deep drawability. When using JFE443CT, it is therefore best to form it by drawing without stretching[3].

Table 3 indicates physical properties of JFE443CT. As with SUS430, this grade has magnetic properties. Compared with SUS304, it has a small thermal expansion coefficient and excellent thermal conductivity.

2.2 Weldability

Because of the reduced levels of carbon and nitrogen impurities and the addition of Ti as a stabilizing agent, the weld zones of JFE443CT also have excellent corrosion resistance and mechanical properties.

A combined cyclic corrosion test was performed to measure and compare the corrosion resistance of TIG weld zones of JFE443CT, SUS304, and SUS430 according to JASO M 609-91 (Society of Automotive Engineers of Japan, Inc.) (1 cycle: salt spray (a 5% NaCl aqueous solution) at 35°C, 2 h → drying (60°C, relative humidity 20 to 30%, 4 h) → wetting (50°C, relative humidity 95% or more, 2 h) and the test results are shown in **Photo 1**(a). In SUS430, the C and N in the steel precipitate as Cr-carbides and Cr-nitrides at the grain boundaries during the cooing state of welding. This results in a deficiency of Cr at the grain boundaries, a loss of corrosion resistance (sensitization), and severe rusting in the weld zones. In contrast, the weld zones in JFE443CT and SUS304 have good corrosion resistance. In JFE443CT, the reduction of the C and N contents and the addition of 0.3% Ti as a stabilizing element convert the remaining C and N into harmless Ti-carbides and Ti-nitrides, thereby preventing sensitization. Thus, the corrosion resistance of the weld zones is ensured.

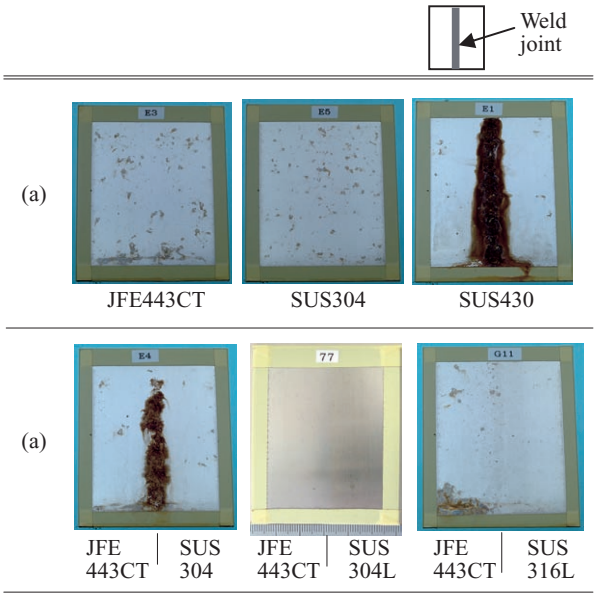

Photo 1 (a) Corrosion resistance of TIG butt welding joint of JFE443CT, SUS304 and SUS430, (b) Corrosion resistance of TIG butt welding joint of JFE443CT with other stainless steels (Sample size : 0.8 × 60 × 80 mm. The samples was polished to #600 finish after welding without welding wire. Corrosion test was carried out by 30 cycles JASO mode CCT(JASO: Japanese Automobile Standards Organization))

When welding this grade, the welder must pay attention to the following points to ensure good mechanical properties and corrosion resistance:

(1) Welding to different kinds of stainless steels: The weld zone is sensitized and the corrosion resistance of the weld zones decreases when JFE443CT is butt welded to stainless steels with high carbon concentra-

tions (e.g., SUS304) by tungsten inert gas welding (TIG welding). It is therefore better, in butt welding, to use SUS304L (18%Cr-9%Ni, C ≦ 0.030%) instead of SUS304 (C ≦ 0.08%, in general, 0.05 to 0.06%).

Photo 1(b) shows the results of a corrosion test conducted on the TIG butt-weld zones of JFE443CT with different kinds of stainless steels. The weld zone of JFE443CT with SUS304 is sensitized and shows a decrease in corrosion resistance. In contrast to this, the weld zones formed with SUS304L and SUS316L (0.02%C-18%Cr-12%Ni-2%Mo) with low C concentrations show good corrosion resistance. When JFE443CT and different stainless steel of high C content are welded together by TIG welding, the corrosion resistance of the weld zones will decrease if the cooling stage after the welding is slow. This decrease in corrosion resistance is less apt to occur in electric resistance welding (spot welding and seam welding), as the cooling after the welding is fast. In fillet welding, a technique carried out with a welding wire (**Photo 2**), the weld metal acquires a mainly austenite structure, which prevents decreases in corrosion resistance due to sensitization. An austenite weld zone also results after MIG welding and MAG welding, by using austenitic weldin wire.

Thus, a corrosion resistance almost identical to that of the base metal is obtained by metal inert gas welding (MIG welding) and metal active gas welding (MAG welding) even when JFE443CT is welded with SUS304.

(2) Welding wire: To prevent decreasing the corrosion resistance in weld zones due to sensitization, the welder should use welding wires with a low C content, such as the steel grade Y308L (example of chemical composition: 0.02%C-20%Cr-14%Ni) or the steel grade Y309L (example of chemical composition: 0.02%C-23%Cr-14%Ni).

(3) Shielding gas: To prevent oxidation and carburization, it is recommendable to shield the arcs with a sufficient volume of argon gas from both the front and rear surfaces.

(4) Appropriate heat input: Compared with SUS304 steel, JFE443CT requires some more heat input during welding. However, this calls for careful attention, because high heat input may coarsen the grains and decrease the toughness of the steel.

JFE443CT has sufficient strength and toughness in welded joints with other work pieces of the same grade or with SUS304. Furthermore, as shown in Table 3, the thermal expansion coefficient is low and the thermal conductivity is high. Thus, this steel grade is less susceptible to deformation by welding.

2.3 Functional Finished Products and 2B Surface Finished Products

This steel grade is available for functional finished products with high productivity (tandem-CAL finished products), as well as for generally used surface finishes of stainless steels 2B (annealed and pickled products) and BA (bright annealed products).

A 2B finish for a ferritic stainless steel such as JFE443CT is often highly valued for its luster. Compared with the white 2B finish for SUS304, the lustrous 2B finish for JFE443CT is sometimes found to have conspicuous fine scratching, generated during working, and inferior anti-dazzling properties, manifested depending upon applications. To cope with this problem, JFE Steel developed a white 2BW finish for this steel grade.

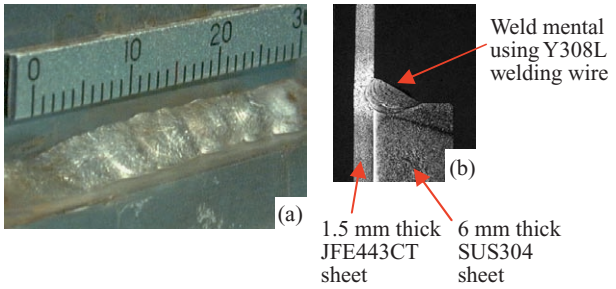

Photo 2 Corrosion resistance of TIG fillet joint of JFE443CT with SUS304 ((a) Appearance of fillet joint after 30 cycles JASO-CCT(JASO: Japanese Automobile Standards Organization), (b) Cross section of joint)

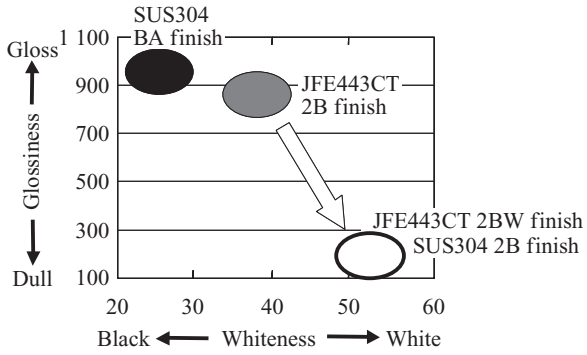

Fig. 1 Comparison of tone of a color between 2BW or 2B finish of JFE443CT and 2B or BA finish of SUS304

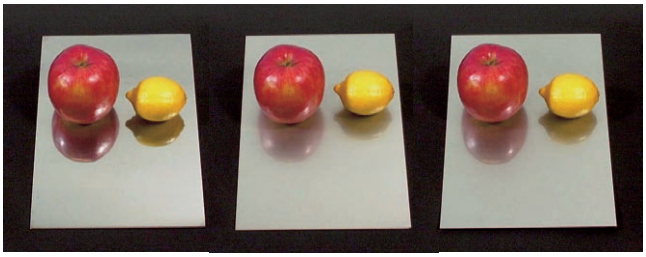

Photo 3 Appearance of 2B or 2BW finish of JFE443CT and 2B finish of SUS304

Figure 1 compares the whiteness and luster of each of the 2B and 2BW finishes for JFE443CT, and the BA and 2B finishes for SUS304. **Photo 3** shows the 2B and 2BW finishes for JFE443CT and the 2B finish for SUS304. The luster and whiteness of the JFE443CT with the 2BW finish are equivalent to those of the SUS304 finished with 2B: both finishes are white, with low luster. When JFE443CT-2BW, and the 2B finish for SUS304 are used in combination, a 2BW finish can be used to reduce the difference in color tone.

2.4 Ridging Resistance

When ferritic stainless steels are press formed, linear asperities along the rolling direction, so-called "ridging," may sometimes appear. Ridging impairs the beauty of the appearance and increases polishing loads. This possess problems when the steels are used to make products that require polishing finishes after working, such as kitchen utensils. Because ridging never appears on SUS304, the ridging must be reduced when JFE443CT is used as a substitute for SUS304. Severe ridging used to occur during earlier applications of JFE443CT, but JFE Steel has solved the problem by improving the ridging resistance through optimized manufacturing conditions. Since this improvement, the surface polishing load for worked products of JFE443CT is almost the same as that for SUS304. **Photo 4** shows the ridging resistance of JFE443CT measured after a 20% tensile test. Before the ridging resistance was improved, the convexities in JFE443CT had a waviness height on the order of 4 μm. After the improvement, the waviness height decreased to the order of 1.5 μm.

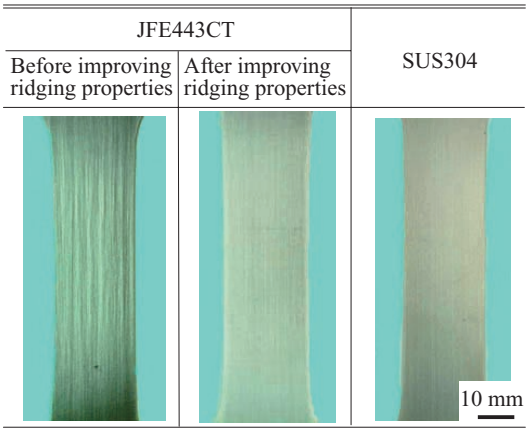

Photo 4 Appearance of JFE443CT and SUS304 after 20% tensile test

3. Examples of Application of JFE443CT

3.1 Application to Outdoor Uses

When stainless steels are used outdoors, airborne salt particles from the sea can rust them. A salt spray test (JIS Z 2371) to investigate the corrosion resistance of JFE443CT, SUS304, SUS430, and hot-dip galvanized steel sheets was conducted with the results shown in **Photo 5**. In a hot-dip galvanized steel sheet with a light-weight coating, the rust-inhibiting function of zinc. Red rusting appeared by 672 h and the entire steel sheet was covered with red rust by 2 000 h. Even in the hot-dip galvanized steel sheet with a heavy-weight coating, red rusting appeared by 2 000 h and the entire steel sheet was covered with red rust by 5 000 h. In SUS430, rusting occurred in the end portions by 168 h. In contrast, no rusting appeared on JFT443CT or SUS304 after even

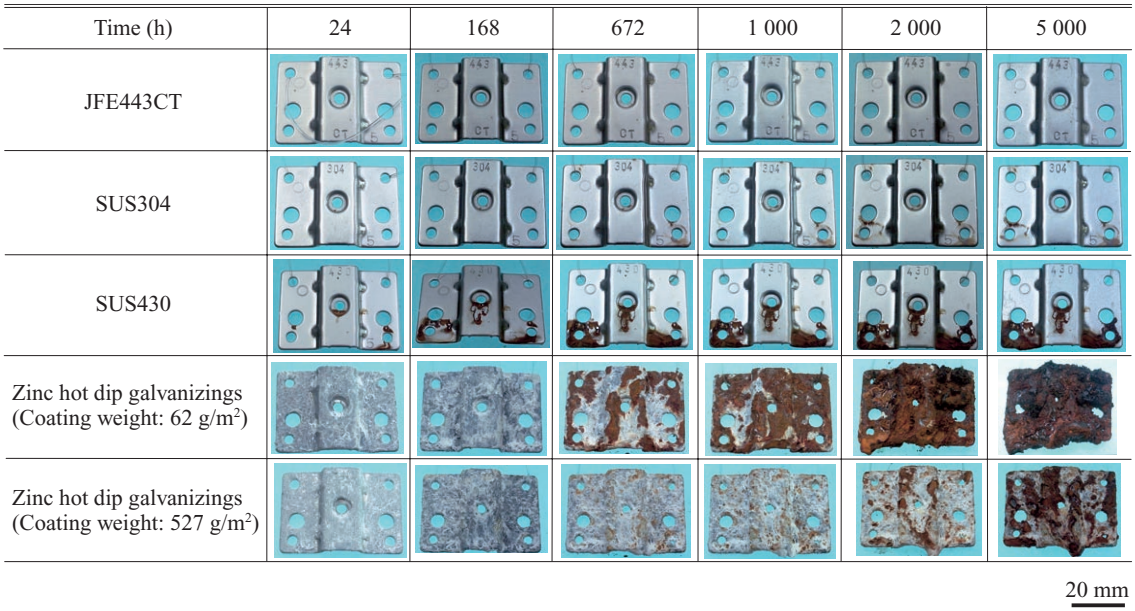

Photo 5 Results of neutral salt spray test of building fittings made of JFE443CT, SUS304, SUS430, and Zinc coated steel

Photo 7 Application of JFE443CT for outdoor use ((a)Clothes pole and stand (by courtesy of Mory Industries Inc.), (b) Gutter bracket (by courtesy of Takayama Metal Industrial Co., Ltd.), (c) Garbage container (by courtesy of Wakui Co., Ltd.), (d) Ashtray stand (by courtesy of JAPAN Tobacco Inc.), (e) Mailbox, (f) Barbecu grill, (g) Drum can (by courtesy of JFE Container))

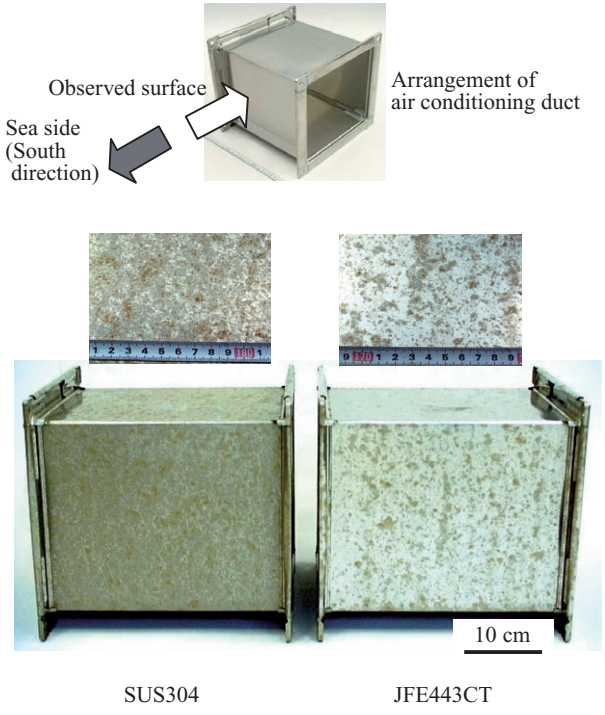

Photo 6 Results of 3 months field exposure test of air conditioning ducts made of JFE443CT or SUS304 in a coastal area at Chiba

5 000 h. Thus, JFT443CT and SUS304 showed excellent corrosion resistance.

Simulated air-conditioning ducts (ducts with shortened longitudinal dimensions compared to with actual ones) made of JFT443CT and SUS304 in production trials were exposed for three months in a coastal area of Chiba (10 m spaced from the revetment). The results of the exposure are shown in **Photo 6**. Compared to with a simulated duct made of SUS304, the rusting was slight in the simulated duct made of JFT443CT. The test confirmed that this steel grade can be adequately used as a substitute for SUS304 in such an environment.

As described above, JFT443CT has excellent corrosion resistance even in outdoor uses. In consequence, JFT443CT in place of SUS304 is beginning to be used for various kinds of building materials and industrial machines installed outdoors, as various applications of JFT443CT are shown in **Photo 7**.

3.2 Application to Indoor Uses

JFT443CT is also being used as a substitute for SUS304 in household electrical appliances and other wares made for indoor use, as **Photo 8** shows the examples of applications.

As shown in Table 2, JFT443CT has magnetic properties and high thermal conductivity. When a pan made of JFT443CT is heated on an induction heating cooker, it heats more quickly and thus saves energy. **Figure 2** shows behavior of temperature increase exhibited when water was heated under the same conditions in two electromagnetic cocking pans of the same type, one made of JFT443CT and one made of SUS304. In the pan made of JFT443CT, the heating time elapsed until the temperature reached 100°C was shortened by as much as about 30%[4].

4. Concluding Remark

JFT443CT is being used as a replacement for SUS304 in the manufacture kitchen utensils, building

Photo 8 Application of JFE443CT for indoor use ((a) Cooking pan (by courtesy of Futaba Industry Co., Ltd.), (b) Temperature keeping box (by courtesy of Isuzu Seisakusho Co., Ltd.), (c) Refrigerator, (d) System kitchen)

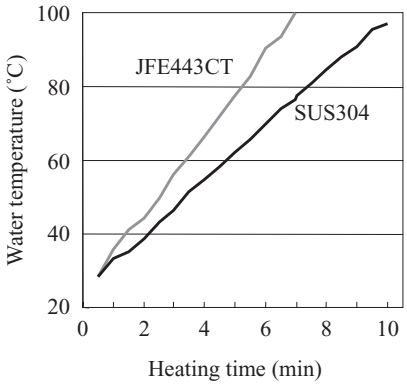

Fig. 2 Comparison of heating rate between pans made of JFE443CT and SUS304 (The amount of water in a pot was 2 *l*)

materials and fittings, electrical equipment, industrial machines, automobiles, and the like. This steel grade is expected be widely used in as a resource-saving stainless steel.

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