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Plasma fuelling on ITER and new requirements for DEMO

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A future fusion reactor is anticipated to mainly utilize pellet injection for particle fuelling. Pellets are mm-sized bodies formed from solid hydrogen fuel. Undoubtedly, delivering an adequate fuel amount with an isotope mixture adjusted to establish the optimum deuterium:tritium composition expected in the vicinity of D:T = 1:1 to the plasma core has to lay the foundation for any pellet actuator concept. In a tokamak, this calls for high-speed injection of pellets from the torus inboard side via guide tubes. Hence, any reactor is in need of a highly capable pellet injection system located at the interface of plasma physics and the fuel cycle technology. Beyond this primary fuelling purpose, hydrogenic pellets have proven their potential to serve for additional actuation tasks.

In ITER, gas fuelling efficiency will be strongly limited by the poor penetration of the neutrals into the core plasma. To access and maintain a core density level adequate for a high fusion gain, controllable steady-state pellet delivery is needed. Inboard launch of pellets containing deuterium and tritium with high reliability for up to 1 hour plasma duration is foreseen. In addition, the ITER pellet system is expected to serve for ELM pacing –the controlled triggering and mitigation of these potentially plasma-facing component damaging edge instabilities that expel significant amounts of plasma energy. This yet unprecedented challenge for a pellet system is expected to be covered by a launcher under development at ORNL. The launcher, based on well proven technology for high mass throughput pellet production and acceleration in a gas gun, will be set up for delivery of pellets with adjustable size and composition via different injection guide tube routes optionally to be chosen as needed for the fuelling and ELM pacing tasks.

For the follow-up project DEMO, requirements for the pellet system are even more challenging. In order to harvest an ample amount of fusion power, here steady operation at core densities significantly above the Greenwald density is envisaged. Operation in this high-density regime is possible virtually only by pellets. Since burn control in DEMO becomes very sensitive to variations in the core density, the demands for reliability and controllability performance are significant. To foster the development of a pellet actuator capable to cover the multifaceted control requirements of a burning plasma, investigations are under way at ASDEX Upgrade (AUG). Efforts reported span a wide range of pellet technology control techniques utilized in plasma physics experiments. For example, fuelling experiments were performed mimicking D/T by H/D pellets demonstrating safe and reversible isotopic control with high core density operation. However, a significant disagreement with scaling predictions of a continuing increase of energy confinement with density was found. Instead, above a distinct level, the energy content can be kept at best constant. Thus far, experimental investigations focussed on the ELMy H-Mode scenario. Recently, encouraging results achieved with naturally ELM-free regimes rendered the possibility for a more benign DEMO scenario. Consequently, a critical review of pellet actuation for its compatibility with these DEMO relevant scenarios is still required.

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