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Plasmoid Formation During Sawtooth Process in a Cylindrical Tokamak Configuration

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Abstract:

For realistic values of Lundquist number in tokamak plasmas, the magnetic island during the nonlinear growth of internal kink mode leads to the formation of secondary thin current sheet. Such a thin current sheet becomes unstable and breaks up into a chain of secondary magnetic islands, called plasmoids [1-4]. Recent studies [5, 6] reveal that these plasmoids can significantly affect the reconnection process in fusion plasmas. However, complete understanding of the plasmoid onset and its dynamics duing the sawtooth process remains an unresolved issue.

In this study, initial simulations are performed to investigate the resistive internal kink mode using the full resistive MHD equations implemented in the NIMROD code [7] in cylindrical geometry. As a benchmark, the scaling of linear resistive kink mode growth rate with resistivity $S^{-1/3}$ is reproduced. For low values of Lundquist number S, the usual kink mode results are obtained, where the m/n=1/1 magnetic island (m, n are the poloidal and toroidal mode numbers) grows exponentially in the linear phase and evolves slowly in the nonlinear phase until saturation. However, for higher values of Lundquist number $S>10^7$, elongated thin current sheet is developed during the nonlinear evolution, leading to the plasmoid formation along the current sheet. The nonlinear simulation results show that the plasmoid can significantly speed up the reconnection process. The onset criteria and the mechanism of plasmoid generation are delineated. Furthermore, it is found that small plasmoids coalesce, forming larger plasmoids that can affect the evolution of primary magnetic island and contribute to partial reconnection. Whereas such results qualitatively agree with previous reduced MHD simulations [8], new features of the plasmoid formation found from our full MHD simulations are reported and discussed.

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