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Extension of numerical matching method to weakly nonlinear regime – beyond the Rutherford theory of magnetic island evolution

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The theory of matched asymptotic expansion for resistive MHD is well established for linear modes [1] and for weakly nonlinear evolution [2]. Since then many applications of the Rutherford equation [2] have made much progress in fusion research, especially in the neoclassical tearing mode (NTM) studies [3]. However, the theoretical framework is still based on the Rutherford equation essentially.
We have recently developed a new framework for linear stability analysis of resistive MHD, the numerical matching method [4]. This method utilizes a finite-width inner region around a resonant surface, instead of an infinitely thin inner layer. We devised the boundary condition for the direct matching at interfaces between the inner and outer regions. Then we succeeded to remove difficulties that remain in the numerical applications of the traditional matched asymptotic expansion even though sophisticated theories were developed [5]. We developed both an eigenvalue and an initial-value approaches.
In this paper, we extend the initial-value approach of the numerical matching method to weakly nonlinear cases. In the presentation, we will explain the theory, and will show numerical results using reduced MHD in cylindrical plasmas that successfully reproduced Rutherford regime of magnetic island evolution. The computational cost is reduced, making inclusion of detailed physical effects easier because such a model requires more efficient solution method. Our new method will certainly aid understanding physics and will substantially contribute to the prediction of MHD activities such as NTMs in fusion plasmas.

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