

Overlay welding with DW-309LNbKOBE STEEL LTD.
WELDING COMPANY

1. Objective

The properties of all-weld-metal and weld metal overlaid on 2.25Cr-1Mo steel by using DW-309LNb 1.2mmφ were studied.

2. The properties of all-weld metal

The chemical compositions of all-weld-metal made of DW-309LNb in the series of tests are shown in Table1. The following tests were carried out.

- 1) Tensile tests
- 2) Impact tests at 0°C (-18F°)
- 3) Microscopic observations of micro structure

2-1. Tensile tests

These were conducted in accordance with JIS Z 3111, specimen size; A1. The results in Table2 meet with AWS A5.22 E309LCbT0-1.

2-2. Impact tests

These were conducted in accordance with JIS Z3112 at 0°C with 3 specimens which have size 4th. Test results are shown in Table3.

2-3. metallographic observations

The test pieces for the microscopic observation were cut out from the center of screw part in the tensile test piece. These were polished, and then subjected to the electric etched in the chrome acid solution. Photo1 shows micro structures observed through the microscope, showing ordinary Austenite and Ferrite structure.

3. Overlay weld test

3-1. Materials used in the test

The same wire as the one in all-weld-metal test was used in this test. The size of 2.25Cr-1Mo steel base metal is 35 x 150 x 250mm and its chemical compositions are in Table4.

3-2 Overlay welding

The overlay welding was carried out at 3 different current: 150A (test piece 1), 180A (test piece 2) and 210A (test piece 3). Table 5 shows the welding conditions. The base material was restrained to the restraint plate in welding. Overlaid weld was subjected to PWHT at two different conditions shown in Table6: 700°C×13hr (Tempering parameter 20.5) and 700°C×30hr (Tempering parameter 20.9).

3-3 Test content and method

1) Bend test

The face-bend and side-bend test were conducted after PWHT. Specimens were 9.5mm thick and bending radius were 19mm. Bended specimens were subject to liquid penetrant test to identify the defect on the surface.

2) Chemical compositions and ferrite content measurements

Chemical compositions in the specimens taken from 1.5-2.2mm depth under the weld metals surface were analyzed. Ferrite contents were measured on the weld bead surfaces by Ferrite Scope before and after PWHT. Measurements were repeated at nine points and reported as their average values.

3) Microscopic and macroscopic metallographic observations

Cross sections were etched by nitro-hydrochloric acid, and then macroscopic structures were observed. The test pieces were polished, subjected to the chemical etching with 3% nitric acid in

ethanol and electric etching in the chrome acid solution, and then observed by microscope at bond area and weld metal.

4) Hardness tests

The hardness was measured by using Micro-Vickers'-Hardness meter with 1kgf loading, along the line across base metal to weld metal every 1mm at weld metal and 0.5mm at heat affected zone.

3.4 Test result

3-4-1 Bend tests

The side-bend test result is shown in Photo2 and face bend test result is shown in Photo3 respectively. No defect was found at any test condition.

3-4-2 Chemical composition and ferrite content

Table 7 shows the analysis result of overlaid weld metal. The dilution rate is approximately 25%, and the lowest in test piece 2. Table 8 shows the measurement result of the ferrite content. The ferrite content of test piece 2 is the highest; meanwhile it turns to 3-4% after PWHT.

3-4-3 Metallographic observation

Photo4 shows the macro structure of the section. The thickness of overlay weld metal is 1.8mm, 2.3mm and 3.2mm in test piece 1, 2 and 3 respectively. Microstructures in Photo5-6 reveal the width of Carburized zone tends to grow as tempering parameter increases.

3-4-4 Hardness

Figure 2 shows the test results: hardness of the heat affected zone decreases as tempering parameter increases. Softening of the base metal around the bond area is because of decarburization.

4. Summary

The results are summarized below.

- 1) The thickness of overlaid weld metal above the base metal was 2.0-3.0mm in first layer.
- 2) Bend tests with the weld subjected to PWHT at tempering parameters less than 20.9 were found to be satisfactory.

(complete)

Table1 Chemical compositions of all-weld metal

	Chemical compositions (%)									Ferrite content	
	C	Si	Mn	P	S	Ni	Cr	Nb	N	Schaeffler %	DeLong FN
DW-309LNb	0.030	0.34	1.27	0.021	0.003	12.81	23.46	0.75	0.019	10.8	>18
E309LCbT0-1	max. 0.04	max. 1.0	0.5 ~2.5	max. 0.04	max. 0.03	12.0 ~14.0	18.0 ~25.0	0.7 ~1.00	—	—	—

Table2 Tensile properties of all-weld metal

	0.2%Proof stress N/mm ²	Tensile stress N/mm ²	Elongation %	Reduction of area %
DW-309LNb	427	579	36	53
E309LCbT0-1	—	520 min.	30 min.	—

Table3 Charpy impact property of all-weld metal (0°C)

	Absorbed energy J	Lateral expansion mm
	47	0.90
	50	0.95
	52	1.05
Average	50	0.97

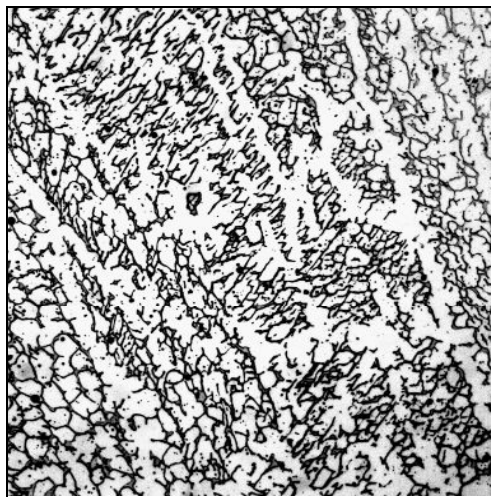


Photo1 Microstructure of all-weld metal of DW-309LNb(x200)

Table4 Chemical compositions of 2¼Cr-1Mo base steel

Chemical compositions(%)						
C	Si	Mn	P	S	Cr	Mo
0.12	0.01	0.44	0.002	0.004	2.40	0.97

Table5 Welding conditions in overlay welding

No.	1	2	3
Welding current	150A	180A	210A
Arc voltage	28V	31V	33V
Welding speed	110mm/min		
Shielding gas	CO ₂ 20L/min		
Wire stick-out	15mm		
Weaving width	12mm		
Weaving frequency	7Hz		
Pass configuration	Edge of the previous pass at the weaving ends		
Pre-heat and inter-pass temperature	150~250°C		

Table6 PWHT conditions

Temperature	Duration	Temp inclination
700°C	13 and 30 hrs	55°C/hr

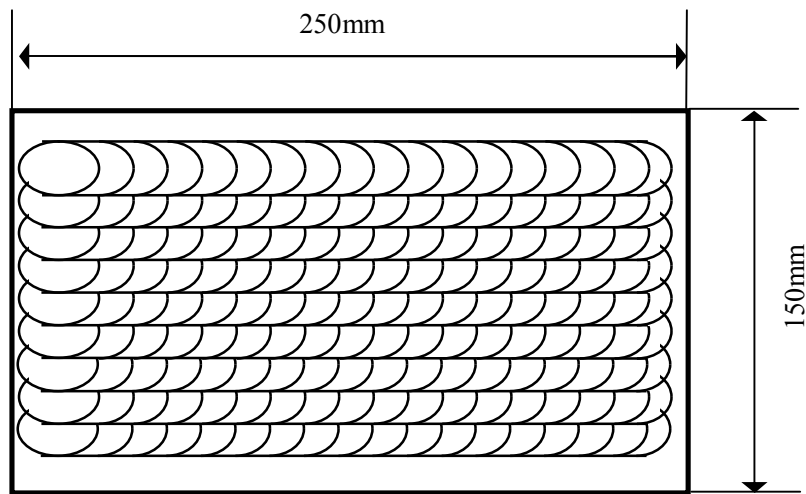


Fig.1 Overlay weld configuration

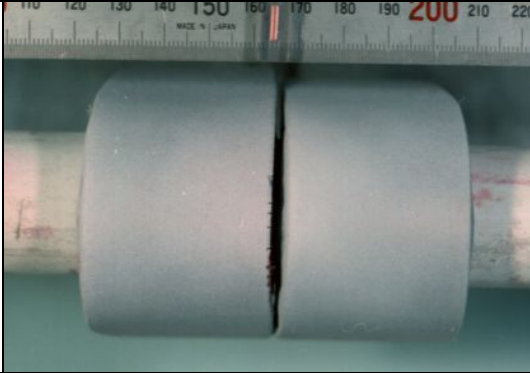
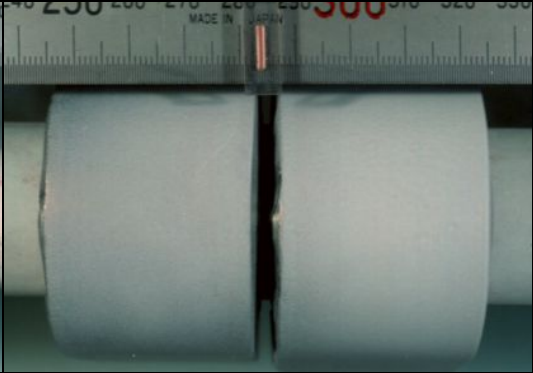
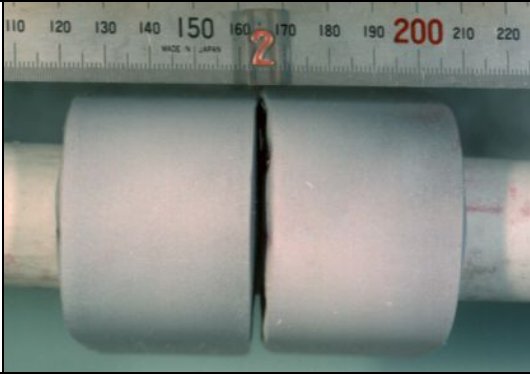
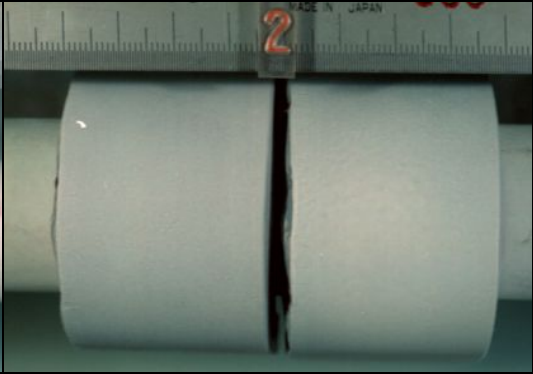
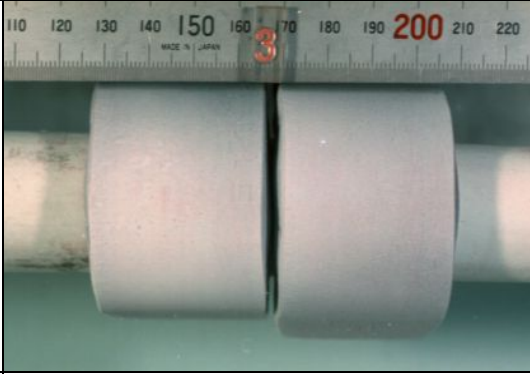
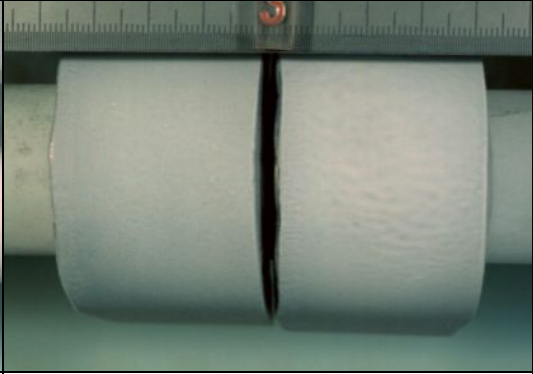
1		
2		
3		
PWHT	700°C×13hrs	700°C×30hrs

Photo2 Side bend test results

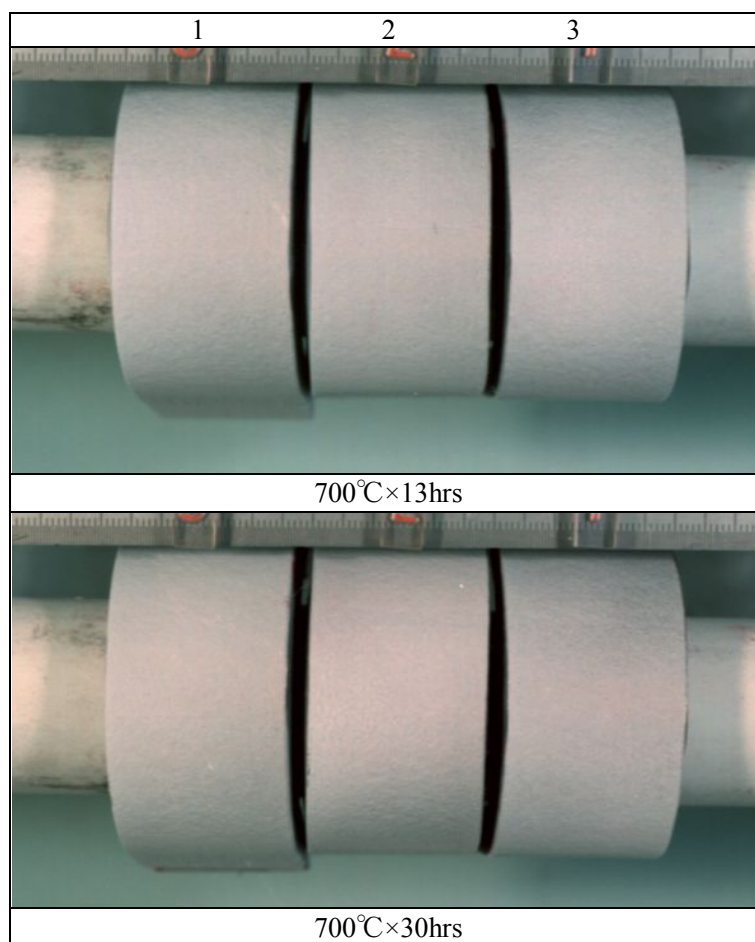


Photo3 Face bend test results

Table7 Chemical compositions of overlaid weld metal (1.5~2.2mm under the surface)

Test No.	Chemical compositions (%)							Ferrite content	
	C	Si	Mn	Ni	Cr	Nb	N	Schaeffler %	DeLong FN
1	0.051	0.29	1.00	9.01	17.53	0.58	0.017	3.8	4.0
2	0.047	0.29	0.88	9.39	18.23	0.59	0.016	5.6	6.1
3	0.047	0.28	0.90	8.98	17.63	0.55	0.021	4.9	4.5

Table8 Ferrite content(%) by ferrite scope

PWHT	Test piece No.		
	1	2	3
As weld	6.4	8.3	5.2
700°C x 13hrs	3.1	4.5	3.5
700°C x 30hrs	3.9	3.8	3.7

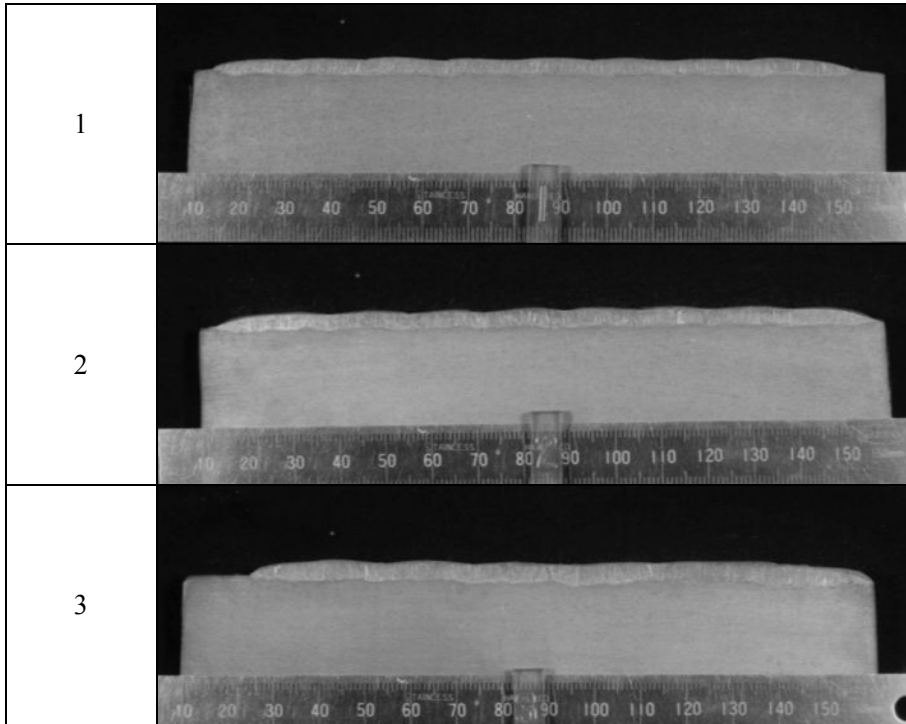


Photo4 Macroscopic observation of overlaid weld

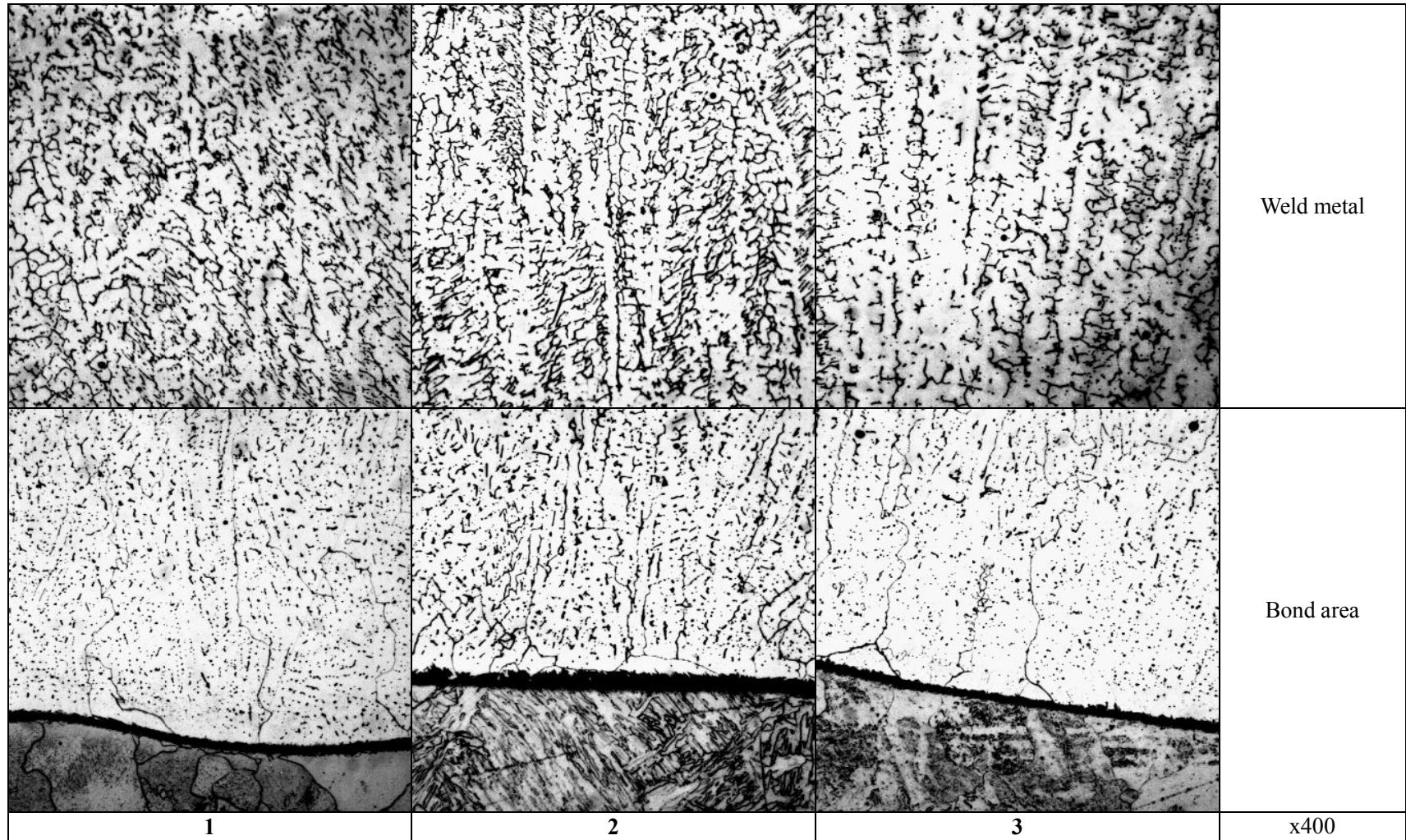


Photo5 Metallographic microstructure (PWHT:700°C×13hrs)

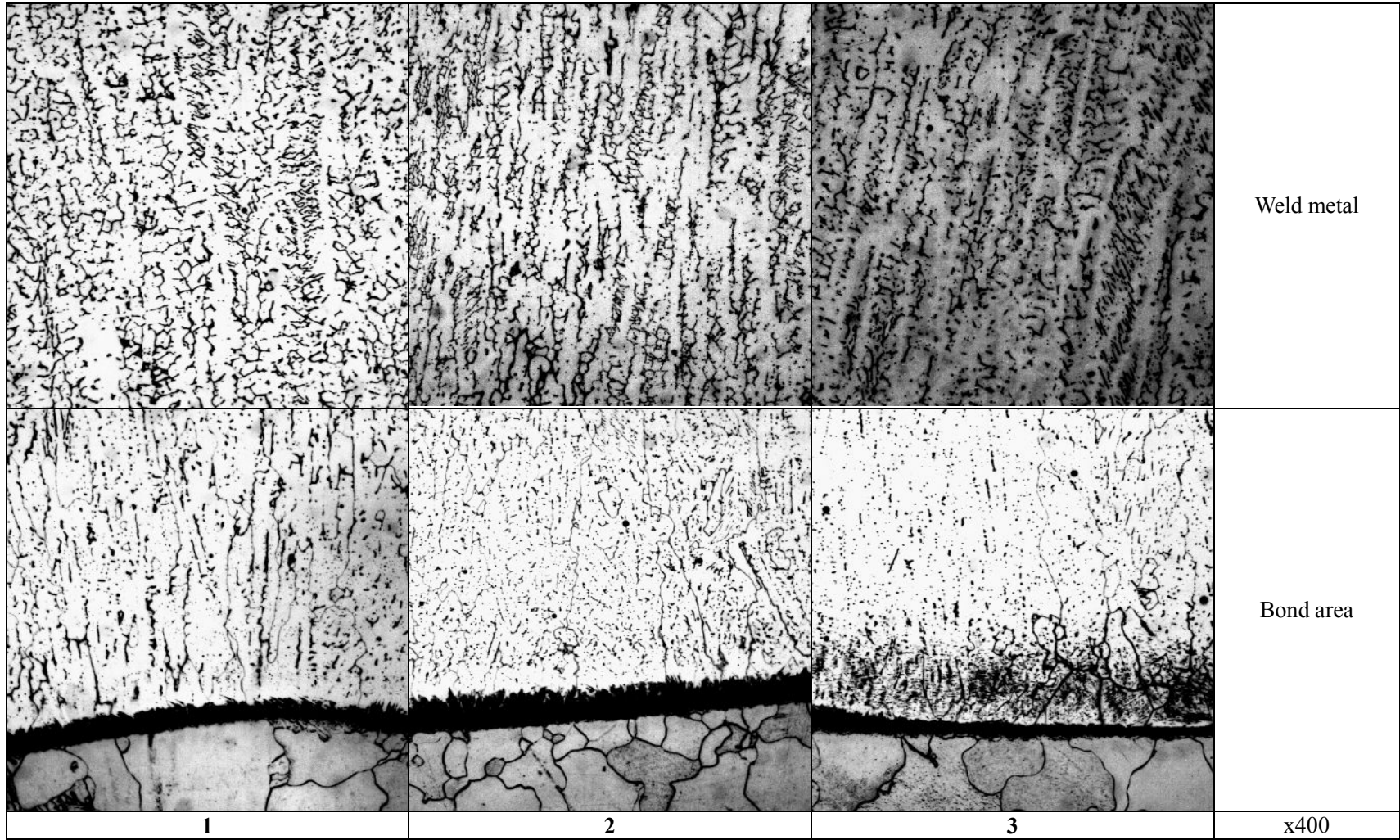
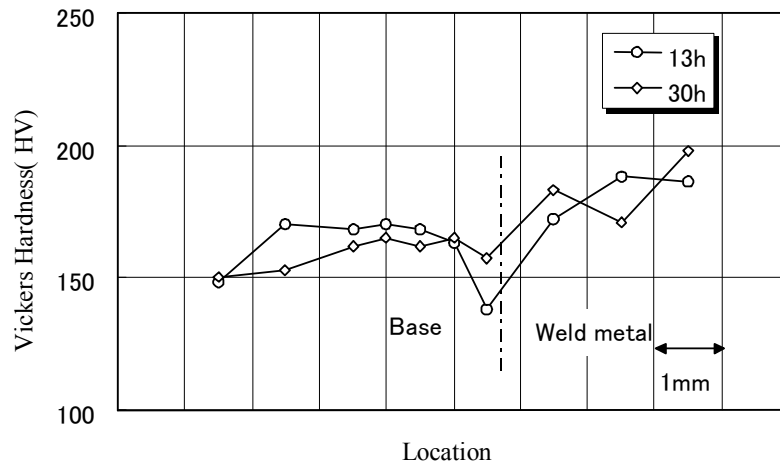
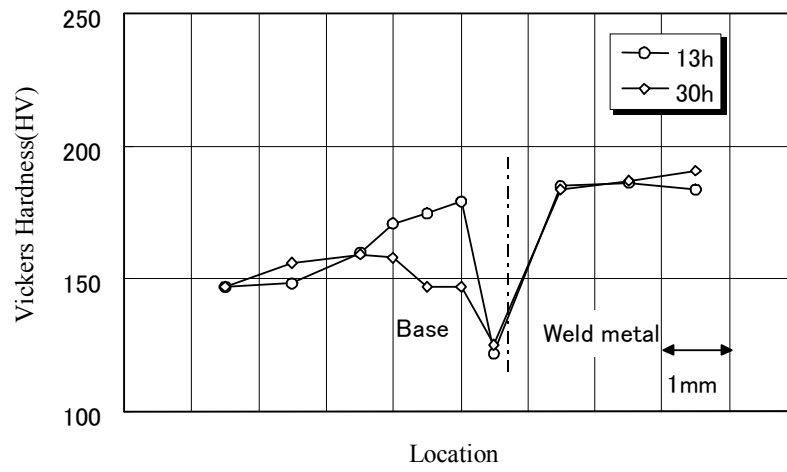


Photo6 Metallographic microstructure (PWHT:700°C×30hrs)

1



2



3

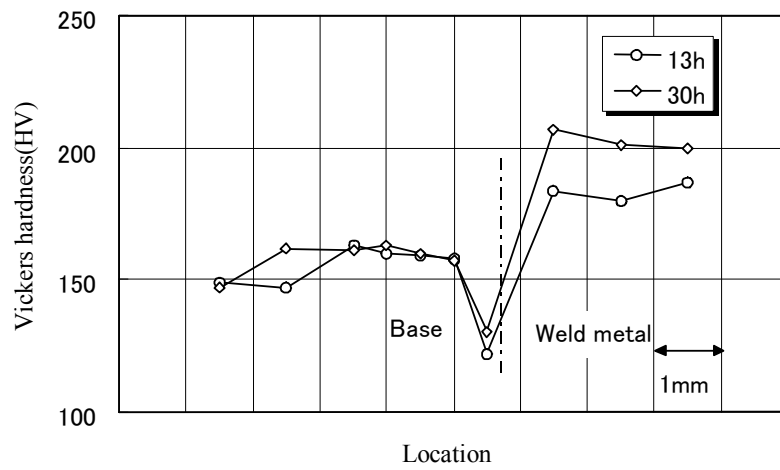


Fig.2 Hardness distribution across overlaid weld

Overlay welding with DW-309LNb

