§15. Tensile Property of Dissimilar Weld Zone in IFMIF Back-Plate and its Structural Analysis

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1. Introduction

R&Ds of a fusion demonstration reactor have been conducted as the next step of the ITER development.[1] The first wall material of the blanket will damage up to 100 ~ 150 dpa due to fast neutron irradiation, and also nuclear transformation helium will be produced simultaneously in the material. Since interaction of the damage and helium strongly affect the mechanical properties of the material, it is necessary to develop an intense neutron source like the international fusion materials irradiation facility, IFMIF [2], which can simulate not only the damage level (~ 150 dpa) but also ratio of the damage level and the helium content (He / dpa = 10).

The IFMIF is composted of accelerator system, target system and test cell system. Liquid lithium target back-plate is in the target system generating fast neutron. The back-plate is a disc-like structure, the center region damage up to about 50 dpa / year. Thus a low activation ferritic/martensitic steel type-F82H is applied to the central region although an austenitic stainless steel type-SUS316L is used in the other region of the back-plate. Since the F82H and 316L steels are TIG-welded, dissimilar weld zone (F82H/316L weld zone) is in the back-plate. It is therefore very important to evaluate jointability of the F82H/316L weld zone in order to survey the optimum welding condition. This report presents results of tensile, hardness and metallurgical tests of the weld zone. Thermal stress analysis of the back-plate is also reported.

2. Experimental

A three-dimensional steady-state elastic thermal stress analysis was performed for design option of back-plate. ABAQUS, a generalized nonlinear finite element analysis program, was utilized for the analysis. Nuclear heat distribution and radiation heat were also considered for the loading conditions.

F82H / 316L weld joint was prepared by TIG welding using welding rod type-Y309. The weld joint have 15-mm-thick, followed by a PWHT at 1013 K for 1 h. Metallurgical observation, Vickers hardness test (9.8 N) and tensile test were performed for the weld joint. The tensile test was conducted using tensile specimen with the cross-sectional dimension of 15 × 6 mm. The test was carried out in accordance with JIS – Z 2241, at RT.

3. Result and discussion

In result of the thermal stress analysis of back-plate model, the maximum von Mises stress (about 290 MPa) appeared 316L region near the F82H/316L weld zone. The Mises stress satisfied allowable design stress of the 316L steel (3 Sm = 328 MPa).

In result of metallurgical observation, No weld defects were confirmed. In result of hardness measurement, the maximum hardness (about 240 HV) appeared in HAZ of F82H, and minimum hardness (about 160 HV) appeared base metal region of 316L.

Fig. 1 shows a macroscopic view of F82H / 316L weld joint after the tensile test. The weld zone can be seen in region enclosed with the dotted lines. As shown in the figure, the weld joint fractured in the base metal region of 316L.

Fig. 2 shows tensile test result of the weld joint. The ultimate tensile stress resulted at about 570 MPa, which was nearly equal to ultimate tensile stress of a base metal of 316L (about 550 MPa). Although the total elongation resulted at about 24 %, the elongation is thought to be equivalent to total elongation of the base metal of 316L (about 48 %) because half of the F82H / 316L weld joint is 316L.

4. Summary

Thermal stress analysis of a back-plate and metallurgical and mechanical tests of F82H / 316L weld joint were performed. The summary is as follows:

(1) The analysis revealed that the maximum von Mises stress satisfied allowable design stress.
(2) No weld defects were confirmed in the weld joint.
(3) The weld joint fractured at the base metal region of 316L.
(4) Ultimate tensile stress and total elongation of the weld joint were comparable to those of base metal of 316L.

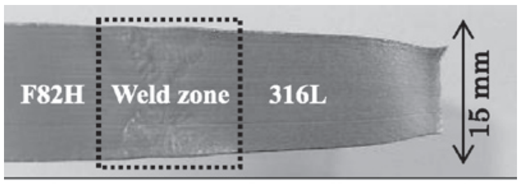

Fig. 1: Macroscopic view of weld joint after tensile test at RT.

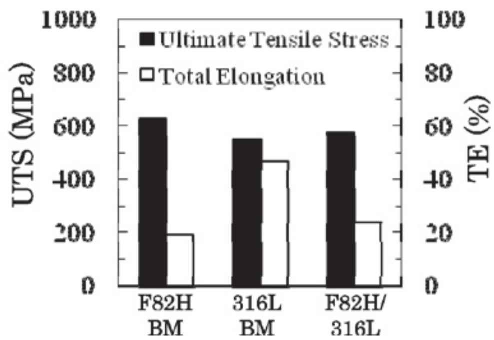

Fig. 2: UTS and TE in base metals and weld joint

1) Kamada, Y., et al.: Fusion Plasma Research toward Fusion Power Plants, J. Plasma Fusion Res., Vol.81, No.11 (2005)849, in Japanese.
2) IFMIF International Team: IFMIF-KEP International Fusion Materials Irradiation Facility Key Element Technology Phase Report, JAERI-Tech, 2003-005 (2003).