MHD Stability in Compact Stellarators

G. Y. Fu, L. P. Ku and W. A. Cooper

A key issue for current carrying compact stellarators [1] is the stability of ideal MHD modes. We present recent stability results of external kink modes, ballooning mode, and vertical modes in Quasi-axisymmetric Stellarators (QAS) [2]. The 3D stability code Terpsichore [3] is used in this study. The vertical stability in a current carrying stellarator is studied for the first time. The vertical mode is found to be stabilized by externally generated poloidal flux [4]. Physically, this is because the external poloidal flux enhances the field line bending energy relative to the current drive term in the MHD energy principle, deltaW. A simple stability criteria is derived in the limit of large aspect ratio and constant current density. For wall at infinite distance from the plasma, the amount of external flux needed for stabilization is given by f=(e**2-e)/(e**2+1) where e is the axisymmetric elongation and f is the fraction of the external rotational transform at the plasma edge. A systematic parameter study shows that the external kink in QAS can be stabilized at high beta (~ 5%) without a conducting wall by combination of edge magnetic shear and 3D shaping [5]. The optimal shaping is obtained by using an optimizer with kink stability included in its objective function. The physics mechanism for the kink modes is studied by examining relative contributions of individual terms in deltaW. It is found the external kinks are mainly driven by the parallel current. The pressure contributes significantly to the overall drive through the curvature term and the Pfirsch-Schluter current. These results demonstrate potential of QAS for disruption-free operations at high-beta without a close-fitting conducting wall and feedback stabilization.

[1] S.P. Hirshman et al., "Physics of compact stellarators", Phys. Plasmas 6, 1858 (1999).

[2] A. Reiman et al, "Physics issue in the design of a high beta Quasi-Axisymmetric Stellarator" the 17th IAEA Fusion Energy conference, (Yokohama, Japan, October 1998), Paper ICP/06.

[3] W. A. Cooper et al., Phys. Plasmas 3, 275 (1996)

[4] G.Y. Fu et al., "Stability of vertical mode in a current carrying stellarator"., to be submitted.

[5] G. Y. Fu et al., "MHD stability calculations of high-beta Quasi-Axisymmetric Stellarators", the 17th IAEA Fusion Energy conference, (Yokohama, Japan, October 1998), paper THP1/07.