NIPPON STEEL

www.nipponsteel.com

NIPPON STEEL CORPORATION
2-6-1 Marunouchi, Chiyoda-ku,Tokyo 100-8071 Japan
Tel: +81-3-6867-4111

Steel Plates for Offshore Structures
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NIPPON STEEL

Steel Plates for Offshore Structures

NET ZERO
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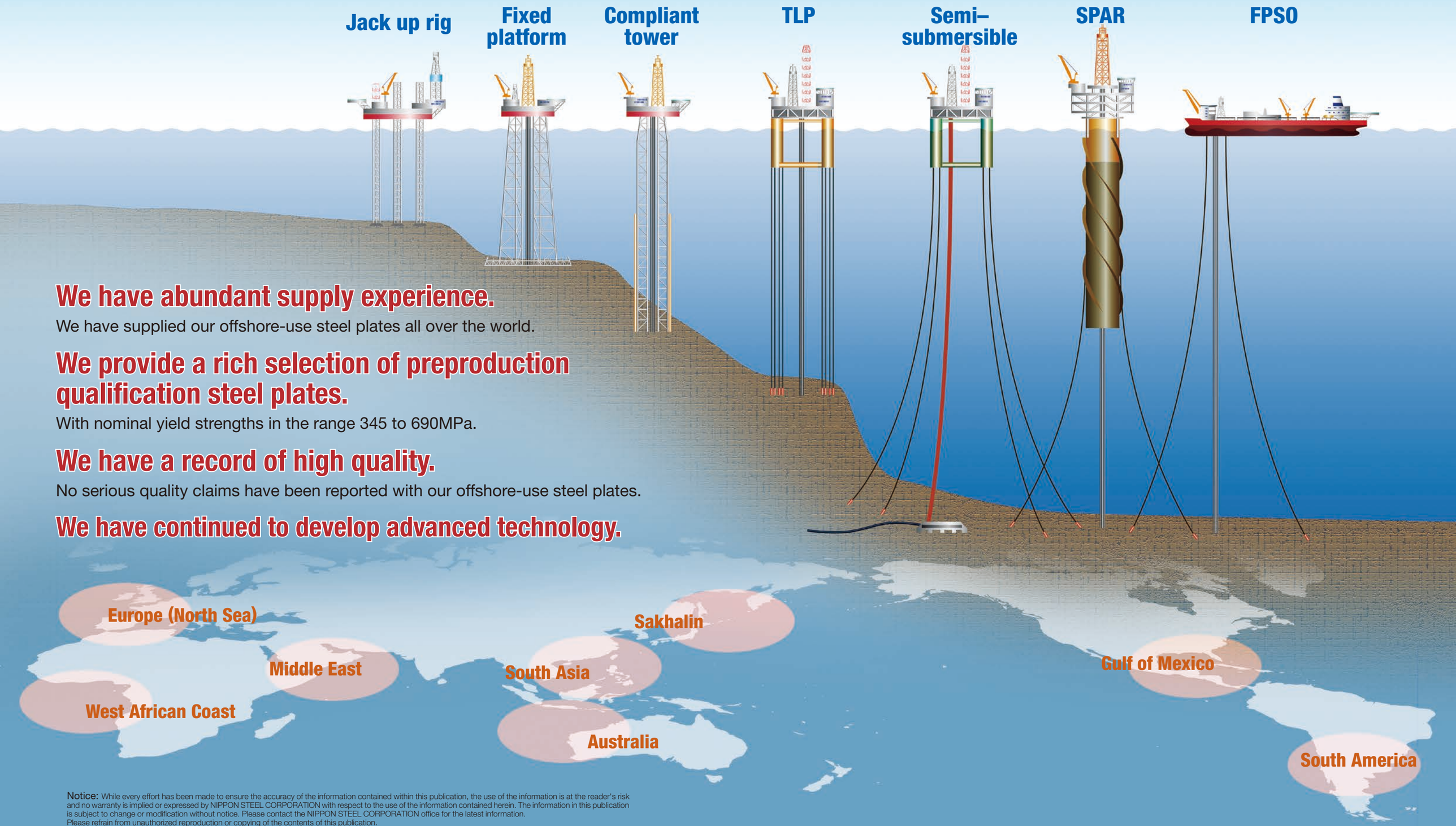
Green Transformation
initiative

NIPPON STEEL CORPORATION

Steel Plates for Offshore Structures



We have abundant supply experience.

We have supplied our offshore-use steel plates all over the world.

We provide a rich selection of preproduction qualification steel plates.

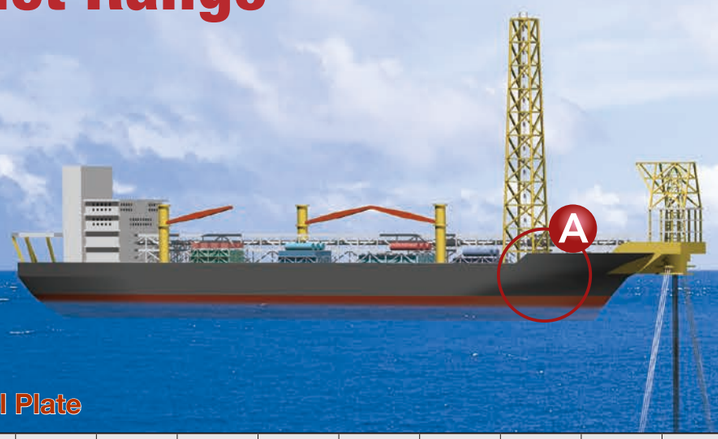
With nominal yield strengths in the range 345 to 690MPa.

We have a record of high quality.

No serious quality claims have been reported with our offshore-use steel plates.

We have continued to develop advanced technology.

Product Range



The majority of plates are supplied in the TMCP (Thermo–Mechanical Control Process) condition up to 101.6 mm (4'') thickness and up to 22 tons weight per plate with nominal yield strengths in the range 235 to 550MPa.

The API, EN and NORSOK standards are applicable for platforms, but the standards of every register of shipping are mainly applied for ship–type structures such as FPSO.

A Hull Steel Plate

Strength Level / Yield Strength (MPa)	AB USA	BV France	CCS China	CR Taiwan	DNVGL Norway Germany	KR Korea	LR UK	NK Japan	Rina Italy	RS Russia
≧235	A B D E	A B D E	A B D E	A B D E	VL A VL B VL D VL E	A B D E	A B D E	A B D E	A B D	A B D E
≧265	–	–	–	–	VL A27S VL D27S VL E27S	–	–	–		–
≧315	AH32 DH32 EH32 FH32	AH32 DH32 EH32 FH32	AH32 DH32 EH32	AH32 DH32 EH32	VL A32 VL D32 VL E32 VL F32	AH32 DH32 EH32 FH32	AH32 DH32 EH32 FH32	KA32 KD32 KE32 KF32	AH32 DH32	AH32 DH32 EH32 FH32
≧355	AH36 DH36 EH36 FH36	AH36 DH36 EH36 FH36	AH36 DH36 EH36	AH36 DH36 EH36	VL A36 VL D36 VL E36 VL F36	AH36 DH36 EH36	AH36 DH36 EH36 FH36	KA36 KD36 KE36 KF36	AH36 DH36	AH36 DH36 EH36 FH36
≧390	AH40 DH40 EH40	AH40 DH40 EH40	AH40 DH40 EH40	AH40 DH40 EH40	VL A40(S) VL D40(S) VL E40(S) VL F40(S)	AH40 DH40 EH40	AH40 DH40 EH40	KA40 KD40 KE40 KF40		AH40 DH40 EH40 FH40
Extra High Strength	FQ43 FQ47 FQ51 EQ56 EQ63 EQ70	E500 E690	E690	–	VL EOW420 VL EOW460 VL EOW500 VL FO420 VL FO460 VL EO500 VL EO550 VL EO620 VL EO690	–	EH42 DH50 DH55 DH62 EH69	KF420 KF460 KF500 KE550 KE620 KF690	–	–

B Primary Structural Steel Plate With Preproduction Qualification

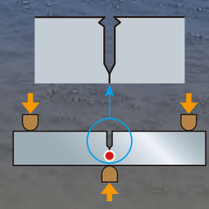
Steel Grade / Yield Strength (MPa)	Maximum Thickness (mm)	API2W	EN10225	NORSOK
355	101.6	Grade 50	S355G7+M S355G8+M S355G9+M S355G10+M	MDS–Y20 MDS–Y25
420	101.6	Grade 60	S420G1+M S420G2+M	MDS–Y30 MDS–Y35
460	101.6 (110)*	—	S460G1+M S460G2+M	MDS–Y40 MDS–Y45
500	70.0	—	—	MDS–Y50 MDS–Y55
550	76.2	Grade 80	(S550M3)	—

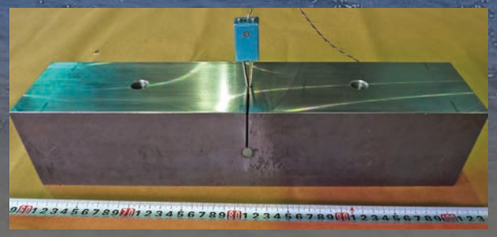
Note: * Supply Condition :QT

Typical Pre-production Qualification Test

Items
Charpy Impact Test, Tensile Test, Through–ThicknessTensile Test, Strain Aged Charpy Impact Test, CTOD Test, Drop Weight Test

CTOD Test

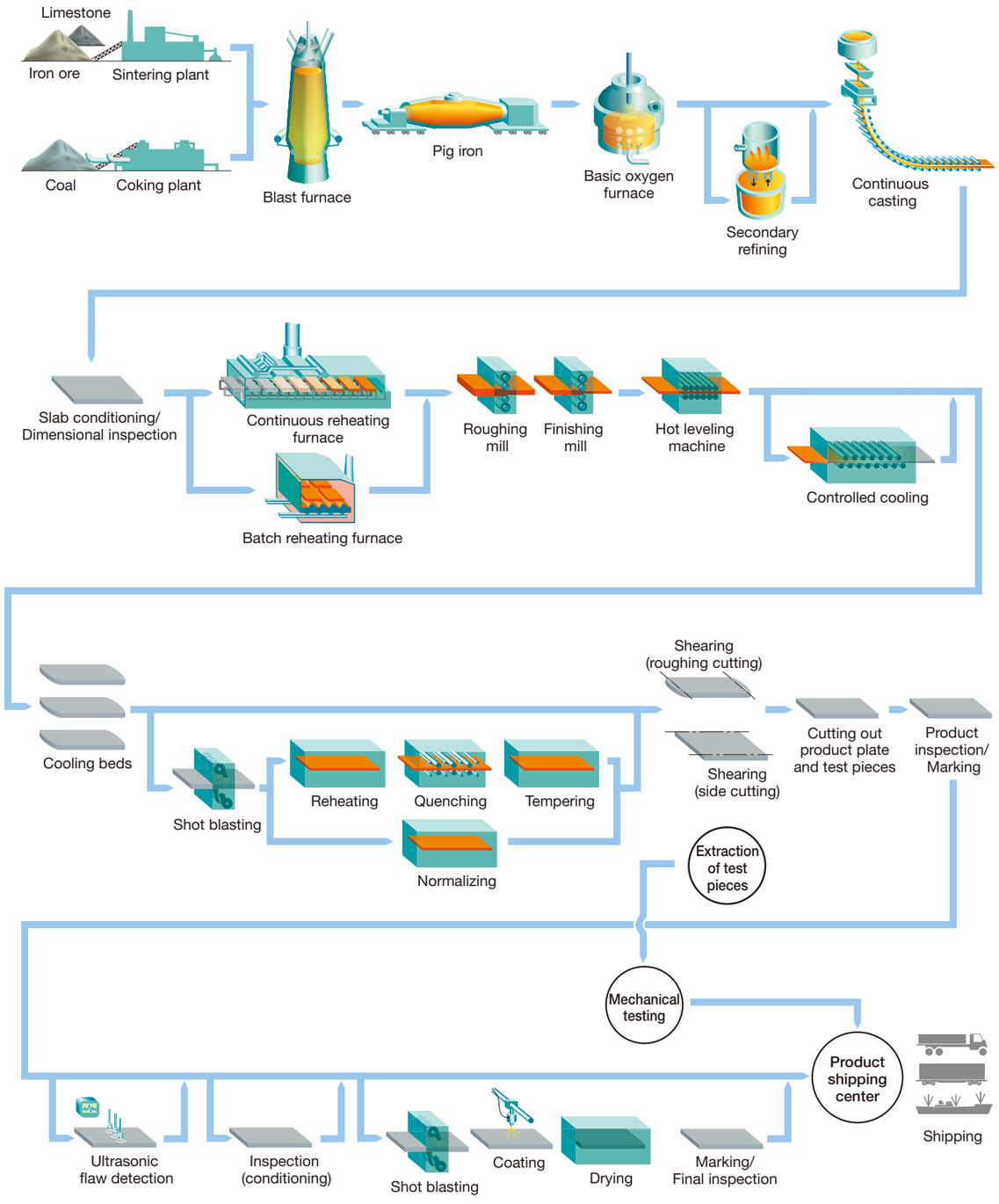




Test Piece

3 Point Bending Machine

Manufacturing Process and Quality Control Points



Thermo–Mechanical Control Process (TMCP)

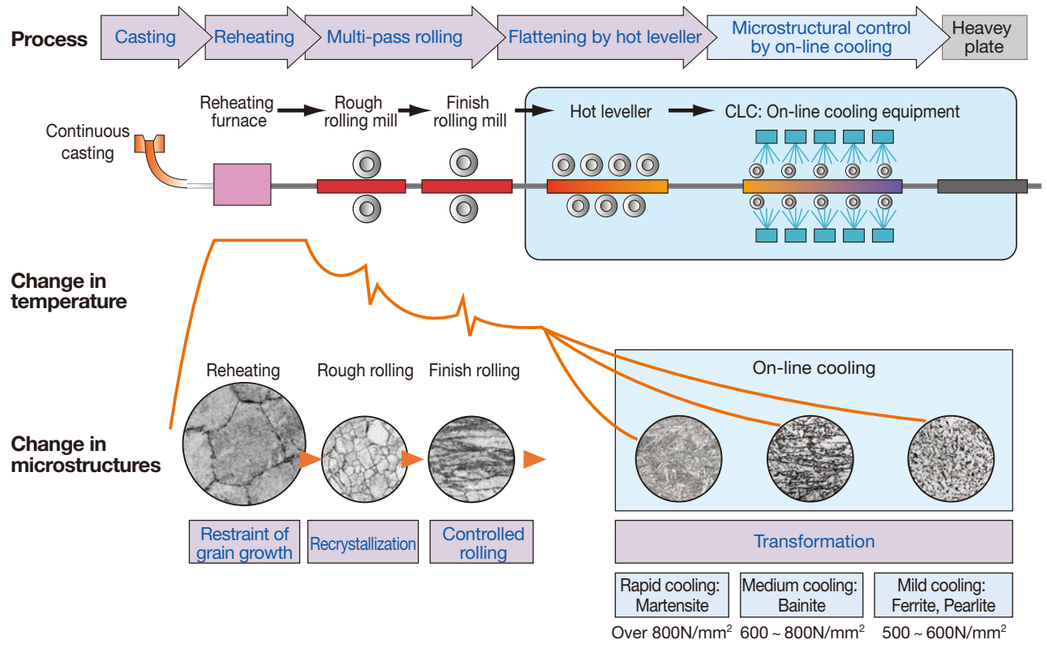
TMCP is applied in high tensile strength thick steel plates of 490MPa or greater, and achieves marked and major improvement in characteristics such as low–temperature toughness and weldability. TMCP is used in a wide variety of fields such as shipbuilding, marine structures, bridges, architecture, industrial machinery, line pipes and tanks.

1. Summary of TMCP

TMCP is a manufacturing process of steel plates based on a combination of controlled rolling and controlled cooling.

When high tensile strength steel of tensile strength ratings of 490MPa or more is manufactured by TMCP, major reduction in the amount of alloying elements added can be achieved, along with lower carbon levels. An outline of equipment used in TMCP is shown in Fig. 1.

Fig. 1 TMCP



* TMCP (Thermo–Mechanical Control Process)
A collective name for all methods of manufacturing steel plates with controlled rolling or controlled rolling combined with accelerated cooling.

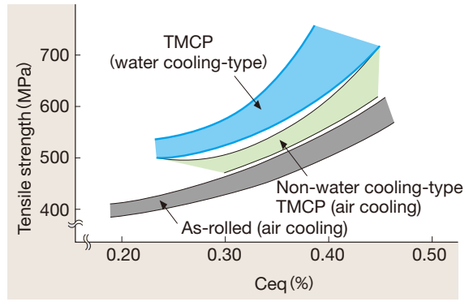
2. Characteristics of high strength TMCP steel

(1) Low Ceq (carbon equivalent)
Toughness has been improved as a result of realization of low Ceq and utilization of TMCP.

(2) About the advantages of using high strength TMCP steel plates
Weldability is greatly improved, and as a result, the following advantages are obtained during use.

- Due to the low P_{CM} level (weld crack sensitivity composition), the preheating temperature at the time of welding can be lower than that of conventional high tensile strength steel
- The maximum hardness of the welded joints can be made lower than that of conventional high tensile strength steel
- Improving toughness of welded joints
- Less deterioration in mechanical properties of the material by linear heat

Fig. 2 Relationship between the conventional manufacturing process and the TMCP in terms of Ceq and strength (plate thickness of 20 to 30 mm)

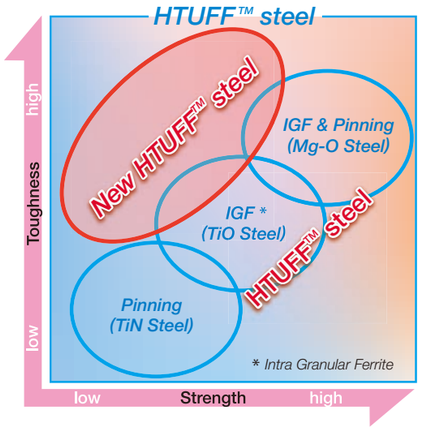


Improvement of HAZ Toughness

● Basic concept

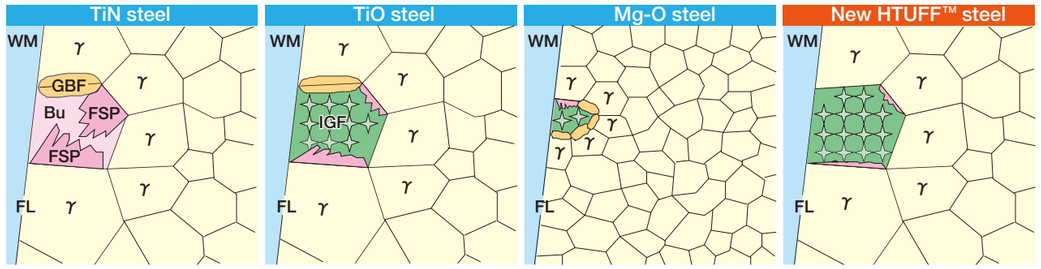
Metallurgical factors	Measures
Refinement of effective grain size in HAZ (HTUFF™)	• Inhibition of austenite grain coarsening by fine particles such as TiN
	• Utilization of intra granular ferrite（IGF）nucleated from particles such as Ti_2O_3
	• Utilization of both the above measures by dispersing high–temperature–stable oxide and sulfide particles
Decrease of MA–constituents	• Reduction in carbon content and carbon equivalent • Reduction in silicon, alminium and niobium content
Improvement of matrix toughness	• Fixation of free nitrogen such as TiN, AlN, etc. • Addition of nickel

● Concept of HTUFF™ steel



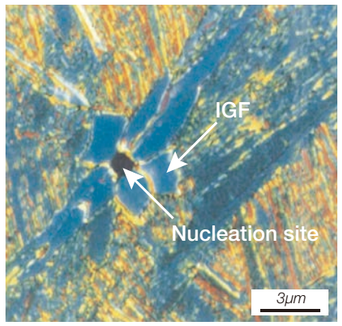
* HTUFF : High HAZ Toughness technology with Fine microstructure imparted by Fine particles

● Concept of controlling microstructure

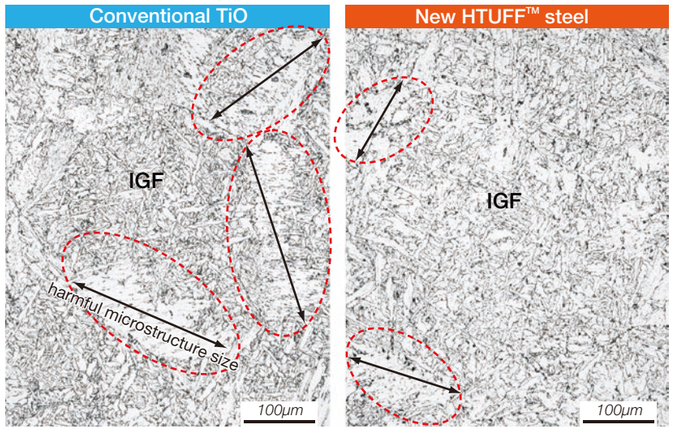


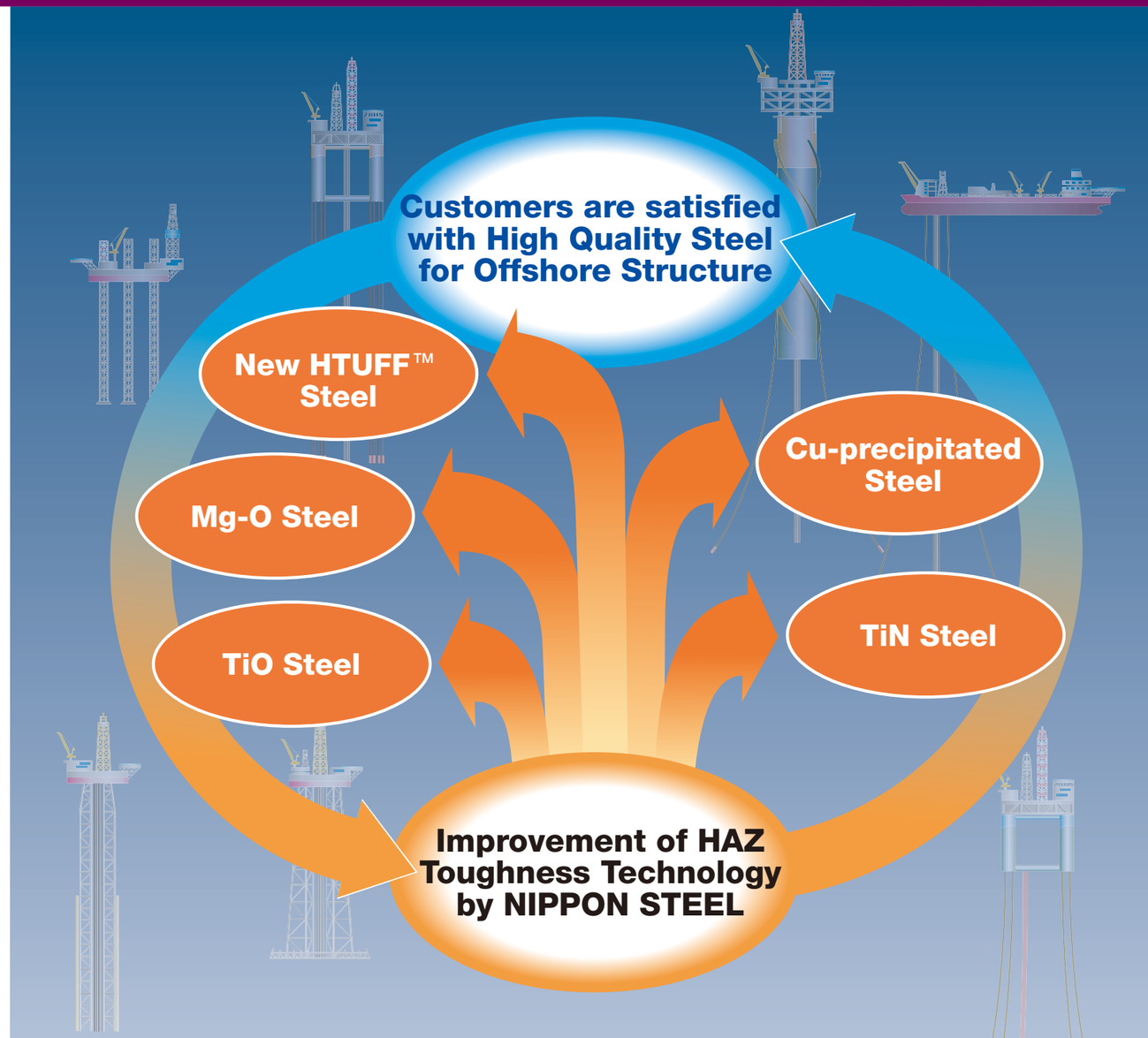
WM: Weld Metal **FL**: Fusion Line γ : Austenite **GBF**: Grain Boundary Ferrite **FSP**: Ferrite Side Plate **IGF**: Intra-granular Ferrite **Bu**: Upper Bainite

● IGF formed in HAZ of TiO

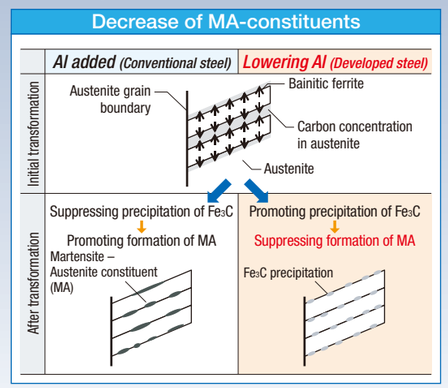


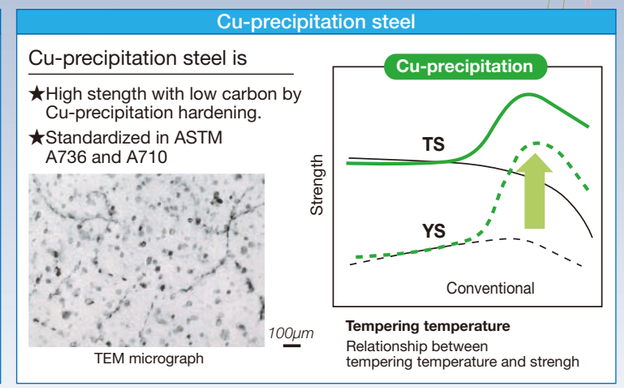
● Comparison of HAZ microstructure of TiO steel and New HTUFF™ steel





● Concept of decrease of MA-constituents and Cu-precipitation steel





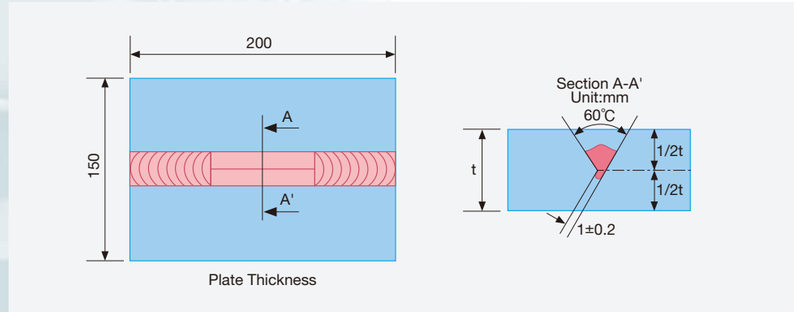
Primary Steel with Pre–Production Qualification

Grade 50～80

(YS355～550MPa)

Typical y–Groove Cracking Test Result

Yield Strength (MPa)	Thickness (mm)	Welding Method	H.I (kJ/mm)	Preheat Temp (°C)	Crack		
					Surface	Root	Section
≧355	101.6	SMAW	1.6	24	0%	0%	0%
≧420	101.6	SMAW	0.7	25	0%	0%	0%
≧460	101.6	SMAW	0.7	25	0%	0%	0%
≧500	70.0	SMAW	1.7	25	0%	0%	0%
≧550	76.2	SMAW	0.7	25	0%	0%	0%



Typical Chemical Composition

(mass%)

Yield Strength (MPa)	Thickness (mm)	C	Si	Mn	P	S	Others	Ceq	Pcm
≧355	101.6	0.07	0.13	1.51	0.003	0.002	Cu、Ni、Nb etc.	0.39	0.18
≧420	101.6	0.04	0.11	1.36	0.003	0.002	Cu、Ni、Nb etc.	0.42	0.19
≧460	101.6	0.04	0.10	1.41	0.003	0.002	Cu、Ni、Nb etc.	0.43	0.19
≧500	70.0	0.09	0.12	1.63	0.007	0.002	Cu、Ni、Nb etc.	0.44	0.21
≧550	76.2	0.03	0.12	1.09	0.004	0.003	Cu、Ni、Nb etc.	0.48	0.19

Note: Pcm=C+Si/30+(Mn+Cu+Cr)/20+Ni/60+Mo/15+V/10+5B
Ceq=C+Mn/6+(Cu+Ni)/15+(Cr+Mo+V)/5

Typical Mechanical Properties

Yield Strength (MPa)	Thickness (mm)	Tensile Test			Through–Thickness Tensile Test		Charpy Impact
		Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%)	Tensile Strength (MPa)	RA (%)	vTrs (°C)
≧355	101.6	395	511	37	505	77	–89
≧420	101.6	505	584	32	548	79	–91
≧460	101.6	471	527	31	510	82.1	–109
≧500	70.0	522	629	22	578	65	–100
≧550	76.2	589	663	30	658	77	–117

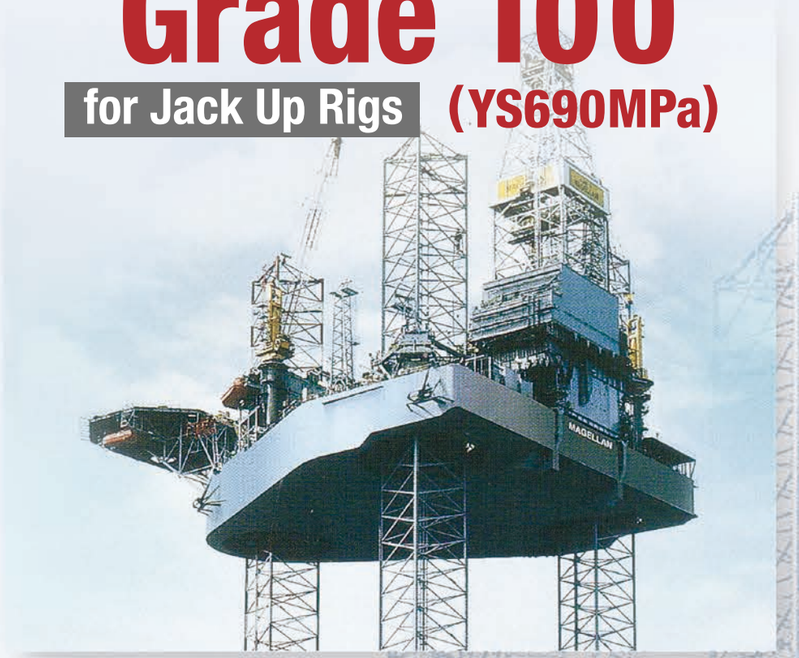
Typical CTOD Test Result of Welded Joint

Yield Strength (MPa)	Thickness (mm)	CTOD Value at –10°C (mm)		
		Low	Middle	High
		0.7 kJ/mm FCAW	3.0~3.5 kJ/mm SAW	4.5~5.0 kJ/mm SAW
≧355	101.6	≧0.44	≧1.33	≧0.99
≧420	101.6	≧0.48	≧1.40	≧0.92
≧460	101.6	≧1.23	≧1.23	≧0.99
≧500	70.0	≧0.85	≧0.92	—
≧550	76.2	≧0.65	≧0.81	≧0.89

Primary Steel with Pre–Production Qualification

Grade 100

for Jack Up Rigs (YS690MPa)



Specification

Class	Tensile Test			
	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%)	Specimen
YS690	≧690	780-930	≧16 (t≦16mm) ≧24 (t>16mm)	JIS No.5 (GL =200mm)
			≧16 (t>20mm)	JIS No.4 (GL =50mm)

Class	Charpy Impact Test		
	Test temperature (℃)	Position	Average absorbed energy (J)
YS690	-40	1/4t-L	≧69
	-60	1/4t-L	≧69

Typical Chemical Composition

(mass%)

Class	Thickness (mm)	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	B	Ceq
YS690	177.8	0.12	0.25	1.07	0.006	0.001	Added					0.001	0.66
	210.0	0.11	0.26	1.05	0.005	0.001	Added					0.001	0.83
	254.0	0.10	0.05	1.03	0.003	0.001	Added					0.09	0.91

Note: Ceq=C+Mn/6+(Cu+Ni)/15+(Cr+Mo+V)/5

Available Thickness

Greater thickness or other standards within this yield strength range may be possible on request.

Class	Grade	Ship Classification	Maximum Thickness (mm)
YS690	NVE0690 EQ70	DNV ABS	254 254

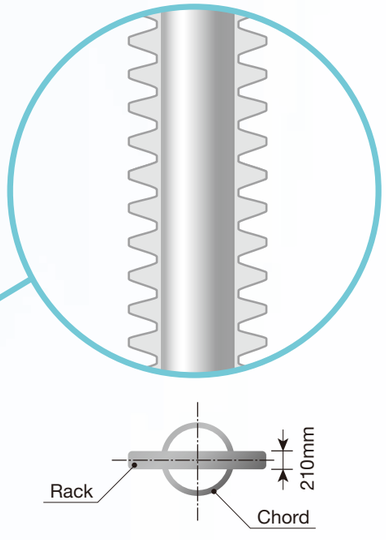
Note: ∗1 NIPPON STEEL's Standard

Typical Mechanical Properties

Class	Thickness (mm)	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%)	Specimen
YS690	177.8	822	884	20	JIS No.4
	210.0	782	866	20	5.65√S
	254.0	745	828	22	5.65√S

Class	Test temperature (℃)	Positon	Average absorbed energy (J)
YS690	-40	1/4t-L	206
	-60	1/4t-L	89

Jack Up Rig



Welding Materials

Steel Grade	Welding Process *1	Production Name *2 (Shield Gas)	AWS Classification	Application		
				Position	CVN (℃)	CTOD (℃) *3
YS305MPa -YS400MPa	Submerged Arc Welding (SAW)	NB-55×Y-DS (Flux) (Wire)	A5.17 F7A8-EH14 F7P8-EH14	Flat Position Welding	–40 ~ –60	–40
		NB-55L×Y-D	A5.23 F7A8-EG-G F7P8-EG-G		–40 ~ –60	–20
		NB–55E × Y-DM3	A5.23 F8A4-EG-G	ditto (Two-run Welding)	–20 ~ –40	—
	Flux Cored Arc Welding (FCAW)	SF-3M (CO_2)	A5.36 E71T1-C1A4-CS1 / A5.20 E71T-9C-J *4	All Position Welding	–20 ~ –40	–10
		SF-3A (Ar-CO_2)	A5.36 E71T1-M21A4-CS1 / A5.20 E71T-9M-J *4		–20 ~ –40	–10
		SF-36E (CO_2)	A5.36 E81T1-C1A8-K2-H4 / A5.29 E81T1-GC *4		–40 ~ –60	–10 ~ –20
	Covered Arc Welding (SMAW)	L-55SN	A5.5 E7016-G	All Position Welding	–40 ~ –60	–40
	Gas Metal Arc Welding (GMAW)	YM-1N (Ar-CO_2)	A5.28 ER80S-G	All Position Welding	–40 ~ –60	–10
YS420MPa -YS460MPa	SAW	NB-55×Y-CMS	A5.23 F8A8-EA4-A4 F8P8-EA4-A4	Flat Position Welding	–40 ~ –60	–40
	FCAW	SF-3E (CO_2)	A5.36 E81T1-C1A4-CS1 / A5.29 E81T1-GC *4	All Position Welding	–20 ~ –40	–10
		SF-47E (CO_2)	A5.36 E81T1-C1A8-Ni1-H4 / A5.29 E81T1-Ni1C-J *4		–40 ~ –60	–10 ~ –30
		SF-3AM (Ar-CO_2)	A5.36 E81T1-M21A8-Ni1-H4 / A5.29 E81T1-GC *4		–40 ~ –60	–10 ~ –40
	SMAW	L-60	A5.5 E8016-G	All Position Welding	–20 ~ –40	—
	GMAW	YM-3N (Ar-CO_2)	A5.28 ER80S-G	All Position Welding	–40 ~ –60	—
YS500MPa	FCAW	SF–50E (CO_2)	A5.36 E91T1-C1A8-Ni2-H4 / A5.29 E91T1-Ni1C-J *4	All Position Welding	–40 ~ –60	–40
		SF–50A (Ar–CO_2)	A5.36 E91T1-M21A4-K2-H4 / A5.29 E91T1-GM *4		–20 ~ –40	–10
	SAW	NB-250H×Y-204B	A5.23 F9A8-EG-G F9P8-EG-G	Flat Position Welding	–40 ~ –60	–10
	SMAW	L-60LT	A5.5 E9016–G	All Position Welding	–40 ~ –60	—
	GMAW	YM-70A (Ar-CO_2)	A5.28 ER100S-G	All Position Welding	–20 ~ –40	—
YS550MPa	FCAW	SF–70A (Ar-CO_2)	A5.36 E101T1-M21A4-K2-H4 / A5.29 E101T1-GM *4	All Position Welding	–20 ~ –40	–20
	SAW	NB-55×Y-DMS	A5.23 F9A8-EA3-G F9P8-EA3-G	Flat Position Welding (AC Only)	–20 ~ –40	–10
	SMAW	L-60LT	A5.5 E9016–G	All Position Welding	–40 ~ –60	—

Steel Grade	Welding Process	Production Name (Shield Gas)	AWS Classification	Appication	
				Position	CVN (℃)
YS690MPa	SAW	NB-250J×Y-80J	A5.23 F11A8-EG-M3	Flat Position Welding	–40 ~ –60
	SMAW	L-80SN	A5.5 E11016-G	All Position Welding	–40 ~ –60
	GMAW	YM-80A (Ar-CO_2)	A5.28 ER110S-G	All Position Welding	–40
		YM-69F (Ar-CO_2)	A5.28 ER110S-G		–60

Note: *1: Applicable polarity; SAW = AC and/or DCEP, FCAW & GMAW = DCEP, SMAW = AC or DCEP
*2: NIPPON STEEL WELDING & ENGINEERING Co.,Ltd. (NSWE).
*3: Information only
*4: AWS A5.20 and A5.29 were replaced into A5.36 on the end of 2015.