Total Steel

TECHNICAL BULLETIN 2

JFE

EHSP

Super Abrasion Resistant Steel Plate

Manufacturer's Testing

total quality total service **Total Steel**

CONTENTS

I INTRODUCTION

JFE's predecessor, NKK, manufactured and marketed abrasion-resistant steel plates as early as 1955 under the name "NK EVER-HARD". These days, EVER-HARD plates have found a place in a broad range of fields, such as civil and architectural engineering, mining, agricultural machinery and other types of industrial applications.

To extend the life of machinery in more extreme environments, the requirements call for steel plates with even higher abrasion-resistance than EH500 and EH500A grades, which have the highest abrasion resistance in the JFE EVER-HARD series with their Brinell hardness of around 500.

In general, the conventional alloy design of abrasion-resistant steel is based on the assumption that abrasion-resistance rises as the hardness of the steel increases. There are, however, some problems in practical applications since weldability and formability decrease with an increase in hardness beyond that of the 500 grade.

JFE has been investigating the effects of alloying elements and manufacturing conditions on abrasion-resistance, weldability and formability. This pursuit has led to the development of JFE EHSP super abrasion-resistant steel, a new type based on a technique that improves the abrasion-resistance without increasing the hardness. This new approach to the alloy design of JFE EHSP has been achieved by a uniform dispersion of a lot of high-hardness precipitates in steel. The abrasion-resistance of JFE EHSP is superior to that of EH500 and EH500A, even though its hardness level is lower.

Product specifications, quality, features and other relevant data are introduced in the following pages. JFE hopes the technical information in this bulletin helps to further inform customers.

Note: JFE is the merged identity of NKK and Kawasaki Steel. EHSP was manufactured under the NKK name at the time of this report.

II SPECIFICATIONS

1. Manufacturing Process and Available Thicknesses

Grade	Thickness	Heat treatment
EHSP	6–65 mm	Controlled heat treatment

2. Chemical Composition

mass%

C	Si	Mn	P	S	Cr	Others
≤ 0.35	≤ 0.55	≤ 1.60	≤ 0.030	≤ 0.030	0.50 ~ 1.50	Other alloying elements are added for enhancing the abrasion-resistant properties.

3. Hardness

Surface Brinell hardness (Load 3000 kgf)	401 min. (Average hardness of 5 points)

Hardness test shall be carried out as per Brinell hardness test method prescribed in JIS Z 2243 for each molten steel and each respective thickness.

4. Appearance, Shape, Size and Tolerance

Appearance, shape, size and tolerance are as per JIS G 3193

III TEST RESULTS

1. Steel Plates Tested

1-1 Steel Plates and Testing Items

Table 1: Steel Plates and Testing Items

Testing items	Plate thickness (mm)					
	9.5	12	25.4	35	50.8	63.5
Mechanical properties of base plates	❍	❍	❍	❍	❍	❍
Abrasion resistant property	❍	❍	❍	❍	❍	❍
Machinability	–	❍	–	–	–	–
Weldability	–	❍	❍	❍	❍	–
Welded joints	–	❍	–	–	–	–

(❍ = test carried out)

1-2 Chemical Composition

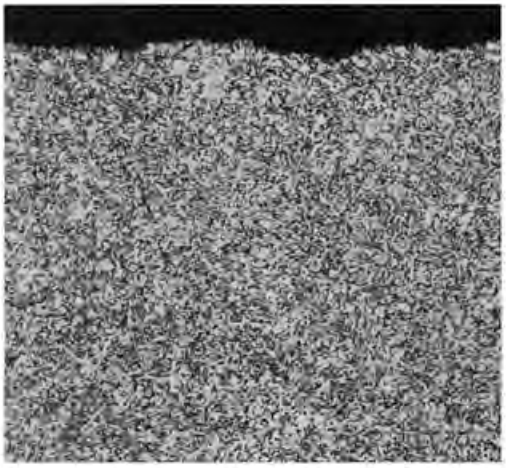
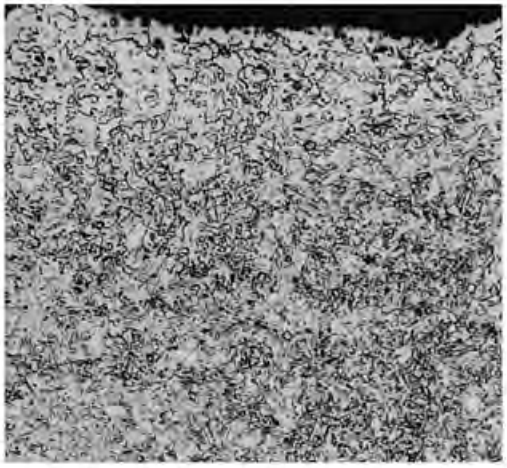
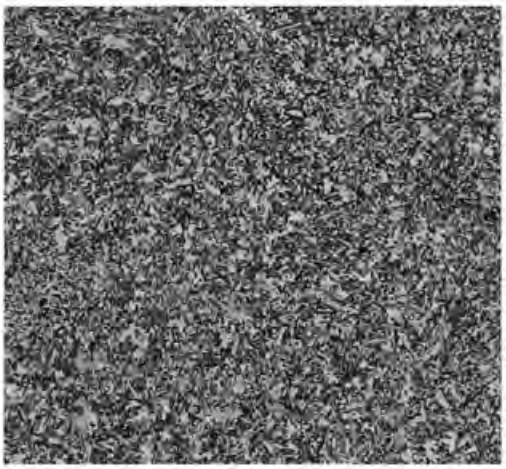
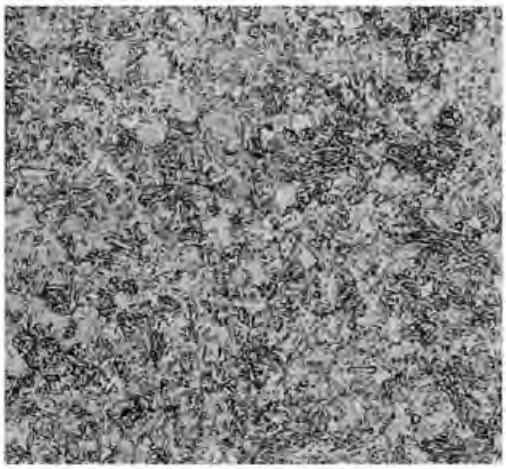
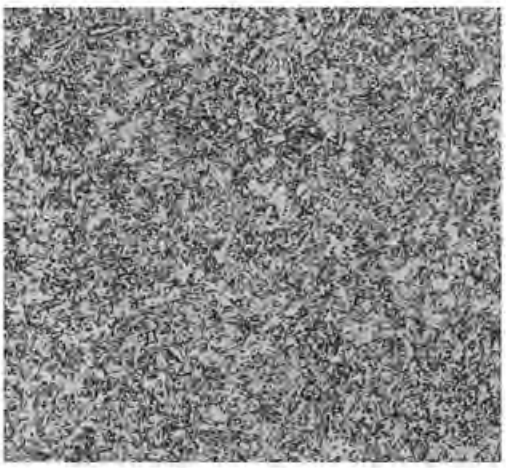
Table 2: Chemical Compositions of Steels Tested

mass%

	t (mm)	C	Si	Mn	P	S	Cr	Others
Product analysis	12	0.29	0.34	0.69	0.007	0.001	0.93	Other alloying elements are added for enhancing the abrasion resistant properties.
	35	0.30	0.33	0.68	0.007	0.001	0.93	
Ladle analysis		0.30	0.33	0.69	0.007	0.001	0.93	

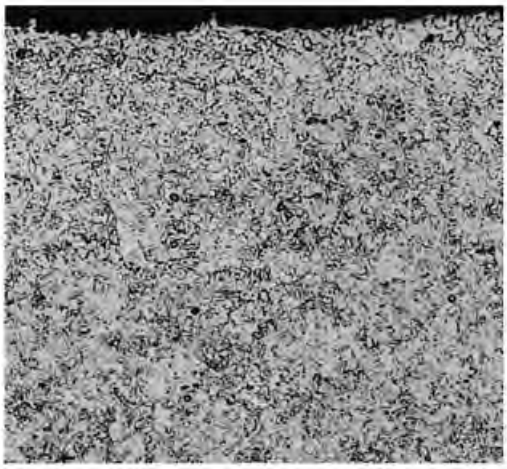
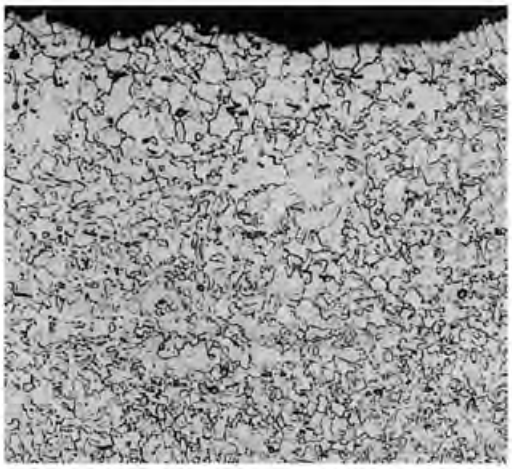
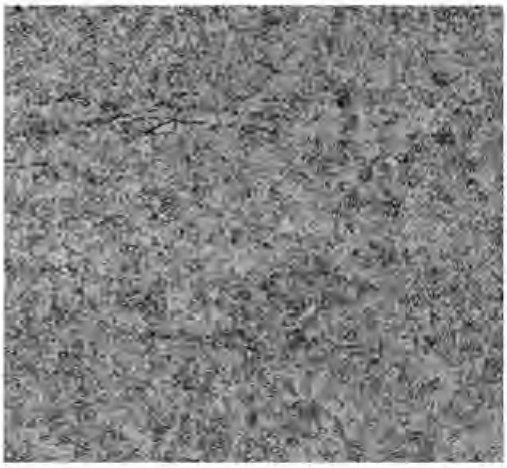
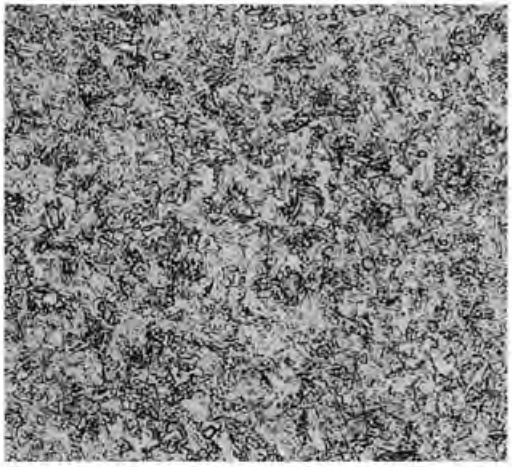
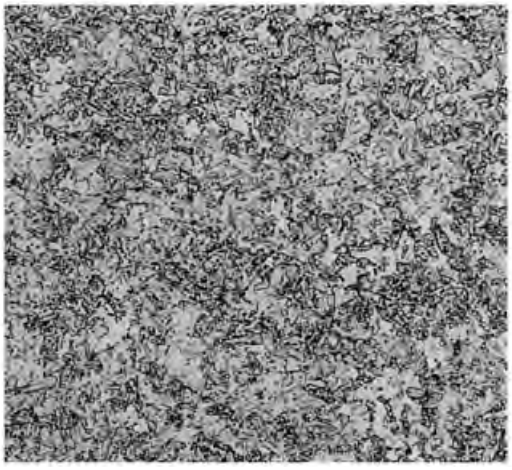
2. Properties of base plates

2-1 Microstructure

	Thickness = 12 mm	Thickness = 25.4 mm
Surface layer		
1/4 t		
1/2 t		

(× 200)

Photo 1: Microstructure

	Thickness = 35 mm	Thickness = 50.8 mm
Surface layer		
1/4 t		
1/2 t		

(× 200)

Photo 2: Microstructure

2-2 Hardness Distribution in Thickness Direction

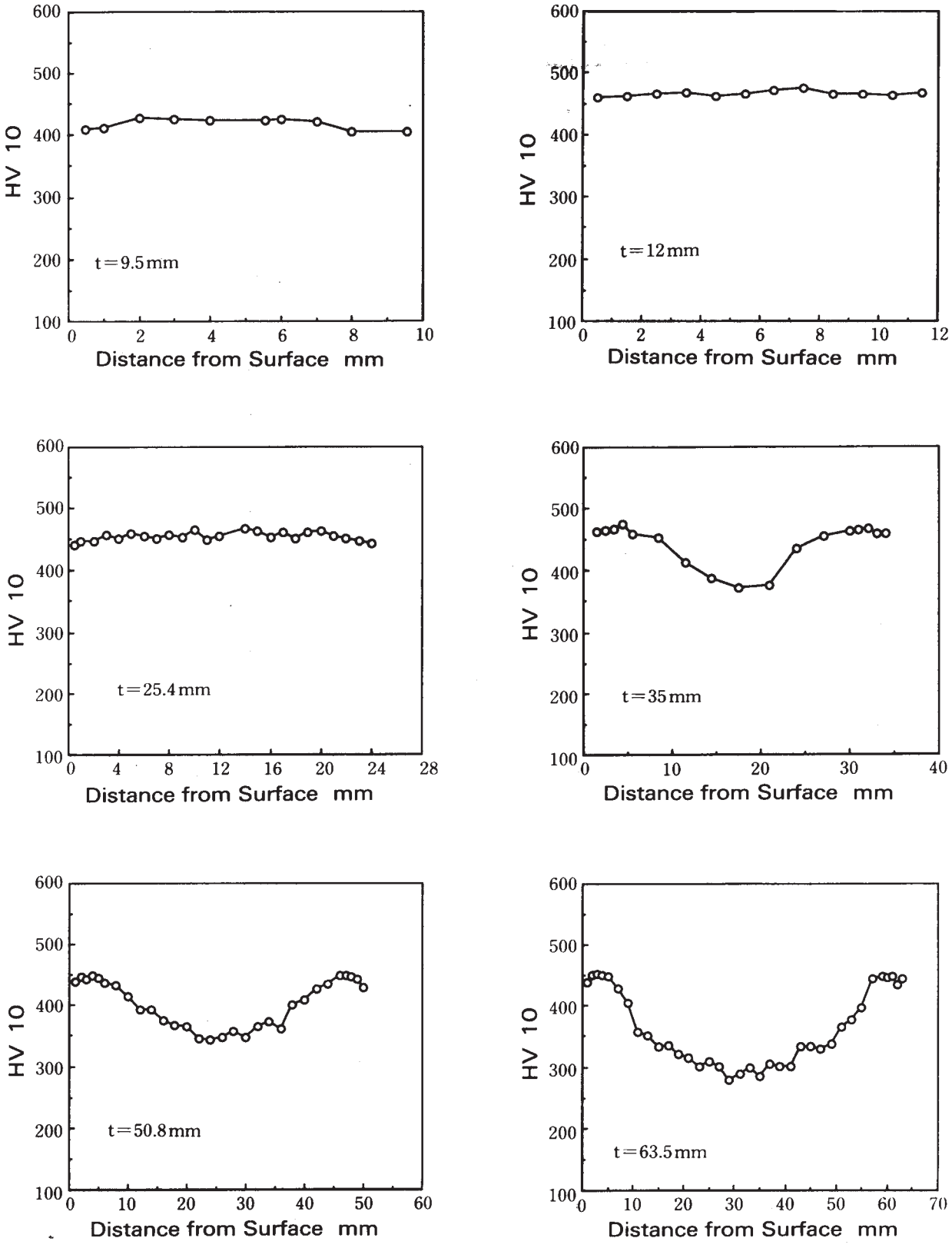


Figure 1: Hardness Distribution in Thickness Direction

2-3 Tensile, Charpy Impact and Brinell Hardness Tests

Table 3: Results of Tensile and Brinell Hardness Tests

t mm	Specimen	Position	Direction	YS N/mm²	TS N/mm²	El %	HB** (Surface)
9.5	JIS No. 5	Full	T	1298*	1401	13.3	409
12	JIS No. 5	Full	L	1270*	1489	13.2	461
			T	1274*	1476	15.6	
25.4	JIS No. 5	Full	T	1279*	1471	16.6	448
35	JIS No. 5	Full	L	1098*	1349	11.3	455
			T	1104*	1352	10.7	
50.8	JIS No. 4	1/4 t	T	1037*	1204	10.4	434
		1/2 t	T	903*	1145	10.7	
63.5	JIS No. 4	1/4 t	T	867*	1070	11.6	442
		1/2 t	T	677*	951	13.8	

* 0.2% Proof stress ** HB: Brinell hardness
Specimen for tensile test JIS No. 5: GL = 50 mm, W = 25 mm
JIS No. 4: GL = 50 mm, d = 14 mm ø

Table 4: Results of Charpy Impact Test

t mm	Specimen	Direction	Position	$_vE_0$* J
9.5	JIS No. 4**	L	1/2 t	15
12	JIS No. 4	L	1/2 t	24
25.4	JIS No. 4	L	1/4 t	18
			1/2 t	17
35	JIS No. 4	L	1/4 t	18
50.8	JIS No. 4	L	1/4 t	15
			1/2 t	16
63.5	JIS No. 4	L	1/4 t	13
			1/2 t	15

* $_vE_0$: Absorbed energy at 0°C ** 3/4 subsize
Specimen JIS No. 4: 2 mm V-notch

2-4 Bending Test

Table 5: Results of Bending Test (JIS No. 1 specimen)

t mm	Direction	Bending radius (t : thickness of specimen)			
		2.0 t	2.5 t	3.0 t	4.0 t
9.5	L	×	❍	❍	❍
	T	×	×	❍	❍
12	L	×	❍	❍	❍
	T	×	×	❍	❍
25.4	L	❍	❍	❍	❍
	T	×	❍	❍	❍
35	L	❍	❍	❍	❍
	T	×	×	❍	❍
50.8	L	❍	❍	❍	❍
	T	×	×	❍	❍
63.5	L	❍	❍	❍	❍
	T	×	×	❍	❍

❍ : No cracking × : Cracking
Specimen Plate thickness t ≤ 35 mm : JIS No. 1 : Plate thickness x 50 mm W
Plate thickness t > 35 mm : JIS No. 1 : 20* mm x 50 mm W
(*reduced the thickness from one side surface)

Table 6: Results of Bending Test (Wide Specimen)

t mm	Direction	Bending radius (t : thickness of specimen)				
		2.0 t	2.5 t	3.0 t	4.0 t	5.0 t
9.5	L	–	×	❍	❍	❍
	T	–	×	×	❍	❍
12	L	×	×	❍	❍	❍
	T	–	–	×	❍	❍
35	L	×	❍	❍	❍	❍
	T	–	×	❍	❍	❍

❍ : No cracking × : Cracking
Specimen Plate thickness t < 35 mm : Plate thickness x 150 mm W
Plate thickness t ≥ 35 mm : 15* mm x 150 mm W
(*reduced the thickness from one side surface)

2-5 Hardness Distribution of Gas-cut Surface

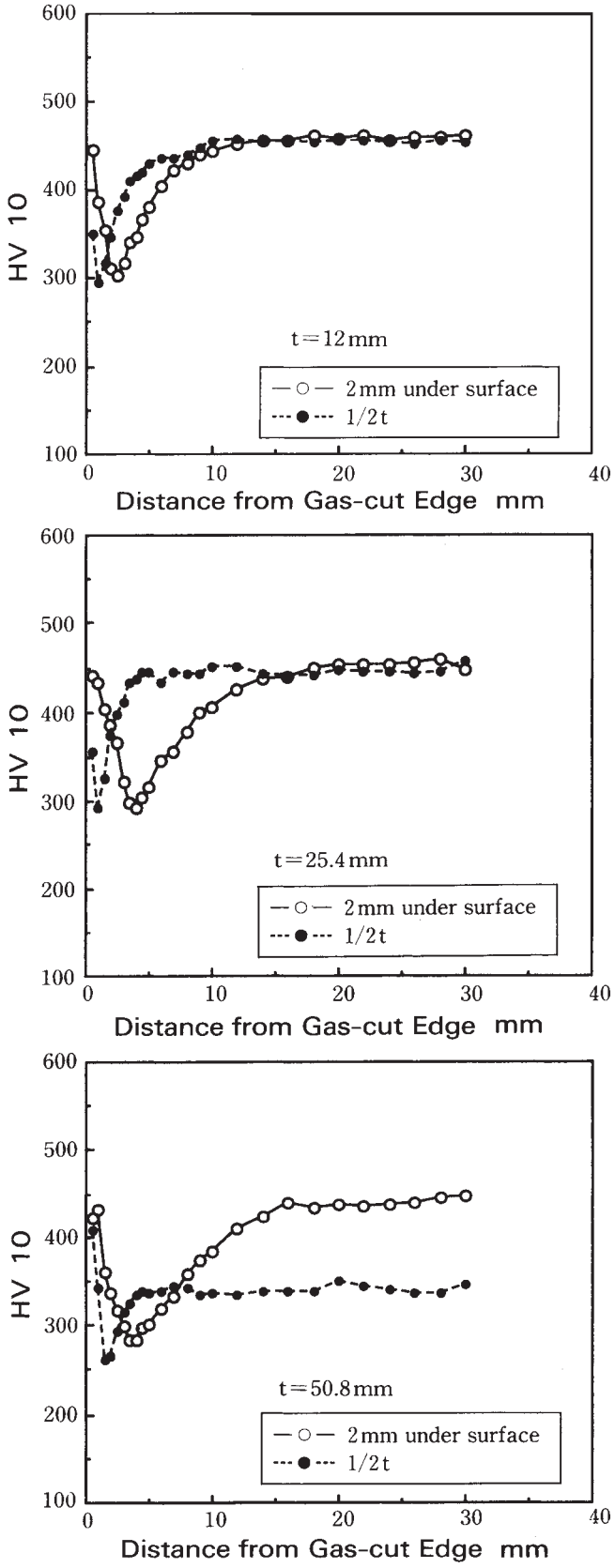


Figure 2: Hardness Distribution of Gas-cut Surface

3. Abrasion Resistant Property

3-1 Test Method

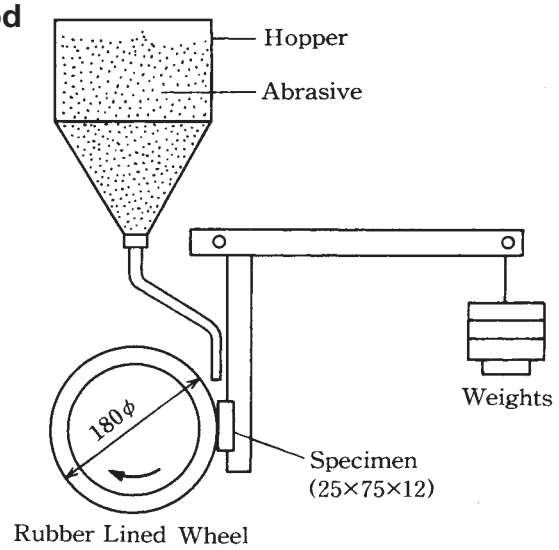


Figure 3: Apparatus of Abrasion Resistant Test

3-2 Test Results

Table 7: Results of Abrasion Resistant Test

Steel	t mm	Position	Abrasion resistant ratio** (SS400 = 1.0)
EHSP	9.5	1 mm under surface	9.1
	12	1 mm under surface	9.0
	25.4	1 mm under surface	8.3
	35	1 mm under surface	8.3
	50.8	1 mm under surface	9.8
		1/2 t	5.5
	63.5	1 mm under surface	9.7
		1/2 t	4.3
Conventional steel	SS400*	1 mm under surface	1.0
	EH500*	1 mm under surface	5.2

* Brinell hardness of conventional steel
HB (SS400 : Mild steel) = 112, HB (EH500) = 512
<Testing condition> Abrasive : Sand (100% SiO_2) ... Flattery sand (Australia)
Wheel revolution : 200 rpm
Applied stress : 130 N
Testing time : 30 min. (Number of rotation = 6000)
** Abrasion resistant ratio = {Weight loss (SS400 : Mild steel)} / {Weight loss (Test sample)}

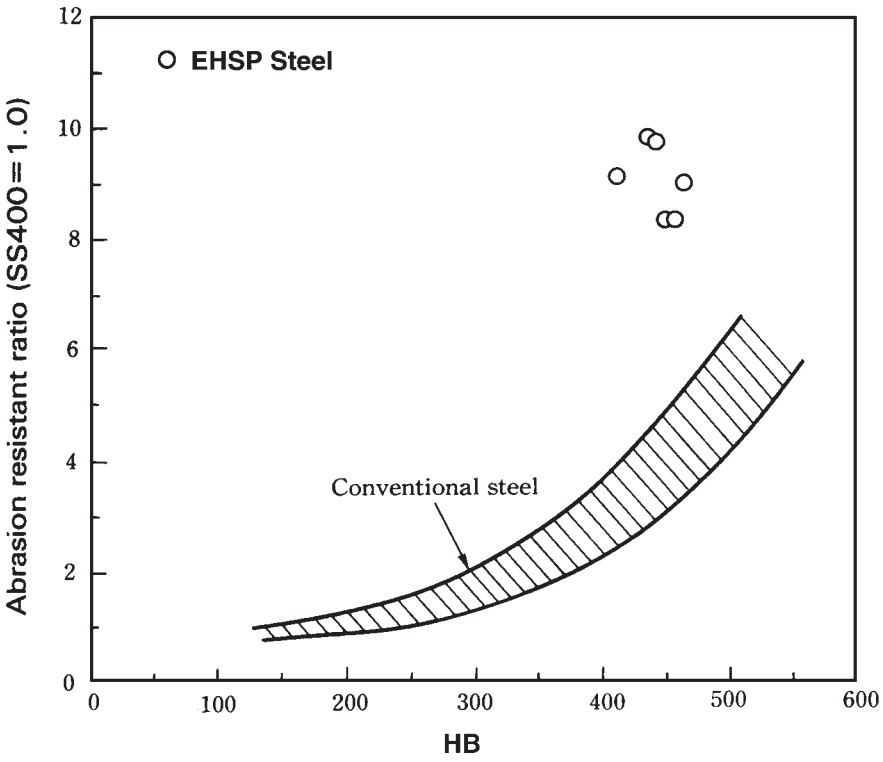


Figure 4: Results of Abrasion Resistant Test

4. Machinability

Table 8: Testing Conditions

Drill	Machining conditions
High speed drill : 5 mm Ø (SKH51)	375 rpm, 0.2 mm/rev through hole
Ultra-hard drill : 5.5 mm Ø (EXCEL-drill*)	2100 rpm, 0.08 mm/rev hole depth = 8 mm (blind)

* NACHI CORP.

Table 9: Test Results

Steel	t mm	High speed drill		Ultra-hard drill	
		Number of holes*		Number of holes*	
		1st test	2nd test	1st test	2nd test
EHSP	12	1	0	>50	>50
EH500	16	1	0	>50	>50

* Each test was carried out two times by using a new drill.

5. Weldability

5-1 Maximum Hardness Test

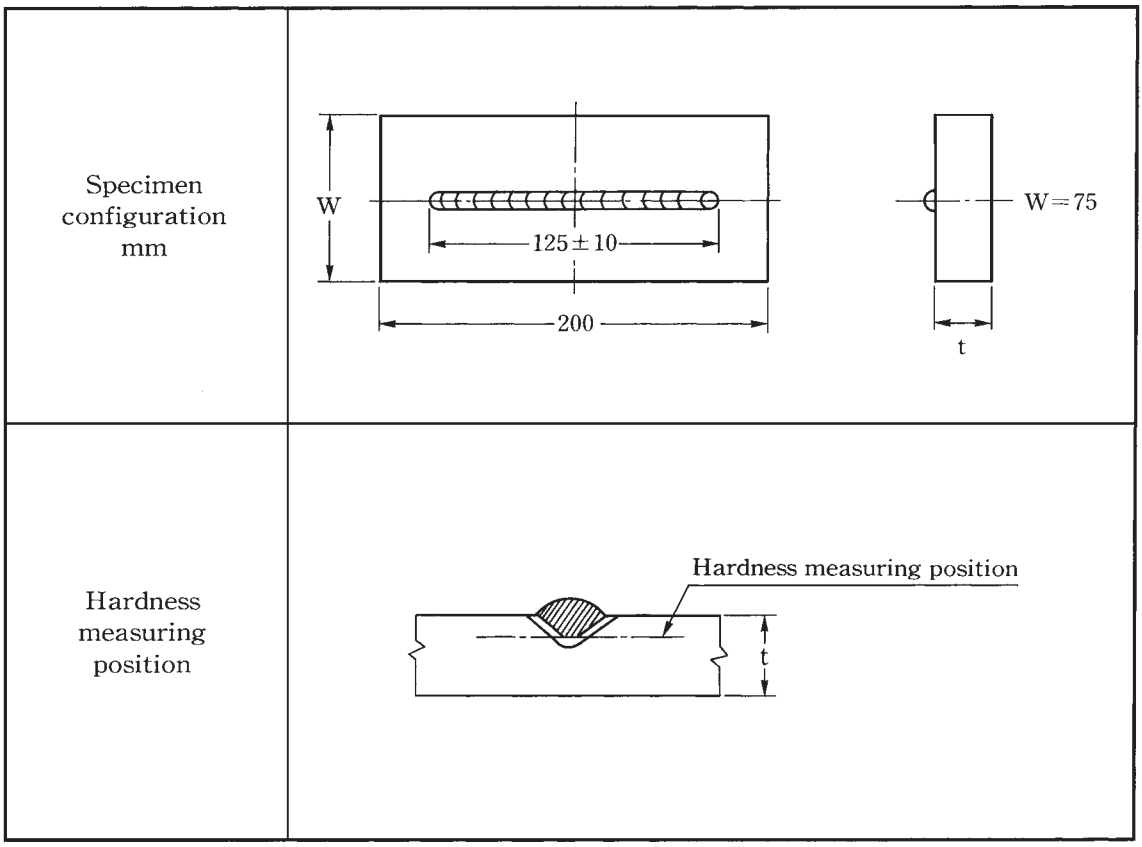


Figure 5: Specimen Configuration and Hardness Measuring Position

Table 10: Welding Conditions

Welding method	Welding material	Welding condition	Heat input kJ/mm	Preheat temperature °C
SMAW	LB 62UL, 4 mm Ø	170A–25V–150 mm/min	1.7	25

Table 11: Results of Maximum Hardness Test

t mm	Welding method	Preheat temperature °C	Maximum hardness HV 10
12	SMAW	25	440
25.4*	SMAW	25	450

* Specimen thickness = 20 mm

5-2 Y-Groove Cracking Test

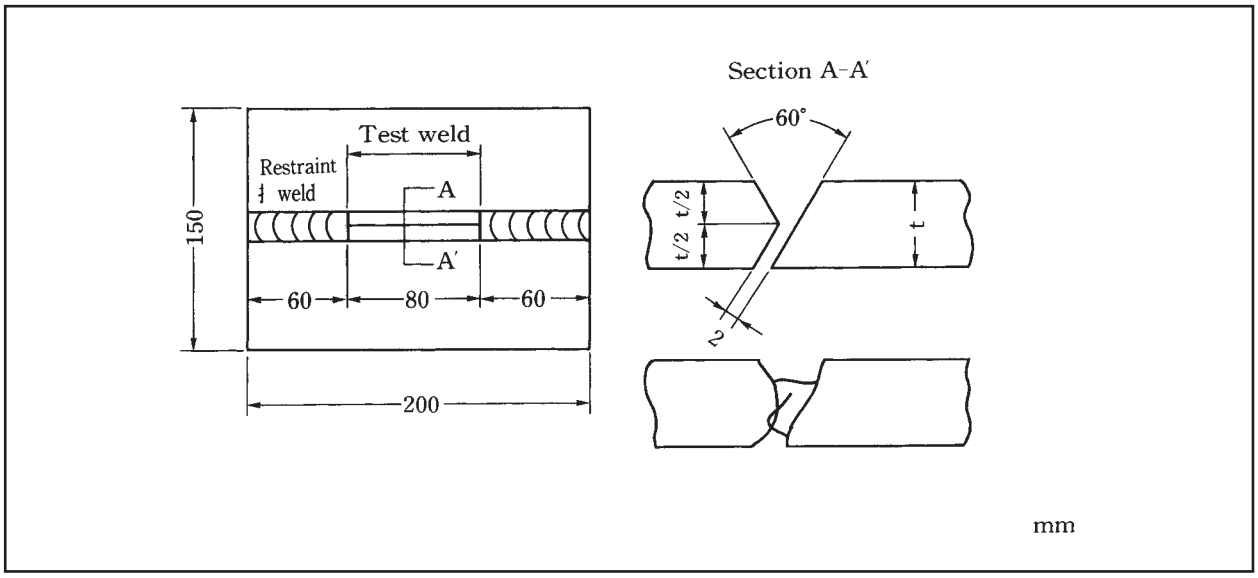


Figure 6: Specimen Configuration

Table 12: Welding Conditions

Welding method	Welding material	Welding condition	Heat input kJ/mm
SMAW	LB 62UL, 4 mm Ø	170A–25V–150 mm/min	1.7
CO_2	MG 60, 1.2 mm Ø	240A–30V–250 mm/min	1.7

Table 13: Results of Y-groove cracking test

t mm	Welding method	Preheat temperature to prevent cracking °C
12	SMAW	100
	CO_2	75
35	SMAW	175
	CO_2	175
50.8	SMAW	200
	CO_2	200

5-3 Controlled Thermal Severity Cracking Test (CTS)

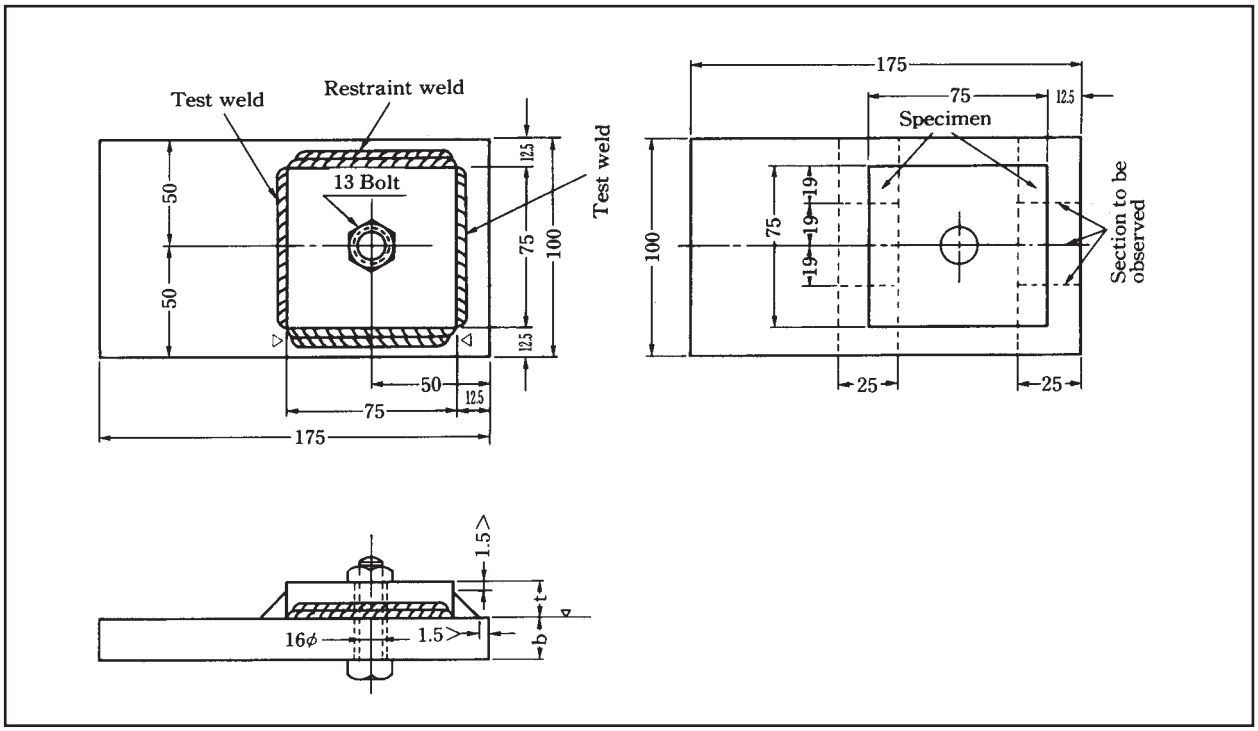


Figure 7: Specimen Configuration and Method for Observation of Cracking

Table 14: Welding Conditions

Welding method	Welding material	Welding condition	Heat input kJ/mm
SMAW	LB 62UL, 4 mm Ø	170A–25V–150 mm/min	1.7
CO_2	MG 60, 1.2 mm Ø	240A–30V–250 mm/min	1.7

Table 15: Results of CTS Test

t mm	Welding method	Preheat temperature to prevent cracking °C
12	SMAW	25
	CO_2	25
35	SMAW	25
	CO_2	50*

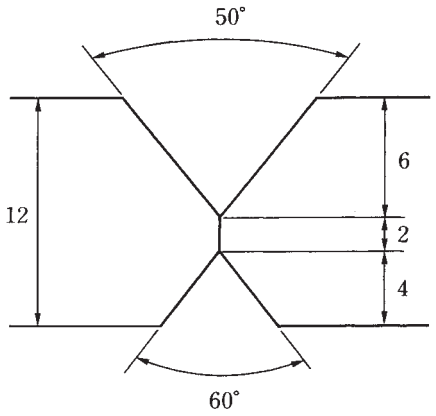
* : Cracking in weld metal

6. Mechanical Properties of Welded Joints

6-1 Shielded Metal Arc Welded Joints

(1) Welding Conditions

Table 16: Welding Conditions

Edge preparation	Steel	
	Thickness mm	12
	Welding condition	
	Welding material	LB62UL (d=4 or 5 mm)
	Preheat temp °C	100
	Inter-pass temp. °C	under 150
	Arc voltage V	25
	Welding current A	170
	Welding speed mm/min	150
	Heat input kJ/mm	1.7

(2) Macrostructure

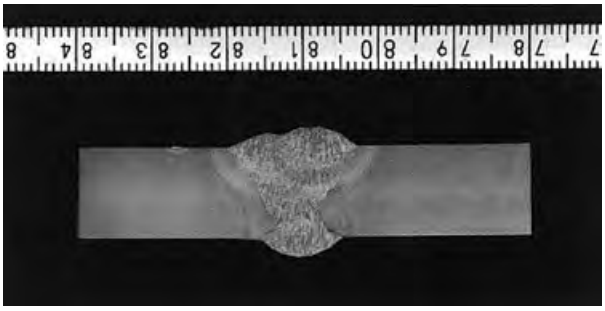


Photo 3: Macrostructure

(3) Hardness Distribution in Welded Joint

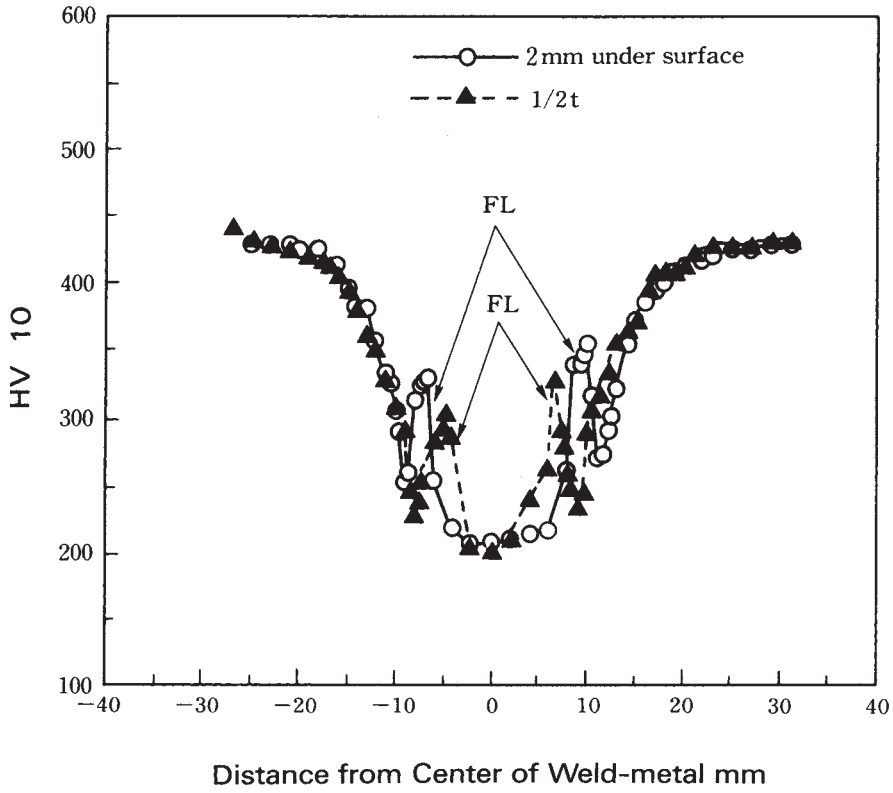


Figure 8: Hardness Distribution in Welded Joint

(4) Charpy Impact Test

Table 17: Results of Charpy Impact Test

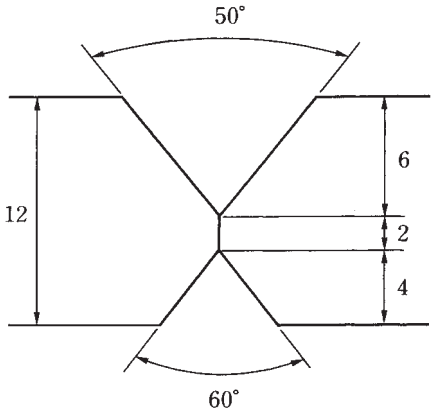
Welding method	Notch position	$_vE_0$ J			Ave.
SMAW	WM	106	114	119	113
	FL	30	56	58	48
	HAZ	67	75	81	74

WM : Weld Metal
FL : Fusion Line
HAZ : Heat Affected Zone

6-2 CO_2 Shielded Arc Welded Joints

(1) Welding Conditions

Table 18: Welding Conditions

Edge preparation	Steel	
	Thickness mm	12
	Welding condition	
	Welding material	MG60 (d=1.2 mm) CO_2 ; 25ℓ/min
	Preheat temp °C	100
	Inter-pass temp. °C	under 150
	Arc voltage V	30
	Welding current A	240
	Welding speed mm/min	250
	Heat input kJ/mm	1.7

(2) Macrostructure

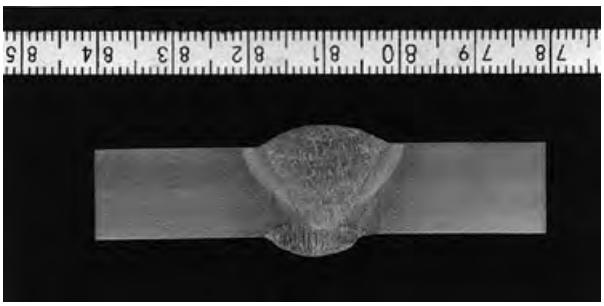


Photo 4: Macrostructure

(3) Hardness Distribution in Welded Joint

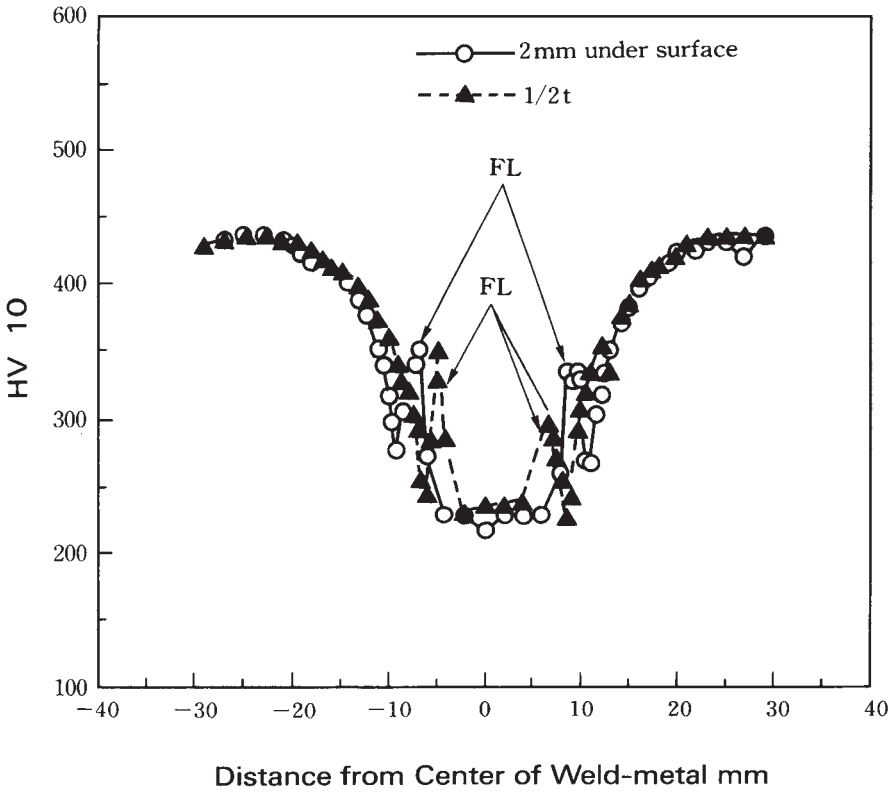


Figure 9: Hardness Distribution in Welded Joint

(4) Charpy Impact Test

Table 19: Results of Charpy Impact Test

Welding method	Notch position	$_vE_0$ J			Ave.
CO_2	WM	71	72	82	75
	FL	15	23	24	21
	HAZ	36	38	38	37

WM : Weld Metal
FL : Fusion Line
HAZ : Heat Affected Zone

IV FEATURES OF JFE EHSP

Features of JFE EHSP Super Abrasion Resistant Steel Plate include:

1 The abrasion resistant properties of EHSP are superior to that of EH500 and EH500A grades which feature the highest hardness of the JFE EVER-HARD series.

2 The hardness level of JFE EHSP steel plate is lower than that of EH500 and EH500A grades. Brinell hardness level of EHSP is HB ≈ 450.

3 Bending, machining (drilling), shearing, gas-cutting and welding properties of EHSP steel plate are almost the same as those of EH500 and EH500A grades.

V RECOMMENDED PRACTICE IN FABRICATION AND WELDING

In the fabrication and welding of EHSP steel plate, some precautions should be taken in order to maintain its excellent qualities. The precautions for EHSP steel plate are almost the same as those for EH500 and EH500A grades.

1 Bending, machining (drilling), shearing, gas cutting, shot blasting and welding

The recommended precautions for fabrication and welding are almost the same as for EH500 and EH500A steel plates. When bending, defects in the plate edge should be removed as much as possible, because the toughness of EHSP is slightly lower than that of EH500 and EH500A.

2 Storage

It is recommended that EHSP steel plates with around HB450 should be waterproofed to prevent the generation of rust and pit corrosion which increases the possibility of cracking while in storage.

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