High-Speed Unsteady Flow Past Spiked Blunt Bodies

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Hypersonic vehicles typically use very highly blunt nose to reduce the high heat loads due to convective heating. The blunt nose results in a strong bow shock ahead of the nose, which causes rather high pressure and temperature on the surface of the body. The high pressure causes high drag on the body. The high temperature behind the bow shock can also cause damage to any sensing equipment mounted on the dome of the nose. The pressure in the nose region can be reduced if an oblique shock is generated ahead of the body instead of the bow shock. This can be achieved by attaching a spike in front of the blunt body. This concept was introduced in 1950s as a means to reduce heat flux and aerodynamic drag on axisymmetric blunt bodies. A variable length spike is also of interest as it provides a compromise to two non-similar characteristics - a large blunt nose for re-entry phase (low heat transfer), and pointed nose (low drag) for atmospheric flight.

A spike of proper length creates a conical region of separated flow ahead of the blunt body shielding it from the high speed flow. The pressures and enthalpy behind the oblique shock created by the spike is lower than that behind a normal shock. Use of a spike tip, for example a disk, allows a fixed length spike to be effective over a wide range of Mach number by fixing the boundary layer separation point. This creates a recirculation region regardless of the Mach number. The net effect is reduction in drag as well as temperature in front of the blunt nose. However, the flow field is complex with presence of expansion, and separation and reattachment shocks. The flow may expand around the disk depending on its shape followed by mild compressions at the base of the disk. The flow separation causes a separation shock which separates the separation region from the inviscid region behind the bow shock. The separated flow reattach on the blunt body creating a reattachment shock. Shock-shock interaction between the separation and reattachment shocks can lead to high localized temperatures.

It has been observed in previous studies that for certain combinations of spike length and body diameter and shape, unsteadiness can occur. Kabelitz [1] found two distinct modes of unsteadiness. The first is a *pulsation* mode where the conical separation bubble periodically inflates and radially expands taking a hemispherical shape. The second is the *oscillation* mode in which the conical shock and the shear layer oscillates laterally, periodically changing its shape from concave to convex. For non-zero angles-of-attack, lee-ward vortices are formed due to the presence of the aerospike. The drag increases drastically as the angle-of-attack is increased which results in reduction in effectiveness of the spike. The separated flow in either case is unsteady and can cause structural fatigue.

There has been a renewed interest in aerospike for blunt noses in the recent past. However, the extensive parametric geometric space of has not been fully explored, e.g. length and thickness of spike, length to body diameter ratio. Also the influence of various disk (also called aerodisk in literature) shapes, heat and mass addition, and causes of unsteadiness has not been fully understood.

In the present project, our aim is to study unsteady laminar flow past spiked blunt bodies. The effect of the following parameters on the unsteady flow would be considered

1. spike length
2. spike head geometry
3. angle-of-attack
4. Mach number

References

[1] H. Kabelitz (1971), Zur Stabilitaet geschlossener Grenzschichtabloese-gebiete an konischen Drenkoerpern bei Hyperschallaus-stroemung. DLR FB 7177.

[2] D. Feszty, K.J. Badcock & B.E. Richards, Driving Mechanisms of High-Speed Unsteady Spiked Body Flows, Part 1: Pulsation Mode (2004), AIAA Journal, vol 42, pp 95-106.

[3] D. Feszty, K.J. Badcock & B.E. Richards, Driving Mechanisms of High-Speed Unsteady Spiked Body Flows, Part 2: Oscillation Mode (2004), AIAA Journal, vol 42, pp 107-113.

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