TECHNICAL
BULLETIN

JFE EVERHARD SUPER (JFE EH-SP)

[Super Abrasion Resistant Steel Plate]

JFE Steel Corporation

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I . Introduction

NKK has been manufacturing and marketing abrasion-resistant steel plates as "NK EVER-HARD" since 1955. Nowdays, NK EVER-HARD steel 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 machinery. The NK EVER-HARD series consists of 10 grades of steel plates with a Brinell hardness of more than 321.

To extend the life of machinery in more extreme environments, the requirements call for steel plates with even higher abrasion-resistance than that of the EH500 and EH500A grades, which have the highest abrasion-resistance in the NK 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.

NKK 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 NK EH-SP 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 NK EH-SP has been achieved by a uniform dispersion of a lot of high hardness precipitates in steel. The abrasion-resistance of NK EH-SP 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. NKK will be pleased if technical information in this bulletin serves its customers.

II. Specification

1. Manufacturing Process and Available Thickness

Grade	Thickness	Heat treatment
NK EH-SP	6～65mm	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 property

3. Hardness

Surface Brinell hardness (Load 3000kgf)	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 Torelance

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	Plates thickness mm					
	9.5	12	25.4	35	50.8	63.5
Mechanical properties of base plates	○	○	○	○	○	○
Abrasion resistant property	○	○	○	○	○	○
Machinability	—	○	—	—	—	—
Weldability	—	○	○	○	○	—
Welded joints	—	○	—	—	—	—

○: Tests were carried out.

1-2 Chemical Composition

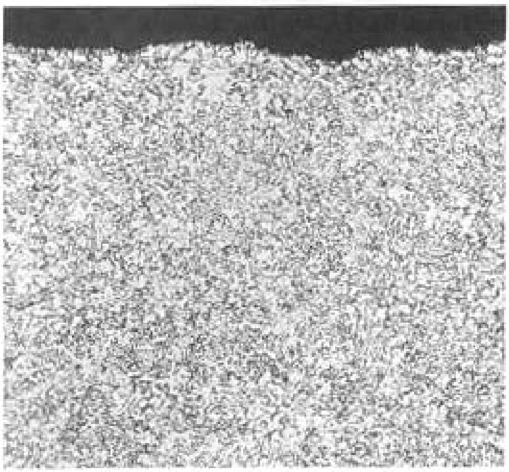
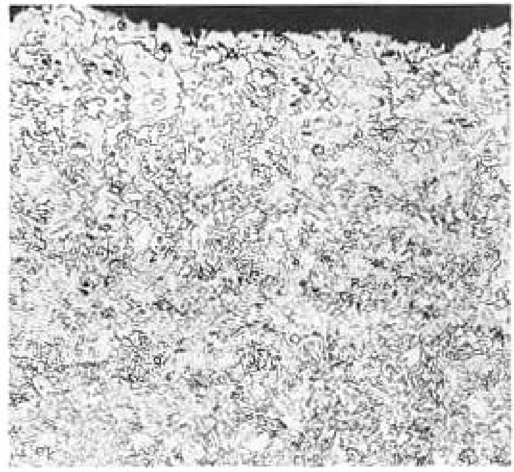
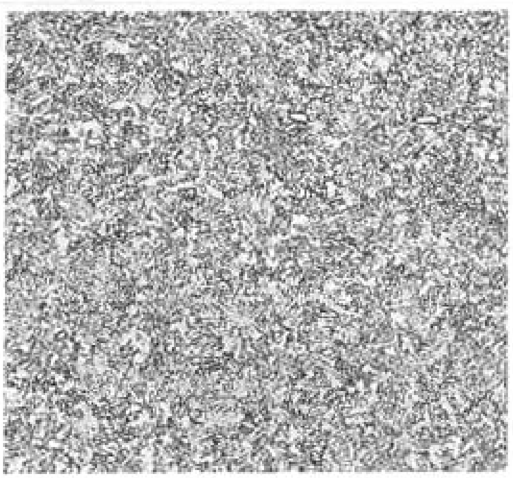
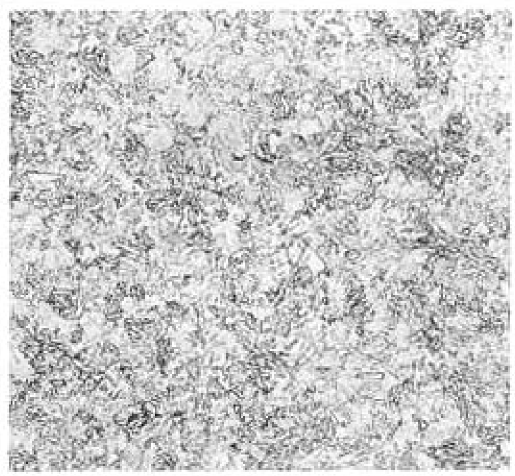
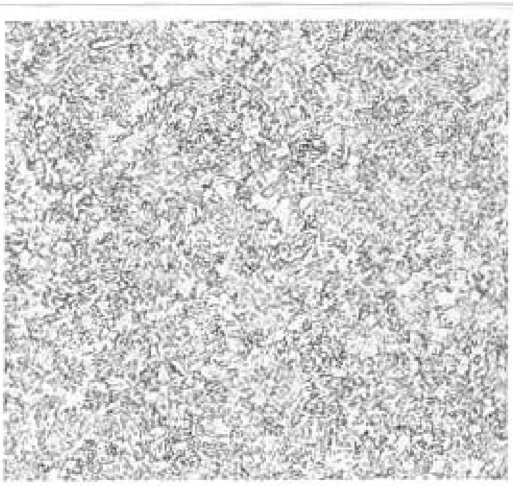
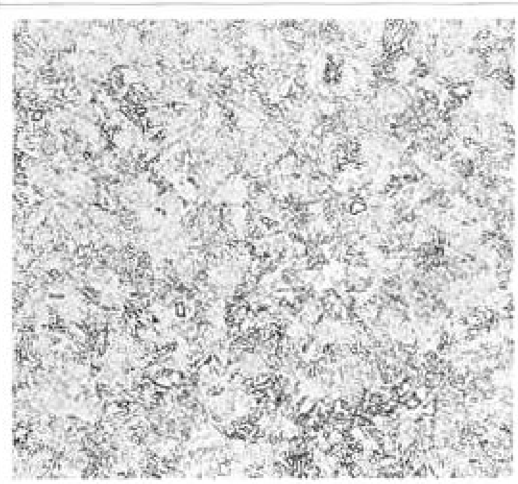
Table 2 Chemical Compositions of Steels Tested

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

(×200)

Photo. 1 Microstructure

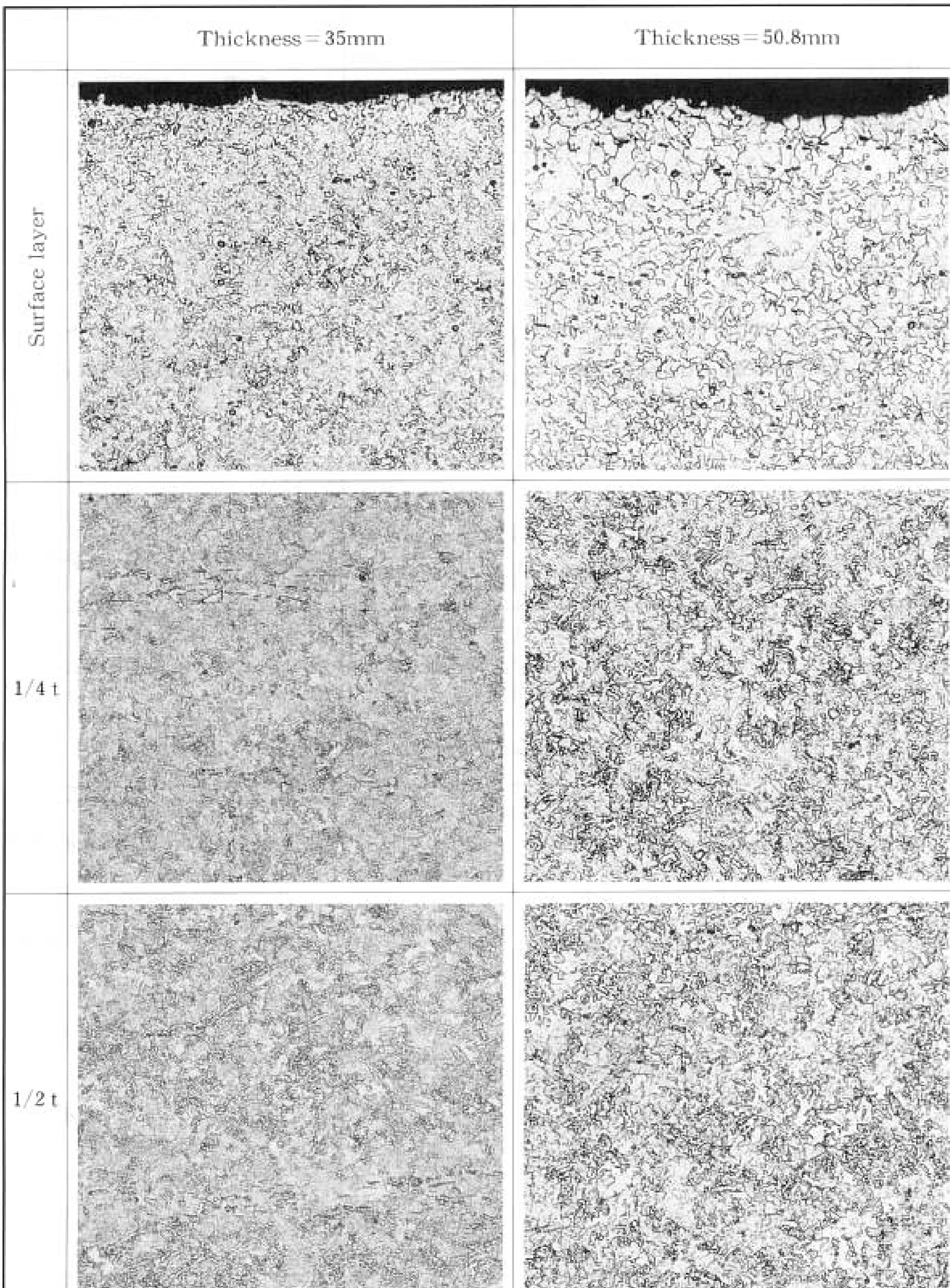


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Photo. 2 Microstructure

2-2 Hardness Distribution in Thickness Direction

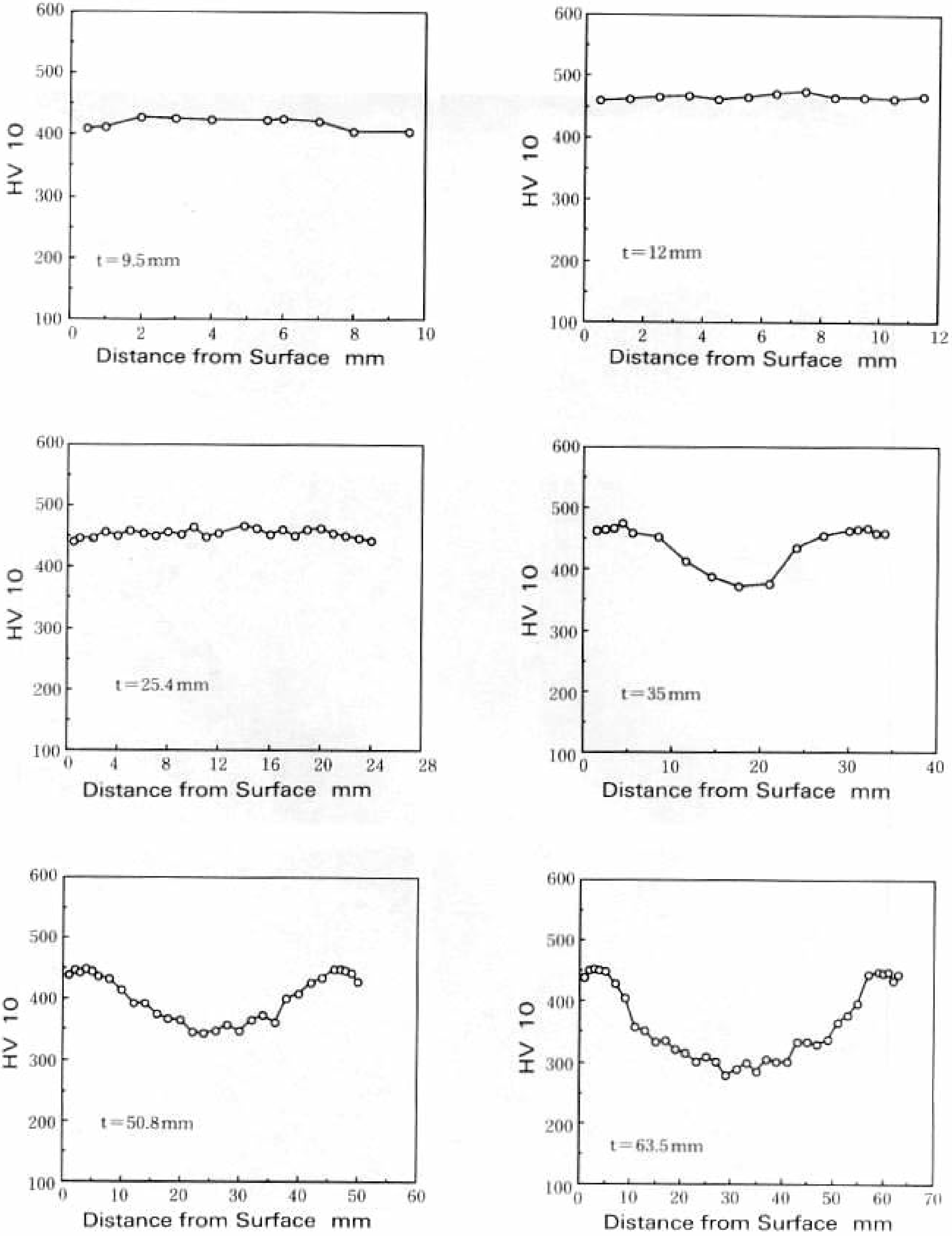

Fig.1 Hardness Distribution in Thickness Direction

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/mm^2	TS N/mm^2	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=50mm, W=25mm

JIS No.4: GL=50mm, d=14mmϕ

Table 4 Results of Charpy Impact Test

t mm	Specimen	Direction	Position	vEo* 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℃　**3/4 subsize

Specimen

JIS No.4: 2mm V-notch

3. Abrasion Resistant Property

3-1 Test Method

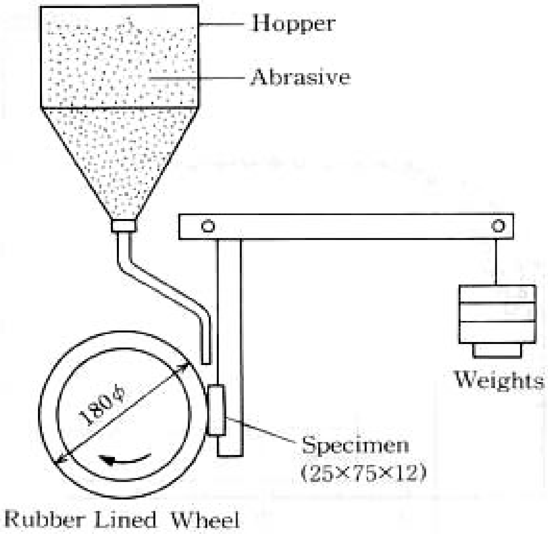

Fig.3 Apparatus of Abrasion Resistant Test

3-2 Test Results

Table 7 Results of Abrasion Resistant Test

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

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

2-5 Hardness Distribution of Gas-cut Surface

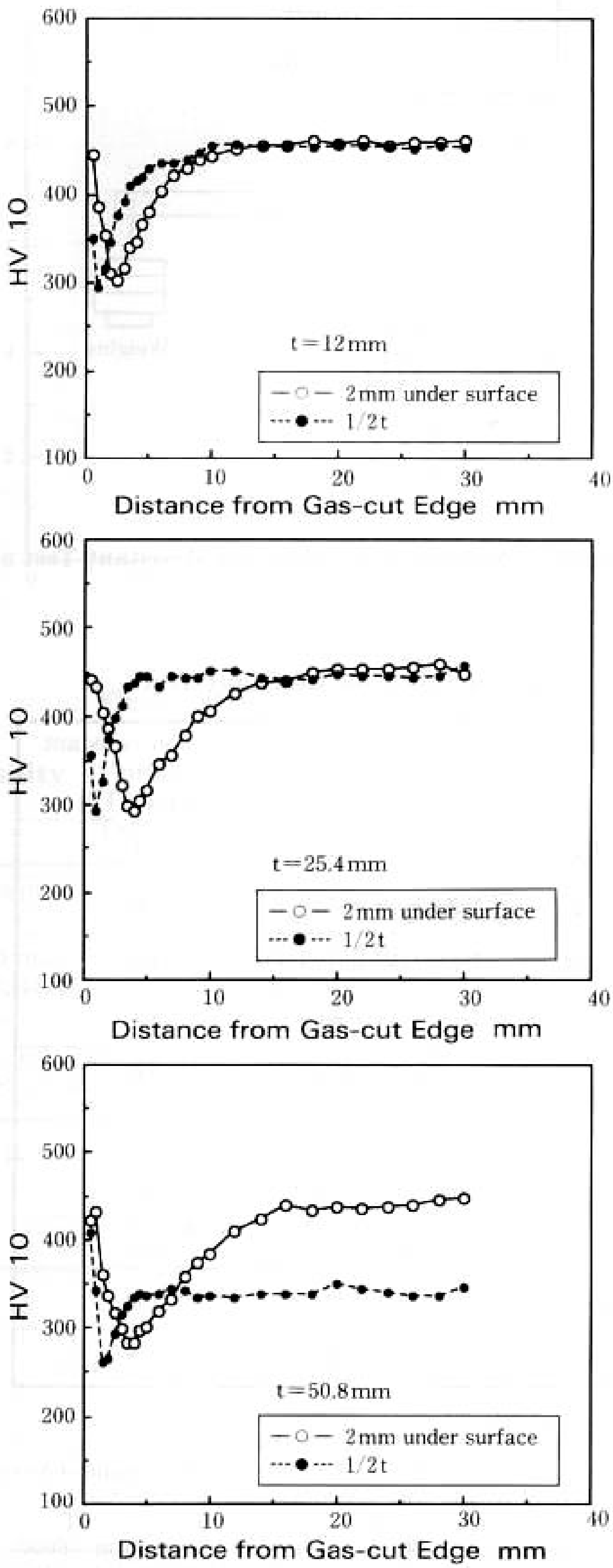

Fig.2 Hardness Distribution of Gas-cut Surface

3. Abrasion Resistant Property

3-1 Test Method

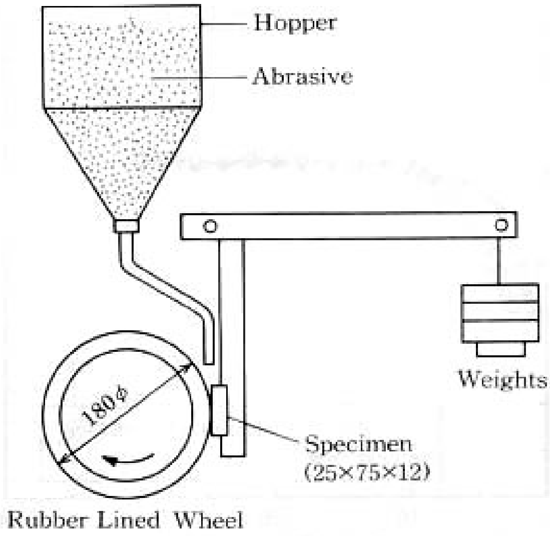

Fig.3 Apparatus of Abrasion Resistant Test

3-2 Test Results

Table 7 Results of Abrasion Resistant Test

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

* Brinell hardness of conventional steel
HB(SS400: Mild steel)=112, HB(NK EH500)=512

<Testing condition> Abrasive: Sand (100%SiO_2)…Flattery sand (Australia)
Wheel revolution: 200rpm
Applied stress: 130N
Testing time: 30min. (Number of rotation=6000)

** Abrasion resistant ratio={Weight loss (SS400: Mild steel)}/{Weight loss (Test sample)}

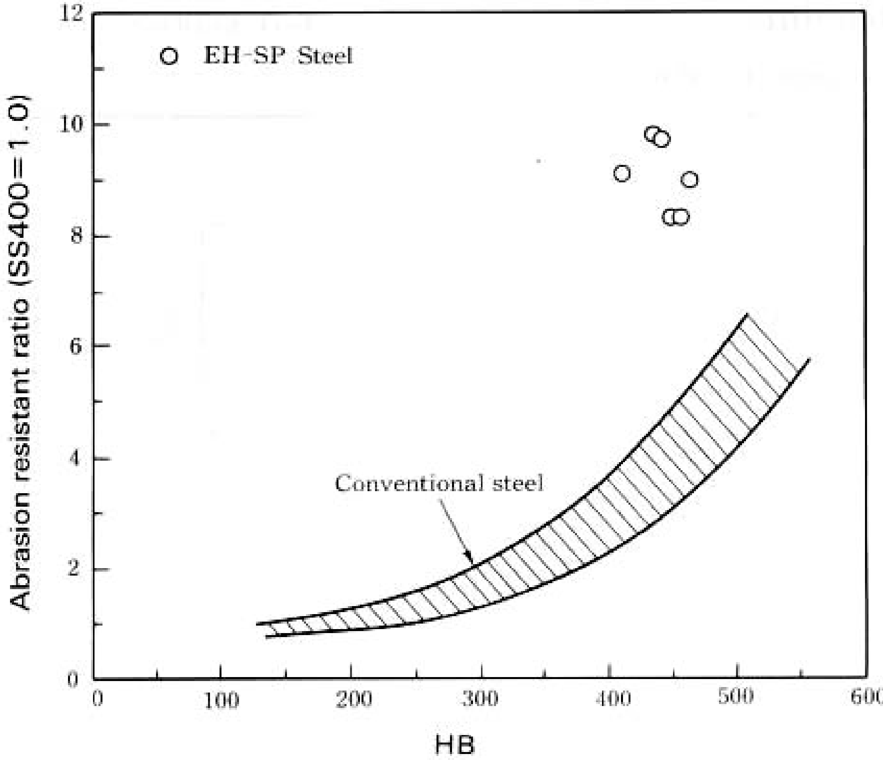


Fig.4 Results of Abrasion Resistant Test

4. Machinability

Table 8 Testing Conditions

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

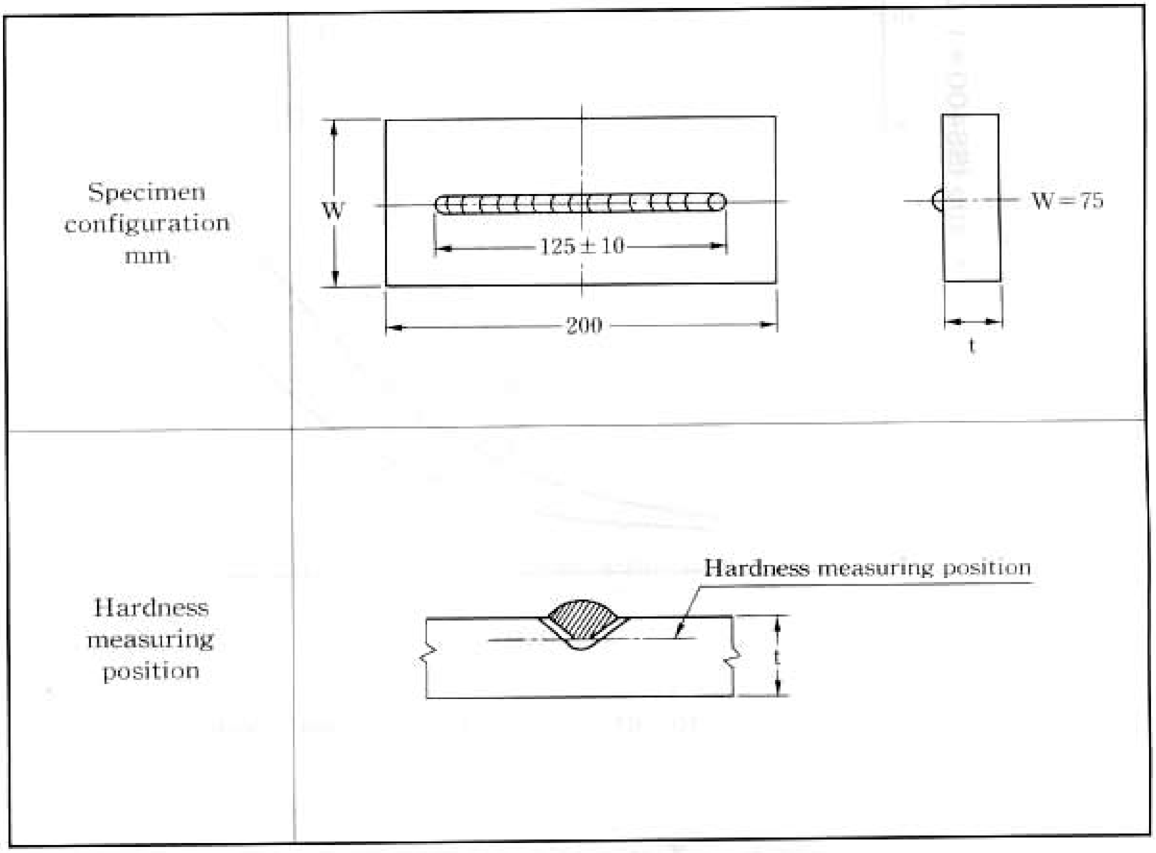


Fig.5 Specimen Configuration and Hardness Measuring Position

Table 10 Welding Conditions

Welding method	Welding material	Welding condition	Heat input kJ/mm	Preheat temperature ℃
SMAW	LB 62UL, 4mmϕ	170A-25V-150mm/min	1.7	25

Table 11 Results of Maximum Hardness Test

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

* : Specimen thickness=20mm

5-2 Y-Groove Cracking Test

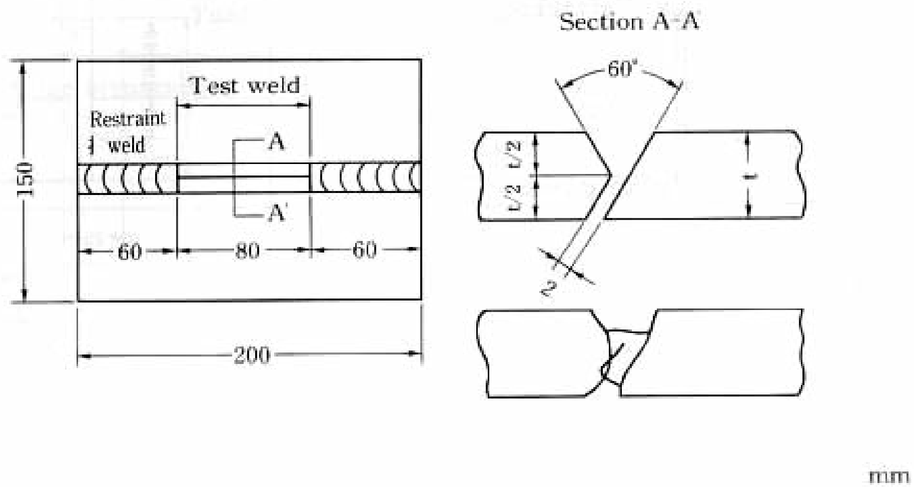


Fig.6 Specimen Configuration

Table 12 Welding Conditions

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

Table 13 Results of Y-Groove Cracking Test

t mm	Welding method	Preheat temperature to prevent from cracking ℃
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)

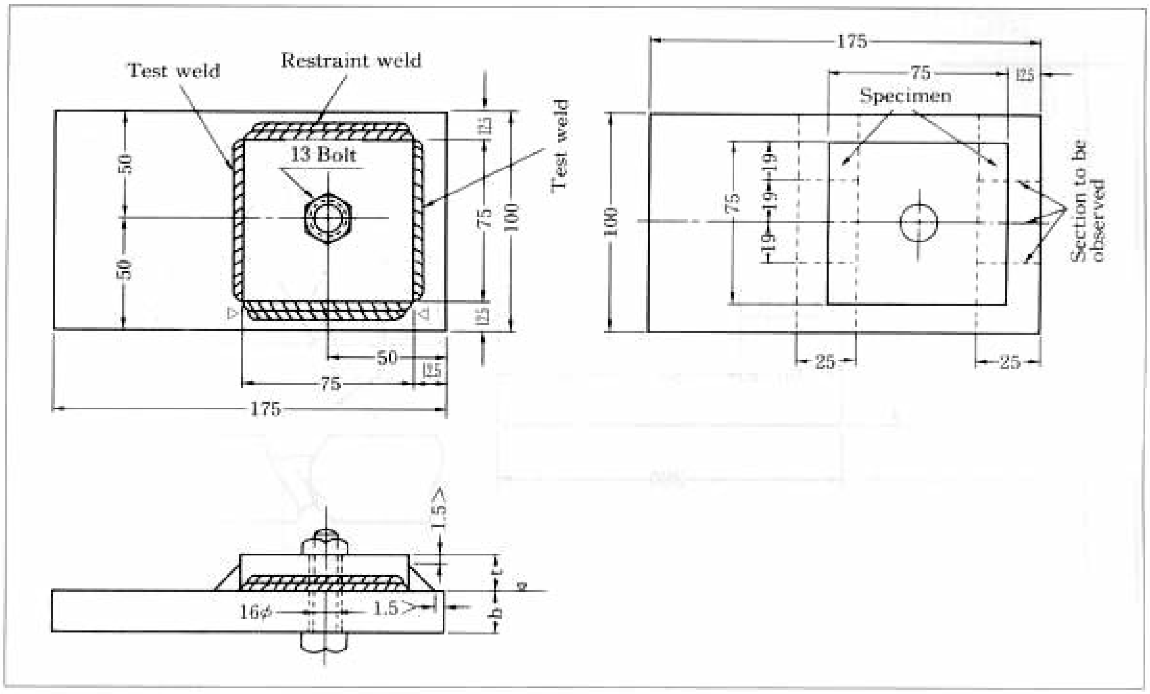


Fig.7 Specimen Configuration and Method for Observation of Cracking

Table 14 Welding Conditions

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

Table 15 Results of CTS Test

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

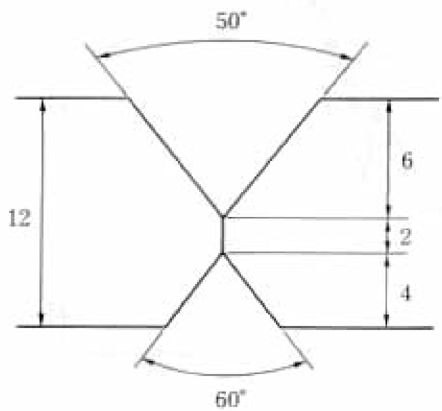
* : Cracking in weld-metal

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 5mm)
	Preheat temp. ℃	100
	Inter-pass temp. ℃	under 150
	Arc voltage V	25
	Welding current A	170
	Welding speed mm/min.	150
	Heat input kJ/mm	1.7

(2) Macrostructure

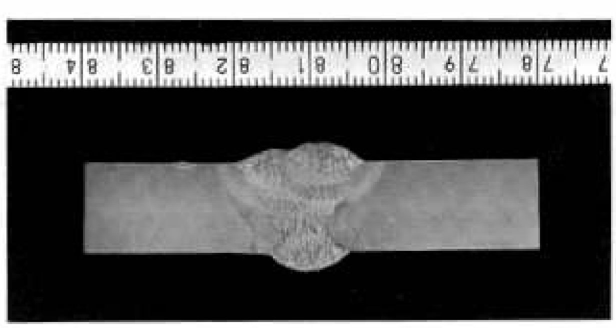


Photo.3 Macrostructure

(3) Hardness Distribution in Welded Joint

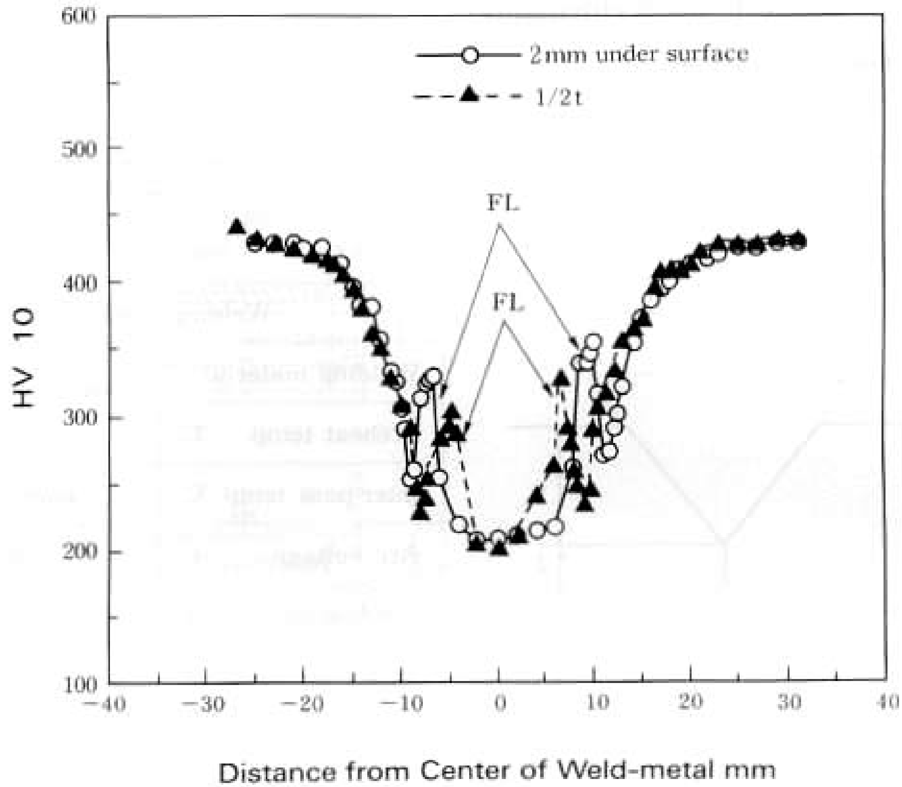


Fig.8 Hardness Distribution in Welded Joint

(4) Charpy Impact Test

Table 17 Results of Charpy Impact Test

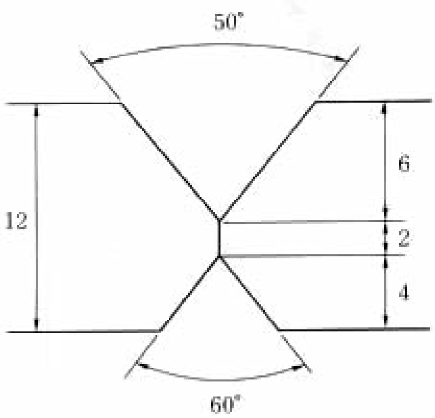
Welding method	Notch position	$_vE_0$ J			Ave.
SMAW	WM	106	114	119	113
	FL	30	56	58	48
	HAZ	67	75	81	74

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

6-2 CO_2 Gas Shielded Arc Welded Joints

(2) Welding Conditions

Table 18 Welding Conditions

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

(2) Macrostructure

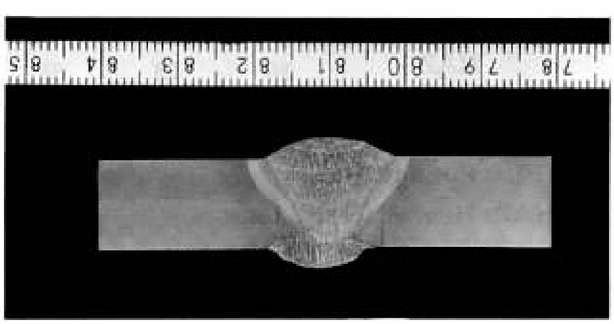


Photo.4 Macrostructure

(3) Hardness Distribution in Welded Joint

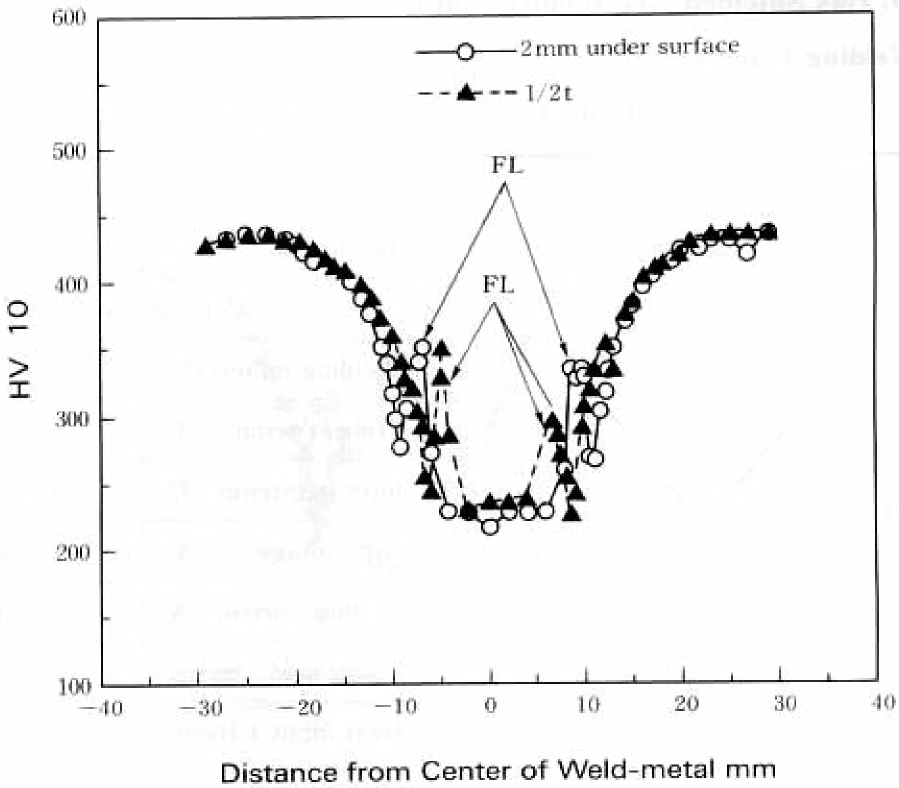


Fig.9 Hardness Distribution in Welded Joint

(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 NK EH-SP

Features of "NK EH-SP ; SUPER ABRASION RESISTANT STEEL PLATE" are :

(1) Abrasion resistant property of EH-SP steel plates is more excellent than that of EH500 and EH500A grades which have the highest hardness of the NK EVER-HARD series.

(2) Hardness level of NK EH-SP steel plate is lower than that of EH500 and EH500A grades. Brinell hardness level of EH-SP is HB≒450.

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

V. Recommended Practice in Fabrication and Welding

In fabrication and welding of EH-SP steel plate, some precautions should be taken in order to maintain its excellent properties. The precautions for EH-SP steel plate are fundamentally almost the same as those of 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 those of EH500 and EH500A steel plates. With respect to bending, the defects in the plate edge should be sufficiently removed, because the toughness of EH-SP steel plate is slightly lower than that of EH500 and EH500A.

(2) Storage method

It is recommended that EH-SP steel plates with around HB450 are to be waterproofed to prevent the generation of rust and pit corrosion which increase the posibility of cracking in storage.