Problems in Hypersonic Flight

To achieve successful flight at hypersonic speeds, the designer must face conditions which require unique solutions of many stability and control problems. Although the first concerns relative to aerodynamic heating is not in the realm of stability and control, the probable consequence of heating—causing distortion of bodies and lifting surfaces—is in this realm. Changes in wing camber, dihedral, and tail dihedral may alter the behavior of the aircraft considerably and must be considered carefully for any proposed design. (a)

The problem of maintaining positive stability at hypersonic speeds (because of diminishing lift slope of the stabilizing surfaces) becomes acute at hypersonic speeds because of the diminishing tail lift curve slope of conventional stabilizing surfaces. It should be appreciated, however, that as the lift slope...
for small displacements decreases, the lift curve becomes increasingly nonlinear and, in fact, approaches the theory of Newton, in which the lift varies as the square of the angle of attack. Linnell \((x = 1)\) has shown that the lift variation of a two-dimensional flat plate is given approximately as

\[
\frac{C_L}{\alpha^2} = \frac{1}{x^2} \left[ x \left( \frac{x+1}{x^2} \right) \right] \frac{1}{1 - \frac{x-1}{x+1}} \left[ 1 - \frac{1}{x} \right]^{2/\gamma - 1}
\]

where \(\gamma\) is the ratio of specific heats and \(M\) is the free-stream Mach number. According to the experiments of McElroy \((x = 2)\), Linnell's expression also is reasonably valid for either rectangular or triangular finite wings, at least for the test Mach number \((M = 6.9)\). Results obtained by Linnell's approximate and compared with the linear Airfoil Theory in figure 1. The correct limits of the varying linear theory are confined to a decreasing
angle of attack begins as the Mach number is increased. For Mach numbers of the order of 5 or above, use of a nonlinear theory is almost essential. The initial slope of time-lag curves appear to agree closely with the correct theory for Mach numbers above about 2.0.\(^{(b)}\)

\[\text{Insert} \]

The aerodynamic contribution of the body, being less dependent on Mach numbers than that of the wing, achieves considerably greater relative importance at hypersonic speeds. This would be true even though the relative sizes of wing and body remain constant; however, the size of the body ordinarily will increase in comparison with the size of the wing as the design Mach number is increased; consequently, the body is likely to have predominant influence on stability characteristics. Of particular concern is the influence of the body on the stabilizing surface. The
Direct body unstable moment also is of much importance, though uncertain in magnitude because of viscosity effects and the critical influence of shape details. 

Shima mixer, Williams, and Young (1), by a refinement of the Newtonian convection theory, an approximation to the aerodynamics of lifting bodies at hypersonic speeds has been provided by Shima mixer, Williams, and Young (1).

Since very high altitudes usually are associated with supersonic flight, controls using lifting surfaces tend to become ineffective. The maintenance of a desired course under operational conditions may require reasonably rapid rotation of the aircraft and thus cannot to direct reaction type controls may be effective. Since aerodynamic coupling effects are negligible, a considerable length of time may elapse before an essentially steady rotational velocity is reached.
reaction
while the controls are being operated. Figure
\[ \text{Figure}\]
provides a comparison of the type
of response resulting from reaction controls
at high altitude and from conventional
control at low altitude.

This difference in response will be
of significance in
the handling qualities
evaluation of a piloted
aircraft. For the reaction controls the
control motion is essentially proportional
to angular acceleration whereas for con-
ventional controls at low altitude the
control motion is essentially proportional
to angular velocity.
(a) A factor of significance is the importance of using suitable hot high sonic speeds. For the same Reynolds number the boundary layer displacement thickness may be many times greater at a Mach number of 7, for example, than at a Mach number of 1.

(b) It has been pointed out that the use of very low aspect ratio for wings at high sonic speeds may be advantageous. Because of the importance of Reynolds number effects at high wings may produce higher lift with appreciable loss of lift curve slope because of the increased chord and Reynolds number resulting from reducing the aspect ratio of a wing of given area.

(c) Experimental evidence indicates good agreement with this calculation method and also shows the importance of body shape. A flat-bottomed body produced appreciably greater lift curve slope.
than a similar body with a circular cross section.

In contrast to the characteristics of wings, the bisectional slopes of cones should increase at very high Mach numbers. The second advantage might be taken of this fact to stabilize a body by terminating it with a conical fore end rather than the more usual boattail.