XA9951031

THP2/11

Time-Dependent One Dimensional Model of MARFES, Detached Plasmas in Divertor Scrape-off Layer of a Tokamak

R. Goswami, M. Warrier, S. Deshpande, S. Jaishanker, P. Kaw and R. Singh

Institute for Plasma Research
Bhat, Gandhinagar 382428, INDIA

Abstract

It is widely recognized that various atomic physics phenomena associated with impurities and recycled neutral gas in the divertor region of a tokamak can be crucial for the drop of temperature and pressure from its high value near the mid-plane scrape-off layer region to acceptably low values near the divertor plate. In this paper we present an analytical and numerical investigation of a time dependent one dimensional plasma model describing the evolution of multiple thermal and/or pressure fronts associated with radiation, charge exchange, ion-neutral elastic collisons, ionization, volume recombination and parallel flow along the lines of force. The radiative thermal front is associated with MARFES and the pressure/temperature drop associated with volume recombination effects essentially leads to a detached plasma configuration with minimal thermal and particle fluxes to the divertor plate. We investigate static thermal fronts, possibility of nonlinear propagating thermal waves and some related questions regarding linear and nonlinear stability of simple 1-d configurations. Our results have relevance to the interaction of ELMS (which are essentially bursts of heat and particle flux into the scrape-off layer) with MARFE/detached plasma configurations in the divertor scrape-off layer region.

XA9951032

THP2/12

Effect of Curvature and Gradient B ion Drift on Formation of Radial Electric Field

X.D. Zhang
Institute of Plasma Physics, Academia Sinica, Hefei, 230031, China

The negative E_r always appear spontaneously in H-mode, and that is related to a larger ions loss than that of electrons in same region. The neoclassical effects of ion and electron lead to better understanding of the physics and mechanism of the E_r formation and may supply a effective method to generate and control the E_r with suitable neutral beam injection in local region for reducing the threshold power.

The theory of single particle motion in toroidal system shows that the orbit of charged particle has a displacement away from its initial magnetic surface driven by curvature and ∇B drift. Because of small Larmor radius, the displacement of electron is very small, generally, smaller than 1 mm, so electrons essentially move on their initial magnetic surface.

The ion curvature and ∇B drift direction and mid-plane decide whether the ion orbit expands or contracts. The side in the direction of ion curvature and ∇B drift is the expanding region, the other side is the contraction region. In the expanding region, charged particles have radial motion toward outside magnetic surface. In the contraction region, that have radial motion toward inside magnetic surface.

We well know that favorable ion ∇B drift direction towards X-point can reduce H-mode threshold power in a single-null divertor configuration. The analysis of theory and simulation of curvature and ∇B drift in toroidal system indicated that the contribution for reducing threshold power is not only from the ion ∇B drift direction. The ion curvature drift is as important as ion ∇B drift. Ion curvature and ∇B drift in toroidal system are in the same direction. Their effects are not separated. Because of curvature and ∇B drift, charged particles can not move along the magnetic line, but move across the magnetic surface. When ion curvature and ∇B drift toward X-point, the ions, inside and close separatrix, can drift out of separatrix. Unlike limiter configuration, the outside magnetic surface of separatrix close to X-point in a divertor configuration is open. Many ions, especially with larger displacement, can drift out separatrix, and do not move into separatrix again. These ions will move to the divertor plate and are then exhausted directly from X-point(Fig. 1). Because of a larger displacement, the loss of ions is larger than that of electrons, so that the negative E_r appears just inside separatrix at first.

When ion curvature and ∇B drift is away from X-point, the ions, inside and close to separatrix, drift out separatrix on the side without X-point. On this side the magnetic surface is close, so that the ions will move to the side with X-point through a long distance in edge region outside separatrix. It will lead to a high collisions and pressure in edge region, especially for a narrow outside gap. High collisions and neutral pressure is unfavorable for formation of negative E_r, they will reduce the negative E_r[1]. The ions with small displacement may move into separatrix again in the side with X-point, because ion curvature and ∇B drift is away from the X-point(Fig. 2). In such a case, the negative E_r is smaller than the case that ion curvature and such a case, the negative E_r is smaller than the case that ion curvature and ∇B drift toward X-point, so larger threshold power will be needed to generate H-mode.

The ion curvature and ∇B drift and displacement in toroidal system can explain the phenomena about the gap between plasma and wall or limiter in L-H transition, The width of transport barrier is about $2qr_{iL}$, where r_{iL} is ion Larmor radius near separatrix. The similar isotope and B scaling to the experimental result can be got[2,3]. Threshold power is $P_{th} \propto Z_i^2 B\bar{n}/A_i$. For H and He plasma, the P_{th} is same. For D plasma, the P_{th} is half of that for H and He plasma. In the threshold power scaling, there is not any temperature dependence. The threshold power of H-mode represents the critical temperature. The steep density and temperature profile of ion also lead to a separation of ion and electron.

The negative E_r always is associated with ions loss or separation of ions and electrons in same layer. The method of generation and control negative E_r with local NBI is that the ions ionized in plasma must move in the expending orbit, which means ion motion in the outside region of initial magnetic surface. The local NBI can supply continual ions loss or separation of ions and electrons, so that the negative E_r for long quasi-steady-state H-mode may be obtained.

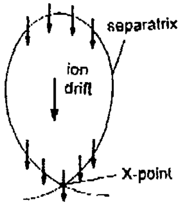

Fig. 1a The ion C-∇B drift toward X-point

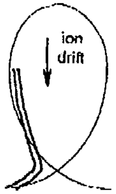

Fig. 1b The ion orbits

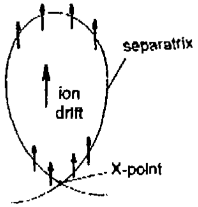

Fig. 2a The ion C ∇B drift away from X-point

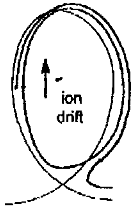

Fig. 2b The ion orbits

References
[1] X.D. Zhang, "Effect of collisional transport of ion and electron on radial electric field" in this conference.
[2] M. Keilhacker, Plasma Phys. and Control. Fusion 29 (1987) P.1041
[3] K.H. Burrell, et al., Plasma Phys. and Control. Fusion 31 (1989) P.1653

THP2/13

THEORY OF ENHANCED CORE CONFINEMENT REGIMES IN TOKAMAKS*

G.M. Staebler, R.E. Waltz
General Atomics, P.O. Box 85608, San Diego, California 92186-5608

J. E. Kinsey
Oak Ridge National Universities, Oak Ridge, Tennessee

The cause of the enhanced core confinement in three regimes observed in tokamaks is investigated: pellet enhanced performance (PEP) [1], radiation improved (RI) [2], and internal transport barrier (ITB) modes with weak or negative magnetic shear [3,4]. Theoretical calculations of the linear stability and quasilinear transport of toroidal drift waves and high toroidal mode number electromagnetic instabilities are compared with experiments. Three theoretical tools are employed: a comprehensive gyrokinetic linear stability code [5] which has been extended to shaped magnetic equilibria, nonlinear 3-D gyrofluid simulations [6], and a reduced gyrofluid transport model [7]. A consistent picture of the transport of both ions and electron energy is found for all three experimental regimes. It is found that generally the low wavenumber part of the linear drift wave spectrum is partially or completely suppressed by E×B velocity shear. This includes trapped ion modes (TIM), ion temperature gradient modes (ITG) and trapped electron modes (TEM). The improvement in the ion thermal transport is explained by this E×B shear suppression. The high wavenumber electron temperature gradient mode (ETG) is not suppressed by E×B shear due to its high growth rate. This explains the generally smaller reduction in electron thermal transport observed. The ETG mode properties give rise to different levels of the electron transport in the three regimes.

The gyrokinetic growth rates (γ) are computed without E×B shear ($\gamma_{E\times B}$) for technical reasons. The measured $\omega_{E\times B}$ is then subtracted from γ to get a positive residual net growth rate. This method of including E×B shear is based on nonlinear simulations of ITG modes [6]. The simulations found that the turbulence was completely quenched when $\gamma_{E\times B} > \gamma_{max}$, where γ_{max} is the maximum linear growth rate. By comparison, nonlinear decorrelation theory [8,9] would only predict a small reduction in the fluctuation level when the E×B shear is at the quench point. The quench point also does not follow linear eigenmode stability (including E×B shear) in a torus but it does in a sheared slab magnetic geometry. Therefore, it is possible to distinguish the quench rule from the other two theories experimentally. The improved thermal confinement of the PEP mode has been ascribed to the stabilization of ITG modes by density peaking. However, density gradients drive the TEM unstable. Thus, density peaking alone cannot reduce ion thermal transport since the TEM mode produces ion heat flow. The ion thermal transport reduction requires E×B shear suppression of the TEM in PEP modes. Peaking the density increases the critical electron temperature gradient of the ETG mode which improves the electron energy confinement. For large enough particle source and high density a bifurcation to neoclassical electron transport, by complete ETG modes suppression, is predicted to be possible [10] but has not been reported.

The RI–mode has reduced transport after impurity injection. Analysis of a DIII–D discharge [11] with improved energy confinement after neon injection showed substantial E×B shear suppression of the ion transport. The electron transport is also found to be improved experimentally. The ETG modes have reduced growth rates in the outer part of the plasma due to the neon kinetic response. There is a good correlation between the measured electron thermal diffusivity and the ETG mode trends. Improved electron energy confinement persist in both the L– and H–mode phases of the discharge. The energy confinement reaches three times its pre-neon L–mode value during the improved H–mode (IH) phase. Sawteeth and

---

*Work supported by the U.S. Department of Energy under Grant No. DE-FG03-95ER54309.