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Title

Dynamic Instability of a Thin-Shell type Aeroshell Capsule with Pitching Motion in Transonic wind tunnel

Authors

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Abstract

A sample return mission for deep space exploration has been proposed. The orbital velocity into the atmosphere can reach 15 km/s, exposing the sample return capsule to severe aerodynamic heating. To mitigate this heating, a new concept of thin-shell type aeroshell capsule has been proposed. This capsule is lightweight and has a large surface area, allowing it to decelerate at high altitude and avoid aerodynamic heating. The capsule is also designed to use its aerodynamic drag to land without the use of a parachute. Therefore, it needs to be able to be aerodynamically stable at all speed ranges.

To investigate the dynamic instability in the transonic speed, at which the limit cycle oscillation has been observed in previous research[1], we conducted wind tunnel tests with pitching motion using the same capsule shape but different cases of moment of inertia, and also tested a capsule with a bulging back compared to the basic shape.

In all cases, oscillation was small at Mach 0.6 with an angle of attack less than 5 degrees, and limit cycle oscillation was observed at Mach 1.3. If the static pitching moment coefficient of the capsule is the same, the frequency of pitch motion in the same flow field depends only on the moment of inertia by simplifying the system equation which omits the damper term. Therefore, the larger the moment of inertia, the slower the motion frequency. The moment of inertia had little effect on the angle of attack at M0.6, but at M1.3, the motion tended to diverge as the moment of inertia increased. Also, at M1.3, oscillation was suppressed even though the moment of inertia was almost the same by bulging the back of the capsule. If the static pitching moment coefficient is the same, the relationship between the dimensionless moment of inertia and dimensionless frequency is proportion. Here, the case of capsule bulging the back is on the original shape line, so the static characteristics did not change but the dynamic characteristics changed, and the motion was suppressed. This suggests that bulging the back may have potential in suppressing dynamic instability during reentry.

References

[1] K. Hiraki, Experimental Study on Dynamic Instability of Capsule-shaped Body, ISAS Rep. 103 (1999) 1–55.