Progress on shattered pellet injection modelling in ASDEX Upgrade using JOREK

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Major disruptions, which lead to a complete loss of the plasma confinement, are extremely dangerous for future large reactor-size machines due to high heat loads, electromagnetic forces, and the formation of beams of highly energetic electrons. Shattered pellet injection (SPI) is selected for the disruption mitigation system in ITER, due to deeper penetration, expected assimilation efficiency and prompt material delivery [1].

To support development of ITER SPI technology and scenarios, 3D non-linear simulations of SPI in ASDEX Upgrade [2] are carried out to test the mitigation efficiency of different injection parameters for neon-doped deuterium pellets using the JOREK code. The simulations are executed as fluid simulations with additional marker particles that allow for tracing the charge states of the massive amount of injected deuterium and impurity atoms [3]. The fragmentation distribution is based on Park's model [4], and the velocity distribution is based on lab characterization [5], containing 50 - 1000 fragments varying from different injection scenarios. To obtain the optimum Ne/D mixture ratio in the pellet for an effective disruption mitigation, neon fraction scans from 0 - 10% are performed. Numerical results show that the thermal quench (TQ) occurs in two stages. In the first stage, approximately half of the thermal energy is lost, primarily through convective and conductive processes due to the stochastic fields. This stage is relatively independent of the injection parameters. In the second stage, where the majority of the remaining thermal energy is lost, radiation plays a more significant role. In cases of very low neon content, this second stage may not occur at all. A larger fraction (~20%) of the total material in the pellet is assimilated in the plasma for low neon fraction pellet (0.12%) due to a longer pre-thermal-quench phase, the absolute assimilated neon quantity increases with increasing neon fraction though. The effects of fragment size and penetration speed are further studied. We found that slower and smaller fragments are beneficial to more effective edge cooling. Faster fragments result in higher assimilation as they reach the hotter plasma regions more quickly. Using synthetic diagnostics, comparisons between simulations and experiments are conducted.

References

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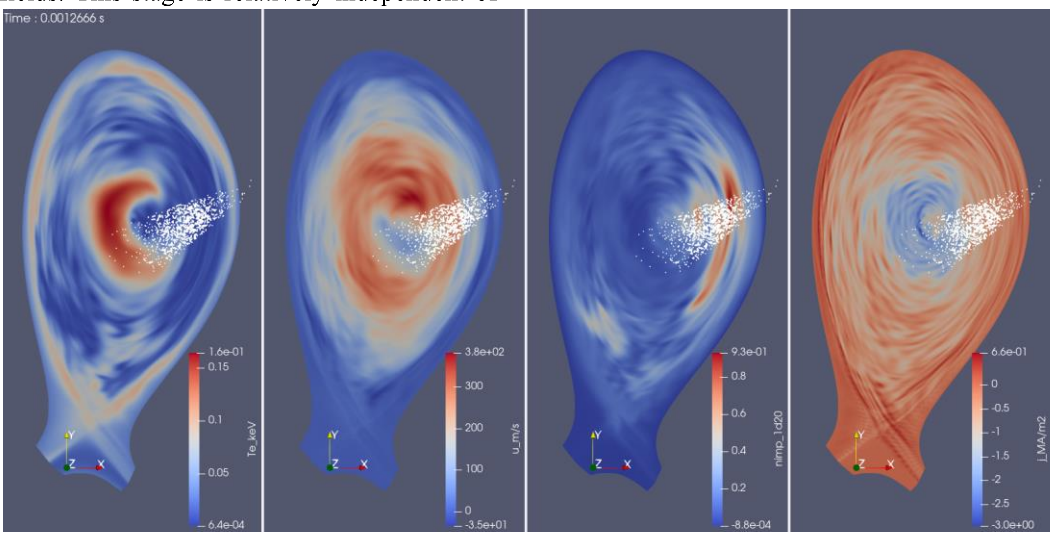

Figure 1. (From left to right) Electron temperature T_e, stream function u, impurity density n_{imp} and plasma current density j_ϕ at 1.27 ms after injection. A 10% neon pellet with 443 m/s speed was injected after shattered into 1105 fragments. The white markers indicate the real-time locations of these fragments.

†:Deceased