§3. Global Mode Analysis of Ideal MHD Modes in a Heliotron/Torsatron System: II. Mercier-stable Equilibria

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By means of a global mode analysis of ideal MHD modes for Mercier-stable equilibria in a planar axis \( L = 2/M = 10 \) heliotron/torsatron system with an inherently large Shafranov shift, the conjecture from local mode analysis for Mercier-stable equilibria given in Ref.[1] has been investigated. The properties of ballooning modes inherent to such three-dimensional systems have been clarified. Moreover, new modes, which are driven by both Pfirsch-Schliuter current and the geodesic curvature, have been found. Those modes were different from kink-driven instabilities in Ref.[2], because present modes become unstable under the fixed boundary condition, on the other hand, kink-driven instabilities only become unstable under the free boundary condition.

According to the degree of the reduction of the local magnetic shear by the Shafranov shift, the MHD equilibria are categorized into toroidicity-dominant (strong reduction) and helicity-dominant (weak reduction) ones. The Mercier-stable equilibria belong to toroidicity-dominant equilibria, so that ballooning modes are easy to be destabilized.

Since the local magnetic curvature due to helicity has the same period \( M \) in the toroidal direction as the toroidal field period of the equilibria, the characteristics of the pressure-driven modes dramatically change according to the relative magnitude of the typical toroidal mode number \( n \) of the perturbation compared with the toroidal field period of the equilibria \( M \).

Since equilibria are Mercier stable, there are no unstable modes for low toroidal mode numbers \( n < M \). For both moderate toroidal mode numbers \( n \sim M \) and fairly high toroidal mode numbers \( n \gg M \), both poloidally and toroidally localized ballooning modes purely inherent to three-dimensional systems appear as the most unstable modes. Those modes localize in the stellarator-like global magnetic shear region with the average unfavorable magnetic curvature. For \( n \sim M \), modes consist of two dominant groups of Fourier modes with different toroidal mode numbers as shown in Fig.1, and the number of dominant groups increases for \( n \gg M \).

For moderate toroidal mode numbers \( n \sim M \), new modes appear in the tokamak-like global magnetic shear region with the average favorable magnetic curvature as shown in Fig.2. Those modes are driven by both kink-term due to Pfirsch-Schlüter current and a part of pressure-driven term attributed to the geodesic curvature.

![Fig.1](image1.png) Radial distribution of the Fourier components of the normal displacement with their dominant toroidal mode numbers for ballooning mode.

![Fig.2](image2.png) The same one as Fig.1 for new mode driven by both Pfirsch-Schlüter current and geodesic curvature.

References