Impurity powder injection experiments in LHD

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Injection of impurities in the form of sub-millimeter powder grains is performed for the first time in the Large Helical Device (LHD) plasma. This technique has been recently employed in both tokamak \cite{1-4} and stellarator \cite{5} experiments, showing in general beneficial effects on plasma performances, both through the modification of the edge plasma and the real-time conditioning of the first wall. LHD features a unique magnetic configuration, different from both tokamaks and existing stellarators. Indeed, in these devices the magnetic field at the divertor plates is predominantly toroidal, while in LHD it is almost completely poloidal. The effective injection of dust grains impurities into the main plasma needs therefore to be confirmed in this peculiar magnetic configuration through dedicated experiments. Furthermore, the superconducting magnets of LHD allow to perform long plasma discharges (of the order of one hour), and offer therefore the opportunity to test this technique in steady-state operation (SSO) conditions.

The Impurity Powder Dropper (IPD) \cite{6}, developed and built in PPPL, is therefore mounted on LHD. The installation of IPD was supported by predictive simulation of dust trajectories coupling the EMC3-EIRENE and DUSTT codes \cite{7}. In this set of dedicated experiments, we drop, for the first time, controlled amounts of boron (B) and boron nitride (BN) powder into the helical plasma. Visible camera imaging and spectroscopy measurements of BV and NVII lines show that the injected impurities effectively penetrate into the plasma.

The effects of the impurities on the edge and divertor plasma are characterized as the injection rate is scanned systematically. Preliminary results show that the temperature of the confined plasma increases, together with the total radiated power, while the stored energy remains approximately unchanged. The effect on plasma temperature is reduced as the plasma density is increased. As an effect of the impurity injection, the particle flux at the divertor is reduced in a toroidally asymmetric pattern for BN but not for B powder injection. Moreover, as an effect of cumulative B and BN injection, the oxygen level in LHD is shown to decrease by spectroscopy measurements.

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\cite{2} R. Lunsford et al., 2019 Nucl. Fusion 59 126034
\cite{3} E. Gilson et al., this conference
\cite{4} A. Bortolon et al., 2019 Nucl. Mater. and Energy 19 384-389
\cite{5} R. Lunsford et al., in preparation
\cite{6} A. Nagy et al., 2018 Review of Scientific Instruments 89 (10):10K121
\cite{7} M. Shoji et al., Contributions to Plasma Physics, accepted for publication