Physics of neutral gas jet interaction with magnetized plasmas

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Density control and fuel retention are two critical issues for future fusion devices with long pulse and high performance of plasma discharge. Active fuelling is a useful method to maintain the plasma density. It is critical to understand the physics and transport dynamics during the plasma fuelling process. Plasma and neutral interactions involve the transfer of charge, momentum, and energy in ion-neutral and electron-neutral collisions. Thus, a seven field fluid model of gas jet fueling, which couples plasma density, heat, and momentum transport equations together with neutrals density and momentum transport equations of both molecules and atoms, is obtained by reduction of the Braginskii equations with source and sink terms due to plasma and neutral interactions. The behavior of neutral atoms and molecules in tokamak geometry has been investigated with a newly developed 3D neutral transport module called trans-neut[1,2], within the original BOUT++ boundary plasma turbulence framework. The simulations of mean profile variations and fueling depths during fueling have been benchmarked well with other codes and also validated with experiment results which are semi-quantitatively consistent well with each other[3].

We have further studied neutral penetration depth with varying fueling intensities. The key observations are: i) the penetration depth of gas jet fueling obviously increases with the increase of the injection velocity; ii) the penetration depth does not vary much due to the dramatic increase of the dissociation rate, once the fueling injection density exceeds a critical value; iii) with the same injection flux of gas jet fueling, the larger the injection velocity, the deeper the molecules penetrate into the plasma. Thus, our simulation results suggest an effective method to achieve a better penetration depth and fueling efficiency during gas jet fueling, by injecting molecules at a larger radial injection velocity and at a critical molecule injection density.

References