§8. Behavior of Ice Pellet in Drift Tube

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When the pellet is traveling in the curved drift tube, it is expected that the pellet undergoes mass attrition due to melting/evaporation caused by radiation from the tube wall and friction heat with the wall and the erosion by collision with the wall. Present study aims to estimate the effect of behavior of pellet in vicinity of wall, especially heat transfer at the contact and frictional heat, on the mass attrition of it numerically.

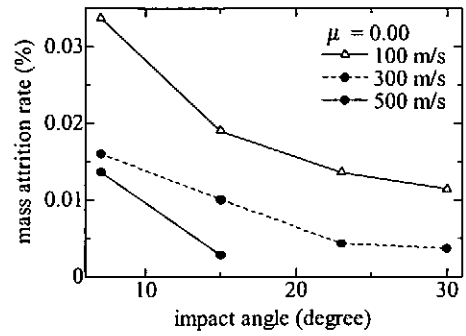
MPM (Material Point Method) [1] [2], which is a kind of so-called particle method and can capture the change of interface, is applied for calculation of pellet's motion. For thermal field, SPH (Smoothed Particle Hydrodynamics) method [3] is used. That is, in present method, both pellet and tube wall are regarded as assembly of material particle. For SPH method, the resultant reproduction of heat conduction at the interface of contact between pellet and wall strongly depends on the distance between each material particle, that is, the heat transfer rate between pellet and wall is determined by the distance. Therefore, contact heat conduction is calculated by the model derived by Sun et al. [4]. Sliding friction is described by means of Amonton and Coulomb's law and frictional heat is assumed that the decrease in total energy of pellet is converted to the heat. After calculation of input energy of pellet as frictional heat, the temperature of material particles of pellet located in vicinity of contact surface T_p^* is calculated. If T_p^* exceeds the melting point of hydrogen, the exceeded energy is assumed to be spent for sublimation of pellet. Then mass attrition for the sublimation is calculated from the latent heat of sublimation as follows.

$$\Delta m_p = m_p C \frac{T_p^* - T_m}{L} \qquad (1)$$

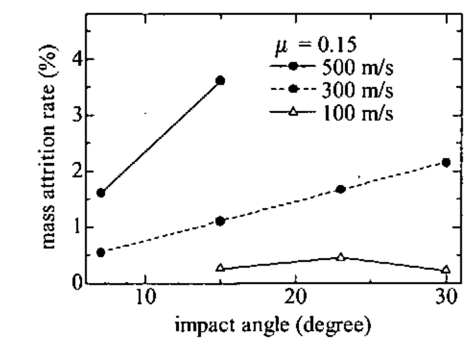
where m_p is mass [kg], T_m melting temperature [K] L latent heat of sublimation [kJ/kg].

Fig.1 show the effect of impact angle of pellet on the rate of mass attrition. Fig.1 (a) is the case with frictionless and (b) is the friction coefficient 0.15. In Fig.1 (a), the rate of mass attrition is decreased with increase of impact angle, because the contact time is shorten by increasing impact angle, that is heat transfer from wall to pellet is decreased. The mass attrition rate of (b) is much larger than that of (a), so that it is clarified that the mass attrition is strongly affected by the frictional heat. Fig.2 shows the temporal change of input heat in the case of very small friction coefficient 0.06 . From this figure, it is also found that the frictional heat is much larger than the conducted heat. Varying the initial impact speed, impact angle and friction coefficient, the relationship between such parameters and mass attrition rate is derived as follows.

$$dm = 7.65 \times 10^{-5} V^{2.1} (\sin\theta)^{1.0} \mu^{1.4} \qquad (2)$$



(a) frictionless



(b) friction coefficient is 0.15

Fig. 1. Dependency of impact angle on mass attrition rate

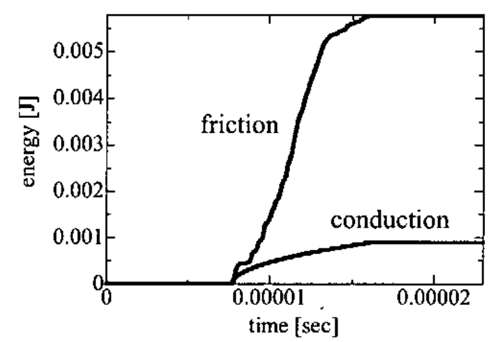


Fig. 2. Frictional heat and heat conduction

In this study is based on the assumption that a pellet is a cube and the contact surface is constant. As next step, actual pellet form, the effect of gasified hydrogen near the heat transfer interface and plastic deformation of pellet should be taken into account.

Reference
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