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Disruption mitigation by shattered pellet injection on J-TEXT

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Disruption is an essential issue for ITER because of potential damages from heat loads, halo current and runaway electrons.1 Owing to harmfulness of disruption, it is necessary to develop effective disruption mitigation methods to guarantee the success of ITER project. The shattered pellet injection (SPI) will be used to disruption mitigation and runaway current dissipation on ITER.2 It can increase radiation, reduce halo current and suppress runaway electrons acceleration by increasing plasma density. Compared to the means of massive gas injection (MGI) and "killer" pellet injection (KPI), the disruption mitigation by SPI has the advantage of deeper deposition and high mixing efficiency.

The J-TEXT tokamak has developed a new SPI system in 2018 and carried out disruption experiments with SPI3. The whole SPI system is about 3.5 m long. The pellet will be shaped with a 5 mm diameter and a 4-8 mm length by a cooler, which contains 2 × 1021 - 5 × 1021 Ar atoms, injected with speed of 150-300 m/s. The performance of disruption mitigation by Ar SPI has been compared with identical Ar massive gas injection (MGI).

The penetration process of the shattered pellets into the plasma is widely interested. It can be found that the penetration depth of SPI is much deeper than MGI. The time evolution of the ECE profile can reflect the penetration process of the cold front of argon shattered pellets. The positions of q profiles are calculated by EFIT during the pre-disruption phase. The final penetration depth is pointed out in the figure by the red arrow, and is much deeper than q=2 profile and close to the q=1 profile. The penetration of MGI gas is stopped at q=2 surface.

According to the deeper penetration depth of shattered pellets than gas jet, more argon impurities may be deposited in the core and increase the electron density. A time evolution of the line integral electron density for SPI and MGI has been studied. The discharges selected in this case are still #1057814 for SPI and #1057795 for MGI. It can be found that the density increase in the core and edge of SPI case is earlier than that of two MGI cases during the penetration phase. The density in the SPI case can reach to a higher value than that of the MGI case. Note that the radial density ratio ncore/nedge of SPI can reach to 5 and the ratio of MGI is around 1 during the CQ phase. This result suggests that the argon impurities injected by SPI deposited in the core are more than MGI.

The effect of SPI on runaway current dissipation in J-TEXT has been compared with similar amount of Ar MGI injection. The plasma was rapid shut down by argon MGI at about 0.422s with a 105 kA runaway current platform. The argon impurity used to dissipate runaway current were injected by MGI and SPI respectively at 0.426s and 0.428s. The argon quantity is about 2.12 × 1021 and the pellet velocity is 220 m/s. It is clearly figured from the evolution of Ip that the dissipation of runaway current by Ar SPI is about 12 MA/s, which is lower than that with MGI (18 MA/s).

In summary, the SPI technique has been successfully tested on J-TEXT and the experimental result of plasma rapid shut down by SPI and MGI shows that SPI has certain advantages on plasma disruption mitigation. The time evolution of the ECE signal profile indicates that SPI has deeper penetration. The shatter pellets can reach the position near q=1 profile, but the argon gas jet only reach the q=2 profile. While the dissipation rate of runaway current by SPI shows no advantage compared to MGI.

Reference

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