§14. Measurement and Control of the Sheath Heat Flux onto High Temperature Tungsten Surface

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Tungsten is the candidate of the first wall of the future fusion reactors. But it is reported that tungsten suffers many kinds of surface damage from plasma irradiation with helium ions. This surface damage decreases heat conductivity and increases emissivity. The former effect would make it difficult to remove heat load onto divertor plate, while the latter effect would make it easy. Thus development of real time heat flux measurement method is a very important issue.

In the GAMMA 10 tandem mirror, high heat-flux generation experiments (E-divertor) with high-power plasma heating systems have been started[1]. Heat flux from the end-mirror exit is estimated with calorimetric method. Figure 1 shows the signal of type-T thermocouple(TC) of calorimeter used in the GAMMA 10. Plasma shots is repeated every 13 minutes and temperature of the calorimeter target jumps up and does not recover to the previous level in the shot interval. Total heat load from plasma is estimated as the product of heat content of the target and temperature jump. But this method can not give us information on time evolution of head load. Moreover, the time resolution of the recorder is not so good and temperature peak value might be underestimated.

Simple heat conduction model to consider the calorimeter target temperature response to plasma heat flux is constructed. Figure 2 shows three temperature response of 14 mm copper plate measured with TC at $x = 6, 10, 12$ mm, where x is the distance from plasma irradiation surface. Plasma irradiation with heat flux of $20\mathrm{MW/m^2}$ lasts 100 ms. The blue line ($x = 10$ mm) corresponds to the experimental results obtained with GAMMA 10 Calorimeter. During plasma discharge, no temperature increment is observed and after about 1 s, temperature peak appears.

As shown by this calculation, time resolution of Fig.1 is not sufficient to catch the temperature peak and temperature gradient exists in the target. Such TC data analysis needs to consider heat pulse propagation in a target. So simple calorimetric method may lead estimation error of plasma heat flux. Recently a new analysis model was developed for LHD experiment[2]. It would also reproduce heat flux change of GAMMA 10 plasma from TC data obtained with high sampling speed recorder.

Another important result of Fig.2 is that, if TC is set closer to the surface, temperature response during the irradiation could be measured and time dependent measurement of heat flux would become possible. For 2012FY experiment, a new calorimeter head was designed constructed. Figure 3 shows the photo of the calorimeter head. While TC of the old sensor was connected to backside of the target, TC connection point of this new sensor is moved through the left tube shown in the figure to $x = 2$ mm position. This would improve time response significantly.

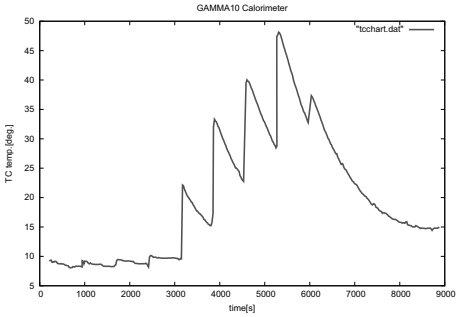

Fig. 1: Photo of combined probe with a Cu GTP tip.

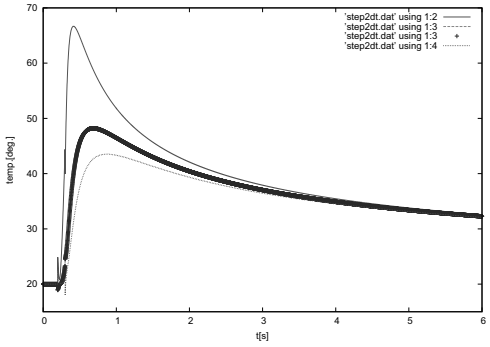

Fig. 2: Model calculation results of calorimeter temperature.

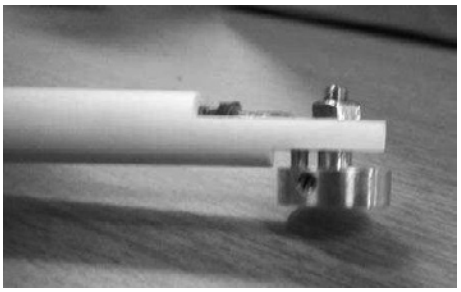

Fig. 3: Constructed calorimeter head.

1) Y.Nakashima *et al.*, Ann. Rep. NIFS, Apr.2010-Mar.2011(2011)483.

2) H.Matsuura *et al.*, Ann. Rep. NIFS, Apr.2010-Mar.2011(2011)48.