§2. Thermal Property and Stress Analyses of Tungsten Coating/Joint Materials

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Tungsten is potential candidate for an armor of the first wall and the divertor plate of the fusion reactor because of its low erosion yield and good thermal properties. Joint material with tungsten and cooling channel will be used as the divertor plate. Cu is one of high thermal conductivity material for the cooling channels. In the fiscal year, mock-ups have been fabricated by jointing of tungsten and Cu and high heat loading experiments for the mock-ups have been carried out under active cooling condition.

Tungsten used in the present works were fine-grained tungsten (ST-1) and coarse-grained tungsten (ST-2) made by NIPPON TUNGSTEN CO.,LTD. Mock-ups were fabricated by jointing four W rods (ST-1 and ST-2) on oxygen-free high thermal conductivity Cu (OFHC) block with a cooling tube using non defective bonding (NDB) by NIPPON TUNGSTEN CO.,LTD. They are simply denoted as W(ST-1)/OFHC and W(ST-2)/OFHC, respectively.

Heat load experiments were performed using the active cooling test stand (ACT) at National Institute for Fusion Science (NIFS). Uniform electron beam at 30 keV was irradiated on the tungsten surface through a beam limiter with an aperture of 20mm×20 mm. Figure 1 shows the mock-up which is connected to cooling tube in ACT. Beam duration during ramp-up, plateau and ramp-down were 20, 40 and 0 s, respectively. Heat flux was changed from 1 to 14.6 MW/m^2. Thermal fatigue tests were also carried out for up to 50 cycles at a heat flux of 14.6 MW/m^2. Surface temperature of the W is measured with an optical pyrometer. Temperature of OFHC (down side of interface of joint area) is also measured with thermocouples. The position measured by thermocouples is 1.5 mm underneath of joint area (OFHC part) and 7mm depth from the side surface. The heat flux experiments have been carried out under the condition that the water flow velocity, pressure and temperature were 18.8 m/s, 0.7 MPa and 296 K, respectively. After the heat flux experiments, the mock-ups were observed with a scanning electron microscope to investigate modification such as crack and exfoliation.

Time evolutions of the electric current through the mock-up, temperatures at its surface and OFHC part under heat loading showed that the temperatures closely follow the changing electric current and temperatures became to be steady state. Figure 2(a), (b) show heat flux dependence of plateau temperatures measured at the W surface and OFHC. It can be seen that the temperatures increased monotonically with increasing heat flux except the W surface temperature of W(ST-1) at low heat flux. In the case of low heat flux, hot spots by electron beam irradiation were formed on the W(ST-01) and these hot spots were considered to influence temperature measurement using the optical pyrometer. Surface temperature of the W(ST-01)/OFHC is always lower than that of the W(ST-2)/OFHC; for example, the difference between them is about 673 K and 973 K at the heat flux of about 8.5 MW/m^2, respectively.

Comparing results of previous experiments[1)], temperature increase of W(ST-1)/OFHC is very low and this indicates that jointing between W(ST-1) and OFHC using NDB is extremely good. Temperatures difference of OFHCs of W(ST-1)/OFHC and W(ST-2)/OFHC is considered to be due to non-uniform temperature distribution of W(ST-2). In addition, in the case of W(ST-1)/OFHC, it is demonstrated that the mock-up successfully withstood 50 cycles with heat load of 14.6 MW/m^2 at steady state.

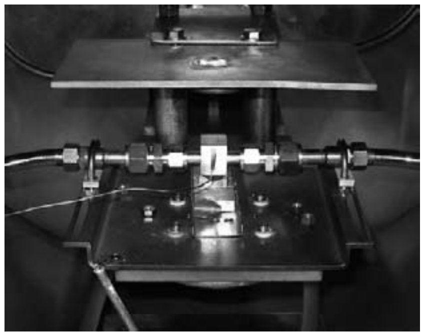

Fig. 1. W/OFHC Mock-up in ACT at NIFS

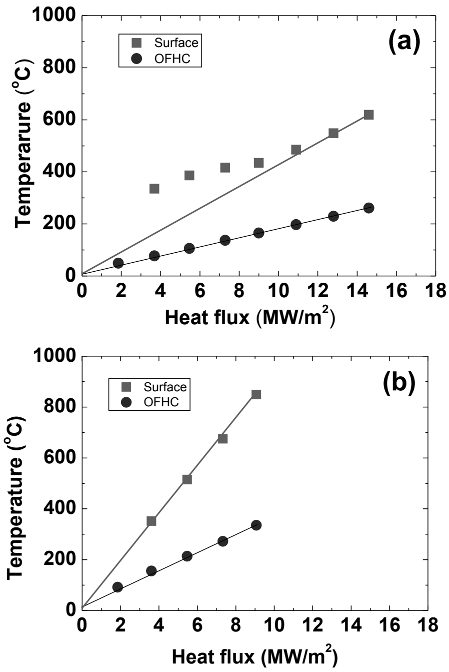

Fig. 2. Temperatures as a function of heat flux of W(ST-1)/OFHC(a) and W(ST2)/OFHC(b)

1)Tokunaga, K. et al.:Fusion Engineering and Design,49-50(2000)371-376