TIG of Reduced Activation Ferrite/Martensitic Steel for the Korean ITER-TBM

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1. Introduction

Test Blanket Modules (TBM) will be tested in ITER to verify the capability of tritium breeding and recovery and the extraction of thermal energy suitable for the production of electricity. A Helium Cooled Solid Breeder (HCSB) TBM has been developed in Korea to accomplish these goals [1~4]. Reduced Activation Ferritic/Martensitic (RAFM) steel has been chosen as the primary candidate structural material for Korean TBM. Due to the complexity of the First wall (FW) and Side wall (SW), it is necessary to develop various joining technologies, such as Hot Isostatic Pressing (HIP), Electron Beam Welding (EBW) and Tungsten Inert Gas (TIG) welding, for the successful fabrication of TBM. In this study, the mechanical properties of TIG welded RAFM steel were investigated. Various mechanical tests of TIG-welded RAFM steel were performed to obtain the optimized TIG welding process for RAFM steel.

2. Experimental

2.1 Material

The material used in this study is F82H RAFM steel with chemical composition in wt% of Fe-0.09C-7.9Cr-1.81W-0.2V-0.03Ta. This steel was normalized at 960 °C for 30 minutes and tempered at 750 °C for 90 minutes followed by air cooling.

2.1 TIG Welding

The edges of 10 mm thick plates were machined for single-V welding with the groove angle of 60 degrees and 2 mm root opening. Table 1 shows TIG welding condition in this study. TIG welding was performed with different ampere (270 A with pulse mode and 145 A with no pulse mode) in order to observe the effect of welding current. To control the grain size and to reduce the residual stress, a Post-Welded Heat Treatment (PWHT) was applied to the plates by tempering at 720 °C for 90 minutes followed by air cooling [2].

Before and after PWHT, The microstructure of welded specimens was observed by scanning electron microscope. Micro hardness tests and tensile tests were performed to evaluate the mechanical properties. Tensile specimens with the TIG weld metal located in the center of gauge length were fabricated in accordance with ASTM standards E8.

Table 1 TIG welding conditions .

Welding type	Manual	
late thickness	10 mm	
Groove	V-groove	
Voltage	9 -10 V	
Current	270 A (Pulse)	145 A (No pulse)
Layer	8	
Post-Welded Heat Treatment	720°C, 1.5 hr	

3. Results and discussion

The PWHT condition was selected 90 minutes at 720 °C for the recovery of hardening and toughness degradation. The microstructures of the TIG welding before and after PWHT are shown in Fig. 1 [6].

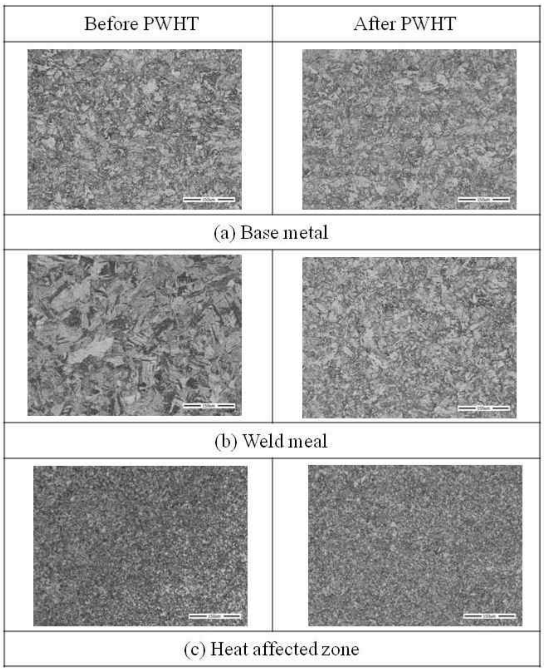

Fig. 1 SEM micrographs of TIG welding in the zone of (a) base metal, (b) weld metal, (c) HAZ

The grain size of weld metal was around 6 as ASTM grain size number, but it decreased to around 7 after PWHT, a size that is close to the grain size of base metal (8~9). Fig. 2 shows the hardness dependence measured using a Micro Vickers tester. In the as-welded condition, the weld zone shows the typical hardness of a martensitic structure. The maximum hardness in the HAZ was 400 Hv and decreased to 240 Hv after PWHT.

Weld current affected the region of HAZ while hardness values were independent of current condition. The HAZ region welded at 145 A (no pulse) shows narrower gap than at 270 A with pulse mode.

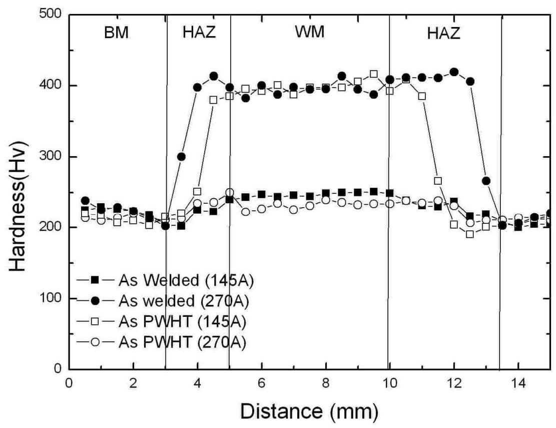

Fig. 2 Vickers hardness profile across TIG welding zones before and after PWHT

Fig.3 shows effect of welding current on stress-strain curve. On the contrary with the result of hardness test, the tensile properties were was independent of current condition.

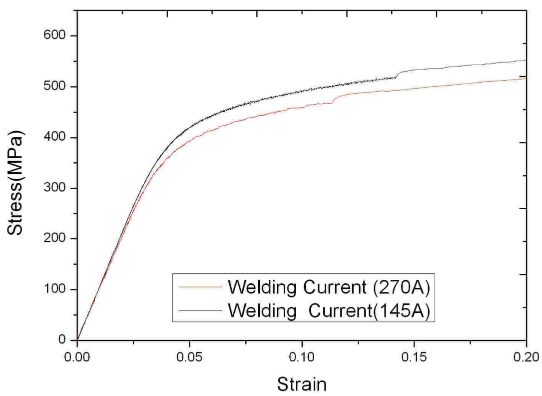

Fig.3 Effect of welding current on stress-strain curve

4. Conclusions

TIG welding of RAFM steel was evaluated for the successful fabrication of the Korean HCSB ITER TBM. Various mechanical tests of TIG-welded RAFM steel were performed to obtain the optimal TIG welding process. Tensile test results of TIG welds showed the yield stress and ultimate tensile stress increased significantly as test temperature increases, especially above 450 ^{o}C. The total elongation of both base metal and weld metal was found to increase when the test temperature is above 450 ^{o}C. Additional R&D is in progress to enhance the joint quality and to have a better understanding of joining processes.

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