Modeling of detachment experiments at DIII-D*

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Edge fluid-plasma/kinetic-neutral modeling of well-diagnosed DIII-D experiments is performed in order to document in detail the aspects of experimental measurements that are not reproduced within the model as the transition to detachment is approached. It is well known that, although a partially detached state has been successfully produced in many tokamak experiments, and can be also produced within 2-D plasma/neutrals transport simulations, to date fluid plasma models have failed to reproduce several major features of the detached state (notably the in-out asymmetry of detachment onset [1,2]). While the gross features that the codes fail to reproduce have been documented previously [3], here we present an effort to determine in detail how the model breaks down as the density is increased through the transition to detachment.

The experiments considered were performed in the DIII-D tokamak, where unprecedented diagnostic coverage of the divertor, including 2-D measurements of the electron density and temperature as well as impurity emission and flow, is available [4]. In the experiments, a series of discharges with increasing density up to full divertor detachment were obtained, in both L- and H-mode. These discharges are modeled with the SOLPS suite of codes, which uses a 2D fluid plasma transport model coupled to a Monte-Carlo kinetic neutral transport calculation [5]. Modeling of L-mode discharges has been performed for modest-density plasmas ($<n_e>$~1.7-2.8 10^{19} m^3/s) where the where both the inner and outer divertors are attached in experiment (with electron temperatures at the outer strike point T_e^{OSP} ~15-30 eV). For these attached cases, the simulations show reasonable agreement with experiment in both the magnitude and profile of the electron density and temperature at the outer divertor, with the upstream profiles also matched using radially varying cross-field transport coefficients in the modeling. The ion flux also agrees with probe measurements made at the inner and outer divertors within a factor of less than two, as does the divertor D_α and C-III emission. At higher densities near full detachment ($<n_e>$~4.5-5 10^{19} m^3/s), discrepancies arise in the spectral emission and ion flux at the inner divertor while the measurements at the outer divertor can be reasonably reproduced. Detailed comparisons of the full 2-D density and temperature distributions from modeling and experiment, as well as flux profiles to the divertor, will be presented for a range of densities up through the threshold for detachment.

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