Available online at www.sciencedirect.com
SCIENCE DIRECT®
Fusion Engineering and Design 75–79 (2005) 423–428
Fusion Engineering and Design
www.elsevier.com/locate/fusengdes

Crack propagation behavior by thermal fatigue around DSCu/SS316 HIP bonded interface

T. Oyama [a,*], A. Yamamoto [a], K. Mohri [b], M. Saito [a]

[a] *Institute of Engineering Mechanics, University of Tsukuba, Tsukuba 305-8573, Japan*
[b] *Kawasaki Heavy Industries, Ltd., Tokyo 136-8588, Japan*

Available online 26 July 2005

Abstract

Hot Isostatic Pressing bonded (HIPed) structure of DSCu/SS316 is proposed for the first wall (FW) of ITER. In this report, the thermal fatigue crack propagation behavior around HIPed interface is investigated with DSCu/SS316 HIPed plate as a specimen which has an initial crack on DSCu side. In addition, numerical analysis is carried out to clarify the mechanism of the interfacial crack propagation and to evaluate crack propagation rate with fracture mechanics. It is concluded that the crack which was propagated very close to HIPed interface did not penetrate into SS316 and changed its propagation direction from perpendicular to parallel to HIPed interface. The interfacial crack is propagated by residual stress in combined mode.

Keywords: HIP; Thermal fatigue; Fracture mechanics

1. Introduction

In operation period of ITER, FW undergoes thermal loads from plasma and there are large temperature gradients because FW is actively cooled. The out-of-plane deformation of FW is almost restricted due to large structure. Hence, thermal stress appears in FW. If FW has an initial defect, thermal fatigue may occur due to pulse operation of ITER. In previous report [1], the thermal fatigue tests and analysis were performed on a specimen made of a single material. But it has not been investigated yet how the thermal fatigue crack is propagated around HIPed interface. In this study, cyclic electron beam (EB) irradiation experiments were carried out on a DSCu/SS316 HIPed plate specimen. In addition, numerical analysis was performed in order to clarify the mechanism of crack propagation near the interface and to evaluate the crack propagation rate with fracture mechanics.

2. Experiment

2.1. Specimen and procedure

The geometry of DSCu/SS316 HIPed plate specimen is shown in Fig. 1. The longitudinal length of DSCu which has high heat conductivity was 30 mm

* Corresponding author. Tel.: +81 29 853 5286;
fax: +81 29 853 5286.
E-mail address: oyama@riko.tsukuba.ac.jp (T. Oyama).

0920-3796/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.fusengdes.2005.06.199

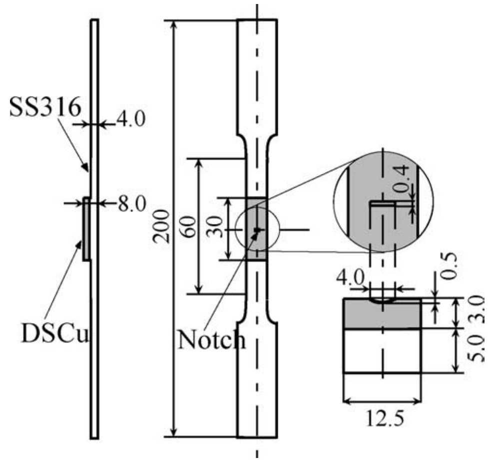

Fig. 1. Geometry of specimen.

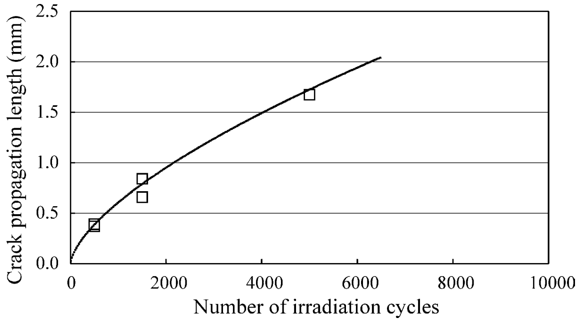

Fig. 3. Result of preliminary test.

in order to be more heated. Specimens were notched at the center by an electron spark machine. A fatigue pre-crack of about 0.1 mm depth was mechanically introduced to sharpen the crack at the bottom of the notch. The experimental apparatus is shown in Fig. 2. The EB irradiation area was an ellipse with 12 mm horizontal and 11 mm vertical diameters. The peak power of EB was 28 MW/m^2. The backside of the specimen was attached to the copper water-cooling board by soldering. Both ends of the specimen were clamped by a servo-controlled machine to constrain bending deformation and to allow thermal elongation in the longitudinal direction. The beam position was changed alternately between the specimen and the cooling board with a specified duration period by means of magnetic deflection coils. One cycle was 5 s EB irradiation and 55 s cooling in all tests. The temperature at a distance of 13 mm over the notch and of the backside were measured by thermocouples. The highest temperature at upper point from the notch was about 400 °C and that of the backside was 120 °C in 1 cycle.

In this experiment, first, the crack propagation behavior in DSCu part was investigated (the preliminary test). Second, the test to investigate the crack propagation behavior around HIPed interface was carried out.

2.2. Results

The result of the preliminary test, the crack propagation length and their fitting curves versus the number of EB irradiation cycles, is shown in Fig. 3.

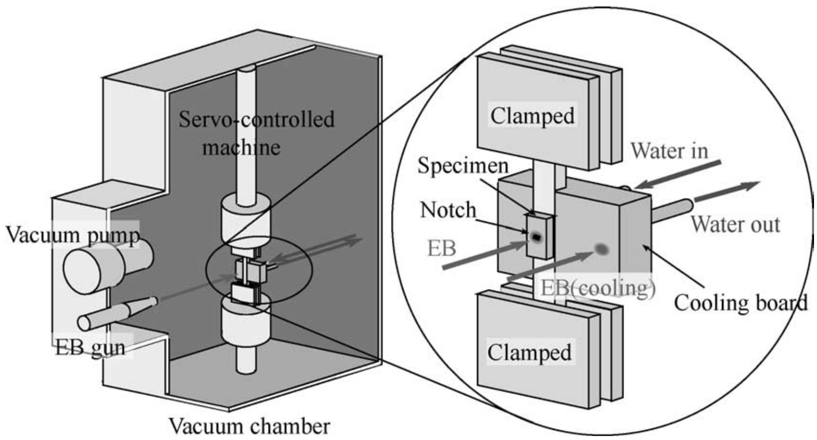

Fig. 2. Experimental apparatus.