研究論文

Effects of the Location of the X-Point on Edge Confinement

by

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Abstract

The collisionality of ions near the separatrix of the diverted tokamak depends on the location of the x-points. The divertor configuration with the x-point on the median plane on the outboard side should behave like a limiter configuration.

The confinement of hot ions just inside the separatrix of the divertor configuration is essentially that of a mirror configuration as described previously⁽¹⁾. The loss of the ions occurs when the Coulomb collisions take the ions into the "loss cone". Therefore, the dimensionless collision frequency ν^* becomes an important parameter. It is given by

$$\nu^* = \nu_{ii} / (\omega_b \varepsilon) \tag{1}$$

where ν_{ii} is the ion-ion collision frequency, ω_b is the bounce frequency and ε is the inverse aspect ratio.

The bounce frequency ω_b is defined by

$$\omega_b = 2\pi \left(\oint \frac{ds_{\parallel}}{v_{\parallel}} \right)^{-1} \tag{2}$$

where the subscript $\parallel$ denotes the direction parallel to the magnetic field. The bounce frequency depends on the pitch angle of the ion orbit. The bounce frequency of a standard tokamak is shown in Fig. 1. The magnitude of the bounce frequency at small $v_{\parallel}/v$ is given by

$$\omega_b = \frac{\sqrt{\varepsilon}\, v_{th}}{Rq} \tag{3}$$

where v_{th} is the thermal velocity, R is the major radius and q is the safety factor. It decreases with the parallel velocity and vanishes for barely trapped particles.

For a divertor configuration, the bounce frequency near the separatrix will depend on the location of the separatrix because the particle orbit stays near the x-point for a long period. For the case where the x-point or x-points are located vertically (i. e., like ASDEX, D-III and PDX), the bounce frequency distribution is shown in Fig. 2. Point A is where the orbit reaches the x-point. The magnitude of the bounce frequency for small $v_{\parallel}/v$ is given

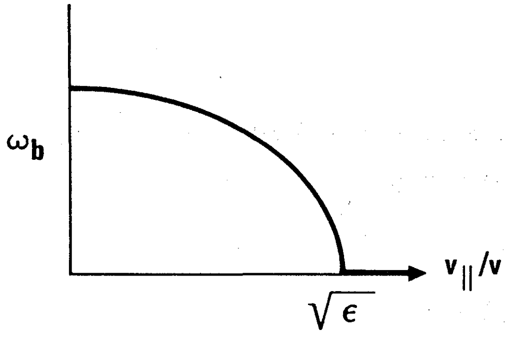

Figure 1

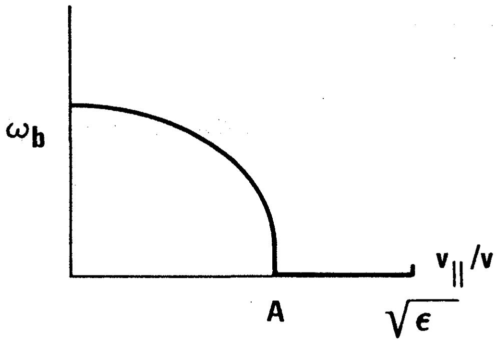

Figure 2

approximately by

$$\omega_b \simeq \frac{\sqrt{\varepsilon}\, v_{th}}{R q^*} \tag{4}$$

where q^* is the current safety factor. If the trapped particle regime is defined as having $\nu^* < 1$, the population of the trapped particles of the divertor configurations is somewhat reduced compared to the standard tokamak configuration for a given collision frequency.

When the x-point is located on the median plane at the outboard side, the trapped population on the separatrix disappears. This is the case for JT-60. The bounce frequency ω_b is given approximately by

$$\omega_b \simeq \frac{\sqrt{\varepsilon}\, v_{th}}{R q_\psi} \tag{5}$$

where q_ψ is the MHD safety factor. The value of q_ψ approaches logarithmically infinite on the separatrix. Since the edge confinement region described in Reference 1 occurs within a few ion banana orbits, the mirror confinement is not possible for this type of configuration.

The hot edge region can withstand a limited amount of recycling. When a cold ion produced by the recycling neutral atoms enters the mirror confined region, it is heated and also changes the pitch angle through Coulomb collisions. The effective pitch angle collision frequency is given by ν_{ii}/ε and is much larger than the energy equilibration frequency ν_{ii}. As a result, the cold ions very close to the separatrix are ejected before they are heated, thus preventing the cooling of the hot ions. It is especially true for the impurity ions. As soon as their charge number becomes greater than unity, the collision frequency increases and they are ejected.

For the case of JT-60, the mirror confinement is not available because of the location of the divertor. A cold ion is confined as well as the hot ions. Hence the recycled cold ions are heated and cool the edge region. The impurity ions are also retained. These are the characteristics of the plasma edge with a limiter. Therefore the divertor configuration of JT-60 types should behave more like a limiter configuration.

REFERENCE

1. T. Ohkawa, "Combined Confinement System Applied to Tokamaks", to be published in Kakuyugo Kenkyu.