§26. Roles of Bumpy Field on Collisionless Particle Confinement in Helical-Axis Heliotron

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Roles of bumpy field on collisionless particle confinement in helical-axis heliotron (HAH) configuration have been considered based on the mod-Bmin structure and orbit calculations in the Boozer coordinates. The typical model magnetic field for conventional planar-axis heliotrons include only helicity and toroidicity components in the Boozer spectrum. However, since the bumpy field component typically appears in HAH, the model magnetic field has been extended to include it.

Mod-Bmin contours projected on a poloidal cross section become elliptic shape depending on the ratio between the toroidicity and helicity. The center of mod-Bmin contour can be shifted with the bumpy field. Thus HAH has a larger flexibility to control the mod-Bmin structure than conventional planar-axis heliotrons. Therefore, the inward magnetic axis shift, which is usually required to align the mod-Bmin contours with magnetic surfaces in conventional planar-axis heliotrons, is not necessarily essential in HAH. This property is favorable to obtain the compatibility between sufficient MHD properties and good particle confinement.

The conditions for the existence of the closed mod-Bmin contours lead to the appropriate range of the ratio, $\varepsilon_b/\varepsilon_h$, depending on the Bmin value or the particle energy. Here ε_b denotes the bumpiness and ε_h the helicity of the magnetic field. It becomes more negative as the ratio, $\varepsilon_t/\varepsilon_h$ is increased. This negative value of $\varepsilon_b/\varepsilon_h$ is required to align the bottom of the magnetic field ripple, which is necessary to close mod-Bmin contours. According to the orbit following calculations, collisionless particle loss rate is decreased as the closed mod-Bmin area projected on the poloidal cross section is increased. Therefore, the closed mod-Bmin area can be utilized as the measure to evaluate the collisionless particle confinement as long as the mod-Bmin contours extend throughout a torus.

Mod-Bmin contours are toroidally localized when the bumpy field amplitude is increased towards the plasma edge. This is due to the formation of local minimum of $|B|$ around the toroidal angle where the bumpy field contributes to weaken $|B|$. The orbit calculations show the significant improvement of collisionless particle confinement in the presence of toroidally localized mod-Bmin contours. The collisionless particles with almost only perpendicular velocity follow these toroidally localized mod-Bmin contours in one field period after being trapped in the bumpy field ripple. This occurs even if they are launched from the toroidal angle where mod-Bmin contours do not pass.

The magnetic topography is also valuable to consider the reason for the improvement. The region with the large poloidal drift is well alinged to the region of the local minimum of $|B|$ with keeping the radial drift unchanged for a configuration with the radially increasing bumpy field. Since the bumpy field can be controlled in a wide range through the coil current control in HAH, it should be worth investigating a suitable coil current distribution based on this study.

Reference:
M.Yokoyama,N.Nakajima,M.Okamoto,Y.Nakamura, M.Wakatani, Nucl. Fusion **40**(2000)261.