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Impurity Entrainment Studies Using Induced SOL Flow in DIII–D*

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Effective entrainment of impurities by the main ion flow in the SOL and divertor is an essential ingredient forachieving high radiative fractions in the divertor plasma while maintaining acceptable core cleanliness. To achieve effective entrainment, the frictional force associated with this flow must be large enough to overcome the thermal gradient force, which act to drive impurities toward the core plasma. One possible method of controlling this balance of forces is to induce an ion flow in the SOL via external D_2 gas injection and divertor exhaust. Experiments have been carried out on DIII–D to determine the efficacy of this technique in controlling impurity entrainment and radiation enhancement in the divertor. In these experiments, substantial improvement in impurity exhaust enrichment (defined as the ratio of the exhaust impurity fraction to the core impurity fraction) with induced SOL flow has been demonstrated with the degree of improvement dependent on impurity species. For example, argon enrichment imcreased a factor of three with enrichment values reaching 17 while neon enrichment improved by ~ 80%. In contrast, little improvement in helium enrichment has been observed. Analysis has shown that the observed Z-dependence cannot be attributed solely to differences in neutral transport (different mean free paths of the impurities) or ion transport in the divertor (changes in the force balance in the SOL due to the induced flow). Instead, the strong Z-dependence results from the interplay between the ionization profile of the given impurity and the distance over which the frictional force exceeds the thermal gradient force in the divertor. Modeling of these discharges using MIST, B2, and B2/EIRENE including the effect of ELMs have shown qualitative agreement with the measurements and the interpretation of the results.

The large improvement in argon enrichment observed in the presence of induced SOL flow suggests that a radiative divertor condition may be possible on DIII–D using this technique. Preliminary attempts at producing this condition have shown some promise with divertor radiation fractions increasing from 0.3 to 0.45 at moderate levels of argon injection while Z_{eff} in the core plasma remained below 2.0. In contrast, experiments with neon as the seeded impurity generally show a rapid evolution from an ELMing H–mode, attached divertor state to a radiative mantle condition with either giant ELM events or a return to L–mode confinement as the neon level is increased. Experiments designed to explore the possibilities of achieving a radiative divertor using argon injection simultaneously with induced main ion flow are presently planned.

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