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Impurity parallel force balance in the SOL using the Zhdanov closure in Soledge3X-EIRENE simulations of WEST discharges

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Next steps machines such as ITER and DEMO will face unprecedented challenges related to heat exhaust. Impurity seeding will play a key role in spreading power on a sufficiently large surface area. Simulating impurity radiation in a given scenario requires i) radiation functions for the different ion stages and ii) the spatial distribution of the ion densities. The latter results from the location of the injection and from a competition between parallel and perpendicular transport. Correct interpretation of current experiments and extrapolation to larger machines all the more so with advanced divertor configurations, have to rely on a solid theoretical basis for impurity dynamics. This work aims at strengthening this basis by evaluating the sensitivity of parallel impurity force balance, which plays a key role on setting the poloidal impurity distribution as well as divertor leakage, to the fluid model used for impurities.

Multifluid equations have been derived by Zhdanov in the 1980's [1], and have been recently revisited by several groups [2,3]. These equations are valid beyond the trace approximation and provide expressions for the friction force, thermal forces and energy exchanges between species from kinetic theory. This closure is implemented in the SolEdge3X-EIRENE code package [4]. In this contribution, WEST 2D transport simulations performed in support of spectroscopic measurements [5] are shown to exhibit strong in/out asymmetry for high Z oxygen ions (oxygen is used as a representative impurity throughout this work), which complex spatial patterns. The parallel force balance is analysed to explain these findings, partly related to the Z dependences of forces, and evaluate the sensitivity of the parallel balance to the collisional closure. The importance of non-trace effects is evaluated in these conditions. In contrast to most of other edge code packages, SolEdge3X solves one energy equation per species and the relative temperature deviations between species are found to reach ˜ 20% in the WEST simulations, with the sheath model used. The impact of these deviations on the parallel force balance is evaluated using recent extensions of the closure [2], properly accounting for the temperature difference between species in the calculation of parallel forces.

[1] V. M. Zhdanov, Transport processes in multicomponent plasma, Taylor and Francis, London, 2002.
[2] M.Raghunathan et al., 2021 Plasma Phys. Control. Fusion 63 064005;
[3] S. O. Makarov et al., 2021 Physics of Plasmas 28 062308.
[4] H. Bufferand et al., 2021, Nucl. Fusion 61 116052.
[5] C.C. Klepper et al., submitted to Plasma Phys. Control. Fusion.

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