Contribution ID: **117** Type: **Invited**

Particle Assimilation During Shattered Pellet Injection

Effective disruption mitigation by shattered pellet injection (SPI) requires the assimilation of a sufficient quantity of the injected material by the plasma. Progress in understanding this SPI particle assimilation, based on experimental measurements and modeling, is described. When the pellet contains radiating impurities such as neon, the resulting disruption evolution is well described based on global energy balance, without consideration of MHD effects. Such a radiative shutdown can be well modeled by the 0D KPRAD code [1] including a shattered pellet ablation model [2]. In DIII-D experiments, simulated densities during the current quench (CQ) are found to be in good agreement with experimental data across a wide range of plasma conditions. The net particle assimilation during neon SPI in DIII-D is <15% of the total pellet mass, limited based on the relative values of stored energy in DIII-D plasmas and the available pellet size. This KPRAD model has also been used to simulate SPI experiments in JET and KSTAR, and simulations in all three devices accurately predict the resulting CQ rates across a range of injection species compositions. The model also successfully reproduces the results of dual-SPI shutdowns in DIII-D, indicating that 3D effects related to multiple injection locations play a lesser role compared to the global energy balance. DIII-D experiments have also measured post-SPI densities under a wide range of plasma parameters, allowing experimental scalings of SPI densities to be derived (for disruptions without runaway electrons). These scalings indicate that plasma electron temperature is the dominant factor determining net particle assimilation, while poloidal magnetic energy plays a role in sustaining the ionization of the plasma later in the CQ. Compared with the assimilation of high-Z pellets, the assimilation of deuterium SPI (without any radiating impurities) is challenging to characterize. Because deuterium SPI does not result in an immediate radiative collapse, KPRAD does not provide an accurate model of such disruptions, and MHD and other stability considerations are likely to play a role. The available experimental data on deuterium SPI will be described.

[1] D.G. Whyte, et al., Journ. Nucl. Mater. 313 (2003) 1239
[2] P.B. Parks, 7th Annual Theory and Simulation of Disruptions Workshop (2017) Princeton, USA

Work supported the US DOE under DE-FC02-04ER54698, DE-AC05-00OR22725, DE-FG02-07ER54917, and DE-AC52-07NA27344, and by the ITER Organization (TA C18TD38FU) and carried out within the framework of the EUROfusion Consortium, receiving funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. Views and opinions expressed herein do not necessarily reflect those of the European Commission.

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Track Classification: Mitigation