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Results of acoustic monitoring of ITER divertor vertical target prototype

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ABSTRACT

Acoustic monitoring is a method under development to indicate the occurrence of critical heat flux (CHF) events on plasma facing components exposed to high heat fluxes (HHFs) from plasma wall interaction, in order to be able to stop plasma operation before irremediable damages appear. It is a non-intrusive promising method thanks to the property of acoustic waves to propagate in channels and to the CHF acoustic precursory indicators which have been observed in several previous HHF experimental studies. This method is on a preliminary assessment stage and HHF experiment on relevant mock-up is an opportunity to collect and analyse data for improving the method efficiency. This paper deals with the post-processing of acoustic signals recorded on a European ITER divertor qualification prototype, on which an unexpected loss of flow accident occurred and caused a cooling channel rupture. The acoustic data have been analysed in the same way as for a CHF scenario, in order to seek precursory indicators of this kind of event.

1. Introduction

Plasma facing components (PFCs) in future fusion devices will have to exhaust steady state heat fluxes from plasma wall interaction up to 20 MW/m^2. This implies the use of advanced technologies in the component design, manufacturing and testing [1], and a high cooling efficiency of the pressurized water circulation into the heat sink channel. This is attained with the help of turbulence promoters and subcooled nucleate boiling regimes. However, a local critical heat flux (CHF) can occur accidentally in the cooling channel and lead to a fast failure of the component (burn out). This can be the consequence of a local increase of incident heat flux, an accidental reduction of cooling flow rate, or a local defect, which may appear after numerous thermal loads during operation. It is therefore essential to develop means of monitoring for stopping plasma operation before irremediable damages appear.

In that aim, experimental studies have been performed in the past on mock-ups exposed to high heat flux (HHF) up to CHF, and acoustic monitoring has demonstrated its capabilities to provide a precursory alarm of the CHF [2–4]. A recent acoustic monitoring was carried out on an ITER divertor target component and is reported in this paper. The component was subjected to HHF cycling tests, while actively cooled by pressurized water. Acoustic piezoelectric sensors monitored boiling phenomena in the cooling channel.

2. Description of the experiment

2.1. Context and mock-up

The tested component is a qualification prototype (QP) for ITER divertor vertical target (VT). The HHF test is destined to demonstrate the capabilities of its supplier, the European domestic agency Fusion for Energy (F4E), to fulfil ITER requirements for the future divertor procurement. This QP has been manufactured by *ANSALDO Ricerche*.

This component consists of W and CFC monoblocks armour bonded onto a copper channel tube via hot radial pressing process [5] (Fig. 1). The 12 mm inner diameter channel tube is equipped with a twisted tape insert (swirl) as turbulence promoter, to enhance the heat exchange between the cooling water and the inner wall of the copper tube, hence increasing the CHF threshold.

2.2. Test bed and instrumentation

The test which is reported was the last one among the 7 QP HHF tests which have been successfully performed at Efremov Institute from August 2008 to March 2009. The test protocol specified by ITER Organisation (IO) for the VT on the CFC part was 1000 cycles of 10 s at 10 MW/m^2 absorbed heat flux and 1000 cycles of 15 s

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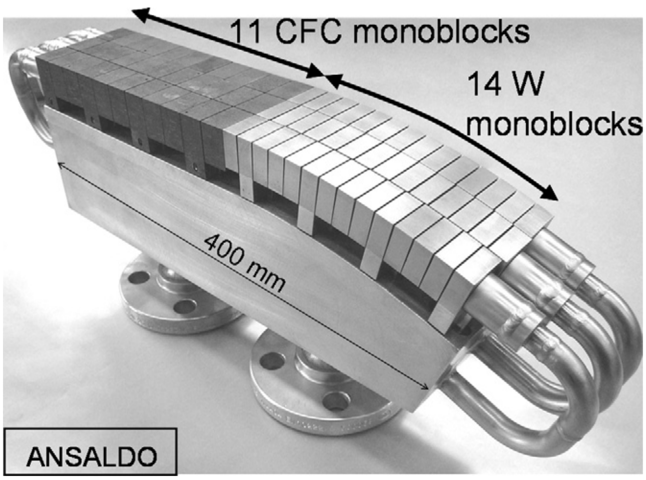

Fig. 1. European vertical target prototype from ANSALDO Ricerche.

at 20 MW/m^2. The QP was installed in TSEFEY-M HHF test facility (Fig. 2). During the test with acoustic monitoring, 3 areas on the CFC part (Fig. 3) were scanned successively during 15 s by the Electron Beam (EB) at 20 MW/m^2, i.e. the second part of the test protocol. The pressurized water cooling parameters in the 3 channels were: 11 m/s, 3.9 MPa, 50 °C.

Acoustic monitoring has been performed using the following instrumentation (Fig. 3):

- Accelerometer 1 (52 KHz resonant frequency) mounted at channel A outlet.
- Accelerometer 2 (40 KHz resonant frequency) mounted 2 m down the 3 channels outlet.
- Microphone (50–500 kHz bandwidth) mounted at channel A outlet. An analogical integrator integrates the high frequency signal before digital recording.
- A Digital recorder, with a 102.4 kHz sampling frequency, connected to a PC.

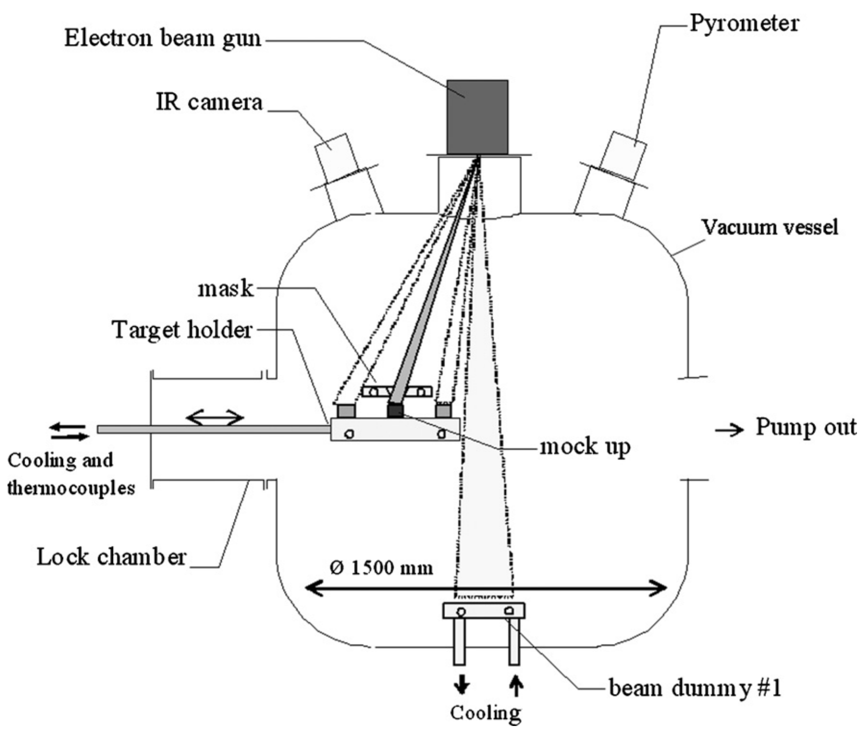

Fig. 2. TSEFEY-M HHF test facility—Efremov Inst., St. Petersburg.

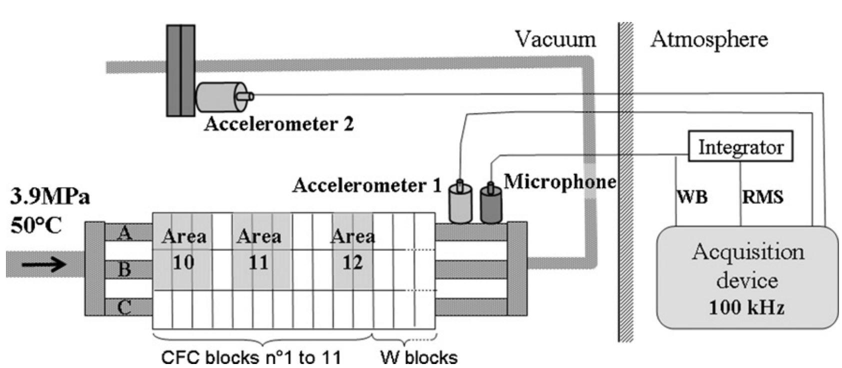

Fig. 3. 3 CFC areas scanned by the EB and instrumentation setup.