Benchmarking of finite-beta effects on tearing modes via linearized resistive MHD RESponse and STability of TOKamak (RESTOK) code

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A DEMO reactor must be operated stably, and the plasma at the operation condition must be robust against various disturbances given externally. The plasma must be stable at least against ideal magnetohydrodynamics (MHD) modes. This is a minimum requirement. When the plasma is stable against the ideal MHD modes, we should also care about resistive MHD modes and other mild instabilities.

It is known that externally-given non-axisymmetric magnetic perturbations cause plasma responses, leading to magnetic island formation and resultant locked modes[1, 2]. On the other hand, intentional application of non-axisymmetric magnetic fields can suppress locked modes, and can also control edge localized modes (ELMs)[3].

Our RESponse and STability of TOKamak (RESTOK) code, previously called ERMHDT[4], can calculate linear, resistive MHD response and stability of tokamak plasmas. Such a code should be useful for DEMO reactor design.

There are some established codes for linear resistive MHD in the Tokamak research community. One of such codes is MARS-F[5, 6], which can calculate both stability and response. Another one is CASTOR[7], which can calculate stability. The formulation used for our RESTOK code follows that of CASTOR in most part. In Ref. [4], some benchmark tests were reported.

In Ref. [8], a variety of resistive MHD stability calculations under free-boundary condition were reported. One of them is a finite-beta effects on tearing modes. In FIG. 4 of Ref. [8], it was shown that the eigenvalues of the first and second unstable tearing modes, without a finite real frequency, coalesced as the plasma resistivity was decreased, and converted to a pair of unstable modes with finite real frequencies. A similar phenomena was also reported in Ref. [9] by using FAR code which solves an initial-value problem of resistive MHD.

In this abstract, we show behavior of eigenvalues of tearing modes similar to FIG. 4 of Ref. [8]. A circular cross-section tokamak with an aspect ratio 4 was calculated numerically. The toroidal current density and the pressure gradient were assumed to be linear in the poloidal flux. Although these profiles seems to be different from those of Ref. [8], we found a similar behavior of eigenvalues as shown in Fig. 1.

In Fig. 1, the eigenvalues of tearing modes are plotted in the complex plane for various values of the Lundquist number S. The poloidal beta was $\beta_J = 0.26$. As its inverse $1/S$ is decreased, the eigenvalues of the first and the second unstable modes, without a finite real frequency, become closer. Then they coalesce eventually and becomes a pair of unstable modes with finite frequencies. As $1/S$ is decreased further, the real frequencies becomes larger and the growth rates becomes smaller. Then the modes becomes damping ones. Further decrease of $1/S$ makes the eigenvalues approach zero. More benchmarking results will be shown in the presentation.

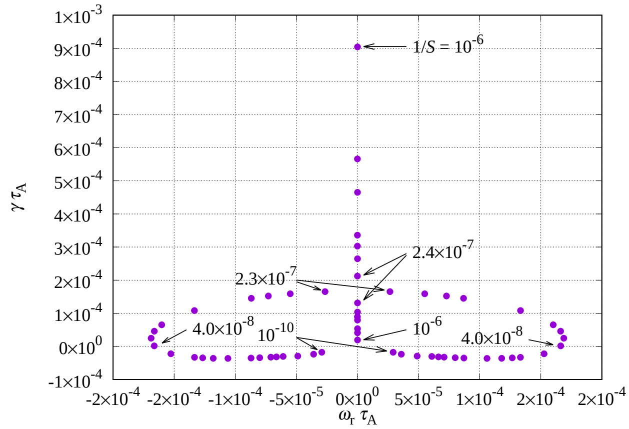

Figure 1: The eigenvalues ω is plotted on the complex plane. As the inverse of Lundquist number $1/S$ is decreased, eigenvalues of the first and second unstable modes coalesce, and converted to a pair of eigenvalues with finite real frequencies. As $1/S$ is further decreased, the growth rates become negative and the modes are stabilized although they still have finite frequencies.

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