§12. Joining and Heat Load Test of Tungsten Divertor

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Tungsten materials have a high heat resistance, a high thermal shock resistance and an excellent erosion resistance. From the viewpoints of thermal characteristics and a plasma particle control, the tungsten materials are expected to be used as an armor tile material of the next divertor plate for the LHD during the steady state and the long pulse operations. In this study, the divertor plate model specimens made of tungsten materials are manufactured to contribute to the development of the plasma facing components having high performances. And the integrity of the divertor plate model is tested by a deflection-type electron beam heating apparatus.

Tested materials are the stress removal and the re-crystalline processing specimens of the pure tungsten material made by Allied Materials Corp. The re-crystalline processing tungsten material is treated further to the stress removal one for obtaining the grain size from 10 to 20 micron.

Fig.1 shows the joining method of tungsten materials. Tungsten materials of 4 pieces (20x5x5 mm) are joined with an oxygen-free copper block (20x20x20 mm) having a cooling pipe (7 mm in inner diameter, 10 mm in outer diameter and 70 mm in length) after polishing and acetone washing. Titanium (0.05 mm in thickness) and copper (0.05 mm in thickness) foils are inserted for the joining. The joining specimens are held for 40 minutes at 1000 degrees C in a vacuum of 1×10^{-4} Torr. [1]

In heat load tests, heat fluxes from 0.5 to 15 MW/m^2 are irradiated to the tungsten divertor plate model specimens by a deflection-type electron beam heating apparatus. The one cycle is 10-sec irradiation and 15-sec interval, The speed and the temperature of the water coolant are 15 l/min and 15 degrees C, respectively. And the temperatures of the surface and the joining part are measured by a radiation thermometer and CA thermocouples, respectively. The microstructures are observed by SEM before and after the heat load tests.

Fig.2 shows a crack in the re-crystalline processing tungsten material near the joining part. The crack parallel to the joining line is considered to occur by the thermal stress due to the difference of the thermal expansion between tungsten and copper materials. The crack is also observed in the stress removal one. The joining technique needs to be improved further.

Fig.3 shows the relationship between temperatures of the tungsten divertor plate model specimen and the heat flux. In this figure, the data of the C/C composite divertor model specimen are also indicated. So the surface temperatures of the tungsten materials are lower at the high heat flux region, the tungsten divertor is considered to be effective in the case of receiving the severe plasma attack. On the other hand, the temperatures of the joining parts are nearly the same because of the good heat transfer.

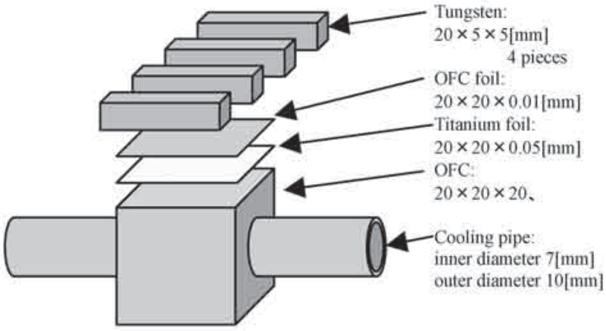

Fig.1 Joining method of tungsten materials.

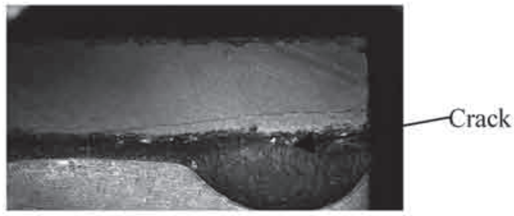

Fig.2 Crack in the re-crystalline processing tungsten material near the joining part.

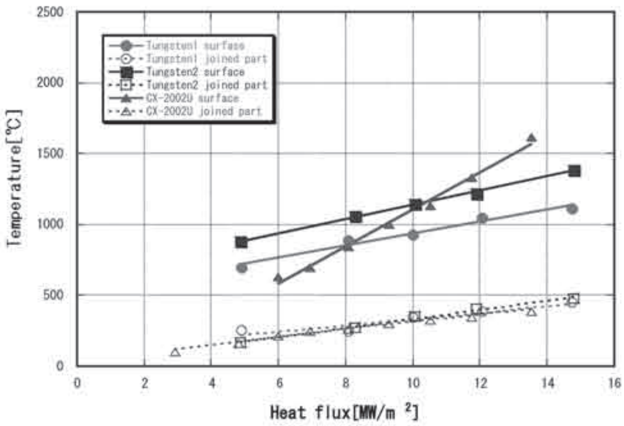

Fig.3 Relationship between temperatures of the tungsten divertor plate model specimen and the heat flux.

Ref. [1] Suzuki,A., Imamura,Y., Kurumada,A., et al., Extended Abst. of Ibaraki District Conf. (2003.9.19) 55-56.