Effects of a Heat Treatment Process on the Microstructure and Mechanical Properties of F82H for a TBM Fabrication

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1. Introduction

The International Thermonuclear Experimental Reactor (ITER) test blanket module (TBM), which will be installed and tested in a specific port of the ITER, is a kind of experimental equipment to test the feasibility of a breeding blanket. The R&D on the TBM is an important step to construct the DEMO reactor, thereby realizing a fusion power plant. ITER participant teams are developing their own TBMs to be tested from a Day-1 operation of the ITER.

One of the main issues about the R&D on the TBM is to develop the fabrication technology for the TBM whose structure consists of many walls having cooling channels to remove the high heat flux from the plasma. Reduced activation ferritic/martensitic (RAFM) steels are the primary candidate alloys for the structural materials of the TBM [1,2].

Hot Isostatic Pressing (HIP) has been considered as the most feasible method for the fabrication of the TBM structure. Since HIP is usually performed above the phase transformation temperature of RAFM to facilitate in the diffusion process, the microstructure of RAFM deviates from its optimized microstructure. The main feature is a grain coarsening which results in a degradation of the mechanical properties [1,2]. Therefore, investigating the effect of a post HIP heat treatment (PHHT) is crucial in developing the fabrication technology of the TBM.

In this study, the effect of heat treatments on the microstructure and mechanical properties of F82H, one of the RAFM steels, is investigated to optimize the joining conditions including a normalizing and tempering treatment in order to recover the thermally altered microstructure.

2. Experimental procedure

The used material is RAFM F82H steel which was produced by KOUFU Co., LTD., Japan. The main chemical compositions were as follows: 8.03-8.06 wt.% Cr, 1.96-1.99 wt.% W, 0.2 wt.% V, 0.027-0.32 wt.% Ta and Fe balance. The produced plates were normalized at 960℃ for 30 min and then tempered at 750℃ for 90 min.

First, in order to get the optimum conditions of a HIP and PHHT, the material properties of F82H are investigated with a focus on the effect of a normalizing and tempering. The details of the experimental condition are listed as follows:

1. After a normalizing at 850℃, 900℃, 950℃, 1000℃ and 1050℃ for 2hrs followed by a tempering at 750℃ for 2hrs (fixed tempering temperature);
2. After a normalizing at 950℃ for 2hrs followed by a tempering at 650℃, 700℃, 750℃ and 800℃ for 2hrs (fixed normalizing temperature).

Also, for the evaluation of the HIP joined F82H properties, F82H is machined in the form of a block with the dimensions of 80(W) x 30(t) x 80(L) mm and encapsulated with 2mm SS304 plates. The canister is out-gassed and HIPed at 1050℃, 100 MPa and 2 hrs. HIPed specimens are normalized at 950℃ for 2 hrs and tempered at 750℃ for 2hrs.

The mechanical properties are examined by tensile and Charpy impact tests, and the microstructure evolution is observed by a optical microscopy. Tensile tests are preformed at a cross-head speed of 1 mm/min, at room temperature. In the case of the HIP joining experiment, tensile tests are measured at 350, 450, 550 and 650℃ for their application to a high temperature operating condition. The tests are performed on cylindrical specimens with a gauge length of 20 mm and a diameter of 3 mm. Charpy specimens are machined with the dimensions of 10 x 10 x 55 mm and have a V-notch geometry of 2 mm in notch depth, 0.25 mm in V-notch root radius and 45° in V-notch angle.

3. Results and discussion

3-1. Normalizing effects

The metallurgical features after a heat treatment are shown in Fig. 1. As shown in these figures, after being heat treated at 1050℃ for 2hrs, HIP joining conditions, a grain coarsening was observed (Fig. 1(b)) and the grain size was increased with an increasing normalizing temperature. The yield strength was also increased with the normalizing temperature by almost two times when compared with the as-received F82H. The thermally altered microstructure and strength were recovered to the as-received state by following the post HIP heat treatment (Fig. 1(d)).

On the other hand, impact toughness was sharply deceased after being heat treated at 1050℃ for 2hrs, and the PHHTed specimens were gradually deceased with an increasing normalizing temperature. The normalizing temperature can be employed in the range of from 900 to 1050℃ based on the results of the mechanical properties and microstructure. In this study, the normalizing temperature is applied at 950℃ after the HIP treatments.

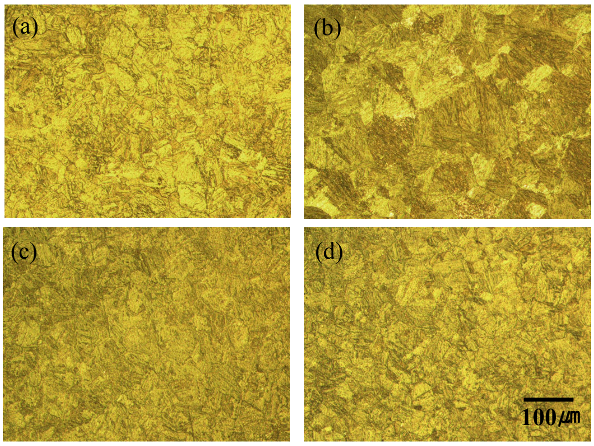

Figure 1. Optical micrographs after heat treatment: (a) as-received, (b) normalized at 1050℃ for 2hrs, (c) normalized at 850℃ for 2hrs and tempered at 750℃ for 2hrs and (d) normalized at 950℃ for 2hrs and tempered at 750℃ for 2hrs.

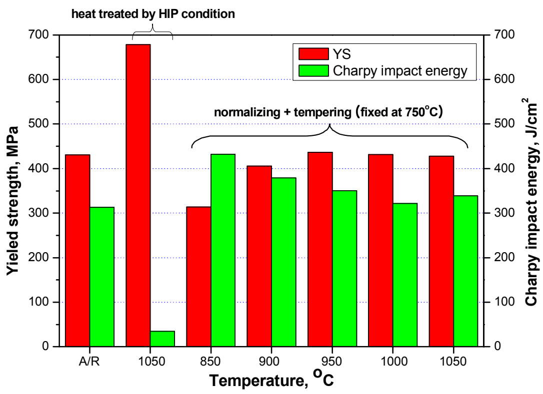

Figure 2. Effect of the normalizing temperature on the yield strength and Charpy impact energy of F82H.

3-2. Tempering effects

The results of the tensile properties tests on tempered F82H are summarized in Fig. 3. The ultimate tensile strength and yield strength were decreased with an increasing tempering temperature, while the elongation was increased and surged above 750℃. The effective tempering temperature can be employed in the range of from 700 to 800℃ based on obtained the as-received result. In this study, the normalized F82H specimens are tempered at 750℃ for 2hrs.

3-3. HIP joint properties

The microstructure of the HIP joined F82H/F82H is given in Fig. 4. The black arrows indicate the HIP joined interface. We found some joined traces in the interface. However, in all the tensile tested specimens, a fracture never occurred at the joined interface, and the strength of the HIP joined specimen was similar to that of the as-received F82H. The strengths were decreased with an increasing testing temperature, and seriously reduced above 550℃.

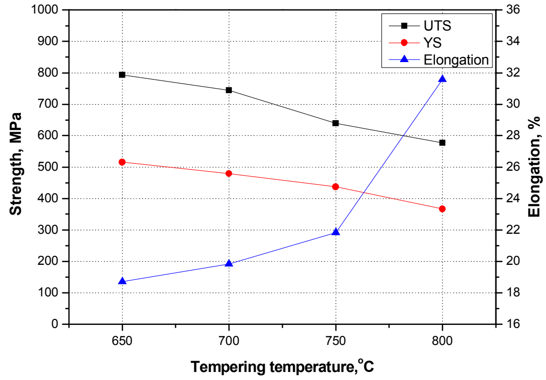

Figure 3. The tensile properties on tempering temperature.

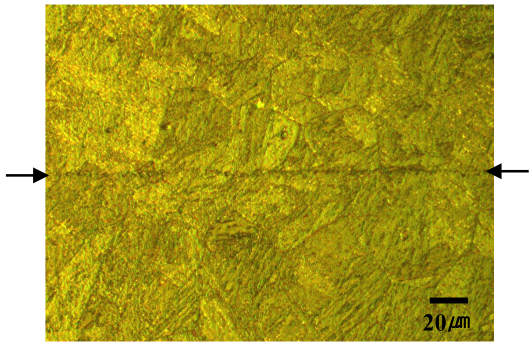

Figure 4. Microstructure of the HIP joined F82H/F82H.

4. Conclusion

The effect of a PHHT on the microstructure and mechanical properties of F82H steel was investigated where the F82H steels were joined by the optimum HIP and PHHT conditions. After being heat treated at 1050℃ for 2hrs, the grain coarsening was observed and the strength was increased by almost two times when compared with the as-received F82H. However, the microstructure and mechanical properties were recovered to the as-received state by the following normalizing at 950℃ for 2hrs and a tempering at 750℃ for 2hrs. The joint specimens of the F82H/F82H were manufactured by HIP at 1050℃, 100 MPa for 2hrs. The tensile properties were very similar to those of the as-received F82H results, and a fracture never occurred at the joined interface. It means that the HIP and PHHT conditions were appropriate for a joining of F82H.

REFERENCES

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[2] A. Cardella et al., J. Nucl. Mater. 329-333 (2004) 133-140.