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MINIMUM-B MIRRORS PLUS EBT PRINCIPLES

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ABSTRACT

Electrons are heated at the minimum-B location(s) created by the multipole field and the toroidal field. Resulting hot electrons can assist plasma confinement by (i) providing mirror, (ii) creating azimuthally symmetric toroidal confinement, or (iii) creating a modified bumpy torus.

The EBT E-ring is a remarkable device that is used to stabilize toroidal plasmas. Present rings are created at regular mirrors. Thus rings are subject to the MHD interchange instabilities. These instabilities are apparently cured by the line tying. It is immaterial whether actual cold plasmas are present or some other mechanism such as ionization of neutrals plays the role of the line tying. The fact remains that stabilization of rings requires the presence of particles near the periphery which apparently causes the need for high-neutral pressure. Hence the ion confinement (through charge exchange) is bad.

One possible solution is to create the electron ring in minimum-B geometry. As shown in Fig. 1, toroidal octupole coupled with toroidal field creates an azimuthally symmetric minimum-B geometry. This configuration has a vacuum minimum-B property, so creation of an electron ring should be easy.

There are several ways to use this electron cloud. We note that, as it is, electrons create a far deeper minimum-B well than that created by the vacuum field. Thus high-energy ions could be mirror trapped, and we have the possibility of an azimuthally symmetric, minimum-B mirror device.

Actually it is better to create a toroidal device. If a toroidal current is induced in the electron cloud, the octupole magnetic field could be shielded.¹ When the electron cloud carries at the center a current equal to that of each conductor of octupole, magnetic field lines are closed in more than the half area (see Fig. 2).

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If the current flows within the electron cloud, the configuration is similar to that of a tokamak. Thus purists in the EBT community might object to this configuration. Furthermore, the aspect ratio must be reasonably small in order to confine high- β plasmas.

The third approach to creating an EBT-like configuration with minimum-B mirror is to vary the toroidal field strength toroidally. In the absence of a poloidal field due to octupole and the magnetic field by electron cloud, the toroidal field variation would create $\int d\ell/B$ equilibria. The electron cloud will carry a small toroidal current to shield out the poloidal field of the octupole. The electron cloud, which is now rings, is contained in the sections of weak toroidal field. The MHD stability must be investigated. The current distribution within the rings is crucial for stability of the overall system.

Three different configurations for the plasma confinement using the EBT technique have been proposed here. The first two are azimuthally symmetric -- one utilizes the mirror principle for plasma confinement and the other allows the current to flow toroidally. The configuration in the second case is a tokamak with high-energy electrons.

The third configuration is more complex. Azimuthal symmetry was violated, and the current in the electron cloud and/or plasmas shielded out the poloidal field. Plasma equilibria are maintained by variation of the toroidal field, $\oint d\ell/B$. Since rotational transform exists, the equilibria are determined by both $\int d\ell/B$ and by rotational transform.

ACKNOWLEDGMENT

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REFERENCE

- ¹ S. Yoshikawa, Phys. Fluids 15, 1683 (1972).

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Fig. 1. Minimum-B configurations with octupole and toroidal field.

Fig. 2. Shielding of external field by the current flowing inside the electron clouds. See also Fig. 1 of Ref. 1.