§20. Effects of Current Profile on Global Ideal MHD Stability in a Compact Quasi-Axisymmetric Stellarator

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Since the role of the bootstrap current (BSC) in a quasi-axisymmetric (QA) configuration is more important than that in other stellarators, ideal MHD stability analysis including plasma current is essential in the physics design of a QA device. In this study we have examined the effects of current profile on ideal MHD stability properties in the representative configuration of a proposed QA stellarator CHS-qa based on the equilibria including self-consistent BSC.

We have employed the SPBSC code to solve finite beta equilibria with self-consistent BSC assuming experimentally achievable density and temperature profiles.[1] For good convergence of BSC in the high beta equilibria, only axisymmetric components of the magnetic field are included in the BSC calculation. This implies that the calculated BSC should correspond to the upper limit in that equilibrium. Three representative cases of plasma parameters assumed are shown in Table I. The ion temperature is assumed to be three quarters of the electron temperature. Though the volume average beta in cases A and B is identical ($\langle\beta\rangle$=3%), the plasma density in A is five times higher than that in B. The plasma density in the case C corresponds to 1.5 times the case A, which results in higher average beta ($\langle\beta\rangle$=4.6%). The SPBSC calculation revealed that the edge rotational transform exceeds 0.5 for B, while not for A.[2]

Under these conditions, the global low-n ideal MHD stability is analyzed with the TERPSICHORE code.[3] We consider 81 perturbation Fourier modes up to n=7 in the calculation for N=1 family including all modes resonant with rotational transform from 0.3 to 0.8 and coupling with the equilibrium component $(m,n)=(1,2)$. The result shows that instability appears only in the case B. The eigenfunction of the most unstable perturbation mode clearly indicates an external kink instability caused by the rational surface of 0.5.

We have artificially changed the magnitude of the parallel current from 25 to 250 kA (per 1 T) while keeping its profile. Figure 1 shows eigenvalues of the most unstable modes for the N=1 family as functions of the total parallel current. The mode number of the dominant Fourier component in the unstable eigenfunction is (m,n) = $(2,1)$ for 150–225 kA, and $(5,3)$ for 250 kA. This implies that the onset of destabilization in the cases A and B clearly corresponds to the crossing of the edge rotational transform beyond 0.5 and 0.6. The difference between A and B can be attributed to the difference in rotational transform profile associated with the BSC profile. In the case C, the global mode is kept stable up to 250 kA total current despite the edge rotational transform being raised above 0.5. However, more realistic calculations based on free boundary VMEC equilibria are necessary to confirm the validity of fixed boundary calculations for the high beta equilibrium.

In summary, this study demonstrated the importance of rotational transform profile on global MHD stability in the QA configuration and the possibility of stabilization of the external kink mode by controlling the parallel current through pressure profile control or various current drive methods.

Table I. Plasma parameters of three representative cases. The average beta and the BSC are calculated per toroidal magnetic field of 1 T.

	n_e ($10^{20}m^{-3}$)	T_e (keV)	$\langle\beta\rangle$ (%)	I_{BSC} (kA)
A	1.0	1.04	3.0	103
B	0.2	5.2	3.0	168
C	1.5	1.04	4.6	122

References

1) M. Isobe et al.: J. Plasma Fusion Res. SERIES **5** (2002) 360.

2) C. Suzuki et al.: J. Plasma Fusion Res. SERIES **6** (in press).

3) Anderson, D. V. et al.: Int. J. Supercompt. Appl. **4** (1990) 34.

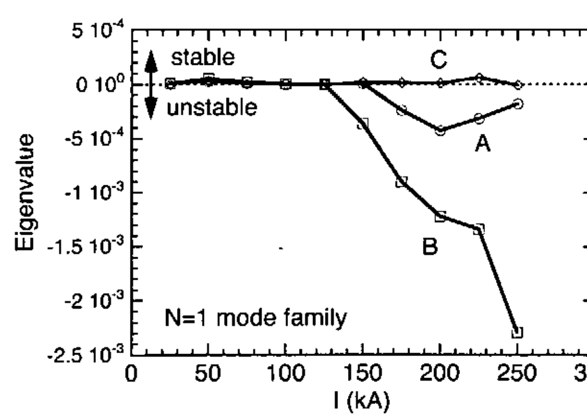

Fig. 1. The most unstable eigenvalues as functions of total current for three representative cases.