EXPERIMENTAL STUDY OF THE 2/1 MODE RMP ON THE RUNAWAY CURRENT SUPPRESSION DURING DISRUPTIONS ON J-TEXT

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1. INTRODUCTION

The avoidance and suppression of runaway electrons (REs) generation in disruptions is a high priority task for the reliable operation in future tokamaks. This is because the REs, whose energies can up to several tens MeV, may cause severe damage to the plasma facing components [1, 2]. Many technical improvements and physical explorations have been attempted to suppress REs on various devices. The resonance magnetic perturbations (RMP) provide an alternative way for REs suppression via destroying the magnetic surfaces and worsening the RE confinement before they are amplified by the avalanche process. However, the RMP will cause mode locking when the plasma exists MHD activities, e.g. an m/n=2/1 tearing mode. Investigations have demonstrated that the pre-existing islands significantly influence the evolution of cooling process, the emergence of higher-*n* harmonic modes and the regions of stochasticity[3-6], thereby indirectly affect the REs generation. A systematic study of the impact of the m/n = 2/1 mode island, induced by the RMP, on the runaway current formation was carried out on the J-TEXT tokamak.

2. EXPERIMENTAL SETUP

The runaway current performed on the J-TEXT tokamak was generated by the massive gas injection (MGI). The MGI valve has been installed at the bottom port of No. 9, corresponding to a toroidal phase of 225°. The low field side (LFS) mid-plane at the east is defined as 0° in toroidal and poloidal directions, and the angle increases in a counterclockwise direction. Four RMP phases with an m/n=2/1 dominated mode were applied in the experiments, and their phase corresponding to a vacuum approximation is 337.5°, 157°, 189.6°, 9.6°, respectively. This RMP phase ($\phi_{RMP}^{2,1}$) is defined as the maximum outward perturbed radial magnetic field B_r at the LFS mid-plane. The O-point phase of 2/1 mode magnetic island corresponds to the phase of the n = 1 mode as the peak of the poloidal field perturbation. Base on the assumption that the excited 2/1 mode magnetic islands phase is consistent with the phase of the RMP, the relative phase ($\Delta\theta$) between the O-point of 2/1 mode islands and the MGI valve is 11°, -79°, -62.7°, 27.3°, respectively. When the relative phase $\Delta\theta = 0°$, the O-point of the 2/1 mode is in phase with the MGI deposition. While the $\Delta\theta = \pm 90°$, the X-point of the 2/1 mode is aligned to the MGI valve. It can be found that the MGI deposition region is close to the island's O-point in RMP phase of 337.5° and closed to the X-point in RMP phase of 157°.

3. EXPERIMENTAL RESULTS

Effect of RMP phase on runaway current—The effect of RMP phase on the runaway generation has been investigate in ASDEX-Upgrade, where the amplitude and lifetime of the runaway current can be significantly impacted by the RMP phase [7]. On J-TEXT, the RMP phases impacting on the REs generation was scanned in different RMP strength. It was found that when the RMP strength is relatively weak, there is no significant influence of RMP phase on the runaway current suppression. Conversely, when the RMP strength is high enough for mode penetration, the 2/1 mode island's phase could make a significant impact on the REs generation. The REs can be significantly suppressed when the island's O-point is close to the MGI deposition region, as shown in figure 1. However, when the island's X-point is in phase with the MGI, the RE current is maintained. This finding differs from the previous simulation results in which the best phase for the RE seeds loss is toroidal 90° ($\Delta\phi = \phi_{MGI} - \phi_{n=1}$). This discrepancy may be due to the omission of RE generation mechanisms in the NIMROD simulation. Both the effect of REs loss and the REs generation should be considered in experiments for the REs suppression. Further increasing the RMP strength, the RE current will be avoided even when the island's X-point in phase with the MGI. This result demonstrates the greater importance of RMP strength relative to the RMP phase.

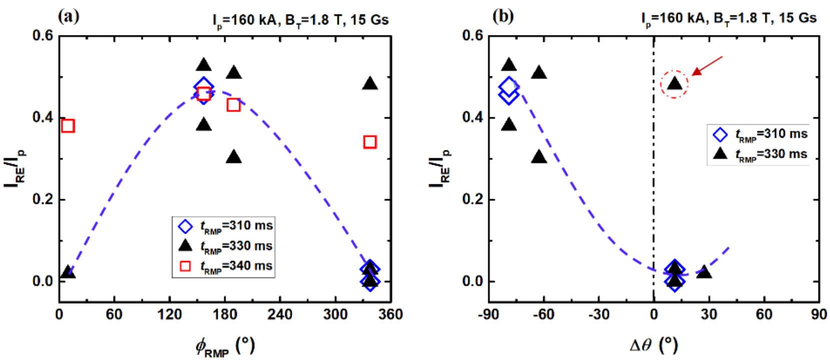

Figure 1. The relationship between (a) the RMP phase, (b) the relative phase and the runaway current conversion. The blue dashed line represents the fitted trend line. The black double dash-dot line in (b) represents the O-point of 2/1 mode island in phase with MGI deposition. The runaway current generated in shot (indicated by the arrow) can be attributed to the insufficient mode penetration duration.

Effect of mode penetration duration on runaway current-- The RMP trigger time is related to the island size, which can significantly influence the suppression of REs. In the experiment with RMP phase of 337.5°, it can be found that the RE current gradually decreases with the increase of mode penetration duration, and finally suppressed when the mode penetration occurs before 0.35 s. The mode penetration duration is calculated by subtracting the mode penetration time from the MGI trigger time (0.4s), which is 50 ms in the experiment for REs suppression. For the experiment with RMP phase of 9.6°, two ranges of the mode penetration duration for RE suppression are found. One range is same as experiment in RMP phase of 337.5°, and the other range is when the mode penetration happened at approximately 0.4 s, within 10 ms mode penetration duration. This result is consistent with the previously simulation results [6], and can be attributed to the high *n* modes which promote a more uniform distribution of impurities and further disrupt the magnetic surface, making the impurity penetrate deeper into the plasma and result in the loss of REs.

4. CONCLUSION

The potentially damaging consequences of runaway electrons are an issue for next step devices. Systematic experiments about 2/1 mode RMP on the runaway current avoidance have been explored on J-TEXT. It was found that the phase of 2/1 mode RMP can significantly affect REs generation, provided that the amplitude of 2/1 mode RMP is larger enough. The runaway current can be easily suppressed when the islands O-point is close to the MGI deposition region. Besides, a longer mode penetration duration (corresponding to a biger island) can be significantly avoided the RE current formation. All results above provide insight into the mitigation of locking mode disruption, where an appropriate island size and phase should be chosen properly to ensure suppressing runaway current efficiently.

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REFERENCES

[1] M. LEHNEN et al., Journal of Nuclear Materials. **463**, 39-48 (2015).
[2] ITER Physics Expert Group on Disruptions, et al., Chapter 3: MHD stability, operational limits and disruptions, Nuclear Fusion **39**, 2251 (1999).
[3] F. WIESCHOLLEK, M. HOELZL, E. NARDON, Physics of Plasmas **29**, 032509 (2022).
[4] V.A. IZZO Physics of Plasmas **24**, 053018-053048 (2017).
[5] Z.H. JIANG et al., Physics of Plasmas **26**, 062508 (2019).
[6] C.H. LI et al., Plasma Physics and Controlled Fusion **62**, 095010 (2020).
[7] M. GOBBIN et al., Plasma Physics and Controlled Fusion **60**, 014036 (2018).