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Post examination of tungsten monoblocks subjected to high heat flux tests of ITER full-tungsten divertor qualification program

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HIGHLIGHTS

- ASIPP manufactured six W monoblock mock-ups that were tested at IDTF for full-tungsten divertor qualification program.
- Ultrasonic test was performed to investigate the defects of interface.
- Destructive test was performed on three mock-ups to analysis the damage.
- FEA was performed to study the temperature and stress distribution of monoblocks.

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ABSTRACT

In 2015, as part of ITER Full-Tungsten Divertor Qualification Program, Institute of Plasma Physics Chinese Academy of Sciences (ASIPP) manufactured six small-scale Tungsten (W) monoblock mock-ups that were tested at the electron beam facility, ITER Divertor Test Facility (IDTF, St Petersburg, RF). The high heat flux (HHF) tests consisted of 5000 cycles at 10 MW/m^2, followed by 300 cycles at 20 MW/m^2 and additional 700 cycles at 20 MW/m^2. All mock-ups fulfilled the requirements of high heat flux performance successfully. One (WTC-5) of the six mock-ups was then selected to carry out critical heat flux (CHF) test with local heat flux up to 37–39 MW/m^2. After HHF test, ultrasonic test (UT) and destructive tests were performed to characterize the damages of monoblocks. The debonding of the Cu/CuCrZr interface was detected by both nondestructive and destructive tests. Intergranular rupture of W was observed by Scanning Electron Microscope (SEM). The recrystallization was found in the W monoblocks and the recrystallized depth were analyzed by metallography and Vickers hardness measurement.

1. Introduction

Full tungsten (W) divertor qualification program have been established to develop and validate the performance of W monoblock technology for W divertor in November 2011 [1–3]. Upon the two years of efforts on engineering and physics aspects, the ITER Council endorsed the proposal to start ITER operation with full-W divertor in November 2013. Domestic Agencies in Japan and Europe have succeeded to demonstrate high heat flux (HHF) performance of W monoblocks for a full-tungsten divertor in col-

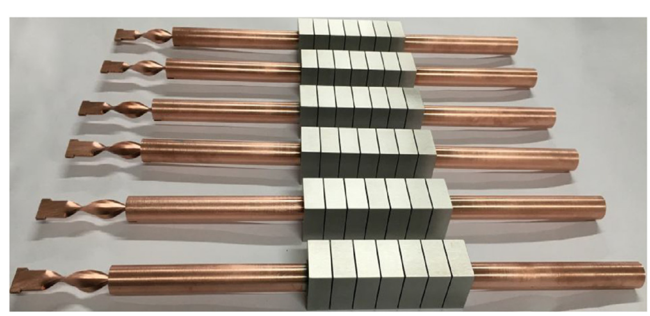

Fig. 1. Tungsten monoblock mock-ups with swirl tapes before HHF testing.

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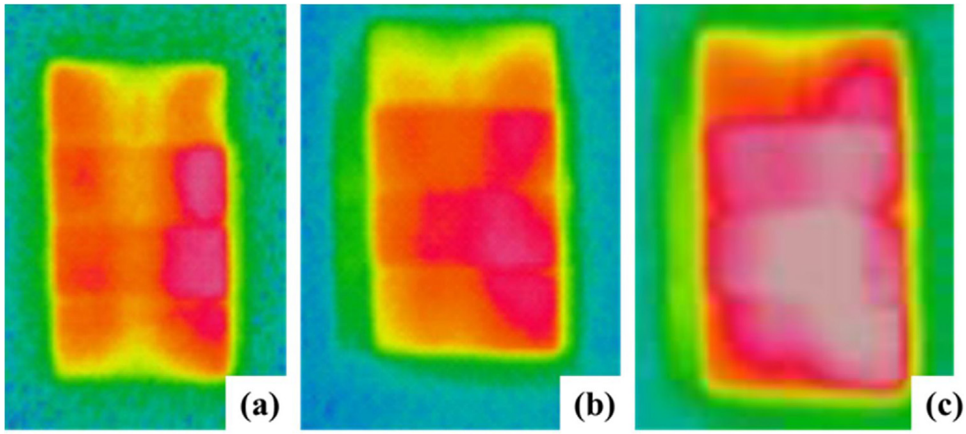

Fig. 2. IR-pictures of average absorbing heat flux at (a)-24.7 MW/m^2, (b)-25.5 MW/m^2, (c)-26 MW/m^2.

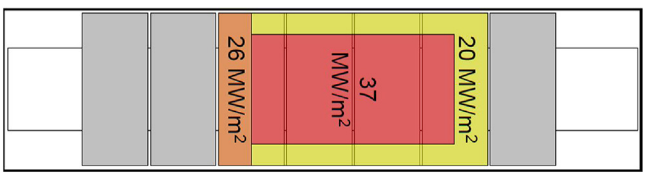

Fig. 3. Possible distribution made by the simulation.

laboration with the ITER Organization (IO) [4,5]. In China, Institute of Plasma Physics Chinese Academy of Sciences (ASIPP) has set up to develop W monoblocks technology since 2010 and applied it to the upper divertor on the EAST Tokamak. In 2015, as a part of qualification of tungsten (W) monoblock technology for ITER divertor, ASIPP and Advanced Technology and Materials Co., Ltd (AT&M) manufactured six small-scale W monoblock mock-ups that were sent to

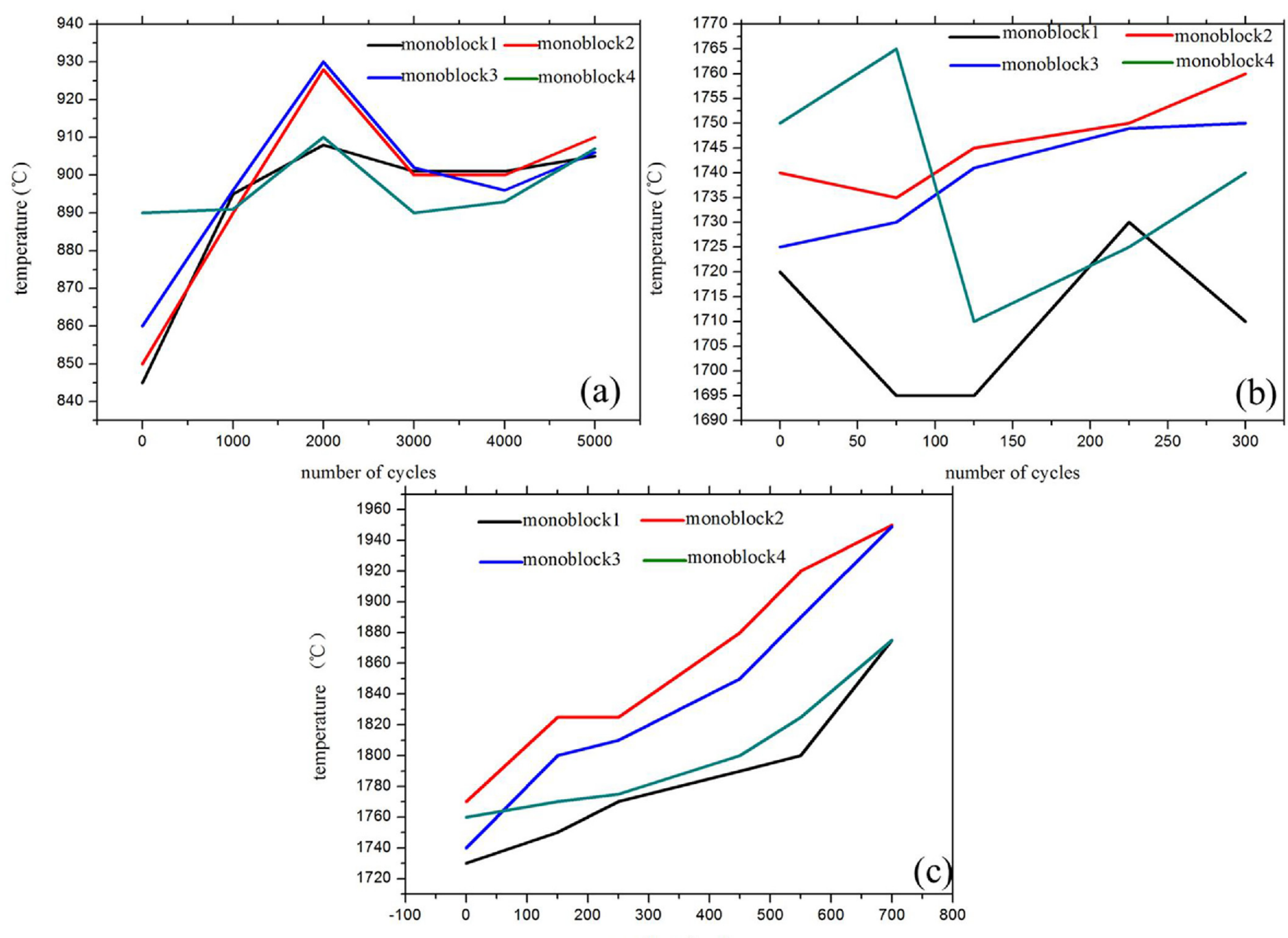

Fig. 4. Average temperature of each monoblock gained by IR-camera of WTC-2 HHF testing: (a)-5000 cycles at 10 MW/m^2, (b)-300 cycles at 20 MW/m^2, (c)-additional 700 cycles at 20 MW/m^2.