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Full toroidal computation of resistive MHD instabilities based on asymptotic matching approach

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An innovative numerical method, based on the asymptotic matching approach, is presented to solve the linearized resistive magnetohydrodynamic (MHD) equations in the full toroidal axisymmetric tokamaks. In the asymptotic matching approach, various outer regions, satisfying the zero-frequency ideal MHD equations, are connected through the resistive inner regions located at multiple resonant surfaces. The challenge of this approach is to solve the reliable outer region matching data (e.g. Δ' matrix) since the numerical instability is a serious issue due to the singularity caused by the existence of big solutions while approaching to the resonant surfaces. The method developed in PEST3 code [1] has successfully solved this outer region matching data. However, PEST3 code has the limitation of solving high beta plasma which requires to retain the high order terms of big and small solutions which are essential to obtain the converged matching data. Our new method develops the small and big solutions with the arbitrary high order terms. The method also has a substantial improvement to introduce the small solution as an extra basis function near the resonant surface while using Galerkin method to discretize the outer region equation. Therefore, the new method, so-called singular Galerkin method, greatly improves the numerical stability of solving the outer regions' matching data and achieves the excellent convergence with high numerical efficiency. This singular Galerkin method is also applied to solve the resistive inner regions' matching data formulated by GGJ model [2] with improved numerical stability. Finally, the outer and inner regions are asymptotically matched through a complex dispersion relation to provide the eigenvalue of mode and the corresponding global eigenfunction in the full toroidal geometry. An extended dispersion relation is also developed to solve the resistive plasma response which allows the small island open while the plasma responds to the external magnetic perturbations. The systematic validation of the new developed code based on this singular Galerkin method will also be presented.

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References

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