Extended hybrid kinetic-magnetohydrodynamic model for fusion burning plasmas

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We will start from a brief review of the existing hybrid kinetic-magnetohydrodynamics(MHD) models for alpha particle physics in burning plasma that demonstrates the pressure-coupling scheme(PCS) is equivalent to the current-coupling scheme(CCS) only in a specific dynamic regime where the alpha particle density is much lower than the background ion and electron. Energetic alpha particles are produced in the fusion reaction and when a part of the alpha particles interacts with the plasma, the temperature can drop below 3 times of the background plasma, and it is called helium ash. Thus, we are motivated to propose a more comprehensive kinetic-multifluid model for a proper account of the dynamical regime of the burning plasma where both helium ash and the energetic alpha particles are present. Then, the proposed kinetic-multifluid model will be further simplified into an extended hybrid kinetic-MHD model using the MHD limit. This reduction process demonstrates that the existing pressure-coupling scheme is more extensive than the current-coupling scheme and sufficient for the wide range of dynamical regimes. This analysis further shows a significant change in the model equations mainly the generalized Ohm's law due to the contributions of a large amount of helium ash present in the system. These models can also be used for studies of the impact of the energetic particles present in a multi-species flow systems such as fusion burning plasma and space plasma where the energetic solar wind interacts with magnetosphere, ionosphere, and the thermosphere.

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