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Pellet Size Optimization for the ITER SPI

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The ITER disruption mitigation system design using shattered pellet injection is reaching maturity, with the current leading strategy being a staggered pellet injection scheme. The first injection in this scheme uses pure hydrogen to reduce runaway electron (RE) generation by increasing plasma density and reducing electron temperature. The second injection consists of neon pellets to efficiently radiate the remaining thermal energy and prevent damaging thermal loads to plasma-facing components. To achieve these goals, the current barrel diameter has been set to 28.5 mm, delivering 1.5×1025 hydrogen atoms through 8 pellets, followed by 3 neon doped pellets delivering an additional 5.6×1024 atoms for a 15MA H-mode DT plasma. However, current modeling predicts that even with such large hydrogen pellets, it may not be possible to achieve RE generation suppression during the nuclear phase, necessitating an RE mitigation strategy.

The most promising RE mitigation strategy is currently low-Z benign termination. This approach requires a low-density companion plasma and a low q-edge to enable a fast-growing MHD instability that expels the confined REs, leading to a “benign”termination of the RE beam. Experiments on DIII-D and TCV have shown a clear upper limit in neutral pressure at approximately 0.5-1Pa, above which the ionisation cross-section between the REs and neutral gas is sufficient to increase the companion plasma density and reduce the mode growth rate. This is problematic as the currently envisaged staggered injection scheme on ITER will result in a neutral pressure of ˜30Pa. Furthermore, the RE density on ITER is expected to be more than double that of DIII-D and TCV, further exacerbating this problem. This incompatibility with the RE mitigation scheme requires a re-evaluation of the pellet sizing.

Further motivation for assessing the staggered injection strategy comes from preliminary results of last year’s JET SPI campaign. Firstly, it was observed that the density rise in the core can take tens of milliseconds after pellet arrival due to density penetration timescales (Figure 1). Secondly, the pre-thermal quench duration was drastically reduced to below 5 ms if the hydrogen pellet was doped with 0.016% neon to prevent plasmoid drift (Figure 2). A similar reduction in pre-thermal quench duration was observed if the plasma was strongly seeded (Figure 3) 1. These factors suggest that there may not be sufficient time for the staggered pellet scheme to achieve its goals.

This talk will propose reduced pellet sizes to enable greater flexibility of the system and provide a contingency should the staggered injection scheme not meet its objectives. A new mitigation strategy addressing thermal load mitigation by leveraging seeded gases, further reducing reduced RE generation and providing a neutral pressure range more compatible with low-Z benign termination will also be presented1.

1 –Sheikh, U, et al., “Impact of Plasma Seeding on Shattered Pellet Injection Mitigations on JET”, submitted to Nuclear Fusion 2024

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