Electron parallel heat transport in the scrape-off layer using a particle-in-cell code

A. Froese, T. Takizuka[a], M. Yagi

Kyushu University, 6-1 Kasuga-kouen, Kasuga 816-8580, Japan
[a] *Japan Atomic Energy Agency, 801-1 Mukoyama, Naka 311-0193, Japan*

aaron@riam.kyushu-u.ac.jp

Tokamak development is proceeding to the phase where significant fusion energy will be produced. The alpha heating power in the core plasma (100 MW in ITER and 500 MW in DEMO) will be lost by anomalous transport and by ELMs, and carred by parallel transport along the open field lines in the scrape-off layer (SOL) to the divertor plates. In order to reduce the heat load on the divertor plates, heat flux in the SOL must be carefully engineered to maximize the temperature differential between the SOL and divertor regions. Fluid codes are the most efficient method for predicting SOL behaviour, due to their low dimensionality. However, assumptions regarding kinetic factors, such as boundary conditions at the wall, heat conductivity, and plasma viscosity, are significant liabilities for the fluid model and valid quantities must be acquired from fully kinetic simulations.

A commonly employed approximation for the electron parallel heat flux q_e in the SOL involves combining the Spitzer-Härm collisional heat flux q_{SH} and free-streaming collisionless heat flux q_{FS}. The transition is adjusted via the free-streaming flux multiplier α_e.

$$q_e = \left(\frac{1}{q_{SH}} + \frac{1}{\alpha_e q_{FS}}\right)^{-1} \qquad q_{SH} = -\chi_{||e}\frac{dT_e}{ds} \qquad q_{FS} = n_e T_e \sqrt{\frac{T_{||e}}{m_e}}$$

A number of studies using kinetic simulations have produced widely disparate values for α_e, ranging from 0.1 to 2 [1]. However, there has been little inquiry into the cause of this range of results, with the exception of Tskhakaya [2] who investigated its dependence on collisionality.

We use the PARASOL code to survey the dependence of α_e on various plasma parameters, such as collisionality. PARASOL is a 1d2v electrostatic particle-in-cell model with a binary collision model. The spatial dimension is parallel to a magnetic field line bordering the plasma core and private plasma, and therefore, hot source particles diffuse into the center of the domain and energy is lost to the divertor plates and as radiation near each end of the domain near the walls. This code has previously been used to determine α_e to be a relatively high value of 0.75 [3]. Our results show that in the collisional case, the heat flux is very close to the Spitzer-Härm limit, so α_e is very small as expected, but grows exponentially with the collisionality. At moderate collisionality, the exact behaviour depends on position relative to the energy sources and sinks, but frequently a peak is observed $\lambda_{mfp} \sim 0.1 L_{||}$. Finally, it is found that in the case of low collisionality, the value of α_e grows with radiation.

[1] W. Fundamenski, Plasma Phys. Control. Fusion **47** (2005) R163-R208.
[2] D. Tskhakaya *et al.*, Contrib. Plasma Phys. **48** (2008) 89-93.
[3] T. Takizuka *et al.*, Trans. of Fusion Technol. **39** (2001) 111-118.