OVERVIEW OF PLASMA DISRUPTION MITIGATION ON J-TEXT TOKAMAK

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1. INTRODUCTION

A disruption in tokamak is a sudden termination of plasma discharge, imposing substantial thermal loads and electromagnetic forces on the surrounding structures, but also generates runaway electrons (REs) which can burn holes through structures [1-2]. Therefore, the mitigation of disruption is a critical issue for the safe operation of tokamaks. To reduce the damage caused by thermal loads and electromagnetic forces, two main methods are used: massive gas injection (MGI) and shattered pellet injection (SPI). These techniques are essential for minimizing disruption impacts and ensuring tokamak safety. While the suppression of REs remains uncertain because a large runaway current will be formed even if only a few RE seeds survive during disruption. Significant progress has been made in recent years in disruption mitigation on J-TEXT by mitigation systems, especially the suppression and dissipation of REs.

2. DEVELOP OF DISRUPTION MITIGATION SYSTEMS

To support plasma disruption mitigation experiments on J-TEXT, two MGI valves have been developed [3]. One 30 ml MGI valve, located at the bottom of port 9, is used to trigger major disruptions and achieve a stable runaway current. Another 60 ml MGI valve, positioned at the top of port 9, is used to dissipate the runaway current. To support the international tokamak physics activity (ITPA) SPI task force, J-TEXT has developed a symmetric dual shattered pellet injection system with a 145° toroidal direction [4]. This advanced SPI system can produce pure argon and deuterium/neon pellets, each 5 mm in diameter and 4-8 mm in length. A key feature is its flexible velocity adjustment, ranging from 150-350 m/s, achieved by setting the propellant gas pressure. The J-TEXT team has developed the electromagnetic pellet injection system (EMPI), which utilizes an electromagnetic injection method. This system can launch pellets at high velocities and is equipped with a specialized deceleration rail, ensuring the safe separation of the armature and pellet [5].

3. SUPPRESSION AND DISSIPATION OF RUNAWAY ELECTRONS

Effective disruption mitigation is a key issue in the safe and reliable operation of future tokamaks. Approaches aimed at suppressing and mitigating runaway current formation by MGI, SPI, supersonic molecular beam injection (SMBI) and resonant magnetic perturbation (RMP) have been investigated in J-TEXT [6-10]. Complete suppression of REs is realized by H_2 SMBI with an earlier trigger time or sufficient H_2 quantity, in which SMBI provokes significant magnetic perturbation that destroys the intact magnetic surface in the core and enhances loss of REs during disruption. The large magnetic islands implemented by mode penetration and mode locking can act as explosive bombs during disruptions and lead to stronger stochasticity in the whole plasma cross section, which can completely suppress the REs. When the secondary impurity gas reaches the plasma edge before thermal quench (TQ), the generation of runaway current can be significantly suppressed by the second MGI valve.

For large-scale devices, a cascade strategy for the control of runaway current is essential. Consequently, the runaway current should be robustly dissipated or soft landed to minimize damage to critical components of the device. With the high-Z impurities injected by secondary MGI, runaway current can be significantly dissipated; the dissipation rate increases with the impurity quantity, and reaches a stable value with a maximum of 28 MA s^{-1}. SPI, as a new disruption mitigating technology, is found to have a deeper penetration and a higher assimilation than MGI, which is inspiring for applications in the future.

4. RADIATION ASYMMETRY DURING DISRUPTION

From the experimental results, the destabilization of low-order MHD modes has been observed to grow rapidly when the gas-jet-initiated cold front reaches the vicinity of the corresponding rational surfaces during fast shutdown by an MGI. In addition, the toroidal phase of peak radiated power can be determined by low-*n* MHD modes. On the J-TEXT, an $m/n = 2/1$ locked mode induced by RMP penetration was terminated by MGI and SPI, the penetration depth and assimilation of impurities are suppressed, leading to a slower TQ when the relative phase is = −90°, and there is a close to sine function relationship between toroidal peaking factor (TPF) and the phase of 2/1 tearing mode [11-12]. The results suggest that the 3D effect between the injected impurities and the 2/1 locked mode is important during the disruption mitigation process.

5. CONCLUSION

The experiments of disruption mitigation on J-TEXT have been carried on, including suppression and mitigation of REs, radiation asymmetry during disruptions. In terms of REs suppression, the REs can be completely suppressed by means of supersonic molecular beam injection and resonant magnetic perturbation which can enhance RE loss. For the formed runaway current, which can be significantly dissipated by MGI, and the dissipation rate eventually stabilizes at 28 MA s^{-1}. At the same time, the results during plasma shutdown by MGI and SPI suggest that the 3D effect between the injected impurities and the 2/1 locked mode is important during the disruption mitigation process. Those will be helpful for the study of disruption mitigation of future large fusion devices.

ACKNOWLEDGEMENTS

This work is supported by the National MCF Energy R & D Program of China (Nos. 2019YFE03010004), National Natural Science Foundation of China (Nos. 12475222, 12205122, and 51821005).

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