§21. Evaluation of Thermal and Mechanical Properties of Joining Materials between Carbon Material and Oxygen-Free Copper for a Divertor Plate of the LHD

Oku, T., Imamura ,Y., Kurumada, A., Tomota, Y. (Faculty of Engineering, Ibaraki University), Kubota, Y., Noda, N., Motojima, O.

Model specimens with a cooling tube were metallurgically joined a C/C composite with oxygen-free copper by a Ti foil, which are expected to be applied to a divertor plate of the LHD, were carried out cyclic rapid heating tests. The integrity of the joining parts was evaluated by measuring thermal and mechanical properties using electron beam heating, 3-point bending, continuous indentation and microstructure examination tests.

Fig.1 shows geometry of a divertor model specimen. A felt-type C/C composite (CX-2002U made by Toyo Tanso Co.) was joined metallurgically with oxygen-free copper with a cooling tube using only Ti foil. The cyclic heating to the specimen was given by using a deflection-type electron beam heating apparatus. The maximum power was 15kV-2A. A constant heat flux of electron beam was given for 10 sec and was stopped for 15 sec due to cyclic rapid heating tests. The heat flux was a range from 5 to 15 MW/m^2. The surface temperature of the C/C composite and the temperatures of upper and lower parts of the joining boundary were measured by a radiation pyrometer and thermocouples, respectively. The pressure, the speed and the inlet temperature of water coolant were 0.2MPa, 0.7m/s and 15°C, respectively. After heat load tests, test pieces were cut out of the divertor model specimens, 4-point bending tests, continuous indentation tests and SEM observation of the joining part were performed.

Fig.2 shows a surface temperature and the temperatures of upper and lower parts of the joining boundary of the model specimen at 10 cycles electron beam heating with a heat flux. The sputtering of graphite materials is known to increase abruptly over 1200 °C due to the radiation-enhanced sublimation. In this study, the surface temperatures at 10 MW/m^2 heat flux reached to about 1200°C, however, the surface erosion was not observed during 1000 cyclic heat load. On the other hand, the surface erosion occurred clearly at 15 MW/m^2 heat flux and the boundaries between carbon fibers and pyrolytic carbon matrix laminated by the CVD method have been eroded.

Fig.3 shows the typical changes of temperatures of the divertor model specimen during 1000 cyclic heat load tests at 10 MW/m^2 heat flux. The integrity of the joining parts was confirmed because these temperatures were constant in spite of increasing of the number of heating cycles. On the other hand, the 4-point bending strength after heat load tests was almost the same as the virgin material of the C/C composite.

Consequently, it was concluded that the divertor model specimens with joining parts would be used as a divertor plate for the LHD under an operation condition of 10 MW/m^2 heat flux.

These results were presented at the 2nd IAEA Technical Committee Meeting (Fukuoka, Oct.25-29, 1999), US-J Workshop on PSI and HHFC (Santa Fe, Nov.1-4, 1999) and 7th JSME Materials and Processing Conference (Higashihiroshima, Nov.5, 1999).

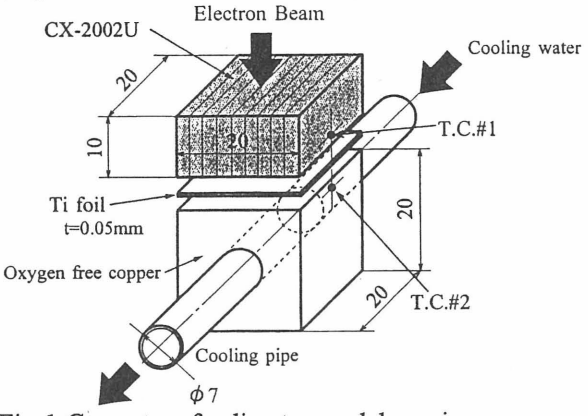

Fig.1 Geometry of a divertor model specimen.

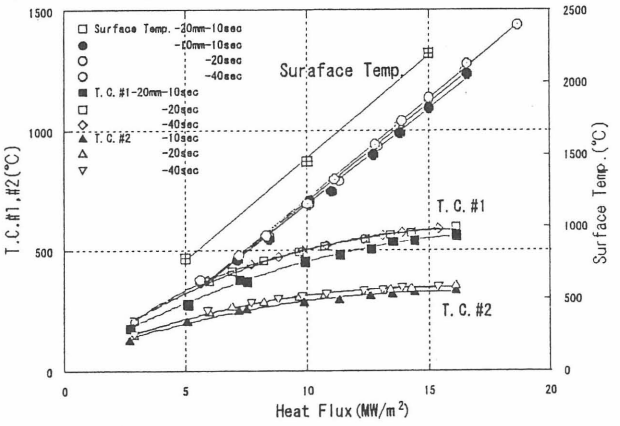

Fig.2 Changes in temperatures as a function of heat flux.

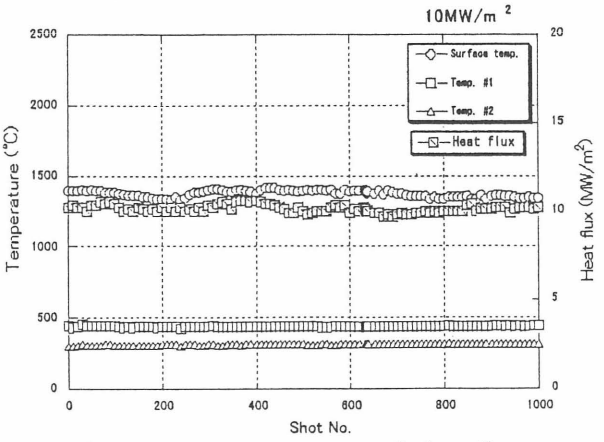

Fig.3 Changes in temperatures of the divertor model specimen during 1000 cyclic heat load tests at 10 MW/m^2 heat flux.