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ScienceDirect
Journal of Nuclear Materials 367–370 (2007) 494–499
journal of nuclear materials
www.elsevier.com/locate/jnucmat

Effects of irradiation on mechanical properties of HIP-bonded reduced-activation ferritic/martensitic steel F82H first wall

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Abstract

HIP-bonded regions in the first wall of a fusion blanket are subjected to intense neutron irradiation. The purpose of this study is to investigate the influence of radiation damage on the tensile properties of the HIP-bonded regions. Tensile tests have been performed on specimens taken from a HIP-bonded mock-up structure, made to simulate the different fabrication processes. The neutron irradiation was carried out at about 423 K and 523 K to doses up to about 2 dpa. The tensile tests were performed at room temperature, irradiation temperatures and at 623 K. The main results are as follows: (1) Before irradiation, the tensile properties in the HIP-interface were equivalent to those of the matrix region. (2) Rupture did not occur at the HIP-interface of irradiated material. (3) The tensile properties in irradiated material were not notably affected due to manufacturing/fabricating histories. (4) Changes in properties produced by irradiation at 423 K show significant recovery for a test temperature of 673 K.

1. Objective

The blanket is one of the plasma facing components of a fusion reactor. The first wall, which is a structural part of the blanket, may be fabricated by hot isostatic pressing (HIP) bonding method. F82H steel, a reduced-activation ferritic steel, is regarded as the primary candidate material for first wall.

In general, the properties of first wall materials are degraded due to the exposure to high neutron fluxes for long times. Consequently, it is thought that the integrity of the HIP-bonded region may also be degraded. The first wall is composed of plates and cooling channels, each manufactured by different methods. In addition, the plates and cooling

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0022-3115/$ - see front matter
doi:10.1016/j.jnucmat.2007.03.011

channels are also subjected to various heat treatment histories in the fabrication process of the first wall. Differences in the manufacturing procedure and/or heat treatment history change the initial microstructure of the material so it is possible that the response of the mechanical properties after irradiation is different from that of as-received material.

In this paper, the influence of neutron irradiation on the mechanical properties in the first wall is discussed for an irradiation temperature range in which significant radiation hardening occurs.

2. Experimental

This study utilized a partial mock-up of the first wall fabricated in a previous study [1]. Plates and cooling channels used for fabrication of the mock-up fell into the chemical composition range designed for the IEA steel F82H [2]. Table 1 shows the heat treatment histories for the cooling channels during their manufacturing and the fabrication process for the mock-up. The heat treatment history of the plate is equivalent to that of the IEA-F82H steel in its manufacturing, and the heat treatment history in the fabrication process of the mock-up is the same as for the plate.

Small tensile specimen, type SS-3, were utilized for the tests. The sheet specimen has a 7.62 mm long, 1.52 mm wide and 0.76 mm thick gage section. Sampling location of the specimens is shown in Fig. 1. The specimens were sampled from matrix regions (plate region and cooling channel region) and regions where the cooling channels were HIP-bonded. Fig. 2 shows microstructure in the IEA-F82H steel and the matrix regions. The specimens were prepared with a surface finish of #1000–1200. Initial tensile tests were performed on material in unirradiated condition. The test temperatures range from room temperature (RT) to 673 K; the strain rate was $5 \times 10^{-4}\,s^{-1}$. Neutron irradiations were carried out at irradiation temperatures of 423 K and 523 K to doses up to about 2 dpa. After irradiation, tensile tests were performed at RT, the irradiation temperatures and 673 K. Number of tensile specimens per conditions is shown in Table 2. For the HIP-bonded region, the surface of the fracture region was polished, followed by chemical etching to reveal the HIP boundary. The HIP boundary location was confirmed by optical microscopy.

The neutron irradiation was carried out in the JAEA materials testing reactor (JMTR) of the JAEA-Oarai Institute, and the post-irradiation experiments were performed at the hot laboratory of the institute.

Table 1
Heat treatment history applied to cooling channel for first wall mock-up

Condition	Purpose
Production of channel	
(1) 1083 K for 30 min	Annealing after hot extrusion
(2) 1083 K for 30 min	Annealing after mill pressing
(3) 1083 K for 30 min (two times)	Annealing after cold drawing
(4) 1083 K for 15 min	Annealing after roll forming
(5) 1083 K for 15 min (three times)	Annealing after cold drawing
Fabrication of mock-up	
(6) 993 K for 1 h	Stress relieving
(7) 1273 K for 10 h	Out gassing
(8) 1013 K for 2 h	Tempering
(9) 993 K for 1 h	Post-weld heat treatment
(10) 773 K for 2 h	Degassing
(11) 1313 K for 2 h	HIP treatment
(12) 1013 K for 2 h	Tempering
(13) 993 K for 1 h	Stress relieving

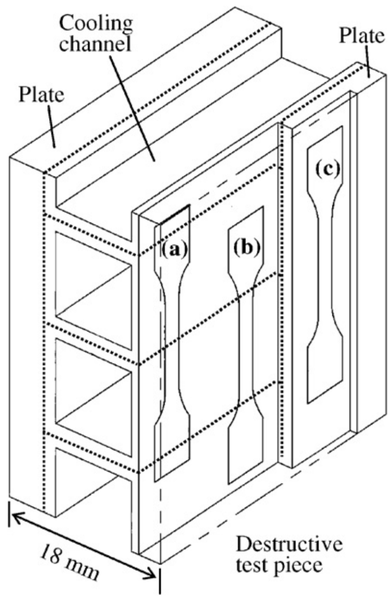

Fig. 1. Sampling location of specimens for tensile tests. The figure shows SS-3-type-tensile specimens sampled from (a) HIP-bonded region, (b) matrix region of channel and (c) matrix region of plate, in first wall mock-up. Broken lines in the figure indicate HIP boundaries.