JFE

STEEL PLATES FOR OFFSHORE STRUCTURES

JFE Steel Corporation

JFE Steel Corp. makes the utmost effort to supply high-quality steel plates in response to customer's requirements, and so is continuously improving its production equipment, expanding the product range, and improving quality control.

Plates used for offshore structures under severe conditions require excellent mechanical properties and strictly controlled quality. JFE Steel has developed plate products with high weldability and a wide range of strengths which are suited for various temperature environments, by combining the latest manufacturing processes and chemical design techniques. This document outlines the characteristics of JFE's steel plates and technologies for offshore structures. JFE Steel believes its steel plates have excellent quality to fully satisfy customer's requirements.

CONTENTS

STEEL PLATES FOR OFFSHORE STRUCTURES

1 High quality products and a wide range of types

JFE steel plates are backed by world-leading technologies and decades of experience. In addition to producing plates that meet domestic and overseas industrial standards, JFE Steel produces a wide variety of unique steel plates. These include high-tensile strength steel plates, steel plates for low-temperature service.

2 Modern controlled rolling and on-line accelerated cooling technology

JFE Steel uses powerful rolling machines for controlled rolling and highly efficient on-line accelerated cooling facilities. It has also developed the TMCP technology and is the leading company in this field. JFE Steel produces and supplies sophisticated high-strength steel plates that offer high toughness, good weldability and high HAZ toughness under high heat input welding by TMCP technology. These products are now used a broad range of offshore fields.

3 Excellent dimensional accuracy and uniformity

JFE Steel produces steel plates by computer-controlled plate mills, and the plates have excellent dimensional accuracy and uniformity. JFE Steel's world-leading technology minimizes plate crown and fluctuation of the thickness along the direction of length, to produce the optimum rolled shape.

4 Optimum delivery control

JFE Steel has built up a total control system from order to shipment using powerful computers. Order information from the customer is exactly input to each production process, and so products which precisely meet the requirements can be delivered with minimum lead time.

Steel Plate Products Meeting Typical Standards

Steel Plates with Preproduction Qualification

YS class	Maximum Thickness (mm)	API	EN		NORSOK M120
			10025	10225	
355MPa	101.6	2H Grade 50 2W Grade 50	S355JR S355J0 S355J2 S355K2 S355N S355NL S355M S355ML	S355G7 S355G8 S355G9 S355G10	Y04 Y05 Y20 Y25
420MPa	101.6	2W Grade 60	S420N S420NL S420M S420ML	S420G1 S420G2	Y15 Y30 Y35
460MPa	101.6		S460N S460NL S460M S460ML	S460G1 S460G2	Y40 Y45
500MPa	76.2	(Grade 70) *			Y50 Y55

* API 2W Mod Grade

Steel Plates of Ship Classification and JFE Standard

YS Class	Ship classification		JFE Standard
	Hull structural steel	High strength quenched and tempered steel	
315MPa	A32 D32 E32 F32		
355MPa	A36 D36 E36 F36		
390MPa	A40 D40 E40 F40		
420MPa		ABS EQ43 DNV GL E420	
460MPa	A47 ** D47 ** E47 **		
500MPa		ABS EQ51 ABS FQ51 DNV GL E500	JFE-HITEN610
550MPa		ABS EQ56 ABS FQ56 DNV GL E550	
620MPa		ABS EQ63 DNV GL E620	JFE-HITEN710
690MPa		ABS EQ70 ABS FQ70 DNV GL E690 DNV GL F690	JFE-HITEN780M JFE-HITEN780ML

** Approved conditions of A47, D47 and E47 are different according to Classes. Please consult JFE Steel before order placing.

JFE's Standard

High Tensile Strength Steel Plates

Since 1952 JFE Steel has been researching and developing JFE-HITEN steel plates which have good weldability and high tensile strength up to 980MPa class. These products are widely used in many engineering fields of offshore structures.

Brand	Features
JFE-HITEN 610	Standard high-strength steel plate with yield strength of over 450MPa and superior weldability.
JFE-HITEN 710	Standard high-strength steel plate with yield strength of over 615MPa and superior weldability.
JFE-HITEN 780M	Steel plates containing Ni alloy, showing high toughness, high strength and superior weldability even for a thickness of 150mm.

Steel Plates for Low Temperature Services

Steel plates are widely used for offshore structures operating in cold regions such as frozen sea. Steel plates are also specified by ASTM, ASME, EN and ship class such as NK. JFE Steel supplies steel plates in conformance with these standards, and has developed its own steel plates that have been certified by authorized associations.

Brand	Features
JFE-HITEN780ML	Steel plate containing Ni alloy, offering high toughness, high strength and superior weldability even for a thickness of 210 mm. Typical application is for the legs and cords of jack-up rigs in cold regions.

JFE's Standard

High Tensile Strength Steel Plates

Designation (Thickness mm)	Chemical Composition (%)															
	Thickness (mm)	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	Nb	B	Ceq* Thickness (mm)	Ceq*	P_{CM}
JFE-HITEN610 (6～150)		≦0.16	0.15/ 0.55	≦1.50	≦0.025	≦0.015	≦0.30	≦1.00	≦0.30	≦0.30	≦0.08	–	–	t≦50 50<t≦75 75<t	≦0.45 ≦0.47 ≦0.49	≦0.26 ≦0.28 ≦0.28
JFE-HITEN710 (6～100)		≦0.16	≦0.35	≦1.20	≦0.025	≦0.015	≦0.40	≦1.00	≦0.70	≦0.50	≦0.08	–	≦0.005	t≦50 50<t	≦0.55 ≦0.59	– –
JFE-HITEN780M (6～150)	t≦100 100<t	≦0.14 ≦0.18	≦0.35 ≦0.35	≦1.20 ≦1.20	≦0.015 ≦0.015	≦0.015 ≦0.015	≦0.50 ≦0.50	0.30/1.50 0.30/1.50	≦0.70 ≦0.80	≦0.60 ≦0.60	≦0.05 ≦0.05	–	≦0.005 ≦0.005	t≦50 50<t≦100 100<t	≦0.53 ≦0.57 ≦0.62	≦0.30 ≦0.32 –

* Ceq = C＋Si/24＋Mn/6＋Ni/40＋Cr/5＋Mo/4＋V/14

High Tensile Strength Steel Plates for Low Temperature Service

Designation (Thickness mm)	Chemical Composition (%)													
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	Nb	B	Ceq*	P_{CM}
JFE-HITEN780ML (6～210)	≦0.16	≦0.35	≦1.20	≦0.020	≦0.010	≦0.50	≦4.00	≦1.00	≦0.60	≦0.10	–	≦0.005	–	–

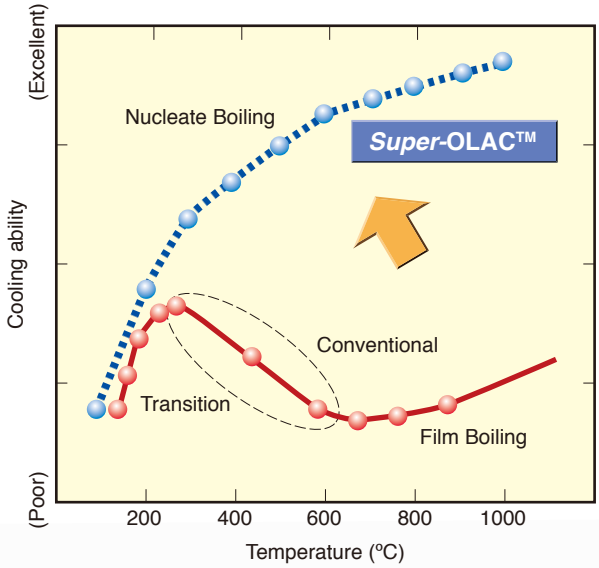
* Ceq = C＋Si/24＋Mn/6＋Ni/40＋Cr/5＋Mo/4＋V/14

	Tensile Test						Bending Test (180°)		Impact Test (2mmV Charpy)		
	Yield Point or Proof Stress		Tensile Strength (MPa)	Elongation			Bending Radius		Test Temperature		Absorbed Energy
	Thickness (mm)	(MPa)		Thickness (mm)	(%)	Test Specimen (JIS)	Thickness (mm)	Test Specimen No. 1	Thickness (mm)	(℃)	(J)
	t≦75 75<t	≧490 ≧470	610/730	t≦16 16<t≦50 20<t	≧19 ≧27 ≧19	No. 5 No. 5 No. 4	—	1.5t	12<t≦32 32<t	−10 −15	≧47 ≧47
	t≦75 75<t	≧620 ≧600	710/840	t≦16 16<t≦50 20<t	≧17 ≧25 ≧17	No. 5 No. 5 No. 4	t≦32 32<t	1.5t 2.0t	12<t≦32 32<t≦50 50<t	−15 −20 −30	≧47 ≧47 ≧47
	t≦75 75<t	≧685 ≧665	780/930	t≦16 16<t≦50 20<t	≧16 ≧24 ≧16	No. 5 No. 5 No. 4	t≦32 32<t	1.5t 2.0t	12<t≦32 32<t≦50 50<t	−20 −25 −35	≧47 ≧47 ≧47

	Tensile Test						Bending Test (180°)		Impact Test (2mmV Charpy)	
	Yield Point or Proof Stress		Tensile Strength (MPa)	Elongation			Bending Radius		Test Temperature (℃)	Absorbed Energy (J)
	Thickness (mm)	(MPa)		Thickness (mm)	(%)	Test Specimen (JIS)	Thickness (mm)	Test Specimen No. 1		
	—	≧665	780/930 760/910	t≦16 16<t≦50 20<t	≧16 ≧24 ≧16	No. 5 No. 5 No. 4	t≦32 32<t	1.5t 2.0t	(12<t) −60	≧34

Examples of JFE's Technologies for Offshore Structures

JFE's leading TMCP technology

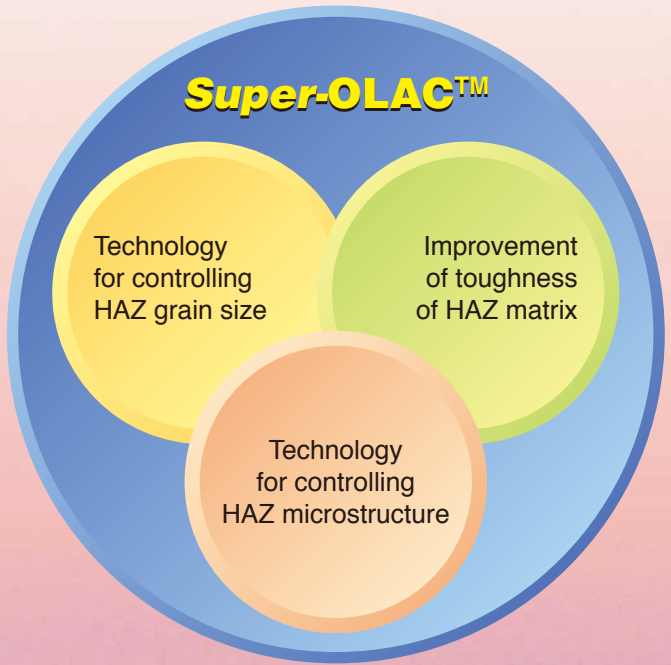


Super-OLAC™ is a leading-edge TMCP technology, and offers a higher cooling rate than conventional cooling systems.

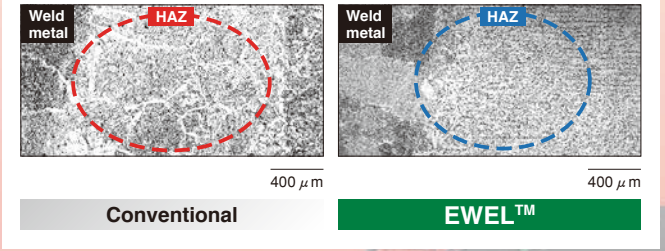
- **Good reduction of carbon equivalent offers high weldability and improves the reliability of structures.**
- **TMCP is also effective for thick plates.**

JFE-EWEL™

Excellent HAZ toughness under high heat input welding.



EWEL™ is composed of three independent technologies based on *Super*-OLAC™. One of them produces finer austenite grains at the peak temperature of welding, one changes the brittle coarse bainite structure to fine ferrite and bainite structure, and the third improves the toughness of the HAZ matrix by reducing free nitrogen through chemical reaction during the welding thermal cycle.



Each technology, or combination with other technologies, is used according to the customer's requirement.

Coarse Grain HAZ Control

CTOD improvement by making grains finer and improving the microstructure.

Grain-fining technology of HAZ
Precipitates prevent HAZ grain coarsening

CTOD improvement

Toughness improvement of microstructure of HAZ and it's matrix

Restricting Nb and V contents
Reducing Ceq

Super-OLAC™

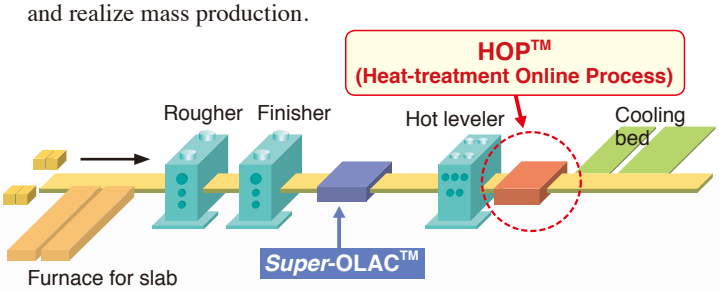
Controlling free Nitrogen

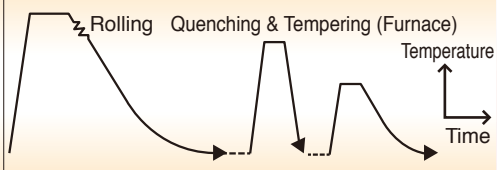
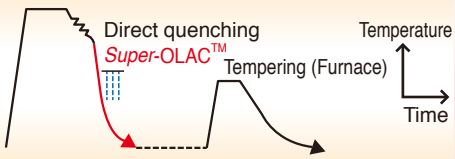
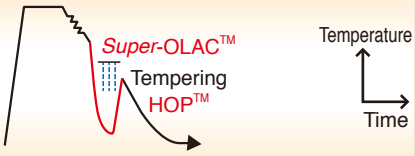
HOP™ Heat-treatment On-line process

The newly developed HOP™ uses an induction heating method in which an induced current is passed through the steel plate by electromagnetic coils and heating is performed by the heat generated, achieving heating with an extremely large energy density.

Features of HOP™

Realizes 100% on-line heat treatment synchronized with rolling. A complete on-line system including rolling – accelerated cooling – heat treatment makes it possible to meet extremely short deadlines and realize mass production.



Process	Heat treatment
Conventional Quench & Temper process	
Advanced Direct quenching by *Super*-OLAC™	
Newly developed leading technology by *Super*-OLAC™ & HOP™	

Application Examples of JFE's Technologies

	Typical Standard
Super-OLAC™	API-2W Ship's Class Standard EN10225
EWEL™	Ship's Class Standard
Coarse Grain HAZ Control	API-2W EN-10225 Additionally with API 2Z pre-qualification

Other standards can be met if required.
Please consult with JFE Steel.

Examples of Mechanical Performance of Typical Products for offshore Structures

API2W Gr.50 t=101.6mm

Base Plate

Chemical composition

(%)

C	Si	Mn	P	S	others
0.07	0.19	1.47	0.005	0.0004	Cu, Ni, etc.

Mechanical properties

Location & Direc.		Tensile test Y.S. (MPa)	T.S. (MPa)	EL (%)	RA (%)	Charpy V-notch impact test Absorbed Energy (J) vE-40	vE-60	vE-80	50% FATT
1/4t	L	411 419	507 507	39 37	—	389	341	319	-85℃
	T	414 406	516 513	38 38	—	394	349	284	-85℃
	Z	407	507	—	81	—	—	—	—

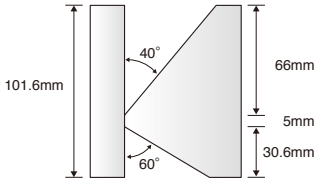
Strain Aged CVN Test

Location	Strain Aging	Direction	Absorbed Energy (J) vE-40	50% FATT
Subsurface	As rolled	T	269	-67℃
	5% Strain 250℃ × 1h	T	205	-50℃

Weldability

Welding Conditions

Welding Method	GMAW	SAW
Bevel Shape	K-bevel	
Heat Input (kJ/mm)	0.8	4.5



Tensile Test of Welded Joint

Heat Input (kJ/mm)	Test Temp.	Weld Metal Y.S. (MPa)	T.S. (MPa)	EL (%)	Welded Joint T.S. (MPa)	Fracture Position
0.8	R.T.	633	633	26	552 553	B.M. B.M.
4.5	R.T.	488	557	33	544 540	B.M. B.M.

Charpy V-notch Impact Test of Welded Joint

Heat Input (kJ/mm)	Location	Notch Position	Absorbed Energy (J) -40℃
0.8	1/4t	W.M. CGHAZ SCHAZ	161 337 257
	Root	CGHAZ SCHAZ	153 273
4.5	1/4t	W.M. CGHAZ SCHAZ	134 228 347
	Root	CGHAZ SCHAZ	249 266

CTOD Test of Welded Joint

Test Temp.	Heat Input (kJ/mm)	Notch Position	CTOD Value (mm)
-10℃	0.8	CGHAZ	1.49 1.37 2.27 1.80 1.88 2.15 1.69 1.49
		SCHAZ	0.63 0.61 0.69
		W.M.	0.99 0.81 0.90
	4.5	CGHAZ	1.03 2.75 1.16 2.39 ≧ 2.81
		SCHAZ	0.86 1.94 1.58
		W.M.	≧ 2.88 1.90 ≧ 2.84

API2W Gr.60 t=101.6mm

Base Plate

Chemical composition

(%)

C	Si	Mn	P	S	others
0.085	0.14	1.57	0.005	0.001	Cu, Ni, etc.

Mechanical properties

Location & Direc.		Tensile Test Y.S. (MPa)	T.S. (MPa)	EL (%)	RA (%)	Charpy V-notch Impact Test Absorbed Energy (J) vE-40	vE-60	50% FATT
1/4t	L	449 426	556 549	32 33	–	446	441	-100℃
	T	446 444	560 559	31 32	–	450	449	-90℃
	Z	434	551	–	80	–	–	–

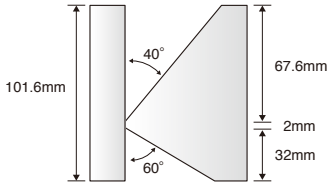
Strain Aged CVN Test

Location	Strain Aging	Direction	Absorbed Energy (J) vE-40	50% FATT
Subsurface	As rolled	T	397	<-100℃
	5% Strain 250℃ × 1h	T	137	

Weldability

Welding Conditions

Welding Method	GMAW	SAW
Bevel Shape	K-bevel	
Heat Input (kJ/mm)	0.8	4.5



Tensile Test of Welded Joint

Heat Input (kJ/mm)	Test Temp.	Weld Metal Y.P. (MPa)	T.S. (MPa)	EL (%)	Welded Joint T.S. (MPa)	Fracture Position
0.8	R.T. -10℃	554 597	576 604	29 30	593 –	B.M. –
4.5	R.T. -10℃	517 535	601 620	32 31	596 –	B.M. –

Charpy V-notch Impact Test of Welded Joint

Heat Input (kJ/mm)	Location	Notch Position	Absorbed Energy (J) -40℃
0.8	1/4t	W.M. CGHAZ SCHAZ	156 478 274
	Root	CGHAZ SCHAZ	395 205
4.5	1/4t	W.M. CGHAZ SCHAZ	252 451 399
	Root	CGHAZ SCHAZ	312 235

CTOD Test of Welded Joint

Test Temp.	Heat Input (kJ/mm)	Notch Position	CTOD Value (mm)
-10℃	0.8	CGHAZ	1.05 1.00 0.97 1.05 0.98 0.77 0.77 1.00
		SCHAZ	1.57 2.17 1.97
		W.M.	1.45 1.15
	4.5	CGHAZ	1.14 0.47 0.41 1.52 1.58
		SCHAZ	0.93 0.67 1.03 1.09
		W.M.	1.83 1.74

Available sizes

Without Heat Treatment

Product Length: m

Thickness (mm) \ Width (mm)	1000～1400	1401～1600	1601～1800	1801～2000	2001～2200	2201～2400	2401～2600	2601～2800	2801～3000	3001～3200	3201～3400	3401～3600	3601～3800	3801～4000	4001～4200	4201～4400	4401～4600	4601～4800	4801～5000	5001～5200	5201～5300	5301～5350
6.0～6.9																	22	22	19	16	13.5	13.5
7.0～9.0																		22	20	16	13.5	13.5
9.1～11.9																			20	20	20	16
12.0～13.9																					22	16
14.0～25.0																						16
25.1～28.0							25															16
28.1～32.0																			24	23	20	16
32.1～38.0															24	23	22	21	20	19	18	16
38.1～45.0												24	23	23	20	19	19	18	17	16	16	16
45.1～50.0										23	22	21	20	20	18	17	16	16	15	14	14	14
50.1～55.0							24	24	21	21	20	19	18	18	16	16	15	14	14	13	13	13
55.1～60.0							24	22	21	19	19	17	16	16	15	14	13	13	12	12	12	11
60.1～65.0					24	23	21	20	18	18	17	16	15	15	14	13	12	12	11	11	10	9.5
65.1～70.0				24	24	22	21	19	18	17	16	15	14	14	13	12	12	11	11	10	10	9.5
70.1～75.0	24	23	24	23	21	20	18	17	15	15	15	14	13	13	12	11	11	10	10	9.2	9	8.5
75.1～80.0	23	23	22	21	21	19	18	17	15	14	14	13	12	12	11	11	10	10	9.6	9.2	9	8.5
80.1～90.0	20	20	20	19	19	17	16	15	14	13	12	11	11	10	10	9.7	9.2	8.8	8.5	8.2	8	7.5
90.1～100.0	18	18	18	17	17	15	14	13	12	11	11	10	10	9.6	9.1	8.7	8.3	8	7.6	7.3		
100.1～110.0	16	16	16	16	15	14	13	12	11	10	10	9.7	9.1	9	8.3	8	7.6	7.2	7	6.7 / 5.8		
110.1～120.0	15	15	15	14	14	13	12	11	10	10	9.4	8.8	8.4	8	7.6	7.2	6.9 / 6.0	6.6 / 5.8	6	6		
120.1～130.0	14	14	14	13	13	12	11	10	9.8	9.2	8.6	8.2	7.7	7.3	7.0	6.7 / 5.8	6	6	5.1	5.3		
130.1～140.0	13	13	13	12	12	11	10	9.7	9	8.5	8	7.5	7.1	7	6	6	5.1	5.1	5.1	5.3		
140.1～150.0	12	12	12	11	11	10	9.7	9.1	8.4	7.9	7.4	7	6.7 / 5.8	6	6	5	5	5				
150.1～160.0	11	11	11	10	10	9.9	9.1	8.5	7.9	7.4	7.0 / 6.0	6.6 / 5.7	6	6	5	5						
160.1～170.0	10	10	10	10	10	9.3	8.6	8	7.4	6.7 / 6.0	6.6 / 5.7	6	5.1	5	5	4.4						
170.1～180.0	10	10	10	9	9.4	8.8	8.1	7.6	7.1	6.6 / 5.8	6.2	5.1	5	5	4.4				Not available			
180.1～190.0	9	9	9	9	8.9	8.3	7.7	7.1	6.7 / 5.8	5.4	5.1	4.8	4.5	4.3								
190.1～200.0	9	8.2	8.2	8	8.5	7.9	7.3	6.8 / 5.9	5.5	5.1	4.8	4.6	4.3	4.1								

1. In case of the diagonal-lined column A/B, "A" shows the maximum product length.
   And the product length between "B" and 6.1m can not be provided.
2. The minimum product size is as follows: 1m wide and 3m long.
3. Please consult with JFE prior to ordering the product width between 5,201 and 5,350mm.
4. 30m length for limited thickness and width is available. Please consult with us.

Heat Treated

Product Length: m

Thickness (mm) \ Width (mm)	1000 ~ 1600	1601 ~ 1800	1801 ~ 2000	2001 ~ 2200	2201 ~ 2400	2401 ~ 2600	2601 ~ 2800	2801 ~ 3000	3001 ~ 3200	3201 ~ 3400	3401 ~ 3600	3601 ~ 3800	3801 ~ 4000	4001 ~ 4200	4201 ~ 4400	4401 ~ 4600	4601 ~ 4800	4801 ~ 5000	5001 ~ 5200	5201 ~ 5300	5301 ~ 5350
6.0~6.9										22	20	15	13	Not available							
7.0~7.9											24	22	20	15							
8.0~8.9													22	18	16	13	11				
9.0~9.9															22	20	16	12			
10.0~11.9																		22	20	18	Negotiable range
12.0~13.9																				22	
14.0~26.0										25											
26.1~28.0																					
28.1~30.0																		24	24	22	
30.1~35.0														24	24	23	22	21	21	20	
35.1~40.0												24	23	22	21	20	19	18	18	17	
40.1~45.0											23	22	20	19	19	18	17	16	16	15	
45.1~50.0									23	22	20	19	18	17	17	16	15	15	14	14	
50.1~60.0					24	24	22	20	19	18	17	16	15	14	14	13	13	12	11	11	
60.1~70.0		23	20	24	22	20	19	17	16	15	14	14	13	12	12	11	11	10	10	10	
70.1~80.0	22	20	18	21	19	18	16	15	14	13	13	12	11	11	10	10	9.7	9.3	8.9	8.7	
80.1~90.0	20	18	16	19	17	16	14	13	13	12	11	10	10	9.8	9.4	8.9	8.5	8.3	7.9		
90.1~100.0	18	16	14	17	15	14	13	12	11	10	10	9.8	9.3	8.8	8.4	8.0	7.7	7.3	7.0		
100.1~110.0	16	14	13	15	14	13	12	11	10	9.9	9.4	8.8	8.4	8.0	7.6	7.3	6.9 / 6.0	6.6 / 5.7	6.4 / 5.5		
110.1~120.0	15	13	12	14	13	11	11	10	9.7	9.1	8.5	8.1	7.7	7.3	6.9 / 6.0	6.6 / 5.7	6.3 / 5.8	5.2			
120.1~130.0	13	12	11	13	11	11	10	9.5	8.9	8.3	7.9	7.3	7.0	6.7	6.4 / 5.5	5.2	5.0				
130.1~140.0	11	10	9.7	11	10	9.7	9.4	8.7	8.2	7.7	7.2	6.8	6.5 / 5.6	5.3	4.8						
140.1~150.0	10	10	9.6	10	9.7	9.4	8.7	8.1	7.6	7.1	6.7	6.4 / 5.5	5.2	4.9							
150.1~160.0	9.7	9.7	9.0	9.7	9.6	8.8	8.2	7.6	7.1	6.7 / 5.7	6.3 / 5.3	5.1	4.8								
160.1~170.0	9.4	9.4	8.4	9.7	9.0	8.3	7.7	7.1	6.7 / 5.7	6.3 / 5.4	5.1	Not available									
170.1~180.0	8.9	8.9	7.9	9.1	8.5	7.8	7.3	6.8	6.3 / 5.5	5.9											
180.1~190.0	8.4	8.4	7.5	8.6	8.0	7.4	6.8	6.3 / 5.5	5.1												
190.1~200.0	7.9	7.9	7.1	8.2	7.6	7.0	6.5 / 5.6	5.2	4.8												

1. In case of the diagonal-lined column [A/B], "A" shows the maximum product length. And the product length between "B" and 6.1m can not be provided.
2. The minimum product size is as follows: 1m wide and 3m long.
3. Please consult with JFE prior to ordering the product width between 5,201 and 5,350mm.
4. 30m length for limited thickness and width is available. Please consult with us.

Recommendations for fabricating JFE-HITEN, high- strength steel plates

1 General

The precautions on forming or welding of high strength steel are the most important in fabrication of offshore structures.

The JFE-HITEN series, despite their high strength, offers outstanding workability.

In fabricating JFE-HITEN steel plates, however, it is recommended that the manufacturing process be taken into full consideration in order not to impair mechanical properties.

2 Marking

With plates that will be subjected to bending, chisel or punch marks on the outer surface to be bent should be avoided because they can induce cracking.

3 Cutting and Drilling

Holes should not be punched. Drilling is more suitable. JFE-HITEN steels can be gas-cut as easily as mild steel. Gas cutting produces a hardened layer up to 2 mm in depth. When bending plates, particularly those of 690MPa or higher tensile-strength steels, removal of the hardened layer by grinder or other methods is recommended to be conducted. Gas-cut edges that are to be welded do not require this removal of the hardened layer, since it is removed by the weld penetration.

4 Cold Working

Because of their high strength, JFE- HITEN steel plates require a larger bending force than mild steel, but their high ductility makes them easy to cold work.

High-strength steel plates exhibit a greater spring back than mild steel, so attention is necessary during the working process. It is desirable to bend these plates parallel to direction of rolling, with a bend radius at least three times that of the plate thickness.

When plates must be bent to a smaller radius, edges should be rounded by grinding as the crack susceptibility of a plate edge increases as bend radius decreases.

5 Hot Forming and Warm Forming

Working quenched and tempered plates at a temperature over the tempering temperature is not recommendable.

Excessive temperature causes deterioration in the properties of the steel. Hot working can also change the properties of contro1-rolled and TMCP plates, so the customer is requested to consult JFE about specific working conditions.

6 Post Weld Heat Treatment (PWHT)

JFE-HITEN steel plates exhibit outstanding welded-joint toughness in the as-welded condition, so they do not require post-weld heat treatment to recover toughness. Quenched and tempered plates may be post-weld heat treated, if necessary, at temperatures not exceeding the tempering temperature.

For TMCP plates, please consult JFE Steel in advance.

7 Welding

JFE-HITEN steel plates are welded by such conventional methods as shielded metal arc welding, submerged arc welding, gas metal arc welding, and electro-gas arc welding.

Welding by any of these methods produces satisfactory weldments.

1) Welding materials

For the welding of quenched and tempered high strength steels, it is necessary to use Materials which provide superior toughness of weld metal. Low hydrogen type for SMAW and high basicity flux for automatic welding are recommended, in order to prevent the occurrence of various possible weld defects associated with the combination of steel plates and welding materials. Typical welding materials are shown below.

2) Re-Baking Before Use

Low hydrogen type welding rods for shielded metal arc welding must be dried for about 1 hour at temperatures between 350ºC and 400ºC before use. Fluxes for submerged arc welding must also be fully dried for about 1 hour at 250～350ºC.

3) Edge Preparation

Edge preparation can be performed by gas cutting. When an intricate groove configuration is involved, or when high precision is required, edge preparation is performed by machining.

4) Preheating Treatment

In order to determine the preheating temperature, variables including welding materials, plate thickness, welding method, environmental conditions, constraint conditions must be taken into consideration.

TS590MPa class JFE-HITEN can be butt welded without preheating, however, preheating is recommended depending on the above conditions. Preheating temperatures between 50 and 100ºC are sufficient.

With 690MPa or higher tensile strength steel plates, a higher preheating temperature between 100 and 200°C is required to prevent cold cracking, though the specific temperature varies based on the above conditions. Please consult with JFE.

5) Tack Welding

Tack welding conditions are the same as those for normal welding, however, it is recommended that welding beads be over 50mm in length. It is absolutely essential that arc striking be performed in the bevel or on other steel plate, and not on the base metal.

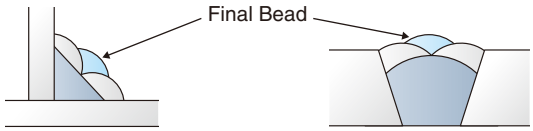
6) Welding

① In case of welding by covered electrodes, it is recommended at the outset that a back start be done for about 30mm in the groove, giving straight beading.

② It is recommended that arc length be as short as possible.

③ Weaving will impair heat input required for welding. If weaving is applied, the width of weaving must be less than 1.5 times rod diameter.

④ In case of SMAW for TS690MPa and over grades, temper bead methods are recommendable, as shown below.



⑤ Slag removal is not easy for low hydrogen type electrodes, particularly compared to ilmenite or cellulose types, but it is recommended by all means. Pre-heating helps to remove weld slag preferably.

⑥ In case of submerged-arc welding, phenomena such as embrittlement and softening at heat affected zone must be considered.
Care must therefore be taken concerning the welding heat input.

⑦ Besides preheating, the control of interlayer temperature is recommended.

Recommended welding materials

Welding process	Shielding gas or polarity	Welding consumables ※	AWS Classification	Minimum applicable YS (MPa, as welded)	Applicable temp (℃) *	
		KOBELCO brand name			vE	CTOD
GMAW(Solid)	80%Ar-20%CO_2	MG-S88A	A5.28 ER120S-G	690	-60	–
GMAW(FCW)	80%Ar-20%CO_2	DW-A55L	A5.29 E81T1-K2M	460	-60	-20
		DW-A55LSR	A5.29 E81T1-Ni1M	420	-60	-20
		DW-A62L	A5.29 E91T1-GM	500	-60	-40**
		MX-A62L	A5.28 E90C-G	500	-60	-10
		MX-A80L	A5.28 E110C-G H4	690	-60	–
	CO_2	DW-55LSR	A5.29 E81T1-K2C	420	-60	-10
SMAW	DCEP/AC	LB-52NS	A5.5 E7016-G	400	-60	-30
		NB-1SJ	A5.5 E8016-G	420	-60	-40
		LB-62L	A5.5 E8016-C1	500	-60	-10
	DCEP	LB-67L	A5.5 E9016-G	500	-60	-20
		LB-67LJ	A5.5 E9016-G	500	-60	-40**
	AC	LB-88LT	A5.5 E11016-G	690	-60	–
SAW	DCEP	PF-H55AS/US-36J	A5.17 F7A8-EH14 F7P8-EH14	400	-60	-20
		PF-H58AS/US-36J	A5.17 F7A8-EH14 F7P8-EH14	420	-60	-20
		PF-H62AS/US-2N	A5.23 F9A8-EG-Ni2 F9P8-EG-Ni2	500	-60	-20
		PF-H80AS/US-80LT	A5.23 F11A10-EG-G	690	-60	–
	AC	PF-H55LT/US-36	A5.17 F7A8-EH14 F7P8-EH14	400	-60	-50
		PF-H55LT/US-36J	A5.23 F8A8-EG-G	420	-60	-20
		PF-H55S/US-2N	A5.23 F9A10-EG-Ni2 F9P8-EG-Ni2	500	-60	-20
		PF-H78AC/US-2N	A5.23 F10A8-EG-Ni2	550	-60	-10
		PF-H80AK/US-80LT	A5.23 F12A10-EG-G	690	-60	–

※Welding consumables with underline are available for PWHT.
After PWHT, applicable YS may change. Please contact the welding consumable manufacturer about minimum applicable YS class after PWHT.

*vE≧47J
δ≧0.25mm or 0.10mm**

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