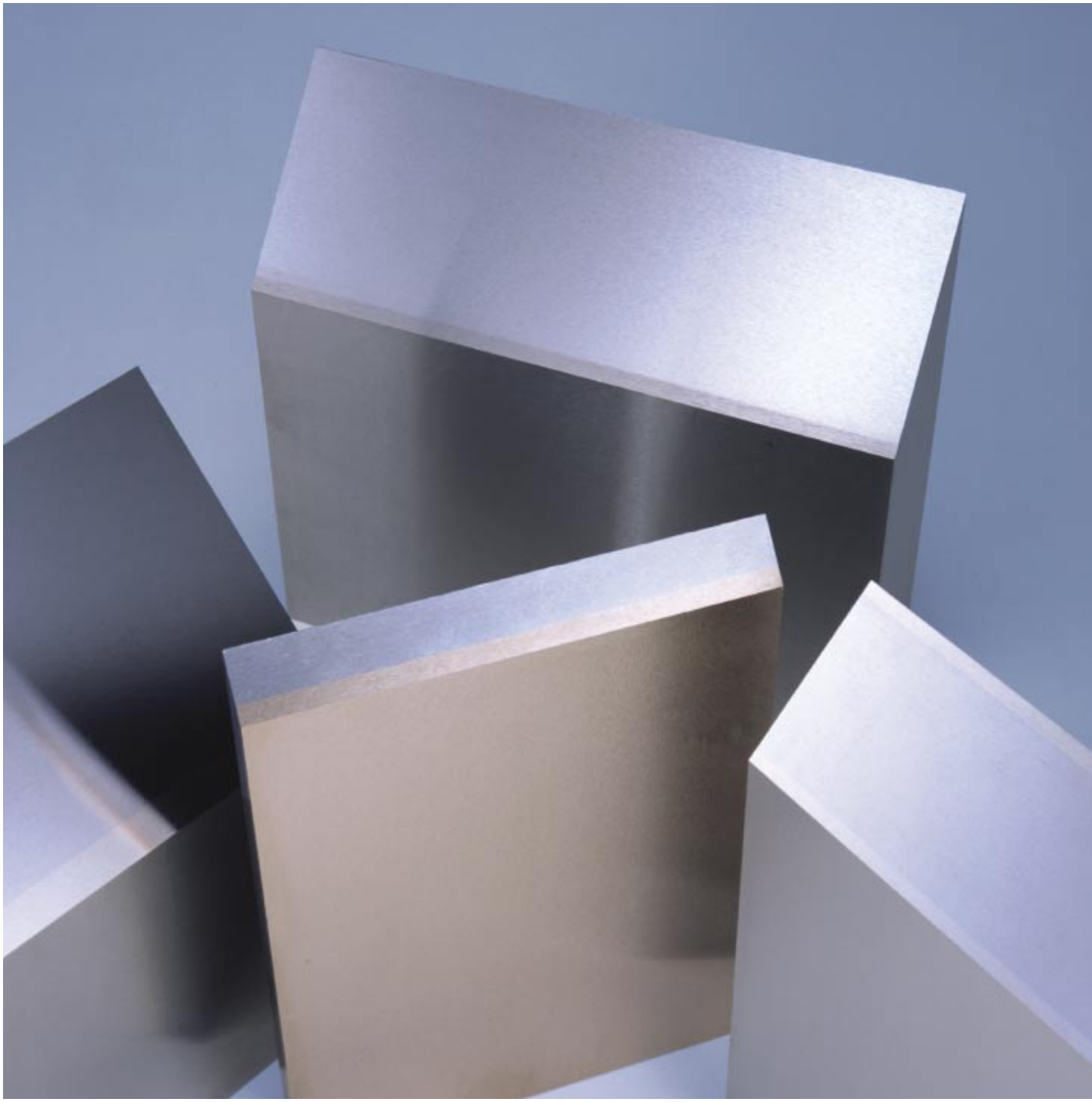
CLAD STEEL PLATE



JFE Steel Corporation

CLAD STEEL PLATE

Contents

Introduction

Clad steel plate is a composite steel plate made by bonding stainless steel plate, etc. (cladding material) to either or both sides of a carbon steel or low alloy steel plate (base metal).

Therefore, clad steel plate not only has sufficient strength required of structural materials (base metal) but provides other functions including resistance to heat and corrosion (cladding material) and is still lower in cost than similar products made entirely of the cladding material.

Consequently, clad steel plate is used in a variety of industrial fields including shipbuilding, construction and manufacturing of various tanks.

JFE started commercial production of clad steel plate in 1983, by combining its production know-how for high-grade steel plates used in the past with the very latest achievements in research and development.

Although the manufacturing method of clad steel plate comes in a variety of versions, **JFE** has been producing "rolled clad steel." Its features include:

(1) Excellent bonding characteristics

(2) Stable performance

(3) Availability of wider and longer steel plate

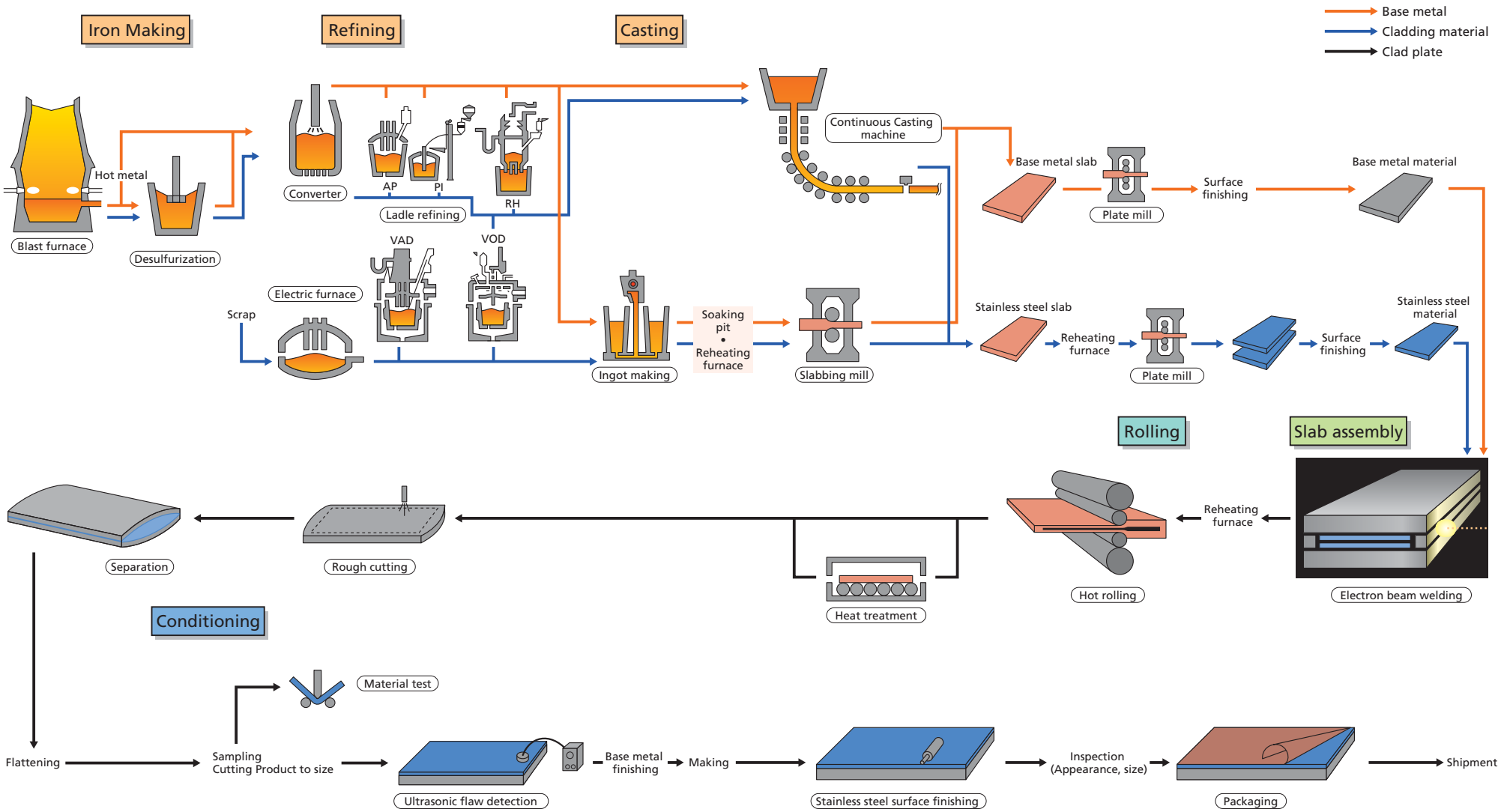
(4) Excellent dimensional accuracy

(5) Quicker and precise delivery

JFE, ever since starting commercial production of its clad steel plate, has been meeting stringent customer's requirements for a wide range of applications. We are confident you too will find **JFE** clad steel plate to be highly satisfactory in every respect.

Manufacturing

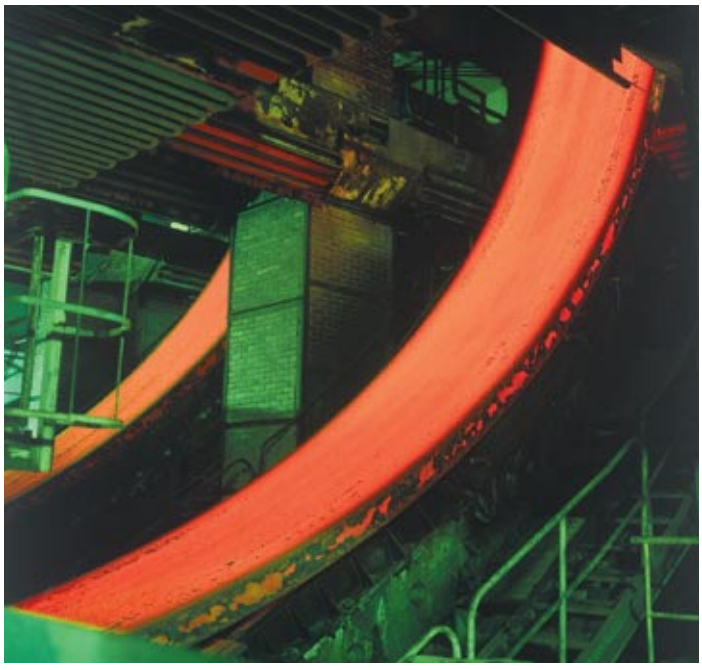
The manufacturing process for stainless clad steel is shown below as an example of JFE's clad steel plate production.



Manufacturing

Blast furnace

Converter (BOF)



Continuous Casting

Plate mill

Surface finishing

Packaging

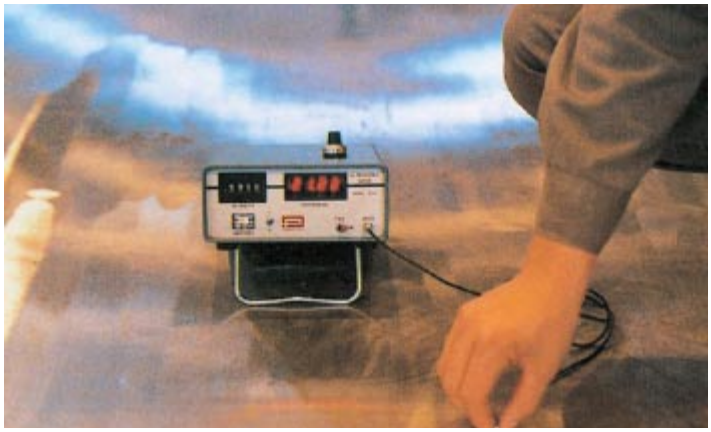


Plate thickness measurement

Shear strength test

Available Products

(1) Applicable standards for clad steel plate

The following standards are applicable as a rule.

JIS G 3601	"Stainless clad steels"
JIS G 3602	"Nickel and nickel alloy clad steels"
JIS G 3603	"Titanium Clad steels"
JIS G 3604	"Copper and copper alloy clad steel"
ASTM A263 (ASME SA-263)	"Standard specification for Corrosion-Resisting Chromium Steel Clad Plate, Sheet and Strip"
ASTM A264 (ASME SA-264)	"Standard specification for Stainless Chromium-Nickel Steel Clad Plate, Sheet and Strip"
ASTM A265 (ASME SA-265)	"Standard specification for Nickel and Nickel-Base Alloy Clad Steel Plate"
ASTM B432	"Standard specification for Copper and Copper Alloy Clad Steel Plate"

(2) Base metal

JIS

G3101	Rolled steels for general structure SS400
G3106	Rolled steels for welded structure SM400, 490, 490Y, etc.
G3103	Carbon Steel and Molybdenum Alloy Steel Plates for Boilers and Other Pressure Vessels SB410, 450, 480, 450M, 480M
G3115	Steel plates for pressure vessels for intermediate temperature service SPV235, 315, 355, 450, 490
G3118	Carbon steel plates for pressure vessels for intermediate and moderate temperature service SGV410, 450, 480
G4109	Chromium-molybdenum alloy steel plates for boilers and pressure vessels SCMV2, 3, 4
G3126	Carbon steel plates for pressure vessels for low temperature service SLA235, 325, 360

ASTM (ASME)

Pressure vessel use carbon steel plate (s) A516, (S)A285, etc.
Pressure vessel use low-alloy steel plate (s) A204, (S)A387, etc
Structural carbon steel plate A36, A283, etc

Other standards to which JFE currently produces steel plates, such as, BS, various ship classification society standards and JFE specifications, are also applicable.

(3) Cladding Materials

Stainless steel

	ASTM Type	Chemical Composition (%)										Available size
		C (max.)	Si (max.)	Mn (max.)	P (max.)	S (max.)	Ni	Cr	Mo	N	Ti	Others	
Ferritic or Martensitic	430	0.12	1.00	1.00	0.040	0.030	≦0.75	16.0 ～18.0	—	—	—		Table1 Table2
	410S	0.08	1.00	1.00	0.040	0.030	≦0.60	11.5 ～13.5	—	—	—		
Austenitic	304	0.08	0.75	2.00	0.045	0.030	8.0 ～10.5	18.0 ～20.0	—	≦0.10	—		
	304L	0.030	0.75	2.00	0.045	0.030	8.0 ～12.0	18.0 ～20.0	—	≦0.10	—		
	316	0.08	0.75	2.00	0.045	0.030	10.0 ～14.0	16.0 ～18.0	2.00 ～3.00	≦0.10	—		
	316L	0.030	0.75	2.00	0.045	0.030	10.0 ～14.0	16.0 ～18.0	2.00 ～3.00	≦0.10	—		
	316LN	0.03	0.75	2.00	0.045	0.030	10.0 ～14.0	16.0 ～18.0	2.00 ～3.00	0.10 ～0.16	—		
	317	0.08	0.75	2.00	0.045	0.030	11.0 ～15.0	18.0 ～20.0	3.0 ～4.0	≦0.10	—		
	317L	0.030	0.75	2.00	0.045	0.030	11.0 ～15.0	18.0 ～20.0	3.0 ～4.0	≦0.10	—		
	321	0.08	0.75	2.00	0.045	0.030	9.0 ～12.0	17.0 ～19.0	—	≦0.10	5×(C+N) min. 0.70 max.		
	347	0.08	0.75	2.00	0.045	0.030	9.0 ～13.0	17.0 ～19.0	—	—	—	Nb:10×C min. 1.0 max.	

(Note) Cladding materials can also be produced to specifications other than those listed in the table, as well as corresponding JIS, ASME and ship clasification society specifications.

Copper and Copper alloy

ASTM		Chemical Composition (%)									Available size
		Cu (including Ag)	Pb	Fe	Zn	Mn	Ni (including Co)	P	others		
B152	C10200	≧99.95	—	—	—	—	—	—	O≦0.0010	Oxygen free copper	Table 3
B171	C70600	remainder	≦0.05	1.0 ～1.8	≦1.0	≦1.0	9.0 ～11.0	—	—	Cupro-nickel(9/1)	
	C71500	remainder	≦0.05	0.40 ～1.0	≦1.0	≦1.0	29.0 ～33.0	—	—	Cupro-nickel(7/3)	

(Note) JIS specifications corresponding above specifications are also applicable.

Nickel and Nickel-Copper alloy

ASTM		Chemical Composition (%)								Available size
		Ni	Cu	Fe	Mn	C	Si	S		
B162	N02200	≧99.0	≦0.25	≦0.40	≦0.35	≦0.15	≦0.35	≦0.01	Nickel	Table 4
	N02201	≧99.0	≦0.25	≦0.40	≦0.35	≦0.02	≦0.35	≦0.01	Low carbon Nickel	
B127	N04400	≧63.0	28.0 ～34.0	≦2.5	≦2.0	≦0.3	≦0.5	≦0.024	Nickel-Copper alloy	

(Note) JIS specifications corresponding above specifications are also applicable.

Titanium

ASTM (B265)	Chemical Composition (%)							Residuals	Available size
	C	H	O	N	Fe	Pd	Ti		
Grade 1	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20		balance	each ≦0.1 total ≦0.4	Table 5
Grade 2	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30		balance	each ≦0.1 total ≦0.4	
Grade 11	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20	0.12 ～0.25	balance	each ≦0.1 total ≦0.4	
Grade 7	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	0.12 ～0.25	balance	each ≦0.1 total ≦0.4	

(Note) JIS specifications corresponding above specifications are also applicable.

Available Sizes

●Stainless clad steel plate

Table1 Ferritic and austenitic stainless (One side cladding)

(Maximum plate length : m)

Thickness (mm) \ Width (mm)	1000 ～ 1500	1501 ～ 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 ～ 5000
6.0 ～ 8.0	13													N.A.	
8.1 ～ 10.0	15														
10.1 ～ 16.0													16	15	Range to be consulted
16.1 ～ 18.0											16	15			
18.1 ～ 20.0	17								16	15					
20.1 ～ 22.0								16	15						
22.1 ～ 24.0						16	15								
24.1 ～ 26.0					16	15									
26.1 ～ 28.0					15										
28.1 ～ 30.0				16											
30.1 ～ 32.0		16		15											
32.1 ～ 34.0		15							14						
34.1 ～ 36.0															
36.1 ～ 38.0															
38.1 ～ 40.0															
40.1 ～ 50.0											13	12		11	
50.1 ～ 60.0							13	12		11	10		9.5	9	
60.1 ～ 70.0					13	12	11		10	9.5	9	8.5	8	7.5	
70.1 ～ 80.0			13		12	11	10	9.5	9	8		7		6.5	
80.1 ～ 90.0			12	11	10	9.5	9	8		7		6.5	6		
90.1 ～ 100.0	12		11	10	9	8.5	8	7.5	7	6.5	6	5.5		5	
100.1 ～ 120.0	11	10.5	9.5	8.5	8	7	6.5	6		5.5	5		4.5		
120.1 ～ 150.0	Range to be consulted														

(Note) 1. Thickness means overall thickness (base metal + cladding material)

2. The thickness of a cladding material is shown in table 6
3. Minimum size : 1m wide × 3m long
4. Plate size exceeding 14m in length is to be consulted.
5. Delivery time and quantity of clad plate in the range to be consulted are restricted.
6. Plate size is further limited for heat treated plate, please consult JFE

Table2 Ferritic and austenitic stainless (Both sides cladding)

(Maximum plate length : m)

Width (mm) / Thickness (mm)	1000 ～ 1500	1501 ～ 2000	2001 ～ 2500	2501 ～ 3000	3001 ～ 3500	3501 ～ 4000	4001 ～ 4500
10.1 ～ 12.0	14				Range to be consulted		Range to be consulted
12.1 ～ 16.0							
16.1 ～ 18.0							
18.1 ～ 20.0						13	
20.1 ～ 22.0						12	
22.1 ～ 24.0					13	11	
24.1 ～ 26.0					12	11	
26.1 ～ 28.0				13	11	10	
28.1 ～ 30.0				12	10	9	
30.1 ～ 35.0			13	11	9	8	
35.1 ～ 40.0			12	10	8	7	
40.1 ～ 60.0	Range to be consulted						

(Note) 1. Thickness means overall thickness (cladding material + base metal + cladding material)
2. The thickness of a cladding material is shown in table 6
3. Minimum size : 1m wide × 3m long
4. Delivery time and quantity of clad plate in the range to be consulted are restricted.
5. Austenitic and 410S 430 stainless steel are applicable as cladding material.

●Copper and Copper ally clad Steel plate

Table3 Copper and Copper alloy

(Maximum plate length : m)

Width (mm) / Thickness (mm)	1000 ～ 2000	2001 ～ 2200	2201 ～ 2400	2401 ～ 2600	2601 ～ 2800	2801 ～ 3000	3001 ～ 3200	3201 ～ 3400	3401 ～ 3500
6.0 ～ 8.0	13						N.A.		
8.1 ～ 10.0	14								
10.1 ～ 16.0									
16.1 ～ 18.0									
18.1 ～ 20.0									
20.1 ～ 22.0									
22.1 ～ 24.0									
24.1 ～ 26.0									
26.1 ～ 28.0									
28.1 ～ 30.0									
30.1 ～ 32.0									
32.1 ～ 34.0									13
34.1 ～ 44.0					13		12	11	
44.1 ～ 50.0				13	N.A.				

(Note) 1. Thickness means overall thickness (base metal + cladding material)
2. The thickness of a cladding material is shown in table 6
3. Minimum size : 1m wide × 3m long
4. Plate size is further limited depending on thickness of cladding material

●Nickel and Nickel alloy clad steel plate

Table4 Nickel and Nickel alloy

(Maximum plate length : m)

Thickness (mm) \ Width (mm)	1000 ～ 2000	2001 ～ 2500	2501 ～ 3000	3001 ～ 3500	3501 ～ 4000	4501 ～ 4200
6.0 ～ 8.0	14				N.A.	
8.1 ～ 10.0						
10.1 ～ 16.0						
16.1 ～ 18.0						
18.1 ～ 20.0					13	
20.1 ～ 22.0					12	
22.1 ～ 24.0				13	11	
24.1 ～ 26.0				12		
26.1 ～ 28.0			13	11	10	
28.1 ～ 30.0			12	10	9	
30.1 ～ 35.0		13	11	9	8	
35.1 ～ 40.0		12	10	8	7	
40.1 ～ 50.0	11	9	7	6	5	
50.1 ～ 60.0	10	8	6	5	4	
60.1 ～ 70.0	9	7	5	4	N.A.	

(Note) 1. Thickness means overall thickness (base metal + cladding material)
2. The thickness of a cladding material is shown in table 6
3. Minimum size : 1m wide × 3m long
4. Plate size is further limited depending on thickness of cladding material

●Titanium Clad Steel Plate

Table 5-1 Available size (For Tube plate)

(Maximum plate length : m)

Thickness (mm) \ Width (mm)	1000 ～ 2000	2001 ～ 2500	2501 ～ 3000	3001 ～ 3200	3201 ～ 3400	3401 ～ 3600	3601 ～ 3800	3801 ～ 3900
6.0 ～ 8.0	10			N.A.				
8.1 ～ 10.0	11			9				
10.1 ～ 12.0							9	8
12.1 ～ 16.0								7
16.1 ～ 20.0	10					9	7	6
20.1 ～ 24.0				9		8	6	5
24.1 ～ 28.0				8		7.5		
28.1 ～ 30.0			9			6	5.5	
30.1 ～ 32.0					7.5			
32.1 ～ 34.0					6	5		
34.1 ～ 36.0	7							
36.1 ～ 38.0								
38.1 ～ 40.0								
40.1 ～ 42.0								
42.1 ～ 44.0								
44.1 ～ 46.0	6							
46.1 ～ 48.0								
48.1 ～ 50.0								
50.1 ～ 52.0								
52.1 ～ 54.0								
54.1 ～ 56.0								
56.1 ～ 58.0								
58.1 ～ 60.0	5							
60.1 ～ 62.0		4						
62.1 ～ 64.0								
64.1 ～ 66.0								
66.1 ～ 68.0								
68.1 ～ 70.0								
70.1 ～ 72.0	4	3						

(Note) 1. Thickness means overall thickness (base metal + cladding material)

2. The thickness of a cladding material is shown in table 6

3. Minimum size : 1m wide × 3m long

Table 5-2 Available size (For Shell Plate)

(Maximum plate length : m)

Thickness (mm) \ Width (mm)	1000 ～ 2000	2001 ～ 2500	2501 ～ 3000	3001 ～ 3200	3201 ～ 3400	3401 ～ 3600	3601 ～ 3800
6.0 ～ 8.0	10			N.A.			
8.1 ～ 10.0	11			9			
10.1 ～ 12.0							9
12.1 ～ 16.0							
16.1 ～ 20.0	10						
20.1 ～ 24.0						9	7
24.1 ～ 28.0				9		8	6
28.1 ～ 30.0				8		7.5	
30.1 ～ 32.0							
32.1 ～ 34.0			9			6	5.5
34.1 ～ 36.0							N.A.
36.1 ～ 38.0						5.5	
38.1 ～ 40.0					7.5		

(Note) 1. Thickness means overall thickness (base metal + cladding material)
2. The thickness of a cladding material is shown in table 6
3. Minimum size : 1m wide × 3m long

Table 5-3 Available size (For Liner plate with sea water corrosion resistance)

(Maximum plate length : m)

Thickness (mm) \ Width (mm)	1000 ～ 2000	2001 ～ 2500	2501 ～ 3000	3001 ～ 3200	3201 ～ 3400
5.0 ～ 5.9	10		N.A.		
6.0 ～ 8.0					
8.1 ～ 10.0	11			9	
10.1 ～ 12.0				10	

(Note) 1. Thickness means overall thickness (base metal + cladding material)
2. The thickness of a cladding material is shown in table 6
3. Minimum size : 1m wide × 3m long

●Cladding material

Table 6 Thickness of cladding material

(mm)

Total thickness (mm)	One side clad stainless steel		Both side clad stainless steel*		Ni, Ni-alloy		Cu-cu alloy				Titanium	
							Cupro (7/3, 9/1)		Oxygen free Copper Al bronze			
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
6.0 ～ 8.0	1.5	3.0			1.5	3.0	1.5	2.5	1.5	2.5	1.5	2.5
8.1 ～ 10.0	1.5	4.0	1.5**	2.0**	2.0	4.0	2.0	3.0	2.0	3.0	2.0	3.0
10.1 ～ 12.0	1.5	5.0	1.5	2.5	2.0	5.0	2.0	4.0	2.0	4.0	2.0	3.0
12.1 ～ 14.0	1.5	6.0	1.5	3.0	2.0	6.0	2.0	5.0	2.0	4.0	2.0	4.0
14.1 ～ 16.0	1.5	6.0	1.5	3.0	2.0	6.0	2.0	5.0	2.0	4.0	2.0	4.0
16.1 ～ 18.0	2.0	6.0	2.0	3.0	2.0	6.0	2.0	5.0	2.0	4.0	2.0	5.0
18.1 ～ 20.0	2.0	6.0	2.0	3.0	2.0	6.0	2.0	5.0	2.0	4.0	2.0	5.0
20.1 ～ 22.0	2.0	6.0	2.0	3.0	2.0	6.0	2.0	5.0	2.0	5.0	2.0	5.0
22.1 ～ 24.0	2.0	6.0	2.0	3.0	2.0	6.0	2.0	5.0	2.0	5.0	2.0	5.0
24.1 ～ 26.0	2.0	7.0	2.0	3.5	2.0	7.0	2.0	6.0	2.0	5.0	2.0	6.0
26.1 ～ 28.0	2.0	7.0	2.0	3.5	2.0	7.0	2.0	6.0	2.0	5.0	2.0	6.0
28.1 ～ 30.0	2.0	7.0	2.0	3.5	2.0	7.0	2.0	6.0	2.0	5.0	2.0	6.0
30.1 ～ 32.0	2.0	8.0	2.0	4.0	2.0	8.0	2.0	6.0	2.0	5.0	2.0	6.0
32.1 ～ 34.0	2.0	8.0	2.0	4.0	2.0	8.0	2.0	7.0	2.0	5.0	2.0	6.5
34.1 ～ 36.0	2.0	8.0	2.0	4.0	2.0	8.0	2.0	7.0	2.0	5.0	2.0	6.5
36.1 ～ 38.0	2.0	8.0	2.0	4.0	2.0	8.0	2.0	7.0	2.0	5.0	2.5	7.0
38.1 ～ 40.0	2.5	8.0	2.0	4.0	2.0	8.0	2.0	7.0	2.0	5.0	2.5	7.0
40.1 ～ 50.0	3.0	8.0	3.0	4.0	2.0	8.0	3.0	7.0	3.0	5.0	3.0	7.0
50.1 ～ 60.0	3.0	9.0	3.0	5.0	2.0	10.0					3.0	7.0
60.1 ～ 70.0	3.0	10.0			2.0	10.0					3.0	7.0
70.1 ～ 80.0	3.5	11.0									3.0***	7.0
80.1 ～ 90.0	4.0	12.0										
90.1 ～ 100.0	4.0	12.0										
100.1 ～ 125.0	4.0	12.0										
125.1 ～ 150.0	4.0	12.0										

(note) * : Range of thickness of one side cladding material

** : Applicable for the thickness of 10mm

*** : Applicable for the thickness within 75mm

Examples of Use

Pressure vessel

Chemical tanker

Desalination plant

Head plate

Paper-making plant

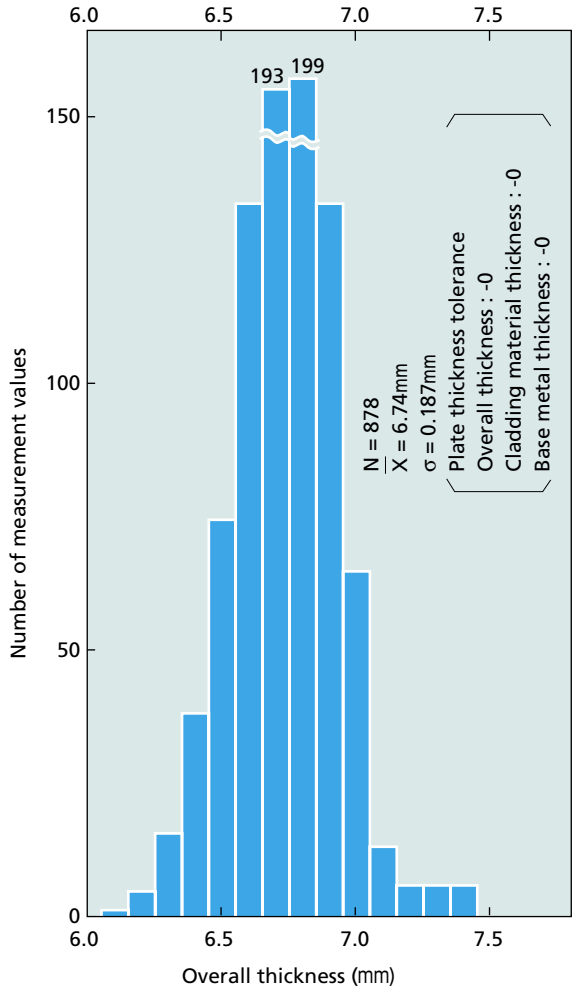
Examples of Use

Quality

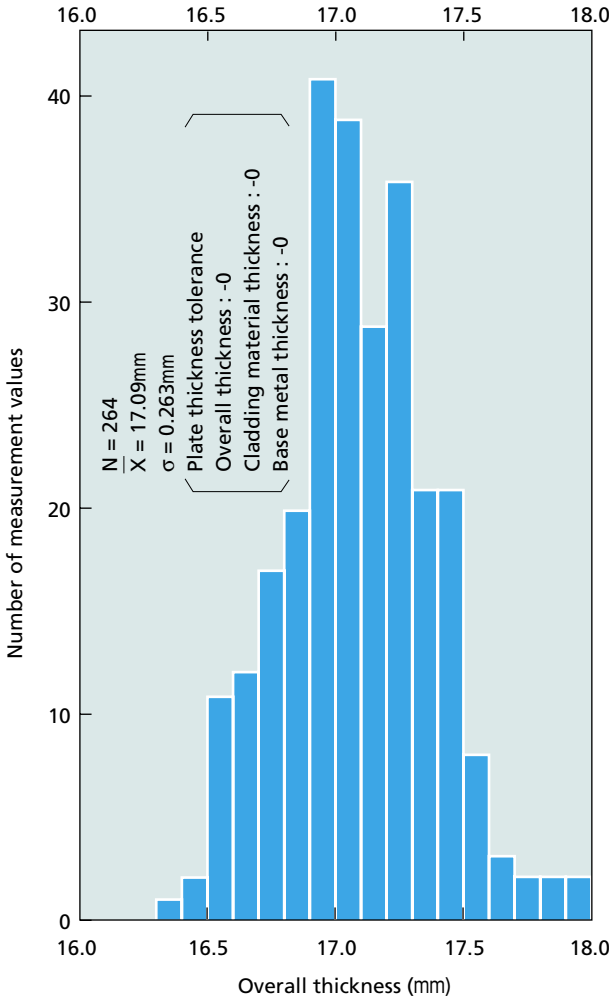
(1) Dimensional accuracy

Given below is an example of plate thickness accuracy of a stainless clad steel plate

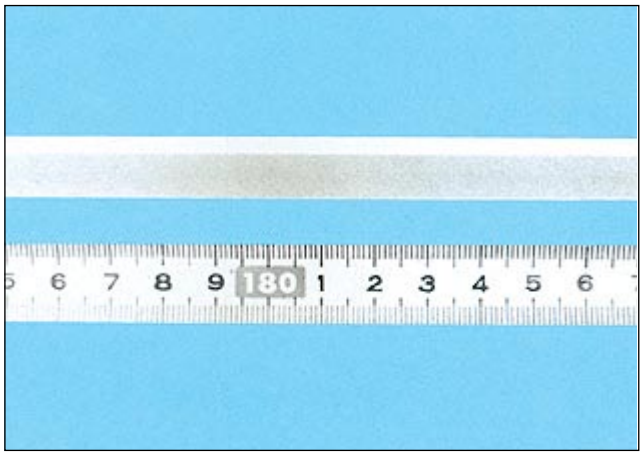
Histogram of plate thickness measurement values
(Overall thickness, 6mm)



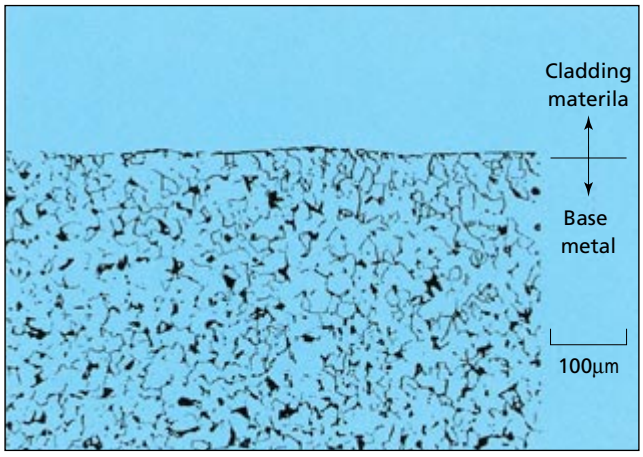
Histogram of plate thickness measurement values
(Overall thickness, 16mm)



(2) Interface of the cladding and base metal



Macrostructure



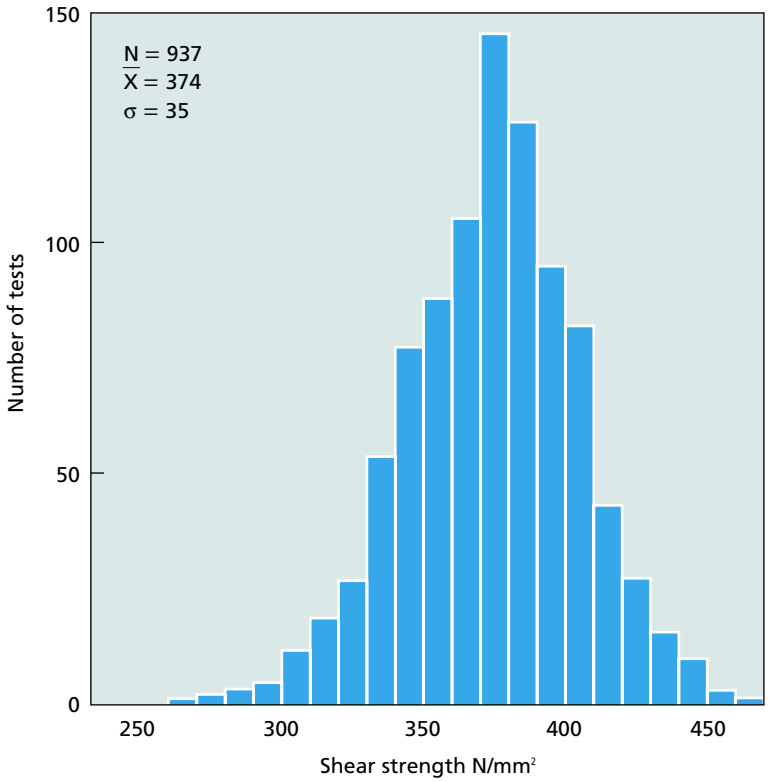
Microstructure

(3) Shear strength

The histogram below shows an actual example of shear strength of a stainless clad steel plate.

Histogram of shear strength

Test method, JIS G 0601
Standard spec.,
200N/m² min.

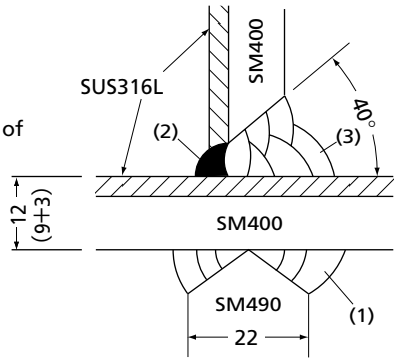


(4) Weldablility

The result of a cruciform joint welding test is given below. It was confirmed that the cladding material did not separate after fillet welding.

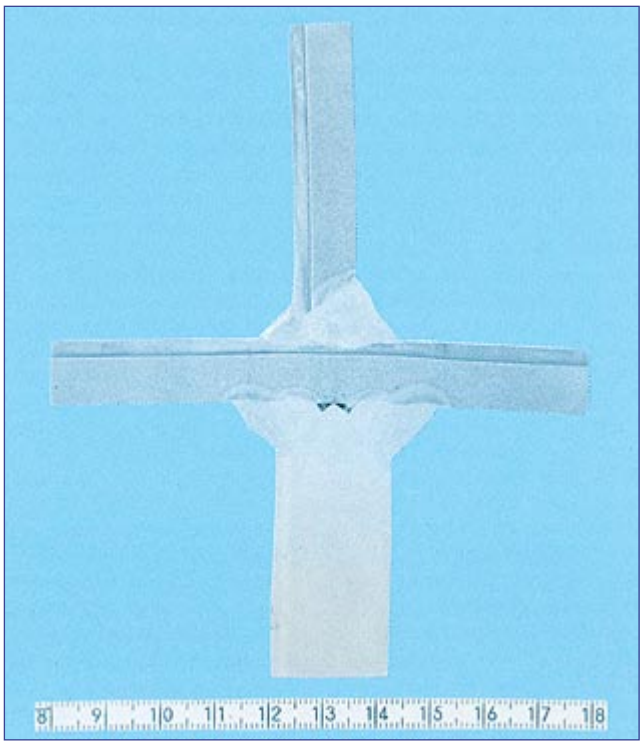
Joint shape

Welding conditions of cruciform joint



Welding conditions of cruciform joint

	(1)	(2) Root pass	(3)
Welding method	SMAW	GTAW	SMAW
Welding material	LBM-52 4.0ϕ	TGS-309L 2.4ϕ	NC-39L 4.0ϕ
Preheating temperature	Room temperature (25°C)		
Interpass temperature	≦ 250°C	—	≦ 150°C
Welding position	Flat	Flat	Flat
Conditions		Shielding gas front and back Ar 20 ℓ /min 110A·12V	140Amp·24V 15cm/min



Macrophotograph of SM400B+SUS316 cruciform joint cross-section

(5) Workability

In order to examine separation of a clad steel plate due to working or a change in its shear strength, a test was made by actually shaping a head plate, the working conditions of which are considered the severest of all.
After the test, no separation was observed as shown below and absence of deterioration in its shear strength was also confirmed.

●Cold-shaping test of head plate using stainless clad steel

Type and Size of Head Plate

Code	Material	Plate thickness (mm)	shaping method	Type	Inner diameter (mm)	Flange length (mm)	Height (mm)
A1	SS400 +SUS304	12(10+2)	Cold-press	Regular half-ellipse	900	38	263
A2	//	//	Cold-spinning	//	//	//	//
B1	SM400B +SUS316	16(13+3)	Cold-press	//	//	//	//

A2
SS400
+ SUS304
12(10+2)mm
Cold-spinning

Appearance after shaping of a head plate

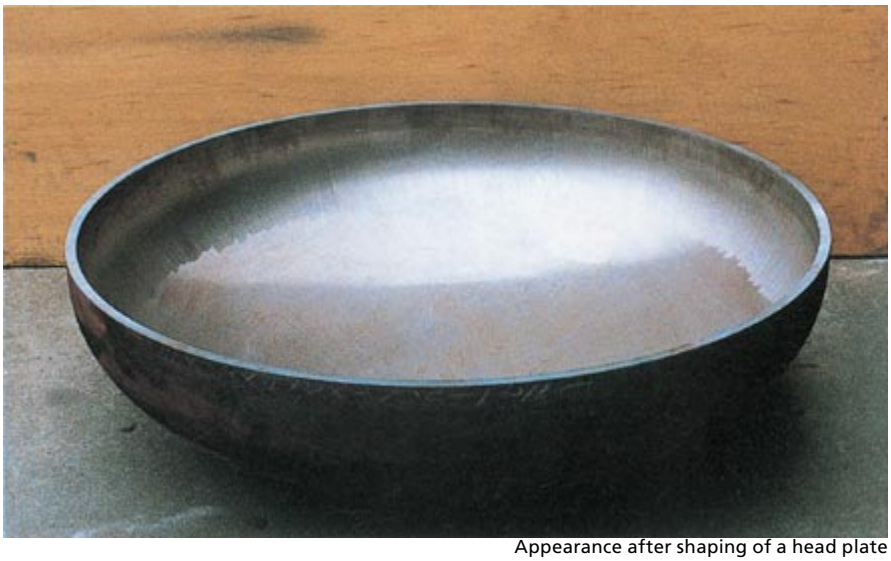
Shear strength and ultrasonic flaw detection result of each section of the head plate N/mm^2

Code	shaping method	Before shaping	After shaping			UST result (JIS G 0601)
			Crown	Knuckle	Flange	
A1	Cold-press	338	340	365	366	Good
A2	Cold-spinning	338	363	368	373	Good
B1	Cold-press	352	357	364	372	Good

●Cold-shaping test of head plate using nickel-copper alloy clad steel plate

Type and Size of Head Plate

Material	Plate thickness (mm)	Shaping method	Type	Inner diameter (mm)	Flange length (mm)	Height (mm)
SS400 + N04400	13 + 2	Cold-press	Regular half-ellipse	1,100	38.0	318



Appearance after shaping of a head plate

Shear strength of each section of the head plate N/mm^2

Position / Individual and average strength	Before shaping	After shaping			
		Center	Crown	Knuckle	Flange
Individual	290 296 282	277 276	302 307	320 328	342 342
Average	289	277	305	324	342

●Hot-shaping test of head plate using stainless clad steel plate

Type and size of Head Plate

Material	Plate thickness (mm)	Shaping method	Type	Inner diameter (mm)	Flange length (mm)	Height (mm)
A516-65+Type316L	13(10+3)	Hot-spinning	Regular half-ellipse	3,260	38	853

Shaping of head in progress

Shear strength of each section of the head plate N/mm^2

Before shaping	After shaping			
	Center	Crown	Knuckle	Flange
337	350 365	345 356	330 358	330 352

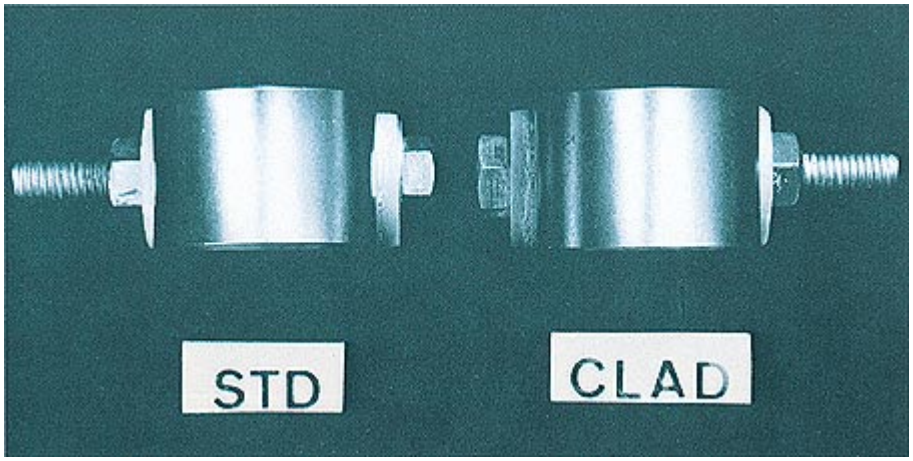
(6) Corrosion resistance

●Stainless clad steel plate

The corrosion resistance of stainless clad steel was tested to compare it with that of solution treated stainless steel plate. As a result, it was confirmed that both were nearly on the same level.

Corrosion resistance of the stainless steel section of SM400B+SUS316L 12(9+3)mm clad material

Test item and condition	Test results	
	Clad material	Comparison material (solution treated)
Putting test (JIS G 0578) – Immersion in ferric chloride – 10%$FeCl_3 \cdot 6H_2O$+1/20NHCl 50°C, 24h (g/m^2·h)	25.63 (27.14、24.11)	24.44 (23.48、25.39)
Intergranular corrosion test (JIS G 0575) – Strauss test – 1t bend after 16h immersion in boiling H_2SO_4-$CuSO_4$ solution	No crack	No crack
SCC test – U-bend method – 8R bending after 500h immersion in boiling 20% NaCl solution	No crack	No crack

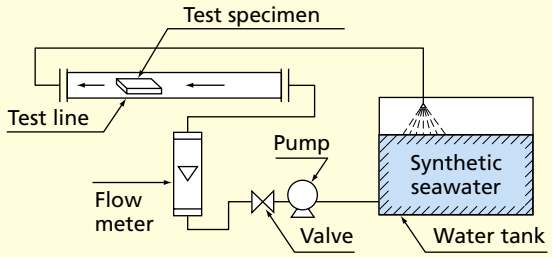


Appearance after SCC test

●Cupronickel clad steel plate

1. Corrosion test by immersion (in flowing water)

Test conditions

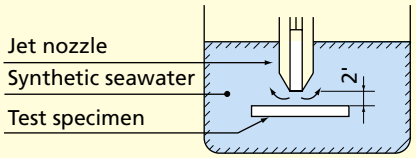
Item	Condition
Solution	Synthetic seawater (ASTM D-1141-52)
Test temperature	25˚C
Testing device	Loop tester  * Flow velocity 2m/sec

Test results

Test specimens	Corrosion speed (mm/year)
Cladding material (surface)	0.024
Welded part	
V-groove, 3-layer (surface)	0.024
(0. 5mm below surface)	0.024
X-groove, 2-layer (surface)	0.024
(0. 5mm below surface)	0.024
X-groove, 3-layer (surface)	0.024
(0. 5mm below surface)	0.024

2. Corrosion test by jet stream

Test conditions

Item	Condition
Solution	Synthetic seawater(3% NaCl)
Test temperature	25˚C
Testing device	BNF jet flow tester  Jet nozzle : Diameter-2ϕ Jet flow : 8.5m/sec, (3% air bubbles)

Test results

Test specimens	Corrosion speed (mm/year)
Cladding material (surface)	0.012
Welded areas	
V-groove, 3-layer (surface)	0.012
(0. 5mm below surface)	0.012
X-groove, 2-layer (surface)	0.012
(0. 5mm below surface)	0.012
X-groove, 3-layer (surface)	0.012
(0. 5mm below surface)	0.012

About Products and Methods of Inspection

(1) Available products

Combinations of base metals and cladding materials on pages 6-7.

(2) Available sizes

Within the scope of maximum product size tables on pages 8-13.

(3) Heat treatment

In compliance with base metal standards as a rule. Depending on steel type, however, clad steel is subjected to suitable heat treatment according to the properties of the cladding material or base metal.

(4) Cladding material surface finish

All surface is polished by #80 or its equivalent, unless otherwise specified. If necessary, however, finish by #120 and under is also available.

(5) Base metal Surface

Unless otherwise specified, the base metal surface is supplied in the as-rolled or as-heat-treated condition.

(6) Dimensional tolerance

The dimensional tolerances are followings unless otherwise required by customers.

- The tolerances of thickness are in accordance with the followings.

Cladding material :	minus side	10% of nominal thickness (nominal thickness 5mm and under), 0.5mm (nominal thickness over 5mm)
	plus side :	not specified
Base metal :	minus side	As per standard specification
	plus side :	not specified
Total shickness :	minus side	(Under tolerance of base metal) + (one of cladding metal)
	plus side	(over tolerance specified by base metal standard for nominal thickness same as nominal total thickness of clad plate) + margin (1-2mm)

- Width and length : in accordance with base metal standard
- Flatness : in accordance with applicable standard

(7) Test and inspection

- Chemical composition: Ladle analysis of base metal and cladding material.
- Mechanical tests: Test items are in accordance with specified standard and customer's request.
- Ultrasonic flaw detection test: each plate in examined.
- Dimension measurement: The thickness, width and length are measured for each plate.

(8) Marking

The standard, size, plate No., company logomark, etc. are marked on the base metal by stencil or die-stamp.

(9) Packaging

Unless otherwise specified, the cladding material side is protected by cardboard paper with water proof.

In Using Clad Steel Plate

(1) Cutting

- Clad steel plate can be sheared by shearing or punching, cut by a planer, etc. or cut thermally by using gas or plasma.
- Shearing can be applied to a plate thickness of up to 12mm. Put the plate so as to show its cladding material side, thereby eliminating the possibility of damage.
- In the case of plasma cutting, the plate is usually positioned such that the cladding material side is showing.
- For both gas cutting and plasma cutting, automatic cutting is recommended to improve cutting accuracy.

(2) Shaping

- Shaping of clad steel plate can be made by roll-bending, pressing and spinning.
- To take advantage of cladding material features, cold working is recommended to the maximum extent possible. However, in the case of a thick plate, if the cladding material is of chromium-base stainless steel or if the base metal is a high tensile steel or Cr-Mo steel of which bend-ductility is inferior, hot or warm working may be required depending on the degree of shaping.
- During shaping, sufficient attention should be paid in order to prevent the surface of cladding material from being damaged.

●Cold working

- Generally, stainless clad steel requires much energy as its deformation resistance and springback are both larger than those of low-carbon steel. Therefore, if the degree of working is large, the use of a base metal excelling in ductility and toughness is recommended along with a proper heat treatment before working, if necessary.
- As oils including a lubricant used during pressing or spinning cause cementation during welding or heat treatment, resulting in the deterioration of corrosion resistance of the cladding material, they should be removed completely after working.
- Scratches on the surface of cladding material impair its resistance to corrosion. Rollers, molds, etc. should be sufficiently smooth and clean and it is also effective to cover the cladding material with vinyl sheets, etc. for protection.
- If the degree of working is considerable, heat treatment may be required during shaping to restore ductility and toughness. Conditions of heat treatment are as given below.

Conditions of heat treatment

Cladding material		Base metal	Temperature ˚C
Stainless steel	Chromium-base	Non-quenched and tempered high tensile steel	625±25
	Austenitic (Stabilized, low-C)		575±25
	Austenitic (other than the above)		525±25
	Austenitic	Cr-Mo steel	620～700
Nickel-Copper Alloy		Low-carbon steel	520±50
Cupronickel (90/10)		Low-carbon steel	600～850
Cupronickel (70/30)			650～815

●Hot working

- Remove oil and other foreign matter completely before heating. (LPG, LNG, kerosene, etc. containing less than 0.01% of sulphur are desirable.)
- The scope of hot-working temperature is as given below.

Scope of Hot-working Temperatures

Cladding material	Base metal	Temperature˚C
Chromium-base stainless steel	Low-carbon steel Non-quenched / tempered high tensile steel Cr-Mo steel	850±50
Austenitic stainless steel		880±50
Nickel-copper alloy	Low-carbon steel	820±50
Cupronickel	Low-carbon steel	825±50

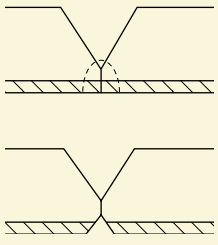
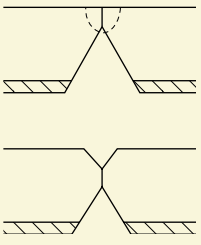
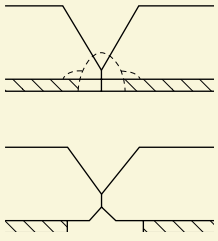
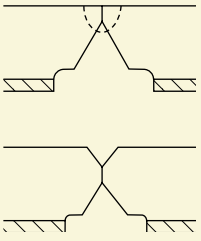
- If clad steel using austanitic stainless steel as its cladding material has to be hot-worked, use either low-carbon steel with a low sensitivity (SUS304L, SUSS316L, for example) or stabilized steel (SUS321 , SUS347, for example). Avoid hot working of clad steel with SUS304 or SUS316 used as the cladding material.

(3) Welding

●Edge preparation

- As a rule, mechanical cutting is desirable to prepare edges but gas cutting or plasma cutting may be used. In the latter case, it is necessary to remove scale, etc. on the edge completely with a grinder, etc.
- Depending on the plate thickness and welding method, a proper groove shape is chosen. Groove shapes of butt-welded joints are given below for your information.

Groove Shapes

Classification	Outside Groove	Inside Groove
Grooves without cutback		
Grooves with cutback		

●Preheating

- Depending on the method of welding, type of base metal, plate thickness, etc., select a proper preheating temperature for welding base metal and boundary sections. The preheating temperature for welding cladding material is between 100° and 300°C as a rule if the welding material is of chromium-base stainless steel. Preheating is not required as a rule if the welding material is of austenitic stainless steel, high-nickel alloy-based or copper-nickel alloy-based.

●Welding and Welding materials

Welding of base metal

- In the case of clad steel, welding base metal is made first as a rule, followed by welding the cladding material. For the base metal, welding materials must be selected that meet requirements of the welded joint to match the material quality, plate thickness, etc. of the base metal. At the same time, attention should be paid during welding to prevent the cladding material from fusing into the weld metal on the base metal.

Welding of cladding material

- Welded joints on cladding materials are required to have corrosion resistance comparable to or better than that of the cladding material. Therefore, welding materials must be used that deposit weld metal exhibiting properties comparable to or better than those of the cladding material.
- For the first layer on the cladding material, use a welding material with higher contents of alloying elements, such as Cr and Ni, in consideration of dilution by the base metal.
- In the case of chromium-base stainless clad steel, an austenitic stainless steel welding material is occasionally used to eliminate post heat treatment.
- Typical combinations of welding materials are shown in the table.
- In welding boundary sections between the cladding material and the base metal, use a low electric current to minimize dilution of the base metal.

Typical Cladding Materials and Applicable Welding Materials

Type of Clad material	1st Layer	2nd Layer and on
SUS304	D309、D309L	D308,D308L
SUS304L	D309、D309L	D308L
SUS316	D309、D309L、D309Mo	D316、D316L
SUS316L	ditto	D316L
SUS317	ditto	D317,D317L
SUS317L	ditto	D317L
SUS321 SUS347	D309、D309L、D309+Nb	D347
SUS410S	D430+Nb, D430, D309	D410+Nb,D410, D309, D308
Nickel-copper	Ni-Cu alloy、Ni	Ni-Cu alloy
Cupronickel (90/10)	Ni-Cu alloy、Ni	90/10Cupronickel
Cupronickel (70/30)	ditto	70/30Cupronickel

●Heat treatment after welding

- In the case of carbon steel and low-alloy steel, heat treatment after welding is usual]y made at temperatures of, for example, between 600° and 650°C to remove stress. If the cladding material is of austenitic stainless steel, this temperature range presents such problems as sigma-phase deposition, embrittlement phenomena, such as deposition of Cr carbides, and the deterioration of resistance to corrosion. In the case of austenitic stainless clad steel, therefore, it is desirable to eliminate heat treatment after welding as much as possible. If post heat treatment is made, the use of stainless steel of a low-carbon type or a stabilized type is recommended. If the cladding material is chromium-base stainless steel, it is common to restore performance by heat treatment after welding.

(4) Storage or Handling

- Sufficient attention should be paid in order to prevent clad steel plates from getting wet in the rain.

Information Required with Orders or Inquiries

When placing an order or making an inquiry, please advise us of the following so that we may deliver products best suited to your needs.

(1) Standards (of base metal and cladding material)
(2) Size and quantity
(3) Special specifications, if any. Chemical composition, dimensional allowances, heat treatment, surface finish, packaging, etc.
(4) Intended application and conditions of use
(5) Fabrication method and
(6) Delivery timing.

Cat.No.C1E-009-00

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