Numerical Study on behavior of hydrogen ice pellet in drift tube

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A fuelling method using a bent drift tube to guide hydrogen ice pellets into fusion plasma is proposed as a flexible one that can have a variety of injection locations and injection angles in plasma. During passing through inside the bent tube, ice pellet is considered to undergo not only friction (or contact) with tube wall but radiation from the wall. This leads to mass deficit of the ice pellet and consequently drastically affects plasma properties such as density and temperature profiles. In order to predict the effect of fuelling the plasma with pellets in a fusion reactor, it is of vital importance to have a pellet ablation model that adequately describes the experimental data.

In this study, we focused on behaviors of hydrogen ice pellet in the vicinity of tube wall, especially on thermal contact conductance and friction with the wall. We numerically estimated contributions of these phenomena to the mass deficit of the pellet. Material Point Method was adopted to simulate motions of the pellet and wall, and Smoothed Particle Hydrodynamics method was for thermal field.

We examined various cases with varying initial velocities of ice pellet, injection angles and coefficient of kinetic frictions as numerical parameters. It was clarified our simulations that when there was no friction between ice pellet and wall, mass deficit tended to decrease as injection angle became large. This is because large injection angle made a contact interval short and input heat from wall to pellet became small. In friction cases, mass deficit became obviously large compared with the no friction cases. In these cases, contribution of frictional heat to mass deficit was dominant compared with that of thermal contact conductance. Finally, we obtained the following correlation equation;

$$\Delta m = 7.65\mathrm{x}10^{-5}\, V^{2.1}\, (\sin\theta)\, \mu^{1.4} \qquad (1)$$

where Δm and V correspond to the ratio of mass deficit and the initial velocity of ice pellet, respectively while θ and μ are injection angle and coefficient of kinetic friction, respectively.

We also examined the decrease rate of ice pellet velocity before and after impact. It was found that the decrease rate became large as large injection angle and large kinetic friction coefficient. It was also clarified from our calculations that the decrease rate of pellet velocity was independent of the initial velocity when the friction coefficient was the same value.