§64. Development and Thermal Control of Ceramics Divertor

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Ceramics (SiC/SiC, B_4C, etc.) are expected to use as a divertor for the LHD during continuous operation, long time and steady state discharges because of the high heat resistance and the excellent nuclear properties. In this study, for the final goal to develop high performance plasma facing component, divertor model specimens made of SiC/SiC composite materials were manufactured. And heat load tests of the divertor model specimens were carried out by a deflection-type electron beam heating apparatus.

SiC/SiC composite materials in this study were the NICALOCERAM and the HINICALOCERAM made by Nippon Carbon co., ltd. and a SiC/SiC by Kyoto University that was made by a polymer infiltration process using the NICALON fiber.

Fig. 1 shows the SiC/SiC composite divertor model specimen manufactured in this study. Five or ten pieces of SiC/SiC composites (5x20x4 mm or 5x20x2 mm) were joined with an oxygen free copper block (20x20x20 mm) having a cooling pipe (10 mm in outer diameter and 70 mm in length). In the joining, titanium (0.05 mm in thickness) and copper (0.01 mm in thickness) foils were used as insert materials, and a molybdenum plate (0.5 mm in thickness) was also inserted for a relaxation of thermal stresses. The joining specimens were held for 30 minutes at 1000 degrees C in a vacuum of 1×10^{-5} Torr. [1]

Heat load tests were carried out up to the heat flux of 6 MW/m^2 as one cycle of 10 sec irradiation and 15 sec interval by the deflection-type electron beam heating apparatus. The water coolant speed was 15 l/min at 15 degrees C. Before and after the heat load tests, the shear strengths and the microstructures of the joining parts of the divertor model specimens were examined.

Copper and titanium alloys entered much in pores of the SiC/SiC composite materials, and thermal cracks weren't observed at the joining parts by SEM. So the SiC/SiC composite divertor model specimens were confirmed the good joint due to insert of molybdenum. And the shear strengths of the joining interfaces increased by insert of molybdenum and were about 70 to 80 MPa.

The SiC/SiC surface temperature increased abruptly with increasing of heat flux and the surface eroded remarkably during heat load tests. On the other hand, the lower temperature of the joining part elevated little. The phenomenon was similar in spite of insert of molybdenum and kinds of SiC/SiC composite materials. One of the reasons was considered that heat transfer didn't occur sufficiently because of the low thermal conductivity of the SiC/SiC composite material. Fig. 2 shows the microstructure of the joining part between the SiC/SiC composite and molybdenum after heat load tests. Small thermal cracks were observed at the joining part.

Consequently, the joining process of the SiC/SiC composite materials was established, however, the SiC/SiC composite material need to be improved the thermal conductivity and the fracture toughness as the next step task to use it for the structural materials. These results are useful knowledge for the development of the ceramics divertor having high performances.

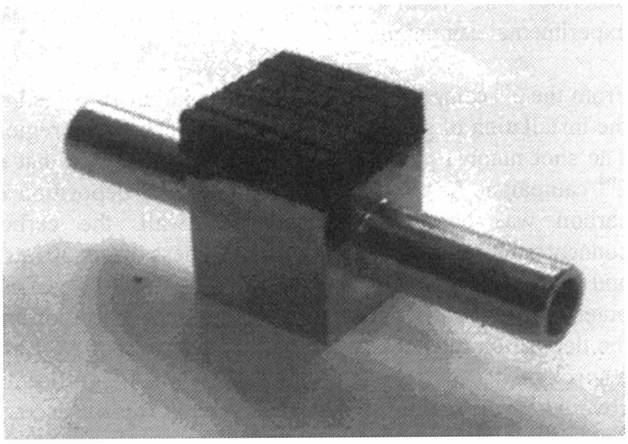

Fig. 1 SiC/SiC composite divertor model specimen.

Fig.2 Microstructure of the joining part after heat load tests.

Reference

1) Imamura, Y., Oku, T., Kurumada, A., Tomota, Y., et al., Proceedings of 1999 US-Japan Workshop (99FT-05), New Mexico, USA, (1999.11.1-4), VIII 23-27.