Contribution ID: **202** Type: **Poster**

Design and Fabrication of the Active Cooling Divertor Components for HL-2M Tokamak

Thursday, 20 October 2016 08:30 (4 hours)

HL-2M is a new tokamak machine under construction and advanced divertor configuration is one of the major targets. Snowflake and tripod divertor configurations can be performed with up to 3 MA plasma current and 25 MW heating power. The maximal wall load on divertor target plates will reach to 3-7 MW/m2, depending on standard or advanced divertor configurations. Carbon fiber enhanced carbon (CFC) is selected as the armor materials, CuCrZr alloy and Inconel 625 are considered as heat sink and structural materials, respectively. Brazed CFC/CuCrZr flat plates with active cooling are designed as the divertor components.
Based on the database of CX-2002U and CuCrZr-IG, an open cassette divertor structure is designed as shown in figure 1 for HL-2M. Thermal analysis of the target plates by Ansys code indicated that the highest temperature under a wall load of maximal 10 MW/m2 for 5s loading time is lower than 1200 C at the cooling conditions of 4Mpa inlet pressure and 4 m/s flux rate, this high temperature region located on a narrow region of the outboard target plates as show in Fig. 2. When the wall load is reduced to 7 MW/m2, the highest temperature will drop to 850 C. Mechanical analysis indicated that the stress is in an acceptable level of the materials and the bonding interface. Moreover, based on the maximal halo current an induced electromagnetic force was estimated and it is also in a safe range.
Two kinds of technologies of CFC joining with CuCrZr alloy are investigated. One is a slurry method and another is direct vacuum brazing method. Small scale samples have been prepared by both methods. Metallurgical observation identified a dense carbides layer formed on CFC surface (Fig. 3). Shear tests indicated that the fracture took place within the CFC tiles, demonstrating the bonding strength was much higher than the shear strength of this CFC. Preliminary thermal fatigue experiments in a 60 kW electron-beam facility (EMS 60) showed that the small scale CFC/CuCrZr mockups can withstand 10 MW/m2 heat flux. Further optimization of the CFC joining with CuCrZr techniques is under way. It is expected that one of the joining technologies will be used for the series production of HL-2M divertor components.

Paper Number

MPT/P5-12

Country or International Organization

China

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Session Classification: Poster 5

Track Classification: MPT - Materials Physics and Technology