§ 42. Single Particle Orbit Calculation of Neutral Beam Injected Fast Ion in FRCs

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The Neutral Beam (NB) injection experiment has been carried out at the FIX device in Osaka University.[1] Improvement of confinement and electron heating are observed so far. The objectives of this study are to discuss how the NB injected fast ion confinement property depends on the mirror ratio, what mechanisms cause the end and orbit loss on the wall, and where and how much the fast ion deposit its energy. Interaction between NB particles and plasma is taken into account by the Monte-Carlo method. In prescribed FRC equilibria with a strong magnetic mirror, single particle orbits calculation starts where NB particles are ionized. Calculation parameters are relevant to the NB experiment on the FIX device. Figure 1 shows the dependences of the confined fast ion fractions to the total ionized NB particles α on the number of fast ions' mirroring motion. These fractions are calculated for various mirror ratios, 2, 4, 6, 8, and 10; these are defined by the ratio of the flux function at the wall and mirror point to the one at the wall and midplane $\psi(r = r_w, z = z_{mir})/\psi(r = r_w, z = 0)$. For the case of the mirror ratio of 2, almost all of the fast ions are lost from the mirror point at the first arrival at the mirror point. A longer confinement and a gradual loss are observed for an equilibrium with higher magnetic mirror. If fast ions move regularly, then mirror reflected ions are confined for infinitely long time; this conflicts with the calculated results. Thus the fast ions are in non-adiabatic motion that destroys the mirror confinement. In order to clarify the non-adiabaticity, the correlation of the magnetic moment between at the first and the third mirror reflection is presented in Fig. 2. As all plotted points are scattered randomly, it is found that the correlation disappears completely. Taking into account the slowing down collision between fast ions and plasma electrons, we also calculate the local energy deposition by fast ions. It appears that the dominant deposition occurs outside the separatrix and between the X-point and the mirror end. The reasons of this are as follows:

1. Fast ions travel for a long duration around the mirror reflection point.
2. There exists a significant plasma density in the edge layer of this equilibrium.
3. Although fast ions move wider radial extent on the midplane, they are concentrated in the mirror region.

For an effective plasma heating, the dominant deposition should be located inside the separatrix. Since NB particles are injected at an angle of 19 degrees to the geometric axis in the same manner as the FIX device, the fast ions travel large axial extent. Although this experimental setup suppresses the wall orbit loss significantly, however, an additional technique to enhance the effect of heating inside the separatrix is necessary, such as a high fluxing of FRC.

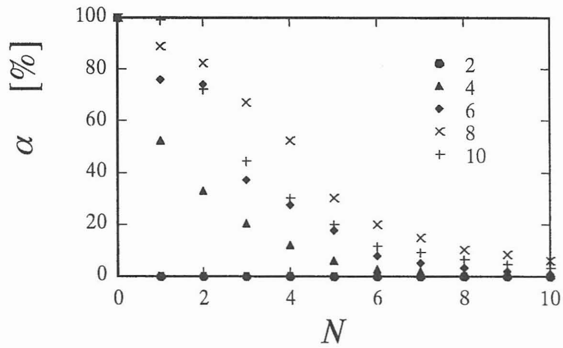

Fig. 1. The fractions of the confined fast ions to the ionized neutral beam injected particles (10 keV) versus the number of their mirroring motion.

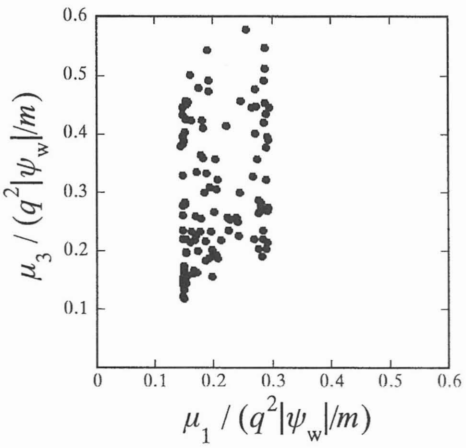

Fig. 2. The correlation of the magnetic moment between at the first mirror reflection and at the third reflection.

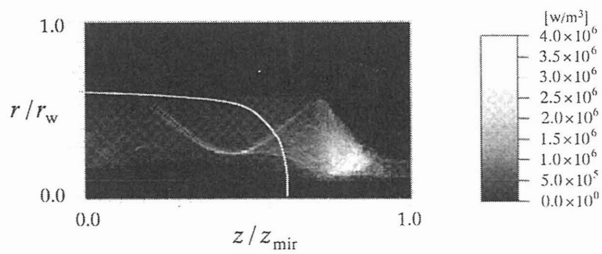

Fig. 3. The deposition power profile on the *r-z* plane ($z > 0$). The white solid line is the separatrix.

1) T. Asai *et al.*, Phys. Plasmas 7, (2000) 2294.