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Effects on characteristics of plasma disruption mitigation using shattered pellet injection on EAST

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A shattered pellet injection (SPI) system designed for disruption mitigation on EAST tokamak was successfully developed and integrated into EAST tokamak in 2022. The SPI system is capable of producing Ne pellets with diameters of ~5 mm and lengths ranging from 7 to 15 mm. The material gas consumption is approximately 20, 25, and 30 Pa·m3, respectively, and the estimated pellet flight speed ranges from 100 to 400 m/s. A bend tube with an angle of ~ 20° is installed at the end of the pellet flight pipe to ensure pellet fragmentation [1-3]. During bench testing, the condensation process of pellets was simulated using FLUENT through numerical simulation methods. It was found that the best cold head temperature of Ne pellet condensation was 8-10 K with a condensation zone pressure of 60 mbar and heat sinks temperature of 100 K [4].

The first rapid shutdown experiments using Ne SPI were performed in EAST, allowing clear observation of the entire process, from pellet injection to plasma disruption, through two CCDs [5]. Experimental results demonstrate a direct relationship between the durations of thermal quench (TQ) and current quench (CQ) during disruption and the parameters of the pellet. Particularly, with the increase in pellet velocity, the durations of tCQ and tTQ will decrease. The timescales for tCQ were about 4-6 ms and for tTQ were approximately 0.05-0.2 ms.

To investigate the influence of various fragment sizes on disruption mitigation characteristics in EAST, the 20°-bend shatter tube was replaced with a horizontal straight tube to develop an insufficiently shattered pellet injection (ISPI) system, producing larger and more concentrated fragments without velocity reduction for comparative analysis with conventional SPI. It was found that after impurity injection, the n = 1 mode in the toroidal signals grows regardless of whether a magnetohydrodynamic (MHD) mode was present in the plasma before injection. And it is observed that the poloidal asymmetry of radiation after pellet injection is influenced by the toroidal field current. Furthermore, diagnostic assessments indicate that ISPI results in a pre-TQ duration about 1.5 times longer and a CQ duration 0.83 times shorter than SPI, attributed to reduced impurity assimilation. Although ISPI facilitates a slightly more uniform poloidal radiation distribution during TQ phase, it is associated with weaker mitigation of halo currents, with a mitigation frequency of 27.3% compared to SPI's 64.7%. These findings from the EAST experiments serve as a valuable reference for establishing SPI technology as the fundamental approach for disruption mitigation in ITER.

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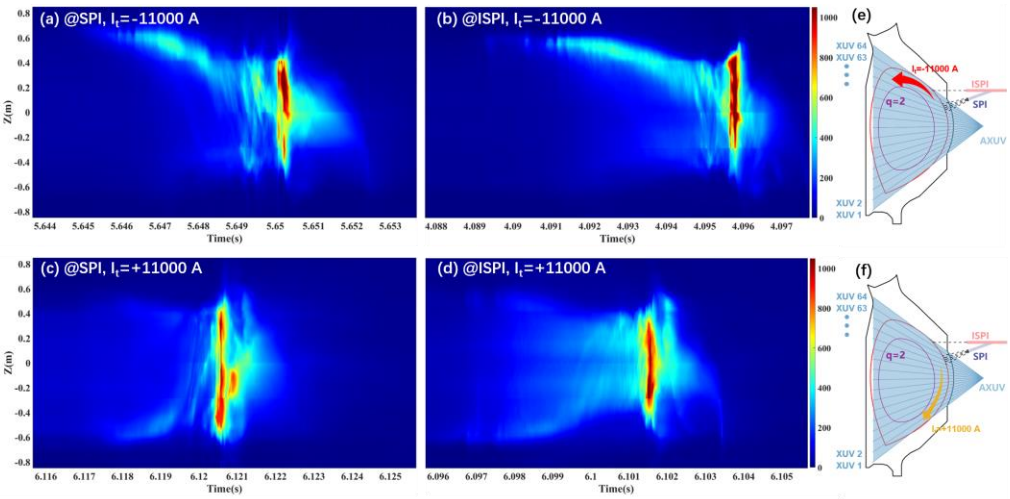

Fig. 1. Radiation contour maps of SPI/ISPI under different toroidal field conditions. The pellet injection quantity was 13.2 Pa·m^3, and the injection velocity was maintained at 320 m/s for all cases.