Theory of mode locking and island suppression by resonant magnetic perturbations in Rutherford regime *†

Wenlong Huang[1] and Ping Zhu[1,2]
[1]University of Science and Technology of China
[2]University of Wisconsin-Madison

Abstract

We demonstrate in theory that the recently observed tearing mode locking and magnetic island suppression by resonant magnetic perturbations (RMPs) in J-TEXT experiments correspond to different states of a same dynamic system that is governed by the torque balance and the nonlinear island evolution equations in the Rutherford regime. In particular, the locked mode is the exact steady state of this system. A new analytical solution has been obtained for such a steady state, which quantifies the dependence of the locked island width on RMP amplitude and yields the RMP threshold for mode locking in different plasma regimes. Furthermore, two different branches of mode locking have been revealed by the new analytical solution and the branch with suppressed island size turns out to be unstable in general. On the other hand, when the RMP amplitude is below the mode locking threshold, our theory analysis indicates that the system admits time-averaged steady states of island suppression along with transient oscillations of the island width and rotational frequency, achieved through the RMP modulation of the tearing mode rotational frequency in absence of mode locking.

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‡Emails: wlhuang@mail.ustc.edu.cn, pzhu@ustc.edu.cn