Collision condition for compound chondrule and compound cosmic spherule formation I: Condition for coalescence

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Chondrules are spherical-shaped, silicate particles that are the main component of chondritic meteorites. Cosmic spherules are extraterrestrial-spherical-shaped dust particles. They are thought to have been formed by heating (melting) events in the early solar nebula and Earth atmosphere, respectively. Both of them have compound objects (compound chondrules, compound cosmic spherules), which are two or more chondrules or cosmic spherules fused together. Some compound objects seem to be formed by collisions of two independent particles during their heating events. Although some researchers noticed collision probability of particles so far, they seldom noticed the collision conditions. If two melting particles experience the high-speed or grazing collision, they cannot coalesce. Moreover, if the viscosities of both components are too low, they will fuse together and we cannot observe them as compound objects.

In this study, we numerically examined the collision of two silicate drops by using the three-dimensional hydrodynamics simulations. In particular, we examined 'condition for coalescence' for various parameters; the collision velocity, the collision angle, the size ratio of drops, and viscosities of drops. We can categorize the results of drops' collisions into three groups; 'Stretching separation', which occurred when the collision angle is large, 'Fission', which occurred when the collision velocity is large, and 'Coalescence'. If the drops have relatively lower viscosities (1poise), our results agree well with water and organic matter drops' collision experiments [1], [2]. In this case, the maximum velocity for 'Coalescence' ($u_{\max}$) is about 5 m/s. In the larger viscosity case, because the viscous dissipation becomes effective, the region of 'coalescence' is expanded to larger collision velocity and collision angle. For example, when the viscous coefficients are 10 poise and 100 poise, $u_{\max}$ is about 15 m/s and 50 m/s, respectively. In addition, we found that the boundary of coalescence and separation can be expressed by comparing the kinetic energy, surface energy, viscous dissipation, and rotational energy. Then we can obtain the 'condition for coalescence' for various parameters. If we add 'condition for keeping their shape' to these results, we will be able to obtain the collision condition for the compound objects formation.

Keywords: Chondrule; Cosmic spherule; Molten dust collisions

References

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