§45. Edge Transport Study of LID Configuration in LHD

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The Local Island Divertor (LID) configuration has been proposed as one of the schemes controlling edge transport physics of heliotron type devices[1]. A separatrix of an m/n = 1/1 island induced at the periphery of the plasma is utilized as a scrape-off layer (SOL) for guiding plasma heat/particles to the divertor region (fig. 1).

In order to analyze the three dimensional transport physics in this configuration, the 3D edge transport code, EMC3[2], has been implemented being coupled with the 3D neutral transport code, EIRENE[3]. EMC3 solves plasma fluid conservation equations of mass, momentum and energy (electron & ion) with a Monte Carlo scheme, while recycling neutrals from plasma facing components and their ionization profiles are treated by EIRENE.

Figure 1 shows time traces of up/down stream temperature, T_{eu} & T_{ed}, and its ratio, T_{eu}/T_{ed}, where the up/down stream are at the O-point of inner separatrix of the m/n=1/1 island and at the surface of the LID head. It is seen that the ratio reaches up to 10 ~ 15. At the typical parameters in LID, a SOL collisionality, $\nu_{SOL}{}^{*}=10^{-16} n_u L_c/T_{eu}{}^2$, is ~ 10 for $n_u=2\times10^{19}$ m^{-3}, T_{eu}=200eV and L_c=200m. According to the two-point model[4] based on a parallel heat conduction transport and a constant pressure, which is widely used in tokamaks,

$$10^{16}\,\nu_{SOL}{}^{*} = C_2(T_u/T_d)^{0.5}(1-(T_u/T_d)^{-3.5}), \qquad (1)$$

where $C_2 \sim 10^{17}$, it gives $T_u/T_d \sim 2$ for $\nu_{SOL}{}^{*} = 10$. The large deviation from the model is attributed to a cross field energy loss, which in the LID case effectively cool down the temperature along the field lines. Figure 2 shows the parallel temperature profiles predicted by the EMC3-EIRENE code. L_c=0 and 190 m correspond to down and up stream (the LID head and O-point of inner separatrix), respectively. One sees that between X-point (L_c ~ 90m) and the LID head there exists significant temperature gradient along the field lines. Because of the short connection length inside the island (private region), the density as well as temperature become low therein. After the flux tunes leave the core plasma at the X-point, therefore, the cross field energy loss takes place at the both sides of the tubes, i.e. towards private region and outside of the island. This geometrical effect gives rise to the effective cooling of the temperature along the field lines, as shown in the Fig. 2.

A power deposition profile onto the LID head was also analyzed with the 3D codes, where we found that the power load is ~ a few tens MW/m^2 at maximum, which greatly exceeds the safety limit imposed by engineering design. This is due to the small wetted area of the LID head, which is estimated at ~ 0.1 m^2, while the total input power to the plasma is several MW. In order to save the LID surface from a severe erosion, it is necessary to smear out the heat load, e.g. by divertor detachment. This is currently an ongoing issue for the LID operation.

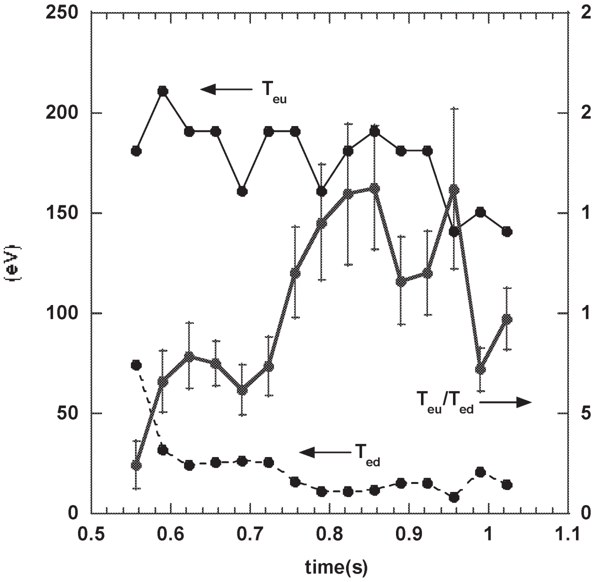

Fig. 1. Time traces of up/down stream temperature (T_{eu}, T_{ed}) and the ratio (T_{eu}/T_{ed}). It is found that the ration increase up to 10 ~ 15, indicating a significant temperature gradient along the field lines.

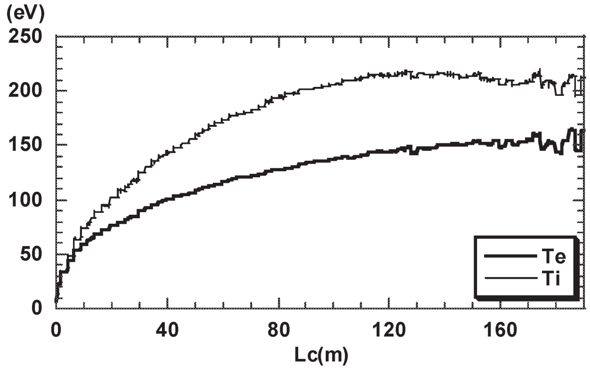

Fig. 2. Parallel temperature profiles calculated by EMC3-EIRENE. L_c = 0 and 190 m correspond to the down stream (the LID head) and the up stream (O-point of inner separatrix), respectively. There appears a significant temperature gradient between the LID and the X-point (L_c = 90 m).

Reference
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3) D. Reiter, Technical Report Jul-1947, KFA Juelich, Germany (1984), and www.eirene.de.
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