Particle Simulation of Plasma Heat-Flux Dissipation by Evaporated Wall Materials

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Erosions of the wall materials via melting, sputtering, and vapourization caused by the intense pulsed heat loads during ELMs and disruptions in the fusion devices are the serious concern. At the same time, experimental observations have shown that the intense heat flux causes the formation of vapour layer which dissipates further incoming plasma heat-flux. Understandings on these vapour-shielding phenomena largely influence the lifetime estimation of the wall armours. Thus, experimental and computational approaches are being taken. In the computational approach, the MHD fluid plasma models have been used to simulate this phenomena. These fluids approaches well describe behaviours of low-Z walls such as carbon. However, these fluid models do not include the sheath and non-Maxwellian effects. Thus, in order to study these plasma-vapour-wall interactions including these effects, a 1D3V particle-in-cell (PIC) code has been developed by the authors. Here, we firstly demonstrate the consistency of the simulation results comparing with experimental observation from a linear plasma device; PISCES-B. Decay lengths of the BeI line intensity from the wall were compared as a function of ejected Be amounts and agreements were obtained between them. Then, the calculations of rates of the plasma heat-flux dissipation by the evaporated vapour (Be, W) in a fusion reactor condition were taken. Compared with Be and W, it was found that W shows less effective dissipation even for the vapour pressure larger than its melting point. A cause of this smaller dissipation of W is the prompt redeposition. The short ionization mean free path and redeposition due to its large gyro radius leads the smaller contribution to the plasma heat-flux dissipation. These kinetic effects simulated by the particle code well explain the behaviour of the high-Z wall materials. Compared with these shielding performance of W, the efficient shielding of Be wall can largely reduce the erosion due to the transient heat load events.

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