Experimental Investigation of Hypersonic Buzz on a Delta Configuration

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Theme

AN experimental study is described which confirms the existence of hypersonic buzz in the separated region of a downward deflected control surface. Wind-tunnel tests in helium at $M = 17.5$ clearly demonstrated the occurrence of large-scale pressure oscillations throughout a substantial range of angles of attack and control surface deflections on a blunt slab, delta configuration. Measurements of surface pressure fluctuations and observations of high-speed schlieren photographs served to delineate the boundaries of the phenomenon and to identify the physical parameters necessary for the onset of a buzz condition. Prominent spectral energy peaks in surface pressures were observed and correlated with the instability. These conditions were found to be strongly dependent on the presence of multiple shock interactions relative to the location of a reattaching shear layer.

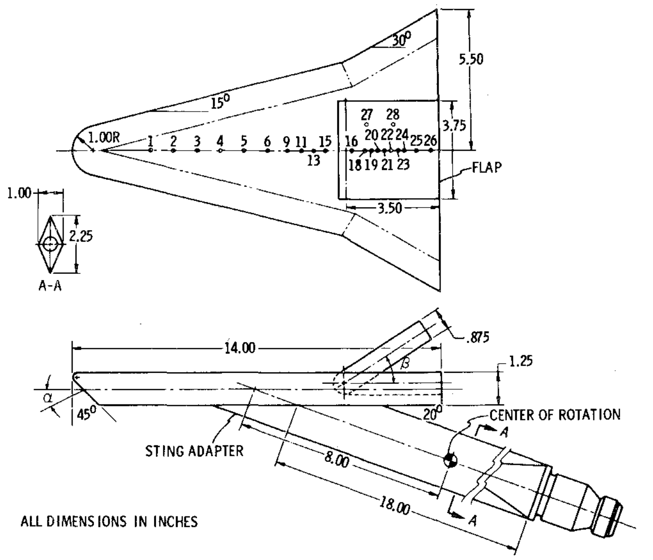

Fig. 1 Schematic of wind-tunnel model.

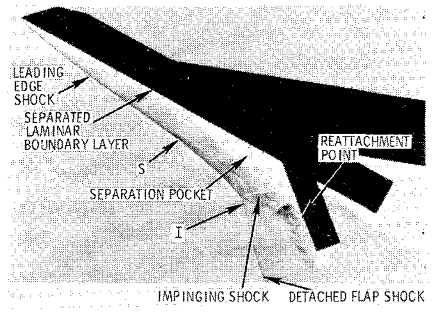

Fig. 2 Schlieren photograph of flow for $\beta = 40°$, $\alpha = 30°$.

Contents

Earlier studies of the unsteady aerodynamics of configurations with flap-induced regions of hypersonic separated flows[1,2] indicated that surface pressure fluctuations and associated flap oscillations involve a complex interaction between flow separation, freestream disturbances, and vehicle geometry. Perhaps the most unusual aspect of the phenomenological observations made during these earlier experiments was the occurrence of a large, irregular, buzz-type excitation of the flowfield when the bow shock on a lifting body model interacted with the separation associated shocks on a downward deflected flap. This excitation seemed to be a purely aerodynamic type of instability, independent of the flap's flexibility or natural frequency, yet clearly related to an unsteady interaction between the model's bow shock and its separation/reattachment shocks.

The present experiments, reported in greater detail in Ref. 3 were conducted in the Mach 20 leg of the NASA Langley high Reynolds number helium tunnel. Figure 1 shows the basic geometry of the model and the location of the various differential pressure transducers. The flap was connected to the forebody by a stiff angular fitting and was adjustable to flap angle settings of 0°, 20°, 30°, 35°, 40°, and 60°. The model's angle of attack in the tunnel could be varied from 0° to 37°.

The pattern of unsteady shock interactions and the separated flowfields associated with these interactions were monitored by a 6000 frames/sec schlieren motion picture camera and a multiple-image still schlieren camera. In addition, a series of oil flow tests were conducted in a nearby 22-in. hypersonic tunnel using a scaled down, wood model of the larger delta configuration.

A schlieren photograph for a flap angle β, of 40° and angle of attack, α, of 30° is shown in Fig. 2. The photograph typifies the conditions under which buzz or large-scale pressure oscillations were observed. The oil flow pattern corresponding to this buzz condition is illustrated in Fig. 3. Such oil flow pictures were useful in determining the nature of fluid flow separation and reattachment. Pressure power spectral densities of surface pressure fluctuations along the forebody and flap during buzz are shown in Fig. 4. The appearance of a prominent spectral

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Index categories: Supersonic and Hypersonic Flow; Nonsteady Aerodynamics.

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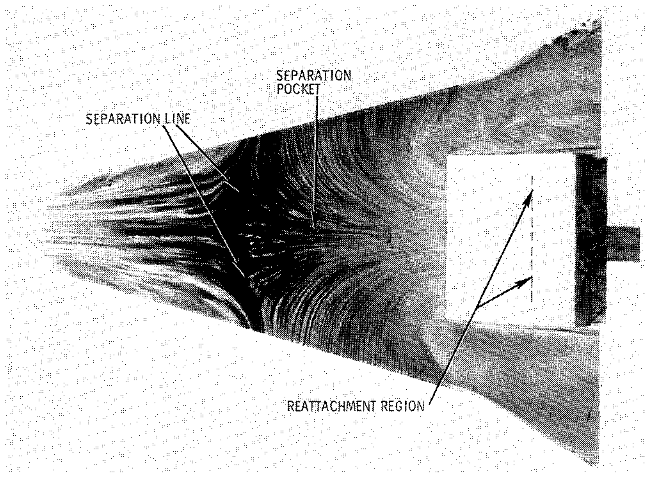

Fig. 3 Oil flow pattern, $\beta = 40°$, $\alpha = 30°$.

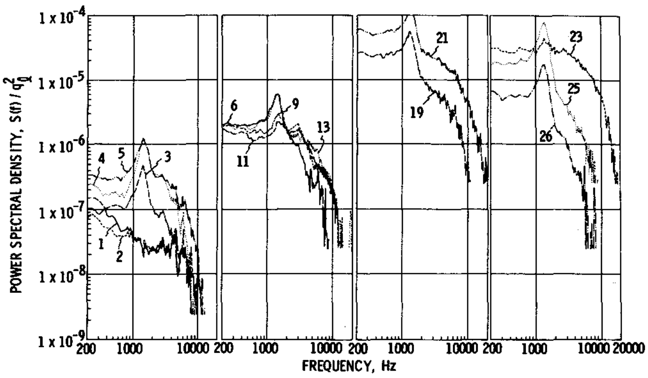

Fig. 4 Surface pressure power spectral densities, $\beta = 40°$, $\alpha = 30°$.

spike and a significant increase in the fluctuating pressures on the flap are typical of the many buzz cases observed.

Hypersonic buzz was first found to be related to angle of attack. With a flap angle of 40° and an angle of attack of 0°, the high-speed schlieren motion pictures indicated that the shock wave and flowfield surrounding the model were generally steady, although tunnel flow fluctuations and wall noise did cause some low-level disturbances. As the angle of attack increased, some unsteadiness appeared, but the level remained very low. As the angle of attack passed through 20° and beyond, the entire scale of the disturbances rapidly changed. The impinging shock (appearing as a white streak in the films) resembled an electric discharge arc as it danced rapidly back and forth along the flap. At the same time, the entire flow structure oscillated wildly. At the maximum angle of attack, 37°, the impinging shock progressed to the forebody and the oscillation amplitudes decreased from their maximum, although they still were large.

Within the confines of a selected range of aerodynamic and geometric parameters, it was observed that the flow underlying the region of a downward deflected flap can be very unstable at hypersonic speeds. Experimental criteria for the existence of large-scale unsteady oscillations were found to be related to the formation of a separation pocket and the presence of multiple shock interactions occurring near the separated shear layer's reattachment point.

Three conditions were required for the onset and continuation of large-scale oscillations: 1) a sizable separation region must develop; 2) the shock resulting from the intersection of the bow and flap shocks must impinge on either the body or the flap surface; 3) shock impingement must be in close proximity to—or upstream of—the shear layer's reattachment point. Within the flow and geometry conditions tested, this third condition was in itself sufficient for buzz to occur.

Apparently, the proximity of the impinging shock and the reattaching shear layer allow pressure fluctuations, which accompany slight unsteady movements of the impinging shock, to be fed back through the separated pocket. The impinging shock then affects conditions at the separation point and modifies the reattachment position of the separated shear layer. The details of this feedback mechanism are far from understood, and the results do not rule out a role for flap motion (at the flap frequency) in the mechanism. The fluctuations are of sufficient magnitude to be important to the design of a hypersonic vehicle with a separated pocket, and experience from this study should aid in establishing general design criteria for such hypersonic vehicle configurations.

References

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