§38. Design and Thermal Analysis for LHD Helical Divertor

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Detailed design of helical divertor is being progressed now. Fig.1 shows the structure of divertor element. In the start up phase of experiment, the helical divertor consists of an isotopic graphite tile, a copper heat sink and a stainless steel backing plate. Heat transfer of a joint layer is improved by inserting a 0.15 mm thick carbon sheet. The cooling pipes are made of stainless steel, because the cooling pipes also serve as a support structure of the divertor. The divertor elements are fixed along by the cooling pipe. The shape of cooling pipe is based on the divertor leg position that is obtained by numerical calculation of the magnetic field line at vacuum. The striking point locate 1475 mm of minor radius.

Total Wetted area of the helical divertor is about $10m^2$. If the all plasma heating power would come to the divertor, the average heat flux could be 0.3 MW/m^2 during 3 MW steady state discharge. With the assumption that peaking factor of the heat distribution is 2.5, the target of steady state heat flux is 0.75 MW/m^2.

For the purpose of obtaining guide to thermal property improvement of the divertor element, a thermal analysis by finite element method (FEM) was carried out. Because of the thermal conductance of a mechanical joint layer is unknown, it is treated as a fitting parameter. These analysis account for the following. 1. temperature dependence of the thermal conductivity and the specific heat of the carbon tile. 2. radiation from the surface. 3. contact pressure dependence of the thermal conductance at mechanical joint layer.

Table shows the thermal conductance of the mechanical joint layer that is result of the thermal analysis. Due to lack of sufficient contact pressure at the center of the tile, the thermal conductance at the tile center is two orders of magnitude smaller than the thermal conductance around the bolts.

Fig. 2 shows the temperature distribution in the divertor at 1000 s during heating of 0.4 MW/m^2. The abscissa is distance from the center of cooling pipe. The ordinate is temperature. As shown in the figure, the heat removal property can be improved by using thinner thickness of cooling pipe. And the use of Cu cooling pipe provide significant improvement.

Table thermal conductance of mechanical joint layer

	Thermal conductance [$W/(m^2K)$]
carbon tile - Cu heat sink (center of tile)	$1.2 \times 10^3 \sim 2.0 \times 10^3$
carbon tile - Cu heat sink (around bolts)	$1.2 \times 10^5 \sim 1.6 \times 10^5$
Cu heat sink - cooling pipe	$5.0 \times 10^4 \sim 6.7 \times 10^4$

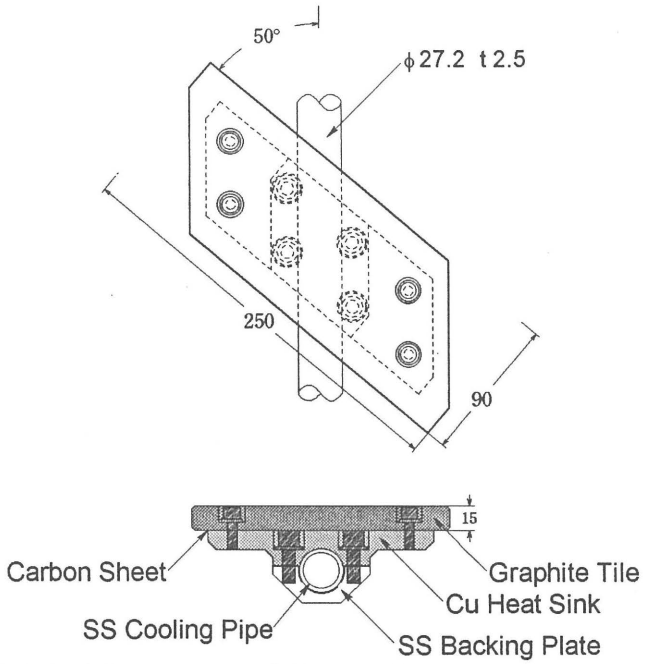

Fig.1 The structure of divertor element

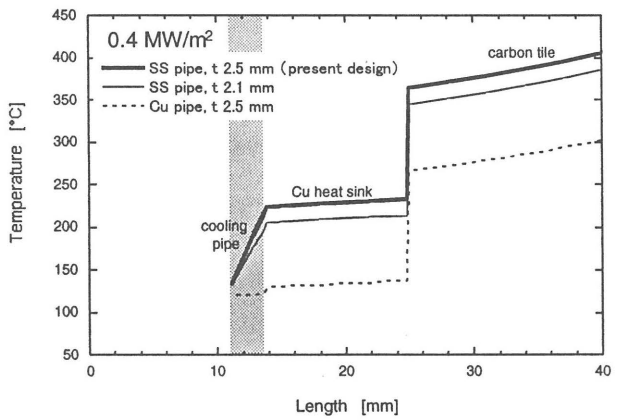

Fig.2 Temperature distribution in divertor after 1000 s