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Flux-cored Wire Electrode for Ar+CO<sub>2</sub> Gas Shielded Arc Welding

“DWA-81Ni1”



Flux-cored Wire Electrode for Ar+CO<sub>2</sub> Gas Shielded Arc Welding  
"DWA-81Ni1"

AWS A5.29-1998    E81T1-Ni1MJ  
EN 758-1997      T46 6 1Ni P M 2 H5

### 1. Description

DWA-81Ni1 is an easy-to-use, titania based flux-cored wire electrode for all positional single pass and multiple-pass welding of mild steel to 550N/mm<sup>2</sup> class high strength steel with Ar+CO<sub>2</sub> shielding gas. This wire is applicable to low temperature service steel being used at down to -60°C.

DWA-81Ni1 wire electrode has a lot of characteristics as follows :

- 1) High notch toughness of welds at low temperature down to -60°C with as welded condition and to -40°C after PWHT (580°C × 1hr/inch).
- 2) Excellent weldability can be obtained in all position.
- 3) All positional welding can be achieved with good bead appearance, negligible spatter losses, and easy slag removal.

### 2. Properties of all-weld metal

Mechanical properties and chemical composition of all-weld metal with DWA-81Ni1 are shown in Tables 2, 3 and Figure 1.

Table 2    Mechanical properties of all-weld metal

PWHT	Tensile properties				Absorbed energy, J		
	0.2% PS N/mm <sup>2</sup>	TS N/mm <sup>2</sup>	EL %	RA %	vE-80°C	vE-60°C	vE-40°C
AW	517	582	29	71	61 (60)	162 (13)	161 (18)
					43 (65)	116 (20)	140 (10)
					19 (71)	147 (15)	156 (16)
					Avg. 41 (65)	Avg. 142 (16)	Avg. 153 (15)
SR	490	578	30	71	—	145 (31)	135 (26)
					—	109 (20)	142 (17)
					—	133 (34)	141 (25)
					—	Avg. 128 (34)	Avg. 139 (23)

According to AWS A5.29

280Amp. -29~30Volts, 14passes-7layers, 80%Ar+20%CO<sub>2</sub>(25 l/min)

PWHT condition : SR, 580°C × 2hr. Heating and cooling rate : 50°C/hr

Values in parentheses show the percent brittle fracture.

Table 3 Chemical composition of all-weld metal (%)

C	Si	Mn	P	S	Ni	Ti	B
0.049	0.32	1.26	0.006	0.006	0.95	0.041	0.0052

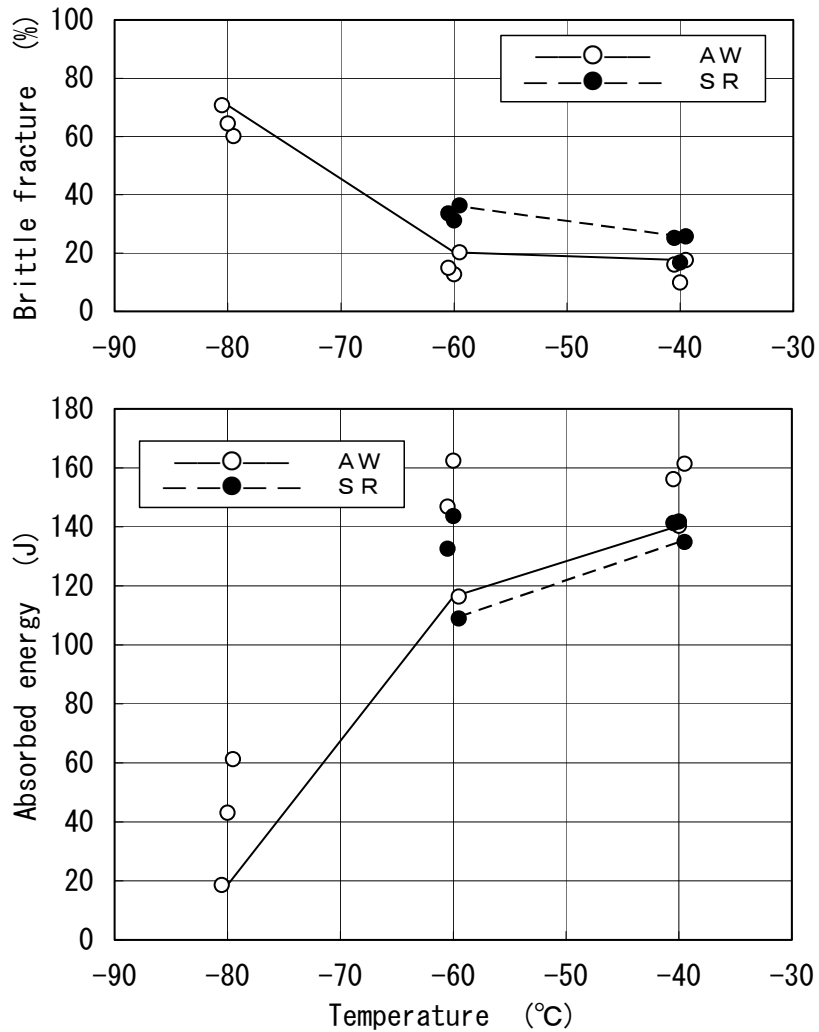


Fig.1 Transition curve of all-weld metal

### 3. Diffusible hydrogen content in weld metal

Table 4 Diffusible hydrogen content in deposited metal (ml/100g)

1	2	3	4	Average
4.1	4.0	4.4	4.9	4.4

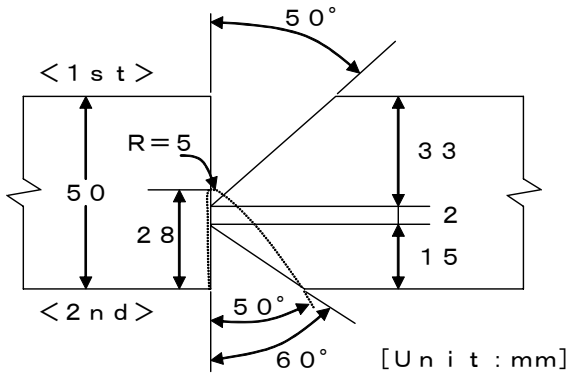
\* 1 Welding conditions : 280A-29V-30cm/min. , Wire extension=25mm

#### 4. Butt weld test result

##### (1) Test conditions

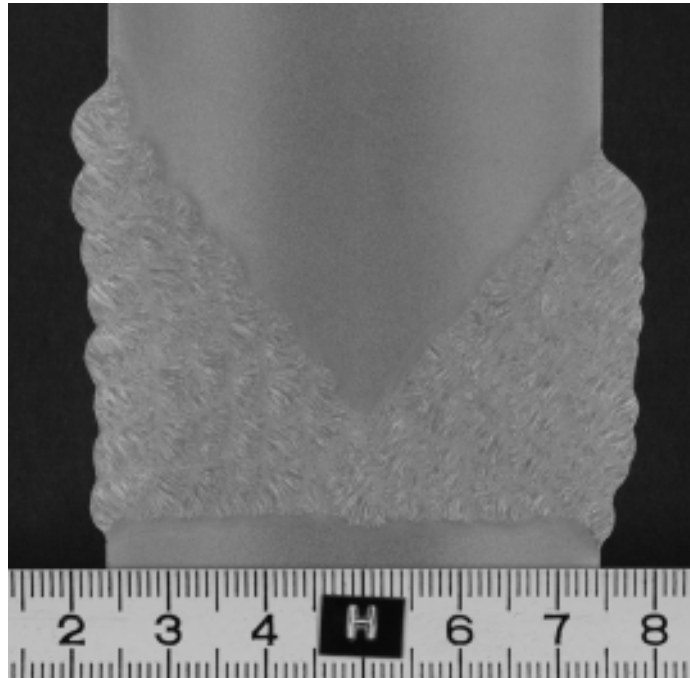
Testing conditions are shown in Table 5.

Table 5 Test conditions

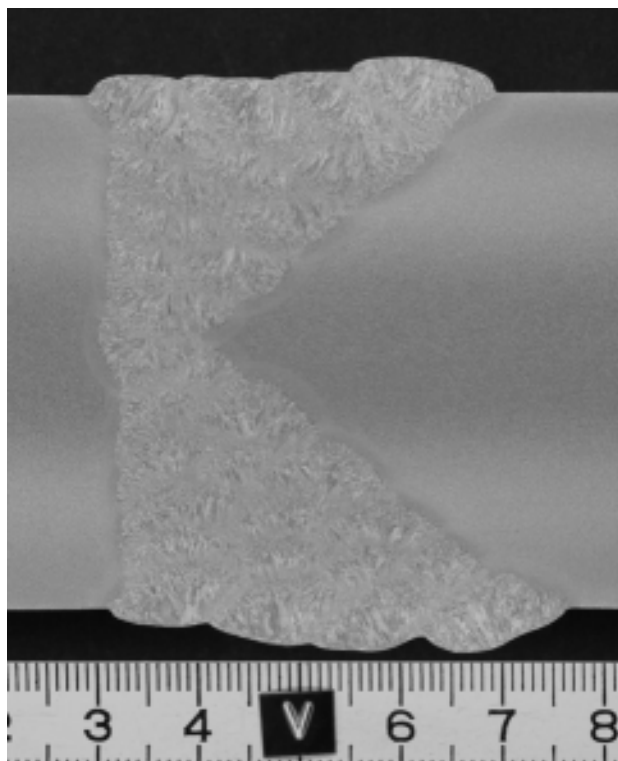
Items	Details
Steel plate	FH36, Plate thickness=50mm 50 <sup>t</sup> × (250+250) <sup>w</sup> × 850 <sup>l</sup> mm , 2 plates in each welding position
Groove shape	<p>Double bevel groove            1st side : Groove angle=50°,            Groove depth=33mm            2nd side : Groove angle=60°            Groove depth=15mm            Root face : 2mm            * After welding 1st side, the groove of 2nd side was machined to the shape of 50° groove angle, 28mm groove depth.</p>  <p>[Unit : mm]</p>
Welding procedure	Manual welding
Welding position	Horizontal (PC) and Vertical upward (PF)
Welding parameters	Horizontal (PC) : 260Amp., 28Volts Vertical (PF) : 220Amp., 25Volts
Pass sequence	Horizontal (PC) : 1st side = 36passes-8layers 2nd side = 39passes-6layers Vertical (PF) : 1st side = 18passes-7layers 2nd side = 13passes-6layers
Heat input	Horizontal (PC) : 0.92kJ/mm Vertical (PF) : 1.86kJ/mm
Shielding gas	80%Ar+20%CO <sub>2</sub> , 25 l/min
Preheating temperature	100°C
Interpass temperature	100~150°C
PWHT	As welded, SR treatment Heating rate : 104~108°C/hr Holding temp. & time : 579~581°C, 2~2.2hrs, Cooling rate : 68~75°C/hr Controlled lower limit temp. : 80°C

(2) Test results

Macrostructures of welded joints are shown in Photo 1. Results of tensile test and impact test are shown in Table 6, Figures 2 and 3. CTOD test results are shown in Table 7. Chemical compositions of weld metals are shown in Table 8.



(a) Horizontal position (PC)



(b) Vertical position (PF)

Photo 1 Macrostructures of welded joints

Table 6 Mechanical properties of welded joints

Welding position	PWHT	Side	0.2% PS N/mm <sup>2</sup>	TS N/mm <sup>2</sup>	EI %	RA %	Absorbed energy, J			vTrs (°C)
							vE-60°C	vE-50°C	vE-40°C	
Horizontal (PC)	AW	1st	592	628	25	71	91 (13) 84 (24) 87 (18) Avg. 88 (18)	118 (11) 95 (14) 105 (13) Avg. 106 (13)	133 ( 3) 106 ( 7) 115 ( 7) Avg. 118 ( 6)	<-60
		Center	-	-	-	-	53 (38) 63 (11) 66 (24) Avg. 61 (24)	89 ( 6) 82 (43) 82 (21) Avg. 84 (23)	89 ( 8) 110 (13) 100 (15) Avg. 100 (12)	<-60
		2nd	581	604	25	68	56 (43) 66 (46) 43 (60) Avg. 55 (50)	105 (14) 129 ( 2) 90 (20) Avg. 108 (12)	103 (13) 90 (23) 123 ( 0) Avg. 105 (12)	-60
	SR	1st	583	647	25	62	21 (61) 16 (70) 18 (60) Avg. 18 (64)	42 (60) 40 (55) 28 (45) Avg. 37 (52)	42 (46) 57 (40) 52 (39) Avg. 51 (42)	-48
		Center	-	-	-	-	46 (57) 43 (63) 44 (43) Avg. 44 (54)	68 (34) 49 (38) 71 (46) Avg. 63 (39)	81 (24) 77 (28) 75 (23) Avg. 78 (25)	-57
		2nd	533	596	26	63	25 (69) 63 (45) 37 (46) Avg. 42 (53)	66 (47) 45 (59) 42 (47) Avg. 51 (51)	70 (35) 125 (14) 64 (41) Avg. 87 (30)	-50
Vertical (PF)	AW	1st	530	586	28	71	49 (34) 82 (29) 72 (31) Avg. 67 (31)	92 (21) 96 (22) 93 (27) Avg. 94 (23)	88 (16) 99 (21) 91 (25) Avg. 93 (21)	<-60
		Center	-	-	-	-	96 (12) 85 (11) 100 (17) Avg. 94 (13)	110 (11) 100 (13) 107 (11) Avg. 105 (12)	127 ( 4) 129 ( 1) 117 ( 9) Avg. 124 ( 5)	<-60
		2nd	544	604	27	71	111 (12) 94 (15) 81 (24) Avg. 95 (17)	130 (12) 115 (13) 121 ( 4) Avg. 122 (10)	128 ( 6) 129 ( 7) 139 ( 7) Avg. 132 ( 7)	<-60
	SR	1st	525	595	26	70	63 (62) 50 (61) 33 (65) Avg. 49 (63)	78 (43) 100 (29) 80 (45) Avg. 86 (39)	107 (31) 110 (23) 110 (28) Avg. 109 (27)	-53
		Center	-	-	-	-	23 (65) 38 (56) 46 (61) Avg. 36 (61)	53 (44) 41 (56) 37 (58) Avg. 44 (53)	63 (34) 55 (54) 69 (32) Avg. 62 (40)	-47
		2nd	509	591	30	71	68 (45) 67 (39) 76 (39) Avg. 70 (41)	96 (35) 113 (28) 63 (44) Avg. 91 (36)	136 (18) 137 (15) 106 (21) Avg. 126 (18)	<-60

Values in parentheses show percent brittle fracture.

PWHT condition : SR, Holding temp. and time : 579~581°C, 2~2.2hrs

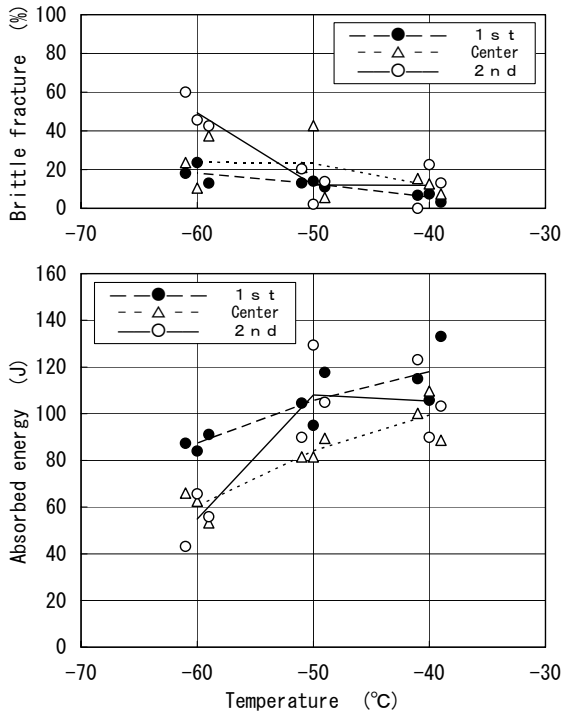
Heating rate : 104~108°C/hr

Cooling rate : 68~ 75°C/hr

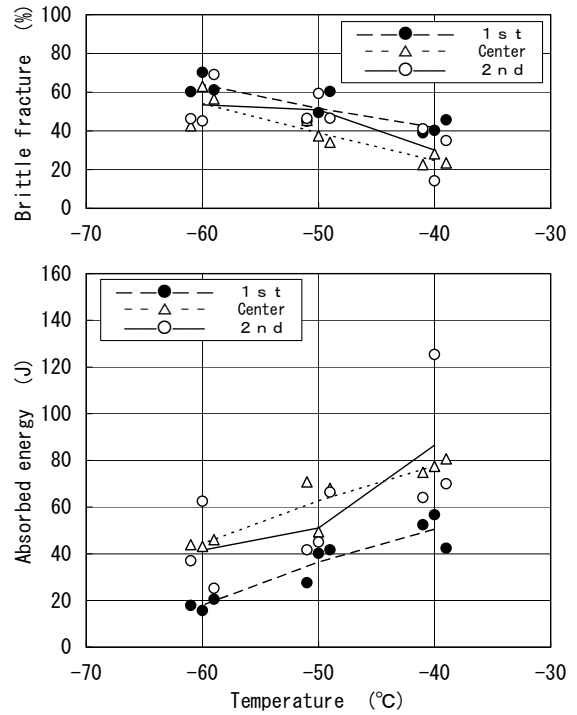
Locations of specimens:

1st, 2nd = 7mm from the face of the test plates, each.

Center = Center of the plate thickness.

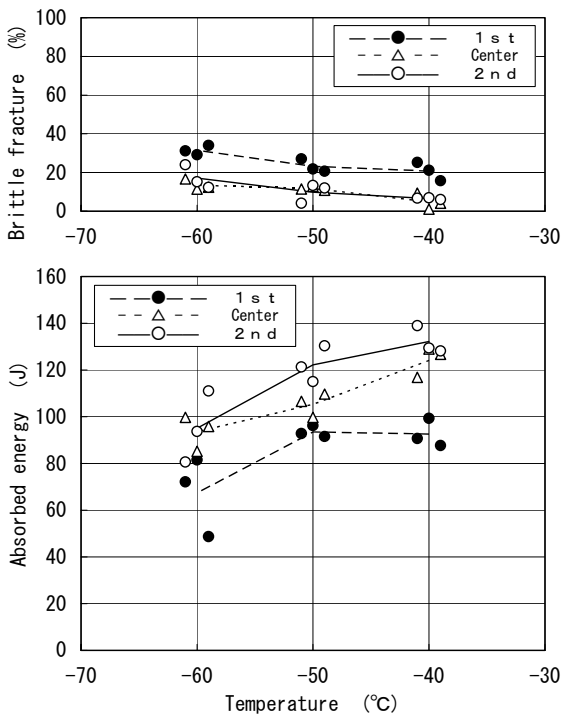


(a) As welded

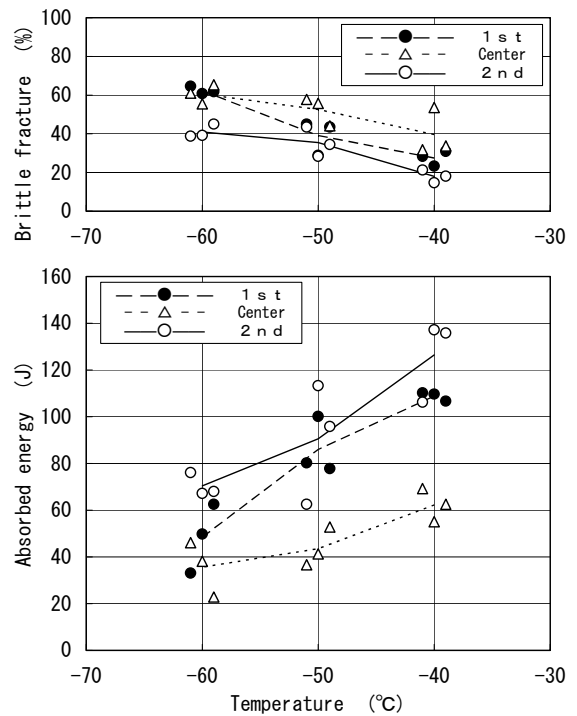


(b) PWHT (580°C x 2hrs)

Fig. 2 Transition curves of weld metals in horizontal position(PC)



(a) As welded



(b) PWHT (580°C x 2hrs)

Fig. 3 Transition curves of weld metals in vertical position(PF)

Table 7 CTOD test results (as welded) \* 1, 2

Welding Position	Test Temp. (°C)	B (mm)	W (mm)	Crack Length a (mm)	Yield Strength $\sigma_y$ (N/mm <sup>2</sup> )	Applied Force F <sub>c, u, m</sub> (kN)	V <sub>c, u, m</sub> (mm)	Type of F-V	Critical CTOD (mm)
Horizontal (PC)	-10	50.31	100.10	51.18	600	212.5	1.11	6 (δ <sub>m</sub> )	0.38
		50.46	100.10	51.07	600	222.5	1.11	6 (δ <sub>m</sub> )	0.38
		50.38	100.08	50.98	600	221.0	1.10	6 (δ <sub>m</sub> )	0.38
Vertical (PF)	-10	50.24	100.09	50.86	550	224.5	2.04	6 (δ <sub>m</sub> )	0.65
		50.35	100.10	50.96	550	231.5	2.43	6 (δ <sub>m</sub> )	0.76
		50.32	100.10	50.75	550	229.0	2.48	6 (δ <sub>m</sub> )	0.77

\* 1 According to BS7448-1991

\* 2 Precompression : 33mmφ, 900kN, 30sec, Actual strain : 0.30~0.48%

\* 3 The value in parentheses shows CTOD when pop-in is ignored.

Table 8 Chemical compositions of weld metals \* 1 (mass%)

Welding position	Side	C	Si	Mn	P	S	Ni	Ti	B
Horizontal (PC) Heat input 0.92kJ/mm	1st	0.048	0.31	1.27	0.007	0.007	0.96	0.052	0.0050
	Center	0.049	0.31	1.28	0.007	0.007	0.98	0.049	0.0051
	2nd	0.049	0.31	1.25	0.008	0.008	0.98	0.053	0.0050
Vertical (PF) Heat input 1.86kJ/mm	1st	0.043	0.29	1.20	0.006	0.005	0.99	0.037	0.0051
	Center	0.050	0.30	1.28	0.007	0.006	0.90	0.044	0.0056
	2nd	0.049	0.31	1.25	0.008	0.007	0.96	0.046	0.0057
Base metal (FH36)		0.07	0.18	1.44	0.006	0.001	C <sub>eq.</sub> = 0.32 * 2 PCM = 0.16 * 2		

\* 1 Locations of analysis : The same locations as the impact tests.

\* 2 C<sub>eq.</sub> = C+Mn/6+(Cu+Ni)/15+(Cr+Mo+V)/5

PCM = C+Si/30+(Mn+Cu+Cr)/20+Ni/60+Mo/15+V/10+B\*5

## 5. Shipping approvals

Shipping approvals are shown in Table 9.

Table 9 Shipping approvals

Classification society	LR	ABS	DNV
Grade	5Y42	5YQ420 4Y400 (MG)	VY42 VY



# Appendices

## A-1. Welding conditions

Details of the welding conditions are shown Tables A-1 and A-2.

**Table A-1 Welding conditions in horizontal position(PC)**

Side	Layer	Pass	Welding Current (Amp.)	Arc Voltage (Volt)	Welding Speed (cm/min)	Heat Input (kJ/mm)	Interpass Temp. (°C)	Side	Layer	Pass	Welding Current (Amp.)	Arc Voltage (Volt)	Welding Speed (cm/min)	Heat Input (kJ/mm)	Interpass Temp. (°C)	
1st	1	1	260	28	38.6	1.13	106	2nd	1	1	260	28	40.2	1.09	121	
	2	2	260	28	53.1	0.82	132		2	2	260	28	44.3	0.98	122	
	2	3	260	28	43.2	1.01	134		2	3	260	28	49.0	0.89	131	
	3	4	260	28	56.7	0.77	127		2	4	260	28	36.4	1.20	121	
	3	5	260	28	47.7	0.92	136		2	5	260	28	41.5	1.05	132	
	3	6	260	28	48.1	0.91	135		3	6	260	28	42.9	1.02	126	
	4	7	260	28	56.0	0.78	124		3	7	260	28	50.5	0.87	132	
	4	8	260	28	54.3	0.81	132		3	8	260	28	36.7	1.19	133	
	4	9	260	28	54.3	0.81	135		3	9	260	28	43.6	1.00	135	
	4	10	260	28	50.0	0.87	130		3	10	260	28	50.5	0.87	132	
	5	11	260	28	51.0	0.86	145		4	11	260	28	51.0	0.86	129	
	5	12	260	28	54.8	0.80	141		4	12	260	28	48.1	0.91	129	
	5	13	260	28	52.0	0.84	145		4	13	260	28	46.4	0.94	128	
	5	14	260	28	56.0	0.78	144		4	14	260	28	47.7	0.92	125	
	5	15	260	28	47.2	0.92	138		4	15	260	28	36.4	1.20	129	
	6	16	260	28	55.4	0.79	139		4	16	260	28	42.9	1.02	128	
	6	17	260	28	56.0	0.78	141		4	17	260	28	48.1	0.91	129	
	6	18	260	28	54.3	0.81	137		5	18	260	28	50.5	0.87	126	
	6	19	260	28	51.5	0.85	138		5	19	260	28	49.0	0.89	130	
	6	20	260	28	52.0	0.84	136		5	20	260	28	47.2	0.92	125	
	6	21	260	28	45.1	0.97	133		5	21	260	28	47.2	0.92	125	
	7	22	260	28	49.0	0.89	143		5	22	260	28	44.0	0.99	126	
	7	23	260	28	48.6	0.90	147		5	23	260	28	44.7	0.98	130	
	7	24	260	28	50.5	0.87	145		5	24	260	28	48.1	0.91	124	
	7	25	260	28	47.2	0.92	143		5	25	260	28	44.0	0.99	125	
	7	26	260	28	50.5	0.87	143		5	26	260	28	42.5	1.03	129	
	7	27	260	28	49.0	0.89	142		5	27	260	28	42.5	1.03	127	
	7	28	260	28	45.1	0.97	142		5	28	260	28	50.0	0.87	128	
	8	29	260	28	46.4	0.94	130		6	29	260	28	47.7	0.92	127	
	8	30	260	28	44.7	0.98	136		6	30	260	28	49.5	0.88	123	
	8	31	260	28	45.1	0.97	138		6	31	260	28	50.5	0.87	130	
	8	32	260	28	46.8	0.93	136		6	32	260	28	49.5	0.88	128	
	8	33	260	28	47.7	0.92	138		6	33	260	28	48.1	0.91	128	
	8	34	260	28	47.2	0.92	137		6	34	260	28	50.5	0.87	127	
	8	35	260	28	43.2	1.01	131		6	35	260	28	51.0	0.86	126	
	8	36	260	28	50.0	0.87	138		6	36	260	28	52.0	0.84	127	
Avg.							0.89	Avg.							0.95	
Average of both side																0.92

**Table A-2 Welding conditions in vertical position(PF)**

Side	Layer	Pass	Welding Current	Arc Voltage	Welding Speed	Heat Input	Interpass Temp.	Side	Layer	Pass	Welding Current	Arc Voltage	Welding Speed	Heat Input	Interpass Temp.		
1st	1	1	220	25	15.0	2.20	104	2nd	1	1	220	25	17.9	1.84	98		
	2	2	220	25	16.6	1.99	126		2	2	220	25	15.9	2.08	116		
	3	3	220	25	19.6	1.68	144		3	3	220	25	25.8	1.28	129		
	3	4	220	25	14.3	2.31	123		3	4	220	25	17.2	1.92	125		
	4	5	220	25	16.5	2.00	133		4	5	220	25	18.5	1.79	131		
	4	6	220	25	21.3	1.55	133		4	6	220	25	15.8	2.09	135		
	4	7	220	25	13.7	2.41	112		5	7	220	25	16.8	1.96	120		
	5	8	220	25	16.3	2.03	138		5	8	220	25	18.7	1.77	130		
	5	9	220	25	17.3	1.91	129		5	9	220	25	13.7	2.41	130		
	5	10	220	25	17.4	1.90	134		6	10	220	25	17.8	1.86	133		
	6	11	220	25	18.2	1.81	131		6	11	220	25	17.4	1.90	138		
	6	12	220	25	19.0	1.73	138		6	12	220	25	20.7	1.59	139		
	6	13	220	25	24.6	1.34	146		6	13	220	25	18.0	1.83	135		
	6	14	220	25	23.4	1.41	136										
	7	15	220	25	17.3	1.90	134										
	7	16	220	25	18.3	1.81	136										
	7	17	220	25	20.7	1.59	134										
	7	18	220	25	19.4	1.70	133										
Avg.							1.85	Avg.							1.87		
Average of both side																1.86	

A-2. Microstructures of weld metal

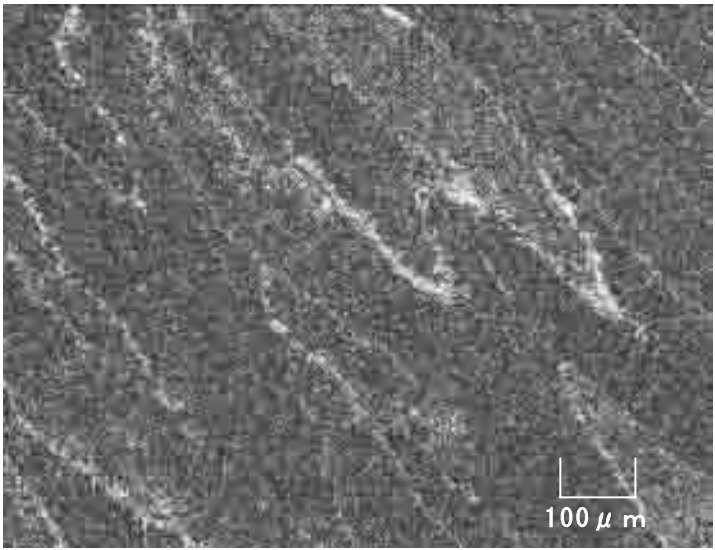
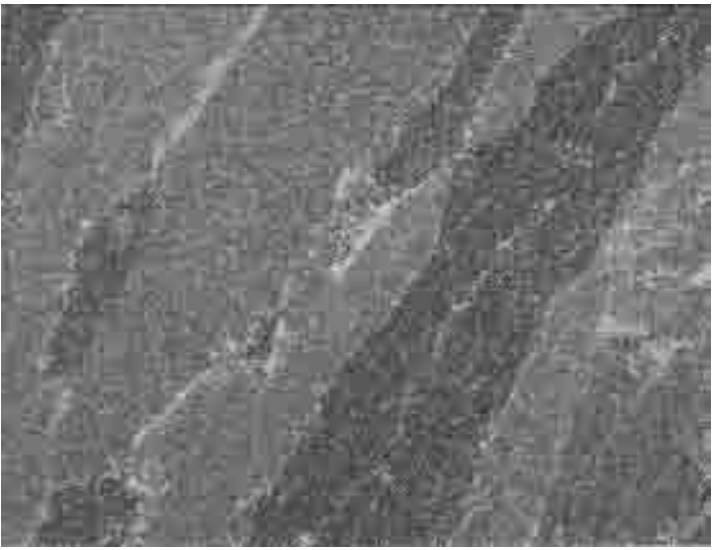
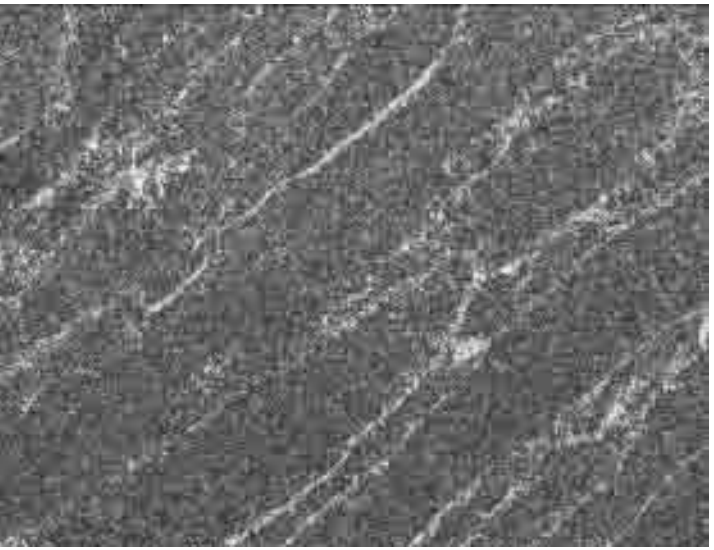
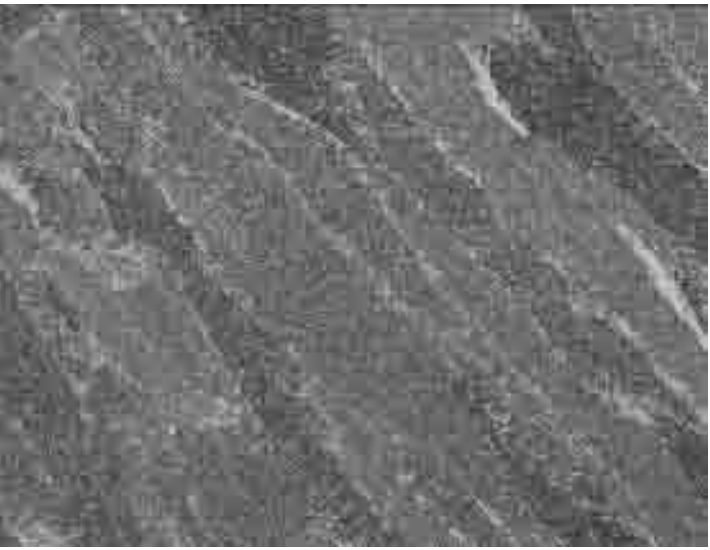
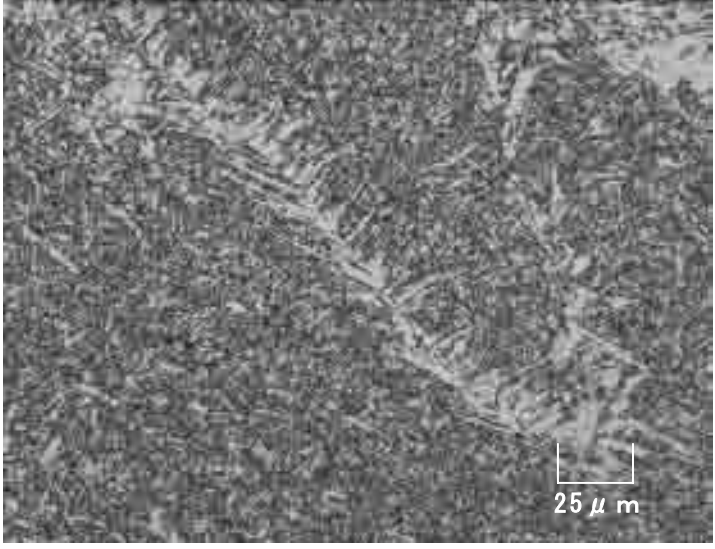
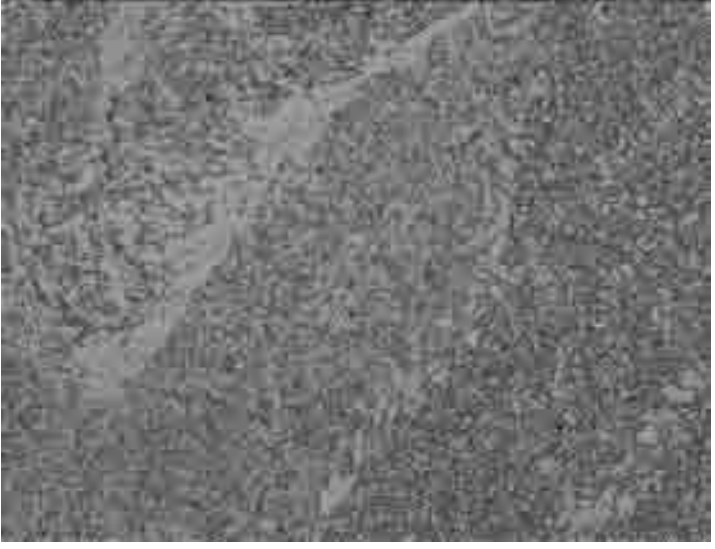
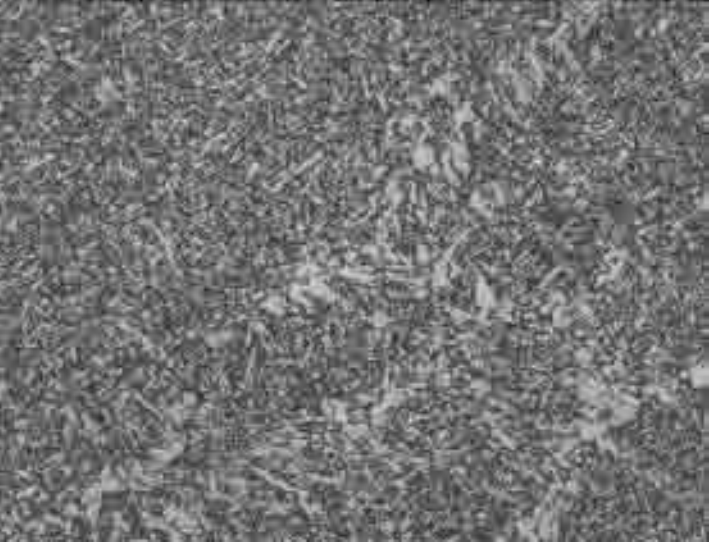
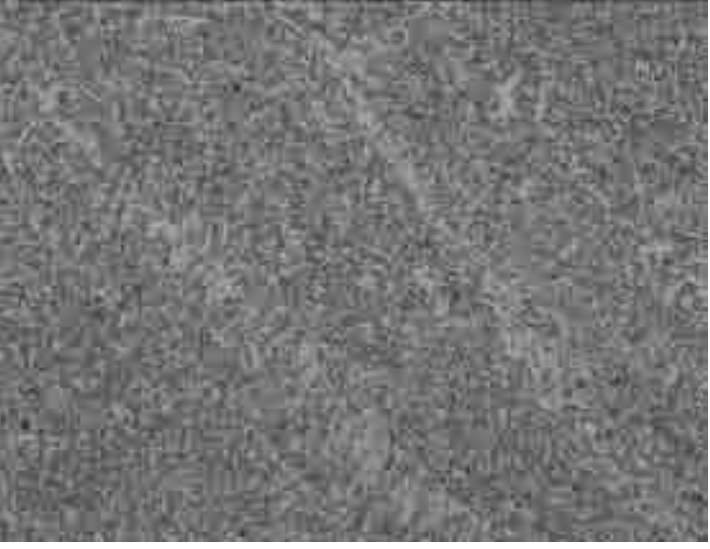
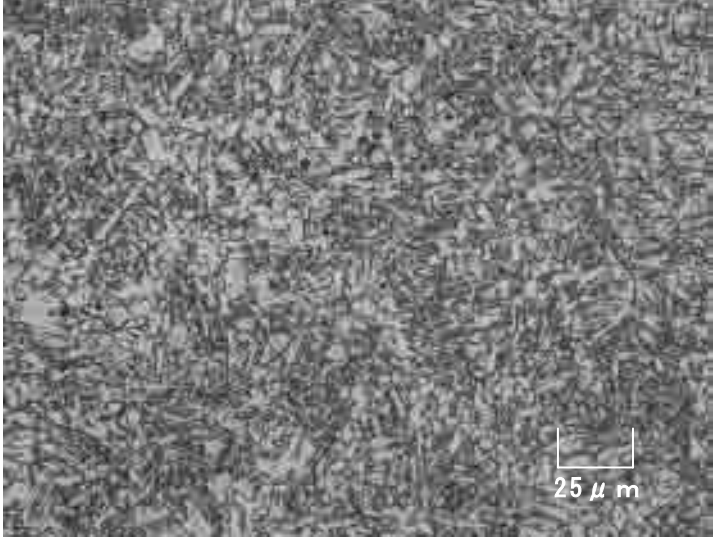

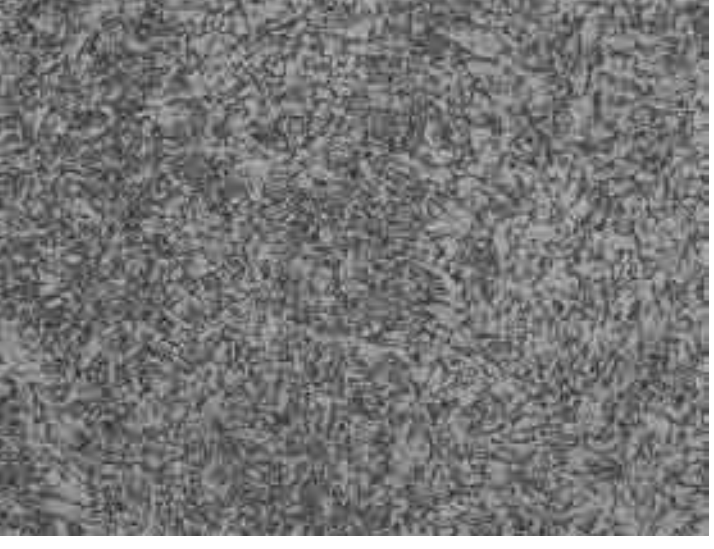

	1st side		2nd side	
	As welded	SR (580°C × 2hrs)	As welded	SR (580°C × 2hrs)
As casted zone (X100)				
As casted zone (X400)				
Refined zone (X400)				

Photo A-1 Microstructure of weld metal in horizontal position(PC)

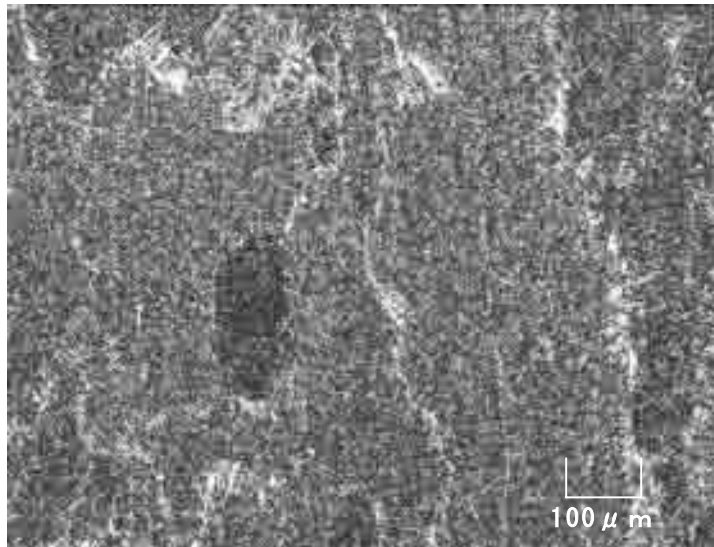
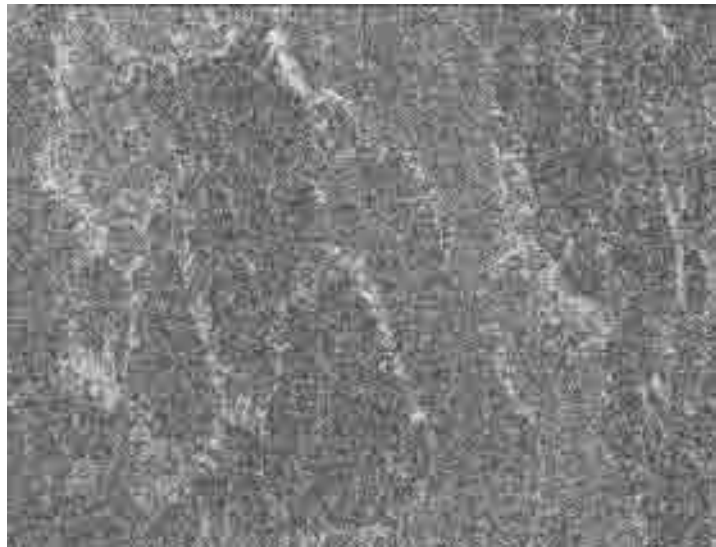


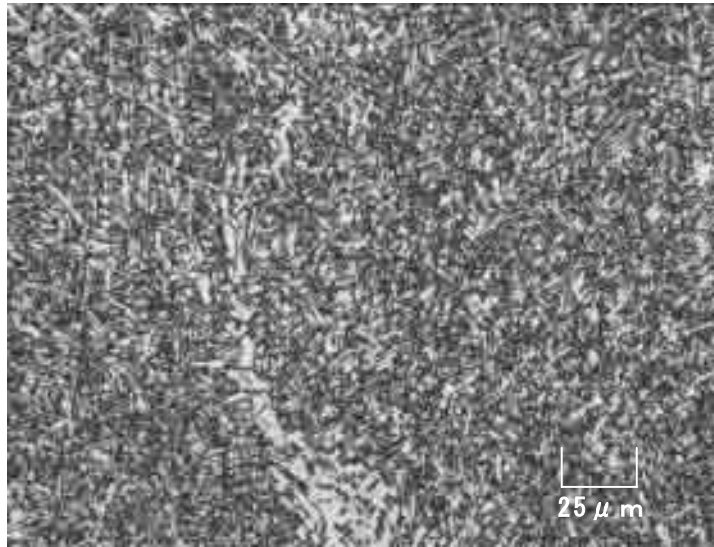
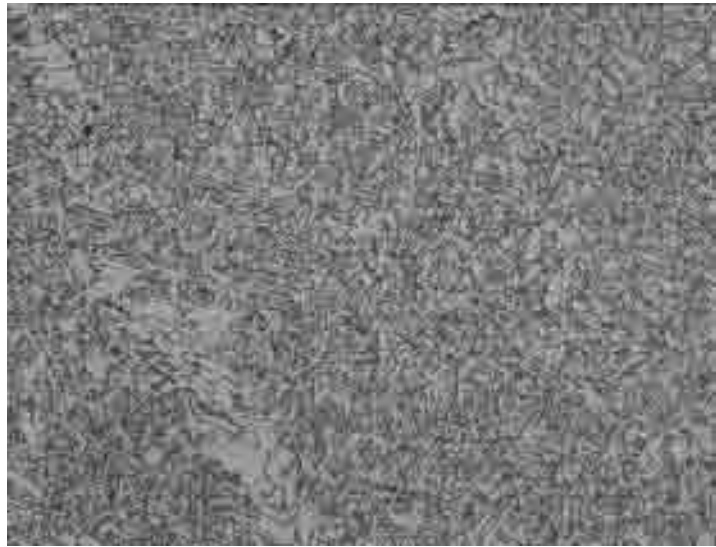
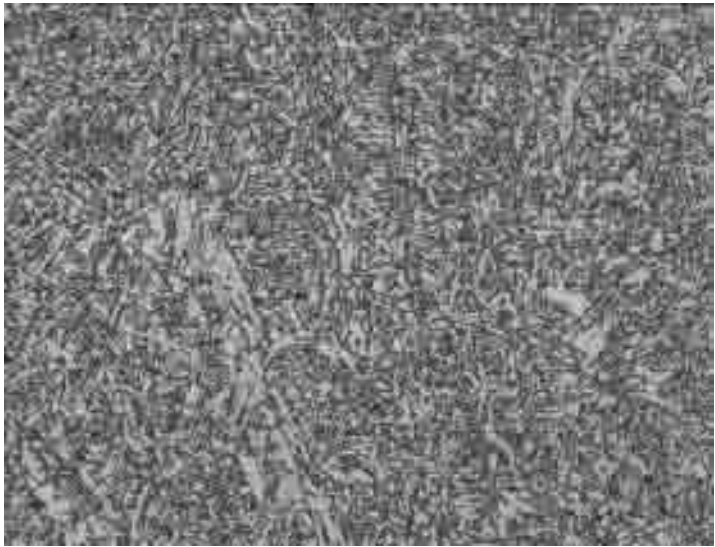
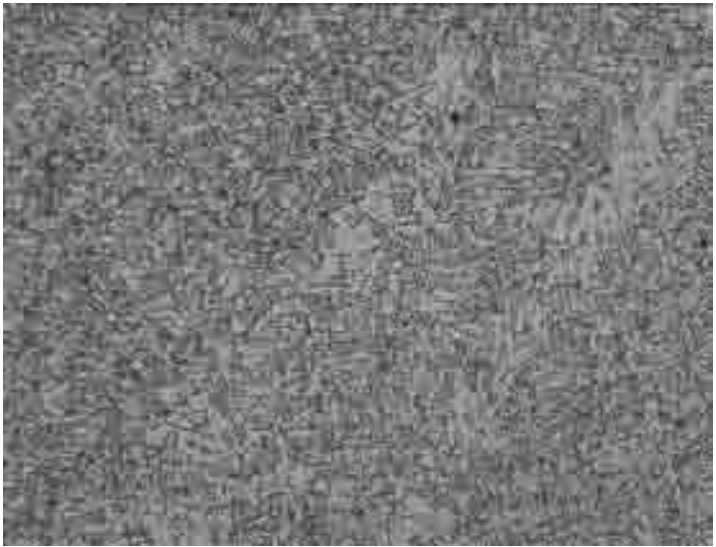
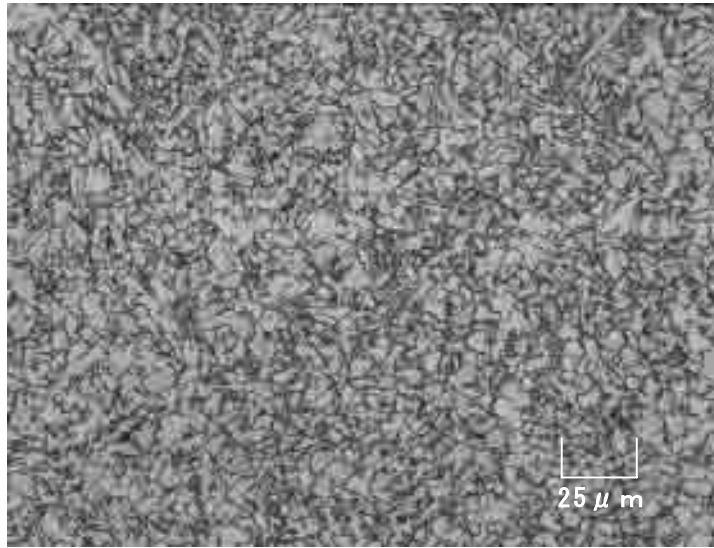
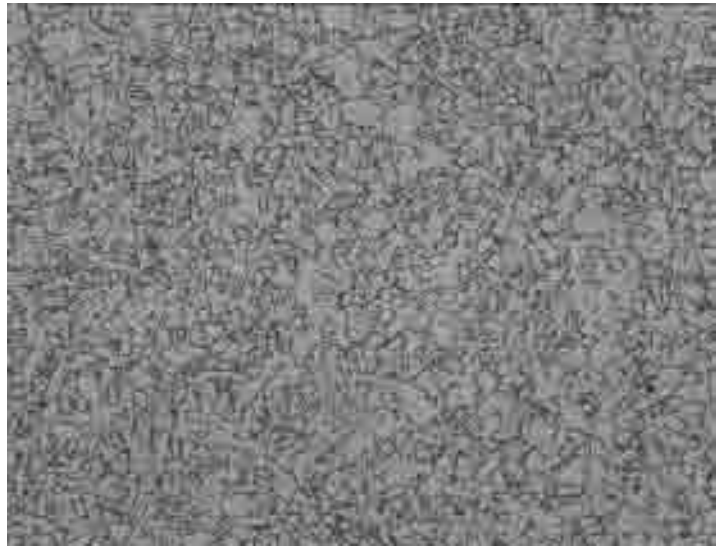
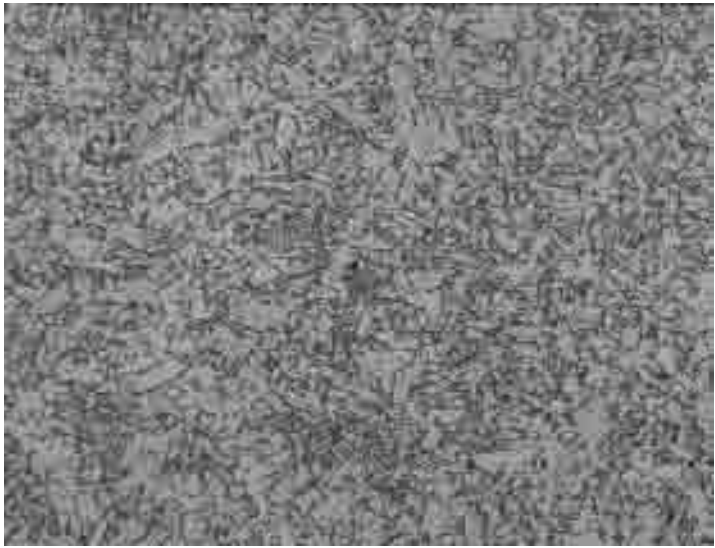
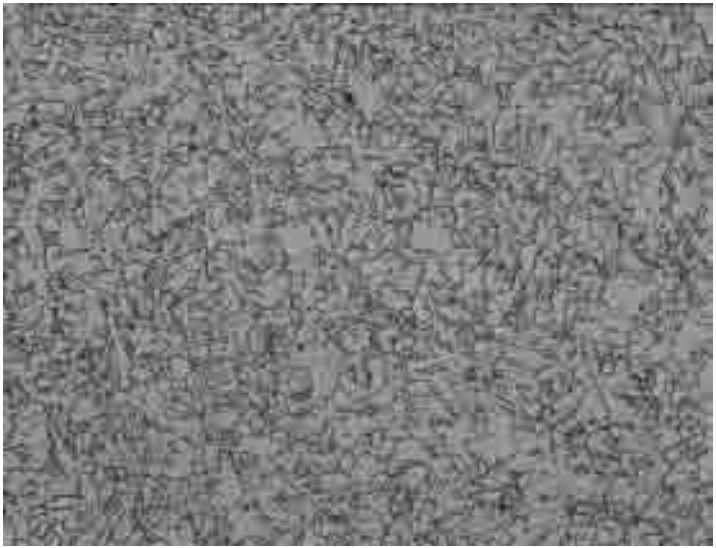
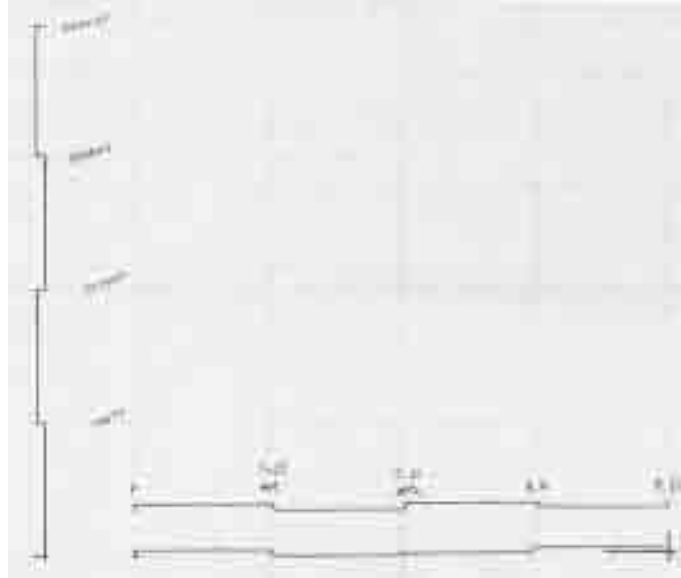
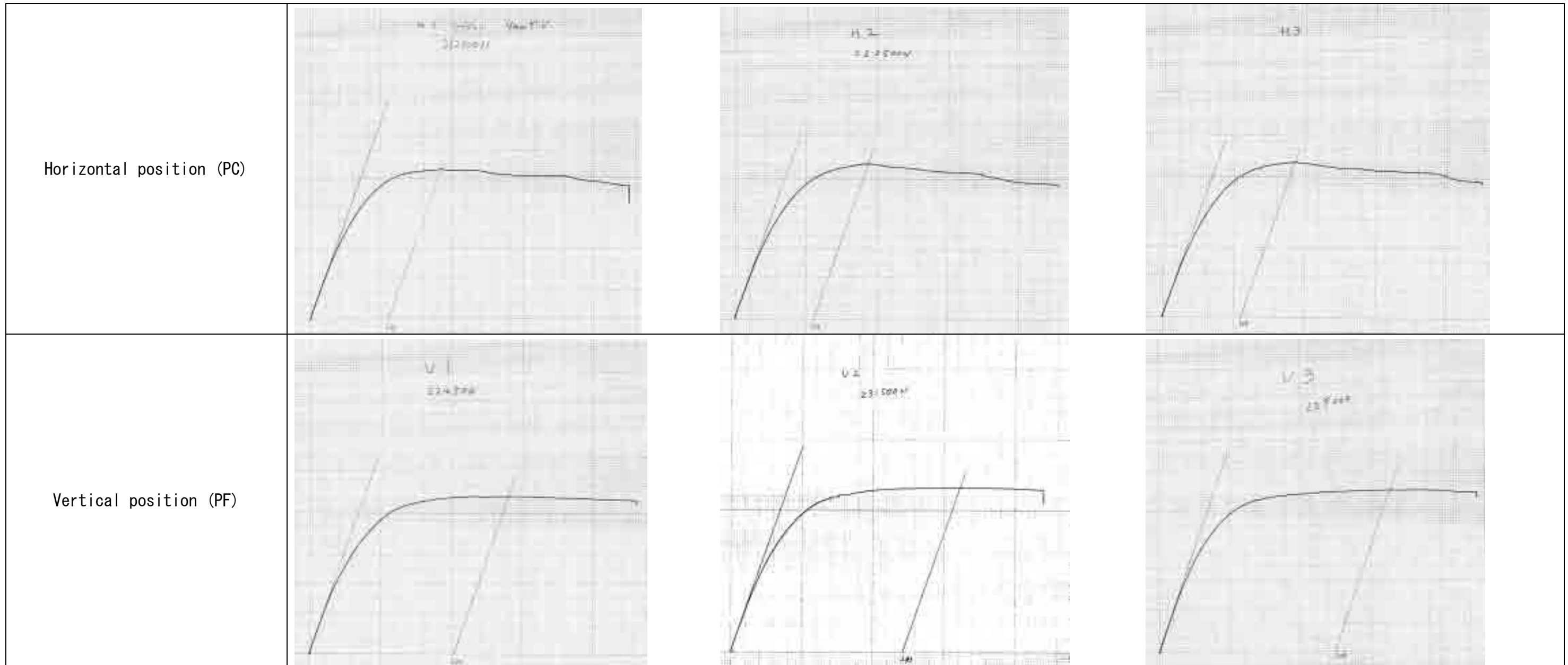
	1st side		2nd side	
	As welded	SR (580°C × 2hrs)	As welded	SR (580°C × 2hrs)
As casted zone (X100)				
As casted zone (X400)				
Refined zone (X400)				

Photo A-2 Microstructure of weld metal in vertical position(PF)

A-3. Load-displacement records in CTOD tests



Scale

Fig. A-1 Load-displacement records in CTOD tests



Welding position	1	2	3
Horizontal (PC)			
Vertical (PF)			

Photo A-3 Appearance of fracture surface of CTOD test specimens