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Neutron irradiation test on TIG-welded specimens of ARAA material

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1. Introduction

Korea has been developing a helium-cooled ceramic reflector (HCCR) breeding blanket for the development of Korean-style DEMOs and nuclear fusion reactors [1]. As part of this effort, Korea is planning to collaborate with Europe to develop a HCCP test blanket module (TBM) that will be installed in ITER for testing. Reduced Activated Ferritic/Martensitic (RAFM) steel is one of the structural material candidates for fusion reactors, and several types of RAFM steel, including EUROFER [2] and F82H [3], have been developed by countries conducting fusion reactor research. In Korea, a type of RAFM steel called ARAA (Advanced Reduced Activation Alloy) has been developed for parts of nuclear fusion reactors, including ITER's HCCR TBM [4-7]. We are currently developing welding technologies necessary for TBM production, including electron beam (E-Beam) welding, Tungsten Inert Gas (TIG) welding, and Hot Isostatic Pressing (HIP) welding [8-10]. Neutron irradiation characteristics of welding materials are also important, and we are conducting neutron irradiation tests on TIG-welded ARAA samples to study the neutron irradiation characteristics of welding materials.

In this study, TIG welding and post-weld heat treatment (PWHT) were performed on ARAA steel sheets using welding conditions and processes developed to study the neutron irradiation test characteristics. Specimens were then fabricated for mechanical property testing. Irradiation tests are currently in progress at the HANARO research reactor. After completing the irradiation tests, a mechanical property test will be performed to compare and verify the characteristics of the non-irradiated specimens.

2. Preparation of the test specimen

To prepare test specimens for mechanical property testing, we used ARAA steel supplied in plate form by WA77 Heat as a large secondary product. The steel was normalized at 1000℃ for 40 minutes, followed by air cooling and tempering at 750℃ for 70 minutes before further air cooling. ARAA plates, 12mm in thickness and 600mm in length, were subjected to TIG welding using specific welding conditions and processes developed to create test specimens for investigating the mechanical properties of ARAA plates for TIG welding. The welding filler was produced by slicing ARAA plates into 2mm x 2mm thicknesses. To conduct Charpy impact tests, test specimens were fabricated according to NF EN ISO 148-1~3. The specimens had notches at the center of the heat-affected zone (HAZ) and weld zone after their surfaces were polished and etched parallel to the weld surface. The tensile specimens were fabricated as dog-bone type specimens with dimensions of 66 mmL x 15 mmW x 1mmT. Figure 1 displays the fabricated tensile, impact, thermal diffusion, and SEM specimens.

a) Fabricated TIG-welded specimens for neutron irradiation test

b) Enlarged TIG-welded specimens for neutron irradiation test

Fig. 1. Fabricated tensile, impact, thermal diffusion, and SEM specimens.

Conclusion

ARAA steel is a crucial material for the development of Korean-style DEMO and nuclear fusion reactor structural materials. TIG welding technology is essential for many joints, particularly for breeding blankets. To investigate the neutron irradiation characteristics of TIG-welded ARAA materials, neutron irradiation tests of specimens are underway at the HANARO research reactor. Following the irradiation tests, mechanical properties will be studied to better understand the behavior of ARAA steel under such conditions.

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