Analysis on Flow Around a Sphere at High Mach Number, Low Reynolds Number and Adiabatic Condition for High Accuracy Analysis of Gas Particle Flows

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ABSTRACT

The exhaust gas from rocket motors generates severe acoustic waves. The acoustic waves reflected from the ground and launch facility is cause of vibration of the payload in the fairing. Therefore, prediction and reduction of acoustic level at the lift-off is quite important. Traditionally, acoustic level has been predicted by an empirical method, NASA SP-8072[1] or subscale tests[2]. In recent, prediction of acoustic level by CFD is required, because an empirical methods does not have enough accuracy. The alumina particles released from solid rocket motors might attenuate acoustic wave, but the mechanism is not well known. Therefore, a new model for prediction of drag force at the high-Mach-number and low-Reynolds-number condition is necessary, in order to perform high accuracy prediction on acoustic wave generated by exhaust gas from solid rocket motors.

In this study, the high-Mach-number and low-Reynolds-number flow analysis of the around a sphere by direct numerical simulation (DNS) of the three-dimensional compressible Navier-Stokes equations is performed, in order to investigate the flow properties. Analysis is performed by assuming the alumina particle as a non-deform sphere, the Reynolds number based on the diameter of the sphere and the freestream velocity set to be between 50-300, the freestream Mach number set to be between 0.3-2.0. In fact, the particle temperature is high, because ones released from solid rocket motors are burning in a practical rocket motor. However, in this study, analysis was performed under the adiabatic condition at the surface of the sphere as the first step of series of analyses including isothermal conditions.

In this study, we focused on the effect of Mach number on the flow properties and drag coefficient. The analysis showed the following results : 1) As Mach number increase, unsteady characteristics become weak and separation point moves to downstream side, 2) in supersonic region drag coefficient does not significantly change with the location of separation point and the detached shock wave effects, and 3) in subsonic region previous drag model shows good agreement with the present results, while the accurate prediction of the drag coefficient at the supersonic regime by the traditional models might be difficult because the previous drag models are based on model of incompressible flow and indirect experiment results.

REFERENCES

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