Microstructure Characterization and Hardness Evaluation of Alloy 52 Welded Stainless Steel 316L Subjected to Ultrasonic Nanocyrtal Surface Modification Technique

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1. Introduction

In nuclear plants, alloy 600 affiliation (Alloy 82/182) is used for material of dissimilar welding on heat-transfer pipe. However, cracks are occurred with increased operating life by primary water stress corrosion crack (PWSCC) on the pipe in expanded transition area [1]. Inlay Welding technique is applying on alloy 600 welded area. However, this technique induces residual stress which is resulted in accelerated PWSCC.

In this study, an ultrasonic nanocrystal surface modification (UNSM) technique was applied to dissimilar weld point between STS316L and Alloy 52. This UNSM technique is a patented technology, which can be described as a type of ultrasonic cold-forging technology [2]. The surface of a workpiece is being struck with a single ball made of tungsten carbide (WC) and/or Si_3N_4 at a frequency of 20 kHz. It has been demonstrated that the UNSM technique is a simple method to produce a nanocrystalline surface layer at the top surface of metallic materials. Microstructure and hardness of STS316L and Alloy 52 are investigated before and after UNSM treatment. It is expected according to the previous study that the UNSM technique is able to release the residual stress which delays PWSCC. Details of UNSM technique and its effectiveness on mechanical and structural properties of Ni-based alloy can be found in our previous publications [3].

2. Experiment and Results

2.1 Specimen preparation

For the experiment, Alloy 52 welded STS316L specimen is used with dimensions of 12 x 15 x 5 mm^3. The welding of Alloy 52 was done using a gas tungsten arc welding (GTAW) method. Table I shows the chemical composition of the specimens. Table II shows the UNSM treatment conditions. Fig 1 shows the photography of Alloy 52 welded STS316L specimen after UNSM treatment. The specimen was etched in HNO_3, HCl and CH_3COOH for 30 s after polishing by 6 and 1 μm diamond powder prior to microscopic observation.

Table I: Composition of specimens (in wt%)

	STS 316L	Alloy 52
C	0.03	0.017
Mn	2.0	0.33
Fe		9.2
P	0.045	0.008
S	0.03	0.003
Si	1	0.26
Cu	-	0.01
Ni	10.0~14.0	60.2
Al	-	0.01
Ti	-	0.03
Cr	16.0~18.0	29.7
Nb+Ta	-	0.06
Mo	2.0~3.0	0.06
Other	-	0.5

Table II: UNSM treatment conditions

Frequency, kHz	20
Amplitude, μm	30
Static load, N	30 N
Feed-rate (interval), mm	0.07
Speed, mm/min	1000
Tip diameter, mm	2.38 (WC)

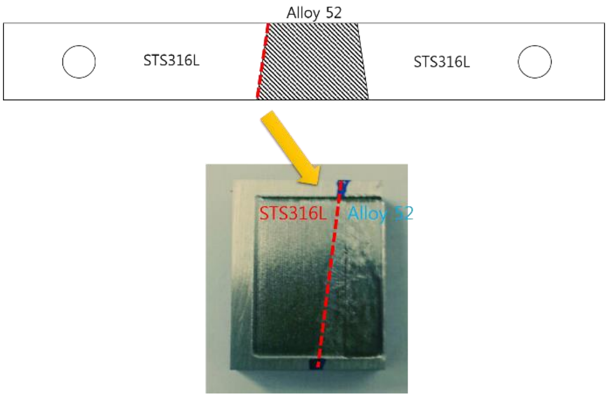

Fig. 1. Alloy 52 welded STS316L specimen

2.2 Surface analysis

Fig. 2 shows the microstructure of STS316L and welded Alloy 52. It can be seen that equiaxed grains are generated on Alloy 52 which was indicated by circle.

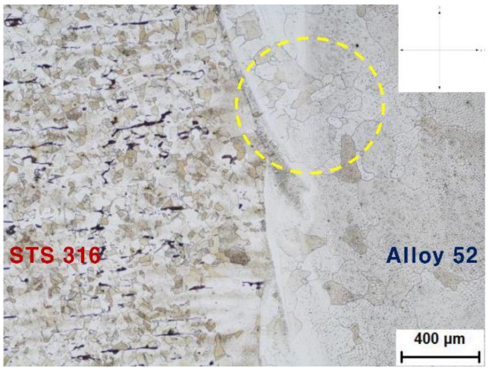

Fig. 2. Alloy 52 welded area into STS316L

Figs. 3 and 4 show cross-section of STS316L and Alloy 52 after UNSM treatment. It is obvious that the grain size of STS316L specimen is refined at the top surface which increased with increasing the depth from the top surface. The thickness of plastically deformed layer of STS316L and Alloy 52 was found to be about 199.2 and 126.9 µm, respectively.

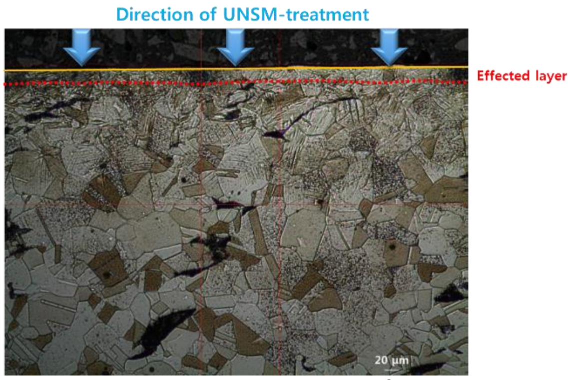

Fig. 3. Cross-sectional OM image of UNSM-treated STS316L.

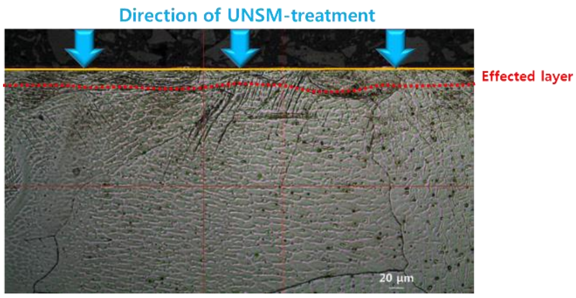

Fig. 4. Cross-sectional OM images of UNSM-treated welded Alloy 52.

2.3 Results

Figs. 5 and 6 show the variation in hardness with respect to depth from the top surface for the UNSM-treated STS316L and Alloy 52, respectively. It can be seen that the hardness of both the materials increased about 10% at the top surface, but it decreased gradually with increasing the depth from the top surface. The increase in hardness of both the materials can be explained according to the Hall-Petch relationship [4].

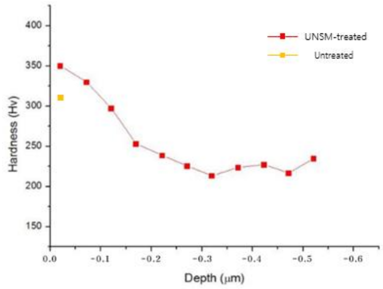

Fig. 5. Hardness of depth profile of UNSM-treated and hardness of top surface of Untreated STS316L

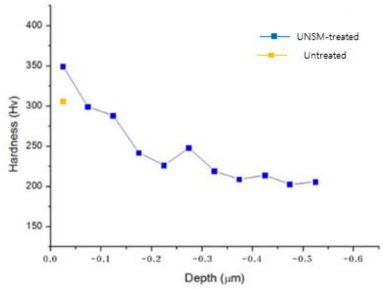

Fig. 6. Hardness of depth profile of UNSM-treated and hardness of top surface of Untreated Alloy 52

3. Conclusions

In this study, microstructural characterization and hardness evaluation of STS316L and welded Alloy 52 subjected to UNSM technique were investigated. The results revealed that the hardness of both the materials increased at the top surface which may be attributed to the refined grains and releasing tension residual stress and increasing compressive residual stress after UNSM treatment. Further study will be conducted about how increased compressive residual stress to affects PWSCC.

4. Acknowledgements

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