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Corrosion Resistant Steel JFE-SIP™-OT1 for Bottom Plate of Cargo Oil Tanks of Crude Oil Tankers†

1. Introduction

The International Maritime Organization (IMO) had revised the Safety of Life at Sea (SOLAS) Regulation as a mandatory for application of either conventional steels with protective coatings or corrosion resistant steels to the bottom and top plates of the cargo oil tanks of crude oil tankers for which contracts are concluded in or after January 2013[1)]. JFE Steel developed a corrosion resistant steel for bottom plates in response to this, and has obtained type approval from Nippon Kaiji Kyokai (ClassNK).

2. Concept of JFE-SIP™-OT1

It is known that the bottom plates of crude oil tankers are exposed to brine originating from crude oil in a condition in which an oil coat forms on the plate surface, and pitting of the plates originates from defects in this oil coat[2)]. When very large crude oil carrier (VLCC) tankers are in dock, pits with depths of more than 4 mm and less than 7 mm must be repaired with paint, and pits with depths of 7 mm or more must be repaired by welding.

The newly-developed corrosion resistant steel for tanker bottom plates, JFE-SIP™-OT1, realizes a corrosion rate of no more than 1 mm/y, which is the criterion for corrosion resistance in the corrosion test simulating corrosion in the environment inside pits specified under the SOLAS Regulation, and thereby prevents pitting that would necessitate repairs in dock. This corrosion resistance performance is realized, without impairing the mechanical properties and weldability of the steel plates, by controlling the chemical composition of the steel using microalloying technology.

Moreover, the fact that growth of pitting can be stopped by tank cleaning while a tanker is in dock has also been clarified[2)].

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"SIP" is registered trademark in Japan.

3. Features of JFE-SIP™-OT1

3.1 Corrosion Resistance

Figure 1 shows the corrosion rates of the base materials of the conventional steel and corrosion resistant steel for tanker bottom plates, JFE-SIP™-OT1. These corrosion rates were obtained from the weight loss of the materials when immersed for 72 h in a solution (10% NaCl+HCl, pH0.85, 30°C) simulating the environment inside pits. The corrosion rate of JFE-SIP™-OT1 is less than 1 mm/y, which satisfied the criterion specified in the SOLAS Regulation[1)]. This corrosion rate is also 1/10

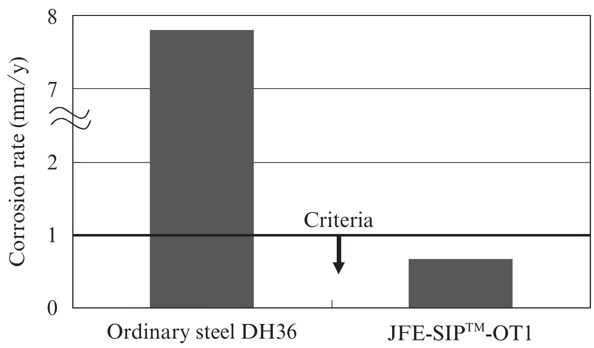
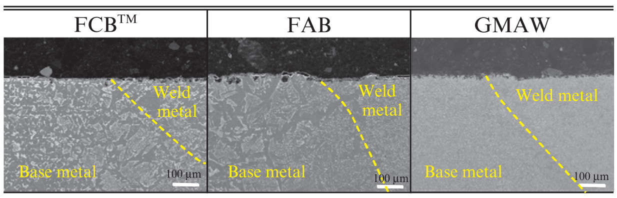


Fig. 1 Corrosion resistance of JFE-SIP™-OT1

Table 1 Welding method and consumables for JFE-SIP™-OT1

Welding method	Welding consumables
GMAW	DW-50JSTB* (FCW)
SAW (FAB)	US-36/PF-I52E/RR-2/FA-B1*
SAW (FCB™*)	US-36/PF-I55E/PF-I50R*

GMAW: Gas metal arc welding
SAW: Submerged arc welding
FCW: Flux cored wire
*Kobe Steel, Ltd.



GMAW: Gas metal arc welding

Photo 1 Cross section view of welded joints of JFE-SIP™-OT1 after corrosion resistance test

Table 3 Mechanical properties of welded joint of JFE-SIP™-OT1

Welded joint	Thickness (mm)	TS (N/mm²)	Bend test		Charpy impact test, $_vE_0$ (J)					
			Face	Root	Face side			Root side		
					WM	FL	HAZ2	WM	FL	HAZ2
SAW (FCB™*)	40	548	Good	Good	116	107	187	127	104	115
Specification		> 490	No crack		> 34					

SAW: Submerged arc metal welding WM: Weld metal *Kobe Steel, Ltd.
TS: Tensile strength FL: Fusion line
$_vE_0$: Absorbed energy at 0˚C HAZ: Heat affected zone

Table 2 Mechanical properties of steel plate of JFE-SIP™-OT1

40 mm*t*	YS (N/mm²)	TS (N/mm²)	EL (%)	$_vE_{-20}$ (J)
JFE-SIP™-OT 1	467	586	23	206
Specification	≧355	490–620	≧21	≧34

YS: Yield strength TS: Tensile strength El: Elongation
$_vE_{-20}$: Absorbed energy at −20˚C

Table 4 y Groove weld cracking test results of JFE-SIP™-OT1

Welding atmosphere	Preheating temperature	Crack ratio (%)		
		Surface crack	Cross section	Root crack
5˚C 60% RH	5˚C	0	0	0
		0	0	0
		0	0	0

Welding consumables: LB-52 UL, 4 mmϕ, Kobe Steel, Ltd.
Welding condition: 170 A×22 V×15 cm/min, 15 kJ/cm

or less than that of the conventional steel.

Welded joints of the corrosion resistant steel were fabricated, and their corrosion resistance was investigated. The welding methods and consumables suitable for use with JFE-SIP™-OT1 are shown in **Table 1**. **Photo 1** shows electron microscope images of the cross sections of the base metal/weld metal boundary area after the corrosion resistance test. In all cases, the step at the base metal/weld metal boundary after the corrosion resistance test is no more than 30 μm. Therefore, based on the Unified Interpretation established by International Association of Classification Societies Ltd. (IACS)[3], it was judged that there are no discontinuous surface, and the welded joints satisfy the criterion for corrosion resistance of welded joints provided under the SOLAS Regulation[1].

3.2 Mechanical Properties and Weldability

Table 2 shows the results of a tensile test of JFE-SIP™-OT1 (40 mm*t*) and the absorbed energy of the base metal at-20°C. In all cases, JFE-SIP™-OT1 satisfies the specification of DH36, which will be applied to tanker bottom plates.

A welding joint was fabricated using JFE-SIP™-OT1 with a thickness of 40 mm, and the weldability of the base metal was investigated. **Table 3** shows the mechanical properties of the welded joint. In all cases, JFE-SIP™-OT1 satisfies the specification of DH36. **Table 4** shows the results of y groove weld cracking test. Absolutely no cracking could be detected at the test specimen temperature of 5°C. From the above, it can be concluded that JFE-SIP™-OT1 has weldability equal to that of the conventional steels.

4. Application Results to Actual Ships

In order to investigate the corrosion resistance of JFE-SIP™-OT1 in actual ship environments, application tests were performed with three crude oil tankers. The corrosion condition of these ships was investigated each time the ships went into dock. The ships to which JFE-SIP™-OT1 was applied were one Aframax tanker (completed Nov. 2007; Afra: Average Freight Rate Assessment) and two VLCC tankers (completed Nov. 2008 and Apr. 2009).

The fifth year investigation of the AFRA max. tanker was completed. The average number of pits of 4 mm < depth≦7 mm per tank in the eight tanks to which JFE-SIP™-OT1 was applied was less than 1. In contrast, in VLCC Tankers using conventional steels, the total number of pits with depths of more than 4 mm is on the order of 100 to 1 000[2]. Thus, this study also confirmed that application of JFE-SIP™-OT1 to bottom plates substantially prevents the occurrence of pitting with a depth of more than 4 mm in actual ships.

5. Conclusion

As discussed in this article, JFE-SIP™-OT1 provides both corrosion resistance which prevents the deep pitting that occurs in the bottom plates of crude oil tanks, and mechanical properties and weldability equal to those of the conventional steels. Type approval as a corrosion resistant steel for use in the bottom plates of cargo oil tanks in crude oil tankers has been obtained from Nippon Kaiji Kyokai (ClassNK) up to the maximum thickness of 40 mm in AH32-36 and DH32-36.

Application of JFE-SIP™-OT1 is expected to contribute to improved safety of crude oil tankers at a low life cycle cost without painting.

References

1) SOLAS. chapter II-1, part A-1, reg. 3-11, as amended by resolution MSC. 291 (87), appendix. Test Procedures for Qualification of Corrosion Resistant Steel for Cargo Tanks in Crude Oil Tankers.
2) Genyu tanka no shingata korojon kyodo no kenkyu-Kenkyu gaiyo sokatsusho-. 2002-03, Nihon Zosen Kenkyukai. dai 242 kenkyu bukai.
3) IACS UI SC 258. for application of regulation 3-11, part A-1, chapter II-1 of the SOLAS convention (Corrosion Protection of Cargo Oil Tanks of Crude Oil Tankers), adopted by resolution MSC. 289 (87). The Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers.

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