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Recent progress on the 3D physics in J-TEXT

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3D physics is an important aspect of the toroidal symmetric tokamak device, with the application of resonant magnetic field (RMP) or the presence of intrinsic error field (EF). Recent researches on J-TEXT concentrate on the plasma responses to the RMP field, especially the formation of locked islands (LIs) at the rational surfaces with the safety factor q = 1, 2 or 3. The RMP induces either linear or non-linear response (RMP penetration) depending on whether the RMP amplitude is above a critical threshold.

With small RMP field, the magnetic response is found to increase linearly with RMP amplitude. The amplitude and phase of this linear response can be modified by the variation of differential phases ($\Delta\varphi$) between the upper and lower row of RMP coils. A transient component during the ramp-up of RMP field is also observed and characterized by a decay time which could be influenced by the ECRH power.

With sufficiently large RMP field, both the thresholds of 2/1 [1] and 3/1 LIs are observed to vary non-monotonically on electron density. For the n = 1 MP field, the variation of $\Delta\varphi$ changes the poloidal spectrum of the MP field, leading to a significantly variation of the ratio between 2/1 and 3/1 RMP. In the 3/1 (or 2/1) RMP dominant $\Delta\varphi$ region, the 3/1 (or 2/1) LI is first observed and the corresponding LI threshold, measured by the vacuum 3/1 (or 2/1) RMP amplitude $b_{r,vac}^{3/1}$ (or $b_{r,vac}^{2/1}$), is found to share a same density dependence at this $\Delta\varphi$ region. This observation indicates the impact of other MP component (e.g. 1/1 or 2/1) on 3/1 LI threshold is small in these low beta ohmic plasma on J-TEXT. However, following the formation of 3/1 LI, the subsequent formation of 2/1 LI is found to require a significantly smaller $b_{r,vac}^{2/1}$ with respect to the 2/1 LI threshold without a pre-formed 3/1 LI. This might be due to the variation of rotation and temperature in the q=2 surface after the growth of 3/1 LI.

The LIs are also found to interacts with other MHD instabilities. The 2/2 LI, excited due to the penetration of 2/2 RMP field, triggers the bifurcation of sawtooth behavior, characterized by the abrupt decrease of sawtooth period and magnitude [2]. The 3/1 LI width is reduced periodically corresponding to each sawtooth crashes, which is enhanced by depositing ECRH power just inside the q = 1 surface. In the presence of 2/1 LI, three kinds of standing wave (SW) structures have been observed to share a similar connection to the island structure, i.e. the nodes of the SWs locate around the O- or X- points of the 2/1 island. The first SW is induced by the RMP field rotating at a few kHz (e.g. 1~6 kHz) [3]; the 2nd SWs is the so called Beta-induced Alfvén Eigenmodes (BAEs) [4] at 20 ~ 50 kHz; while the third appears spontaneously at ~ 3 kHz without any external 3 kHz RMP field.

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References

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