§10. Entrainment Behavior of Activated Dust in Accidental Event

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In a fusion device, it is recognized as a severe problem that fine particles are generated in a vacuum vessel to cool down a core plasma and to absorb tritium to be radioactivated. Understanding the particle transport becomes one of the most important subjects in a fusion device. In case a vacuum vessel which is the first confinement barrier to radioactive materials in fusion devices is broken by some sort of accident, these activated particles have possibilities to be released outside the vessel. From the viewpoint of safety, it is very important to make a prediction about the behavior of the activated particles and a lot of research has been done for this purpose. Authors have conducted experiments for entrainment of accumulated particles and re-adhesion of particles after entrainment, and have elucidated the relation between entraining gas velocity and the amount of entrained particles, and the relation between particle concentration in the gas flow and the amount of particle re-adhesion, and so on.

It is important for the prediction of particle transport to estimate where particle re-adhesion occurs and how much particles adhere there. Study for particle adhesion, however, is still insufficient and we can hardly see the study for the growth process in adhesion layer of particles. In this study, we perform numerical simulation in order to develop a prediction model for particle adhesion. Particle adhesion to solid wall placed in a gas-particle flow is calculated and the adhesion model is validated by comparing numerical results with experimental data obtained from our past experiment.

We consider a gas-particle flow in a 2-dimensional channel and a solid flat wall placed perpendicularly to the flow and investigate the time change in thickness of particle adhesion layer. The gas-particle flow is solved by using low-Reynolds type k-ε model available for a flow with separation and reattachment and the 2-equation model for turbulent thermal field. Adhesion layer is treated as porous media. Particles in the flow is tracked by Lagrangian method and turbulent diffusion is expressed by introducing a stochastic model. In the present adhesion model, it is treated stochastically whether a particle adheres to the wall or no. Incident angle on the wall is the unique parameter that decides whether a particle colliding with the wall adheres or bounces back. This lead that an adhesion rate, S, has the expression of $S(\theta)=a\cos(b\theta)$, where θ is the angle between the normal inward to the wall and a velocity vector of incident particle, a and b are model constants which are determined by being compared with the experiment.

The model constants, a, b, for each numerical condition are listed in Table 1. Fig. 1 shows the shape of adhesion layer for both simulation and experiment in case that temperature of gas-particle flow is 20 °C. At the initial stage of adhesion, large difference can be seen between them in this figure. In the experiment, the initial shape of the adhesion layer is scutelliform and the shape becomes gradually triangular while in the initial stage of the simulation, grow speed of the layer around the center region is large and the shape has triangular geometry from the beginning of the adhesion. As the adhesion layer grows, the shape becomes similar to the experiment. This trend is seen in case that the temperature of gas-particle flow is 106 or 199 °C. The growth of adhesion layer is suppressed in the actual situation because some adhering particles are re-entrained by gas flow. On the other hand, the model used in the simulation does not allow the re-entrainment of adhering particles. In the center region of the wall this difference between simulation and experiment is considered to be remarkable and this is considered to cause the difference in the layer shape between them. We can find from Table 1 that the model constant b is almost constant through the wide range of temperature in the flow while a increases with the temperature. In the simulation, temperature change in the flow was converted into change in Reynolds number and this result means that the adhesion rate becomes small as Reynolds number increases.

In this study, we performed a numerical simulation with a particle adhesion model whose parameter was the angle of incidence of particle on wall. This model should be refined by taking re-entrainment from adhesion layer into account.

Table 1 Numerical condition and model constant in simulation and experiment

Temperature (°C)	20	106	199
Loading ratio	3.6×10^{-2}	5.2×10^{-2}	6.7×10^{-2}
Reynolds number	6205	4542	3144
a	0.5	0.7	0.9
b	1.8	2.2	2.2

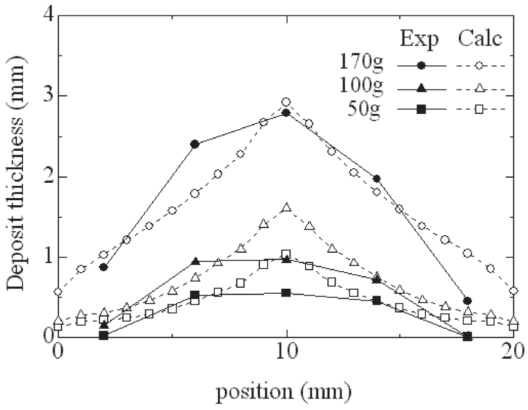

Fig. 1 Thickness of adhesion layer (20°C)