§16. Monte Carlo Scrape-off Layer Plasma

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We concentrate on the Scrape-off Layer (SOL) region between the potential sheaths formed in front of two divertor plates. Assuming that the plasma in the SOL is uniform due to fast streaming of particles along open magnetic field lines, we propose a kinetic SOL model, taking essential physics processes into account. The distribution function $f_a(\vec{v},t)$ evolves only in velocity space as follows

$$\frac{\partial f_a(\vec{v},t)}{\partial t} = C_a + \text{sources/sinks}, \qquad (1)$$

where C_a is Coulomb collision operator. The cross-field plasma transport from the core into the SOL and secondary electron emission from the plates are treated as sources, and particle and energy sink effects due to the absorbing plates are effectively modelled through the magnetic connection length L between two divertor plates. In the source terms, the conductive energy flux from the confinement region into the SOL is effectively modelled for the first time via randomly exchanging the source particles and the SOL particles. The conductive energy flux, which is independent of cross-field particle flux in determining the SOL structure, together with the convective energy flux introduced by the particle source term, ensures integrated balance of energy flowing to the SOL and energy lost to the divertor plates. Coulomb collisions are incorporated by the nonlinear Monte Carlo operator[1] which can accurately simulate the collision effects even when the SOL plasma deviates far from a Maxwellian distribution. Instead of solving Possion's equation, the total potential drop between the SOL plasma and the plate is consistently determined by employing charge neutrality constraint. The model Fokker-Planck equation (1) is solved via particle Monte Carlo simulation under charge neutrality constraint and zero-current condition. A steady state SOL plasma and total potential drop are obtained in terms of total particle flux and input power across the separatrix, the temperature of main plasma near the separatrix, secondary electron emission coefficient, and the SOL size.

The collisional SOL plasma is studied by using the particle Monte Carlo simulation. Figure 1 shows (a) the normalized total potential drop $e\Phi/T_e$ and (b) the electron sheath energy transmission factor γ_e as functions of secondary electron emission coefficient δ_e. The numerical values of $e\Phi/T_e$ and γ_e are in close agreement with theoretical predictions[2]; the validity of the model is confirmed.

Within the present framework, the model can be extended to include other effects, such as neutral recycling and impurity flux, by introducing additional source terms.

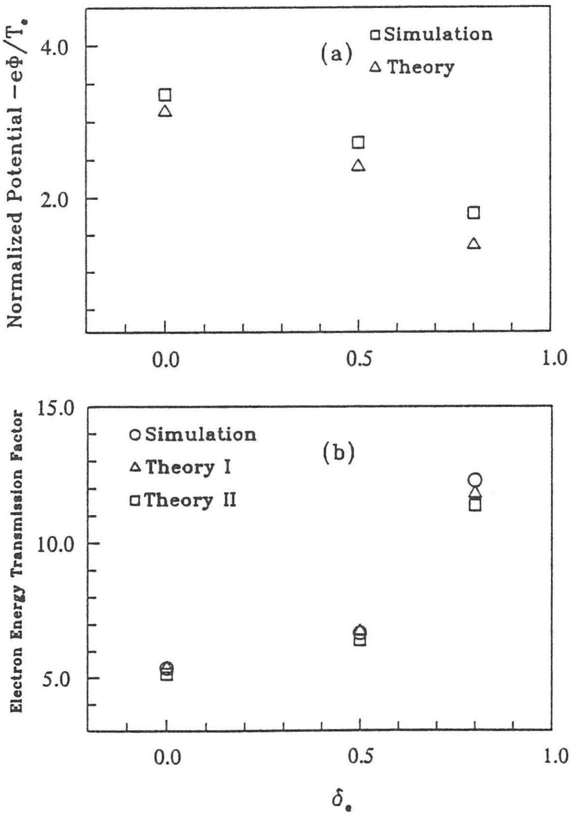

Fig.1

Reference

1) Wang,W.X., Okamoto,M., Nakajima,N. and Murakami,S., NIFS-345, March 1995.
2) Stangeby,P.W., Phys. Fluids 27 (1984) 682.