§19. Electron-ion Collisions in SOL Simulation

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The cooling effect of second electrons emitted from target plates has been investigated with regard to the high temperature divertor operation[1,2]. In the previous simulation, we neglected electron-ion collisions for numerical simplicity. The ramifications of neglecting e-i collisions and the influence of e-i collisions remain to be clarified.

If $T_i \gtrsim T_e$, as is usually case in the scrape-off layer (SOL), the transfer of momentum from ions to electrons and energy exchange between ions and electrons occur in the time $\tau_{ei}^{\epsilon} \sim \sqrt{m_i/m_e \tau_{ii}}$ (τ_{ii}: ion equilibration time). In the situation of previous simulations of collisional SOL plasma, $\tau_{ei}^{\epsilon} \sim 25L/(2v_{ti\|})$ (L: magnetic connection length between two divertor plates; $v_{ti\|}$: ion parallel thermal velocity; $L/(2v_{ti\|})$: ion transit time). This observation implies that, even in a collisional SOL plasma, the momentum transfer from ions to electrons and energy exchange between ions and electrons due to i-e collisions are not significant compared to ion momentum and energy sinks due to the plates. Hence e-i collisions may have little effect on the ion behavior in the SOL. On the other hand, the transfer of momentum from electrons to ions occurs in a time τ_{ei} of the same order as the electron-electron momentum transfer time τ_{ee}. Thus, in the SOL e-i collisions may have an effect on electron behavior as important as e-e collisions do. The consequences of neglecting the momentum transfer from electrons to ions are not explicitly known.

To study the effect of e-i collisions, our Monte Carlo simulation has been extended to include unlike-particle collisions. The Monte Carlo model solves the steady state problem by initial value methods. Since the ion behavior of the SOL is not sensitive to e-i collisions, we start the calculation for electrons including e-i collisions after a steady state of ions is reached so as to reduce computing time.

The principle quantities from the simulations with and without e-i collisions are compared in table 1 for both collisional and collisionless SOL plasma (the secondary electron emission coefficient takes 0.8 in the simulations). The most interested quantity is electron energy transmission factor γ_e which measures the cooling effect of secondary electrons. The e-i collisions indeed have some influence on γ_e especially in collisionless regime. However, although in collisionless regime γ_e is reduced when e-i collisions are included, its value is still smaller than that of collisional regime. This result still supports our previous conclusion from the simulations neglecting e-i collisions: in collisionless SOL plasma the cooling effect of secondary electrons becomes weak and the temperature can be maintained to be high.

Table 1. Principle quantities from the simulations with and without e-i collisions

Collisional case ($L = 2450m$)

	$\frac{n}{n_s}$	$\frac{T_{e\|}}{T_s}$	$\frac{T_{e\perp}}{T_s}$	$-\frac{e\Phi}{T_e}$	γ_e
without e-i	0.94	0.35	0.36	1.78	12.5
with e-i	10.1	0.36	0.37	1.84	12.1

Collisionless case ($L = 122.5m$)

	$\frac{n}{n_s}$	$\frac{T_{e\|}}{T_s}$	$\frac{T_{e\perp}}{T_s}$	$-\frac{e\Phi}{T_e}$	γ_e
without e-i	0.79	0.34	0.67	0.95	7.4
with e-i	0.75	0.30	0.58	0.96	9.5

(n: SOL plasma density; Φ: total potential drop between SOL and plate; γ_e: electron energy transmission factor; $T_{e(\perp,\|)}$: electron (perpendicular, parallel) temperature; T_s: source temperature; n_s: the density used for normalization)

Reference

1) Wang,W.X., Okamoto,M., Nakajima,N., Murakami,S. and Ohyabu,N., Nucl. Fusion 36 (1996) 1633.
2) Wang,W.X., Okamoto,M., Nakajima,N., Murakami,S. and Ohyabu,N., *"Cooling Effect of Secondary Electrons in the High Temperature Divertor Operation"*, NIFS-Report No. 480.