§3. Internal Kink Modes in LHD

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As shown in Fig.1, there are 2 points where the rotational transform(ι) equals to unity in the plasma at $\beta = 0$ when the net toroidal current of 300kA flows with the current density of $J = J_0(1-\Phi)^2$ (Φ :normalized toroidal magnetic flux) in the LHD standard configuration with $B_0 = 3$T. In this case, it is obtained by means of the RESORM code[1] that an internal kink modes with $m = 1/n = 1$ becomes unstable. The mode structure of the stream function is seen to be resonant only at the inner $\iota = 1$ surface as shown in Fig.2.

This property can be explained by the energy principle in the linear analysis. The potential energy derived from the reduced MHD equations at $\beta = 0$ under the assumption of the straight stellarator configuration is given by

$$\delta W = (2\pi B_0^2/R_0^2)\int[(f\xi')^2 + g\xi^2]dr, \qquad (1)$$

$$f = r^3\nu^2, \quad \nu = \iota - n/m, \quad \iota = \iota_h + \iota_J, \qquad (2)$$

$$g = r\nu[(m^2-1)\nu - 3r\iota_h' - r^2\iota_h''], \qquad (3)$$

where ξ is the radial displacement of plasma. Here, ι_h and ι_J denote the rotational transform component generated by the helical coils and the net toroidal current, respectively. The internal kink mode can be unstable when $g < 0$. Since both ι_h' and ι_h'' becomes positive in LHD, $g < 0$ if $0 < \nu$ for $m = 1$. Thus, the $m = 1/n = 1$ mode can be unstable where $\iota > 1$, however, the mode cannot be unstable near the plasma edge according to the fixed boundary condition. Therefore, the mode structure is localized around the magnetic axis as shown in Fig.2. Besides, eq.(3) suggests that the modes with $m \geq 2$ can be unstable if $0 < \nu < (3r\iota_h' + r^2\iota_h'')/(m^2-1)$, which cannot be unstable in tokamaks. We also obtained numerically the unstable modes with $m \geq 2$ which are resonant at $\iota = 1$ in I=300kA case and the growth rates are shown in Fig.3. The growth rate decreases as m increases, and the modes with $m \geq 6$ are stable in this case. This tendency is consistent with eq.(3).

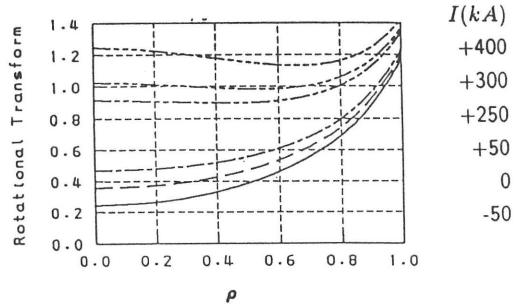

Fig.1 Rotational transform for several net toroidal currents.

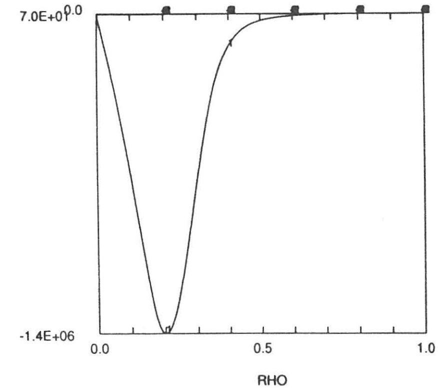

Fig.2 Stream function of $m = 1/n = 1$ mode.

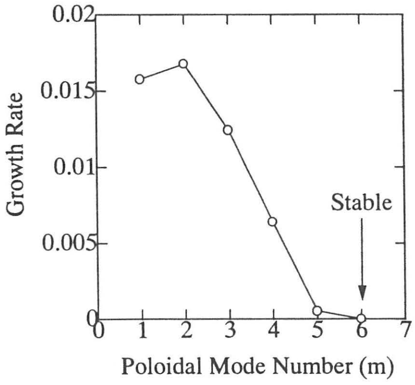

Fig.3 Growth rate versus m.

References

1) Ichiguchi,K.,et al.:Nucl.Fusion31(1991)2073.