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Development of a Numerical Solver for Partially Ionized Plasma for Fusion Using an MHD Scheme

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It appears that a partially ionized plasma is formed around any protruded interface of different material phases in a fusion plasma. Such interface potentially and intrinsically releases neutral gas from outgassing, sputtering and evaporation, and ablated vapor from solid, for examples dust, sublimated plasma facing components (PFC), and liquid, for examples molten droplets, liquid PFCs, materials. This is induced by ambient pressure, heat deposition and mechanical structural stress of the interface in contact with a hot fusion plasma. In addition, neutral gas can be fed from external sources for several objectives, for example heat load mitigation during Type-I ELMs and disruption [1], probing [2], pellet ablation [3]. Even the fuel plasma particles can be neutrally recombined at PFCs, so that neutral particles are produced [4]. Such neutral gas mixes with plasma, and consequently, atomic processes, mainly via collisions, render such a mixture to be a partially ionized plasma. Certainly, some atomic processes can be ensured via visible light emission from fusion devices [5].

For multiple-element plasma, a full set of kinetic equations, as equation of motions, of all species are numerically solved with the coupling terms describing all possible atomic processes. These are associated with an excitation, a de-excitation, an ionization, a neutral recombination, and so on, among dissimilar species [6-8]. These include the source and sink rate, the momentum transfer rate and the energy loss and gain rate via collisions. However, computational power is strongly required to achieve such heavy calculation.

The aim of the presentation is to illustrate the overview of the numerical solver of a partially ionized plasma under a magnetic field using a magnetohydrodynamic (MHD) formulation [7-9] in our project. Apart from a thin sheath next to the interface, beyond the sheath edge, that is from a pre-sheath region, the quasi-neutrality is approximately held for transient events driven by MHD. This means that the MHD effect provided to a fusion plasma within the timescale larger than the electron collision time but less than the MHD time should be well approximated by the MHD scheme. This inspires the development of such numerical code to investigate the impurity transport in a partially ionized fusion plasma affecting the MHD transport, which includes the MHD stability induced by impurities, the triggering of MARFE and disruption, the radiative mantle in a mitigation process. The presentation also aims to provide the potential applications of the MHD scheme for a partially ionized plasma, for example the modeling of the impurity transport in a low power fusion device and the investigation of liquid metal PFC.

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