Nano-structural and Nano-chemical analysis of dissimilar metal weld interfaces

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1. Introduction

Dissimilar metal weld is generally applied to nuclear power plant for manufacturing and machining in structural components such as RPV and Pressurizer nozzles. Alloy 152 is used frequently as filler metal in the manufacture of dissimilar metal welds (DMWs) in light water reactors (LWR) to join the low alloy steel (LAS) pressure vessel nozzles and steam generator nozzles to nickel-based wrought alloy or austenitic stainless steel components. The thermal expansion coefficient of the alloy lies between those of ferrite steel and austenitic stainless steel, and it also significantly retards the carbon diffusion from the ferrite base metal to the weld metal [1]. However, in recent years cracking phenomena have been observed in the welded joints. A concern has been raised about the integrity and reliability in the joint transition zone due to the high susceptibility of heat affected zone (HAZ) and fusion zone (FZ) to stress corrosion cracking (SCC). The dissimilar metal joints which were welded between Inconel 690, Ni-based alloy and A533B, low alloy steel with Inconel 152, filler metal were investigated. This study shows microstructural and chemical analysis between Inconel 152 and A533B by using optical microscope (OM), scanning electron microscope (SEM), transmission electron microscope (TEM), secondary ion mass spectrometry (SIMS) and 3 dimension atom probe (3D AP).

In the root region, OM and SEM analysis show the microstructure which contains the interface of Inconel 152 and A533B near the rooter region. And it shows unidentified band structure which is formed along weld interface. AP and TEM/EDS analyses show the chemical gradient containing higher Fe but lower Mn, Ni and Cr than Inconel 152 and the unidentified band.

2. Materials and Tests

2.1 Materials and Specimens

2.1.1. Materials

A533B was buttered with Inconel 152 by shielded metal arc welding (SMAW) followed by post-welding heat treatment (PHWT) at 607~635 ℃ for 3 hours. After the process, the weld joint of Inconel 152 and A533B was prepared by shielded metal arc welding (SMAW). Chemical compositions of both metals were shown in table 1. The sample containing the interface, and Inconel 152 was cut from the dissimilar weld joint (Fig. 1).

2.1.2. Specimens

The specimen for OM and SEM was prepared by polishing the sample with ~0.05um colloidal silica and etching with 3% natal solution. The specimen for SIMS was prepared by polishing the sample with ~0.05um colloidal silica. After polishing the sample and etching it, the specimens for TEM and 3D AP were prepared by using FIB for thinning (Fig. 2). TEM specimens were deposited with carbon, cut and thinned with gallium ion by Quanta 3D FEG Focused Ion Beam (FIB). The specimens have about 100nm thickness. 3D AP specimens were deposited with Platinum, cut and thinned with gallium ion by Helios Nanolab 600 Dual – beam Focused Ion Beam (FIB). The specimens have a needle shape of about 100 nm diameters.

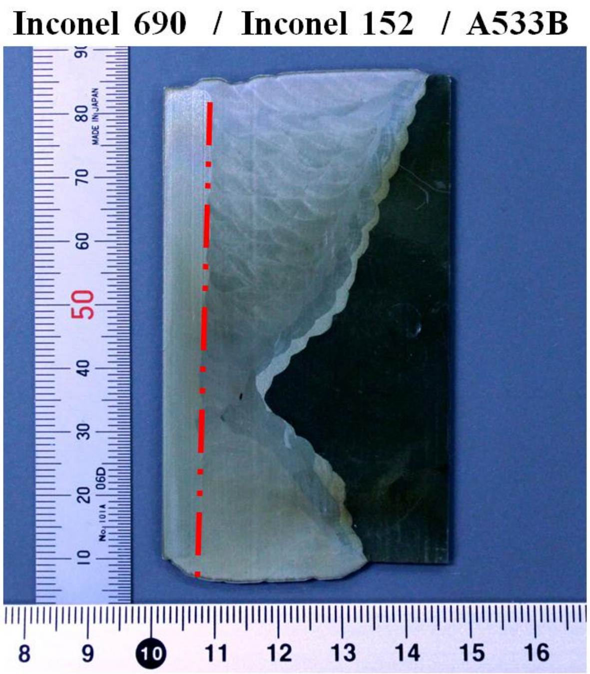
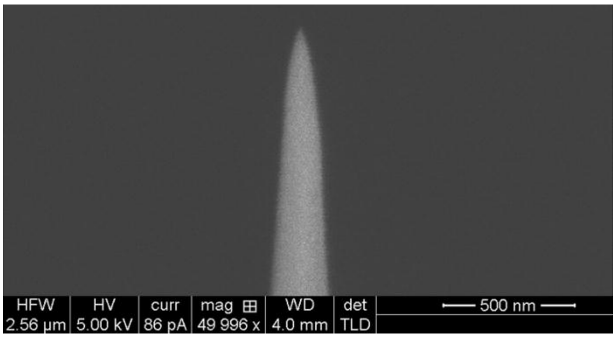


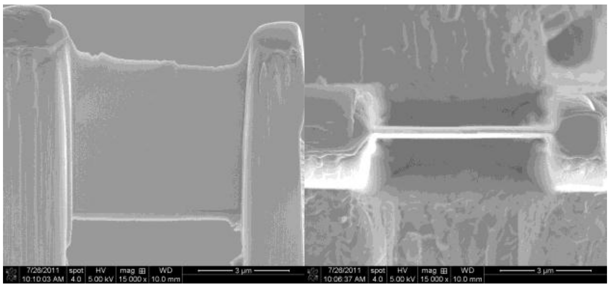
Fig.1 Dissimilar metal weld used in this study

Table 1. Chemical Composition

Element	C	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Nb+Ta	Mo	Ti	others
Inconel 152	0.04	0.24	0.46	<.003	<.001	29.04	3.56	9.36	<0.01	55.25	<0.01	1.84	0.01	0.15	<0.5
A533B	0.2	0.024	0.24	0.01	0.006	0.11	1.42			0.64	0.11		0.54		



(a)



(b)

Fig.2 (a) 3D AP specimen, (b) TEM specimen

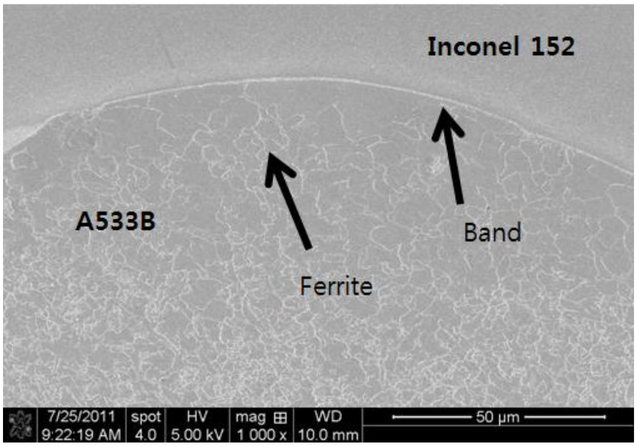


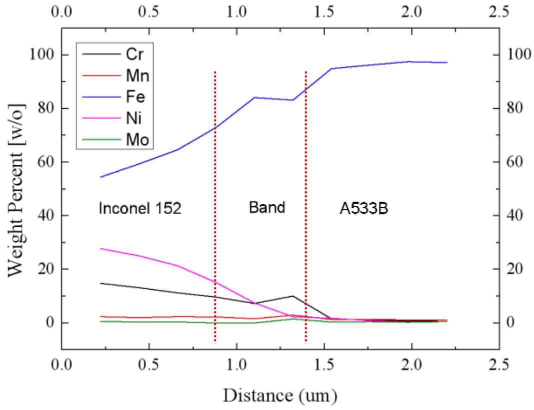
Fig.3 Microstructure containing A533B's ferrite and unidentified band by SEM

2.2 Experimental Analysis

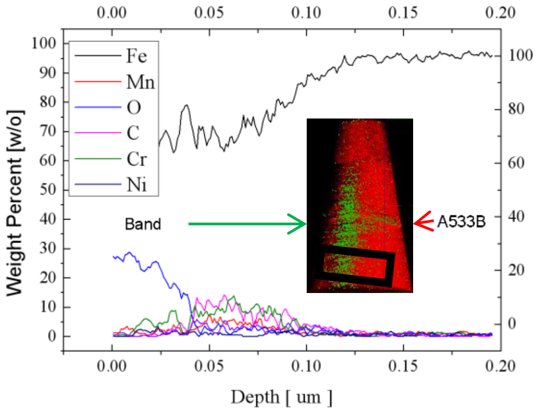
Metallographic microstructure of the fusion boundary region was characterized by optical microscopy (OM) and scanning electron microscopy (SEM). Chemical composition in fusion boundary region was analyzed by (Nano nova 230 SEM) energy-dispersive X-ray (EDX) spectroscopy. Chemical map was characterized by TOF-SIMS.

A JEM-2100F (Cs corrector) transmission electronic microscopy (TEM) was used for analyzing the transition of crystallographic microstructure and chemical composition in the fusion boundary region.

A LA-WATAP 3 Dimensional Atom Probe (3D AP) was used for analyzing the chemical composition in the region containing the A533B and fusion boundary and laser pulsing (wavelength 343 nm) was utilized. The analyses were made with A temperature of 60 Kelvin, a pulse frequency of 100 kHz and a voltage of 2~14 kV.



(a)



(b)

Fig. 4 a) TEM/EDS analysis, b) 3D AP analysis
Two analyses contain gradient of A533B & the band

3. Results

3.1 Results

OM and SEM analysis show the microstructure which contains the interface of Inconel 152 and A533B near the rooter region (Fig. 3). The microstructure has ferrite and unidentified band. TEM/EDS and 3D AP analyses show the chemical gradient near the rooter region (Fig. 4). Figure 4a shows the composition profile from Inconel 152 to A533B measured by TEM/EDS. A522B near the interface has ferrite structure containing higher Fe but lower Mn, Ni and Cr than Inconel 152 and unidentified band. Fig. 4b indicates that chemical gradient between the band and A533B is similar to TEM/EDS analysis. And further studies on the interface are in progress.

REFERENCES

[1] Sireesha M, Albert SK, Shankar V, Sundaresan S , J Nucl Mater 279:65, 2000

[2] J. Hou, Q. J. Peng , Y. Takeda, etc., "Microstructure and mechanical property of the fusion boundary region in an Alloy 182-low alloy steel dissimilar weld joint", J Mater Sci, 45:5332–5338, 2010