NON-LOCAL TRANSPORT IN A TOKAMAK PLASMA DIVERTOR WITH RECYCLING

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I. Introduction

The plasma transport, particle and energy fluxes, near the divertor plate with high recycling has been modeled by using an electron kinetic code (Fokker-Planck International)[1,2,3], in conjunction with a two-fluid ambipolar code[2,3]. We include the effects of ionisation and excitation of the hydrogen atoms. The electron energy distribution calculated from the kinetic code shows a large deviation from Maxwellian especially near the plate. This deviation from Maxwellian is due to the non-local transport of the suprathermal electrons from the SOL, and due also to the absorption of the fast electrons by the target plate[2,3]. The heat flux near the plate is shown to be nonlocal, in that it is not determined uniquely by the local plasma parameters. Therefore the classical transport coefficients in the fluid model must be modified by including a nonlocal effect to produce the kinetic results[4]. The kinetic calculation is compared with those of the fluid code with different values of the electron heat flux limiter factor f. To reduce the computer load, the initial condition we used corresponds to the equilibrium solution already found with the fluid code with f=0.2. The fluid and Fokker-Planck codes are relaxed until all transients associated with electron dynamics have disappeared.

In section II, we present the fluid code. The kinetic code is presented in section III. The boundary conditions used in this simulations are given in section IV. Finally the results and conclusion of these simulations are presented in section V.

II. 1D-2Fluid Code

The one-dimensional, ambipolar two-fluid time dependent code[2,3] including ion viscosity and heat flow has been used to study the plasma transport in a divertor tokamak. The basic equations and transport coefficients used in this code are taken from Braginskii[5]. In our fluid model we limit the electron conduction heat flux by using the harmonic mean between the Spitzer-Härm and the flux-limited fluxes[6]:

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$$Q^{e}_{cond.} = q_{SH}\left[1+\frac{|q_{SH}|}{fnT_e v_e}\right]^{-1} \qquad (1)$$

where $v_e=\sqrt{T_e/me}$, m_e is the mass of the electron and f is the so-called flux limiter.

III. Fokker-Planck International Code:

The Fokker-Planck International (FPI) code[1,2,3] is one-dimensional in configuration space, but two-dimensional in velocity space (azimuthal symmetry is assumed). In this code electrons are treated with a kinetic model but the ions and the neutral particles are treated as fluids. The FPI code advances the Vlasov-Fokker-Planck equation for the electron distribution function in time. Thus the kinetic equation for the electrons is given by :

$$\frac{\partial f}{\partial t}+v_x\frac{\partial f}{\partial x}+\frac{eE}{m_e}\frac{\partial f}{\partial v_x}=\left(\frac{\partial f}{\partial t}\right)_{(e-i,e-e)}+\left(\frac{\partial f}{\partial t}\right)_{(E_{ol})}+\left(\frac{\partial f}{\partial t}\right)_{(e-n)} \qquad (2)$$

The second and third terms in the left hand side of Eq.(2) are the advection and the acceleration due to the electric field, respectively. The right-hand side terms represent respectively electron-ion and electron-electron Coulomb scattering, electron-ion energy exchange and inelastic electron-neutral collisions (ionization and excitation).

IV. Boundary Conditions

1. 1D-2Fluid Code:

At the left boundary we fixed the electron and ion temperatures. The particle flux at this boundary is null. At the neutralizer plate, we assume that the incoming plasma is absorbed, and the drift velocity is assumed to be equal to or higher than the ion sound velocity, i.e,

$$v \geq c_s=\sqrt{(T_e+T_i)/m_i} \qquad (3)$$

The ion and electron heat flux at the plate are taken as:

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kinetic calculations. To understand the discrepancy more clearly we therefore examine the profiles of the electron conduction heat flux, q_e, calculated from the kinetic and fluid codes, see Fig.(4). In Fig. (4) we also plotted the profile of q_e calculated from the FPI profile of T_e, by using the classical formula, Eq. (1), with f = 0.2. This calculation disagrees significantly with the kinetic and fluid calculations, and the discrepancy is worse if a value of the flux limiter f different from 0.2 is used. From this we see that the fluid calculation does not agree with the kinetic calculation for any value of the heat flux limiter and this is due to the non-local effect on the electron transport in the SOL. The classical coefficient of the electron heat flux must be modified every where in the system in order to reproduce the kinetic results. In our model we did this modification numerical as follow: in the fluid code we use the Te profile which is calculated from the kinetic code and also force the local electron conducting heat flux, q_e, to agree with that of the kinetic model by multiplying by the following correction factors:

$$CFQ = q_{e\text{-Kinetic}} / q_{e\text{-Fluid}}(T_{e\text{-kinetic}}) \qquad (6)$$

In Fig.(5) we present the correction factor in the fluid code for the electron heat flux for this particular simulations.

VI. Acknowledgement

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VII. References

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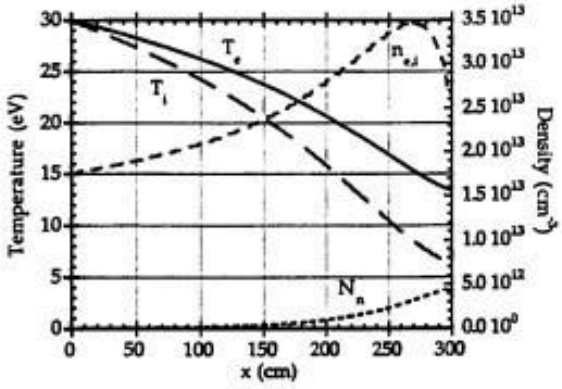

Figure 1 Fluid equilibrium solution: Profiles of T_e, T_i, $n_{i,e}$ and n_n.

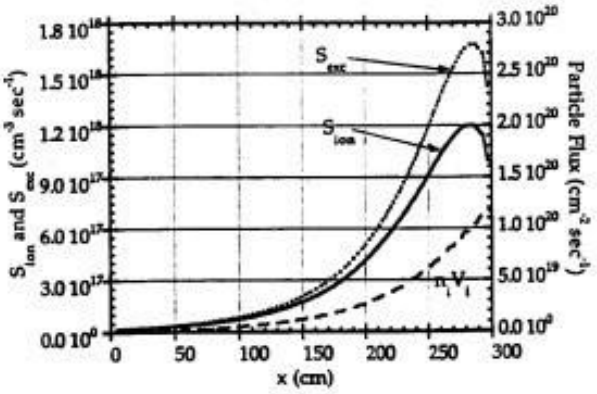

Figure 2 Fluid equilibrium solution: Profiles of $n_i v_i$, $S_{exc.}$, and $S_{ioni.}$.

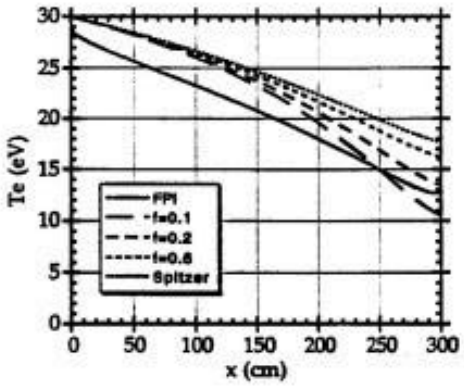

Figure 3 Fluid and Fokker-Planck simulations: Profiles of T_e.

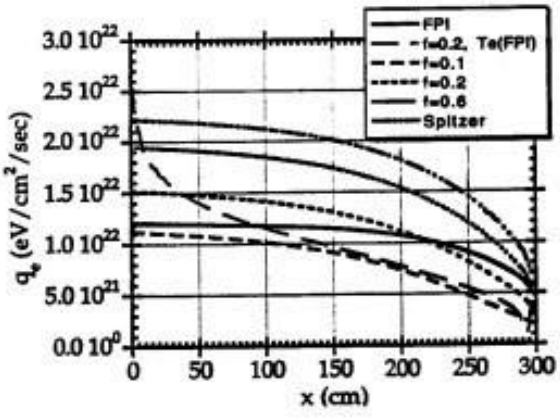

Figure 4 Fluid and Fokker-Planck simulations: Profiles of q_e.

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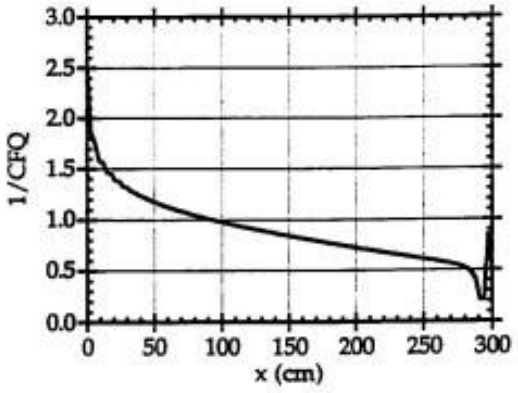

Figure 5 Profile of the electron conduction heat flux correction factor (CFQ).

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