# §73. Evaluation of Thermal Shock Resistances of Joining Materials between C/C Composite and Oxygen-free Copper as a Divertor Plate for LHD

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Joining materials between a C/C composite and oxygen-free copper were manufactured by using only Ti foil as a candidate material of a divertor plate for LHD. The mechanical properties of the joining part was evaluated by continuous indentation and four-point bending tests, and the microstructures were also observed by SEM and EPMA, while the integrity of the joint was examined by heating at 850~1150℃ in ACT.

Fig.1 shows the joining specimen in which felt surfaces of the CX-2002U composite were joined perpendicularly to oxygen-free copper by using only Ti foil (the purity: 99.6%) of 0.05mm in thickness. The joining specimens were held for 10 minutes at each joining temperature (860~1000℃) in an atmosphere of Ar gas. The force applied to the specimen was only the deadweight of the copper piece.

The specimens could be joined at 900~1000℃, however, the materials joined at 900℃ and 950℃ sometimes included cracks produced by thermal stresses within the Ti/Cu alloy layer in the cooling process.

Fig.2 shows the relation between the bending strength of the joining material and the joining temperature. The bending strength was the same as that of the CX-2002U composite because the fracture tended to occur at the C/C composite side. On the other hand, distributions of the parameters in the continuous indentation test indicated that there were not the decreasing spots of the strength. Consequently, the specimens were estimated to be joined well.

Fig.3 shows the SEM image of the joining material joined at 950℃ and it indicates a successful joint. The alloy layer of Cu and Ti existed and the thickness of the layer increased with increasing the joining temperature.

Fig.4 shows the typical EPMA image of the joining material. The specimens joined at over 950℃ tended to distribute Ti inhomogeneously in the Ti/Cu alloy layer because alloy phases of Cu-rich region precipitated at first in the cooling process. On the other hand, the distribution of Ti of the joining material joined at 900℃ near the eutectic temperature of Ti/Cu compound was uniformly and its composition was similar to that of the eutectic point.

The electron-beam heat flux used in ACT of NIFS was 0.75W/m$^2$ at each temperature (850~1150℃). Consequently, the integrity of the joint heated up to 900℃ was confirmed.

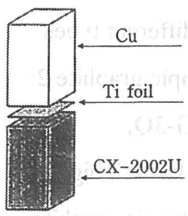



Fig.1 Specimen.

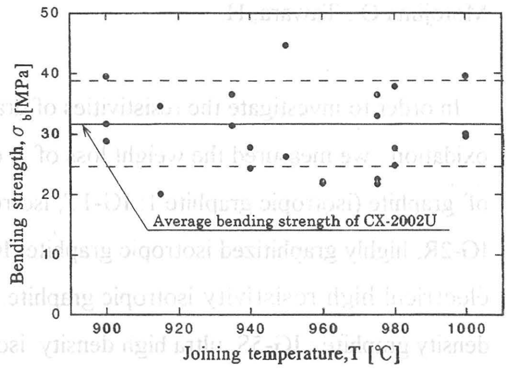



Fig.2 Relation between bending strength and joining temperature.

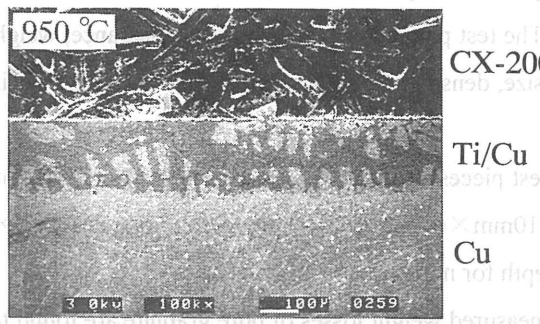
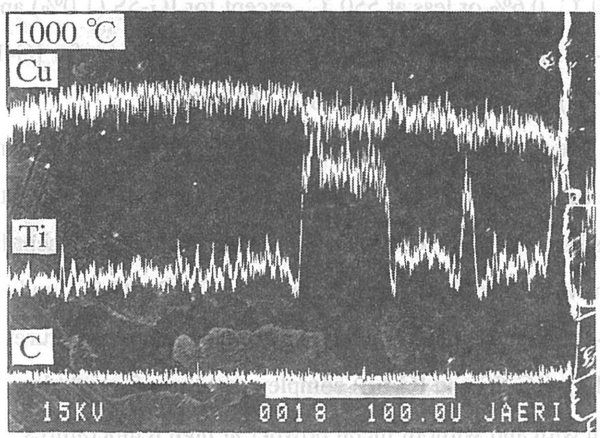



Fig.3 SEM image of joining material.(at 950℃)




Line profile

Fig.4 EPMA image of joining material.(at 1000℃)

These results were presented at the 24th Conference of the Carbon Society of Japan (4-6,Dec.,1997 at Ehime university) and at the 3rd joint meeting of PFC/PSI (5-6,Feb.,1998 at Kyushu university).