Blunt Cones at Angle of Attack in Supersonic Nonuniform Freestreams

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Nomenclature

A = velocity defect parameter [see Eq. (1)]
A_b = local cone cross-sectional area
B = wake width parameter [see Eq. (1)]
C_D = drag coefficient, drag/$q_n A_b$
C_L = lift coefficient, lift/$q_n A_b$
C_{M0} = nose pitching moment coefficient, nose moment/$q_n A_b L$ (positive nose up)
$C_{L\alpha}$ = lift coefficient slope, $dC_L/d\alpha$
$C_{M\alpha}$ = pitching moment coefficient slope, $dC_{M0}/d\alpha$
C_p = pressure coefficient, $(p - p_n)/q_n$
L = reference length equal to nose radius
q_n = dynamic pressure based on wake centerline conditions, $\rho_n V_n^2/2$
S' = nondimensional surface distance measured from the apex of a sharp cone, S/L
$\tilde{S}$ = nondimensional surface distance measured from the forward stagnation point on a blunt cone, S/L

Theme

THE effects of supersonic nonuniform freestreams, as may occur in aircraft wakes, on the aerodynamic coefficients of sharp and blunt cones, representing aerodynamic decelerating devices and separating stores, were investigated analytically by employing an extension of the two- and three-dimensional methods of characteristics. The study was limited to inviscid aerodynamics. The effect of angle of attack on the aerodynamic coefficients was investigated.

Contents

A family of wakes was investigated, characterized by the following equation for the freestream velocity:

$$V/V_\infty = 1 - A\exp(-By^2) \tag{1}$$

where

$$A = 1 - (V_{\text{nose}}/V_\infty)$$

The wake width was changed by varying the value of B. The ratio of the free velocity at wake centerline, $y = 0$, to the velocity at $y = \infty$ was changed by varying the value of A (y is the distance normal to the wake axis). A diagram of the body situated in the wake is shown in Fig. 1. The basic assumptions made were that pressure and total enthalpy remain constant in the freestream. Note that in assuming constant

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Index category: Supersonic and Hypersonic Flow.

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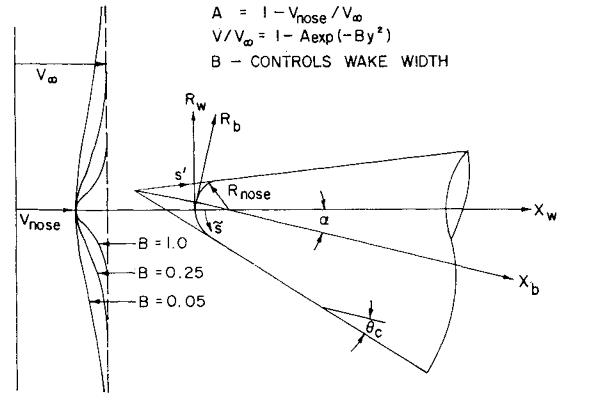

Fig. 1 Sharp and blunt cones in wake-like nonuniform freestreams.

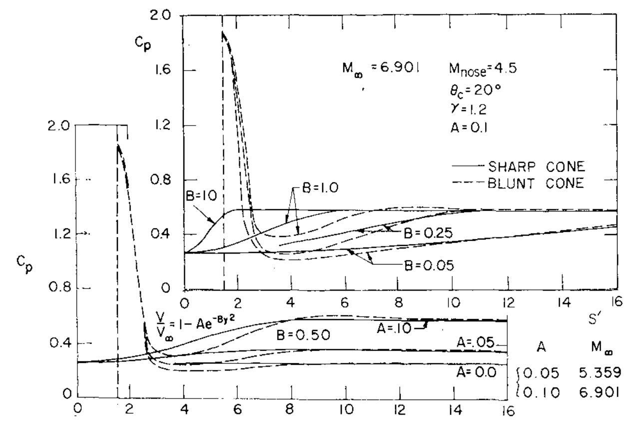

Fig. 2 Sharp and blunt cone surface pressures in wake flow.

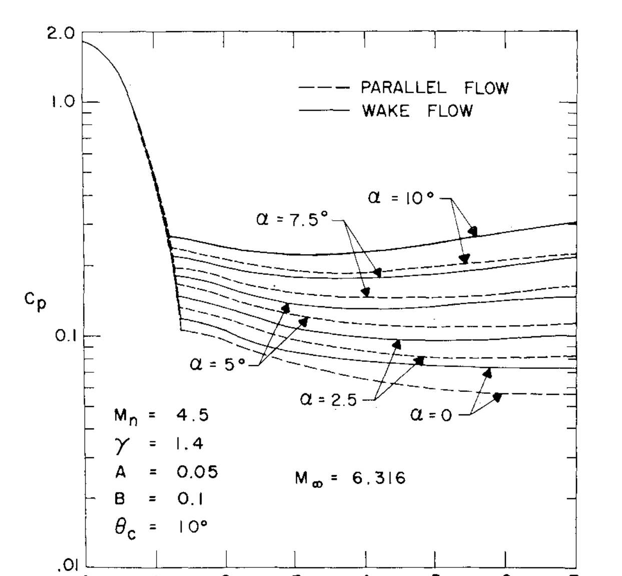

Fig. 3 Windward streamline pressure distributions over blunt cones at angle of attack.

total enthalpy, certain restrictions must be placed on the parameter A such that the temperature in the far wake remains finite. From these restrictions a nose Mach number of 4.5 was chosen to permit a range of wake parameters to be studied.

The computation of wake flows over blunt bodies was accomplished by extending the inverse method of Lomax and Inouye.[1] It was found that the one-parameter shock shape used in that method was sufficient to treat the nonuniform flowfields considered. The only modifications needed were the addition of appropriate freestream conditions and the computation of the modified stream function.

To complete the study a two-dimensional method of characteristics developed by Inouye, Rakich, and Lomax,[2] and a three-dimensional method of characteristics by Rakich[3] were also modified to treat nonuniform freestreams. The modifications in each case consisted of altering the shock-crossing procedure to account for the correct freestream conditions upstream of the shock.

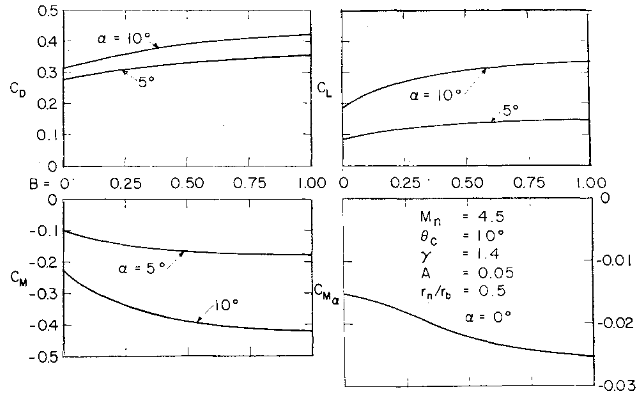

Fig. 5 Effect of wake parameter B on aerodynamic coefficients for a blunt cone at angle of attack.

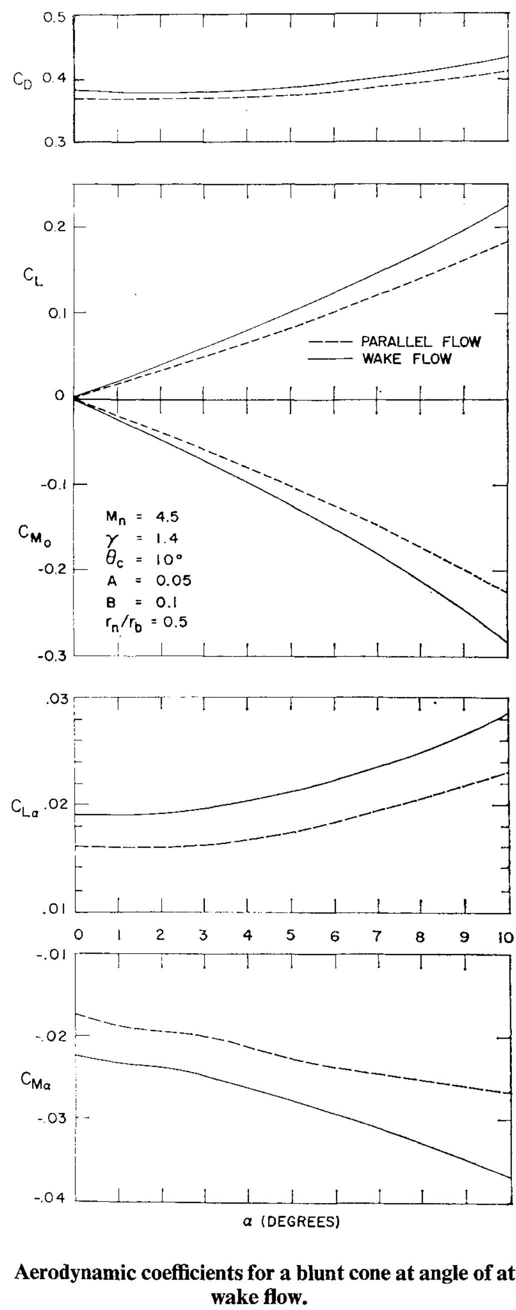

Fig. 4 Aerodynamic coefficients for a blunt cone at angle of attack in wake flow.

Using these solution procedures, many calculations were made in an effort to determine both the operating limits of the methods and the effects on nonuniform flows on pressure distributions and aerodynamic coefficients for the blunted cones. For the results presented, a nose Mach number of 4.5 was used with values of A from 0 to 0.10 and for B from 0 to 1.0. Note that for the case of $A = 0$ or $B = 0$ the freestream reduces to a parallel flow at the nose conditions.

The effects of wake parameters A and B on the surface pressure distributions over sharp and blunt cones at zero angle of attack are shown in Fig. 2. The sharp cone results were obtained using the modified two-dimensional method of characteristics. From surveys of properties across the shock layer, it was found that most of the effects of the nonuniform freestream were confined near the wall where a thin entropy layer was found to exist. All results showed a strong adverse pressure gradient induced by the nonuniform freestream, and this could have a strong influence on viscous boundary-layer development over the cone.

Figure 3 shows the effects of wake flows on the windward streamline pressure distributions for various angles of attack of a 10° blunt cone. The surface pressures were integrated to compute the aerodynamic coefficients presented in Figs. 4 and 5. Figure 4 shows the results of increasing angle of attack for a given set of nose conditions and Fig. 5 shows the effects of varying parameter B for fixed angle of attack.

In conclusion, it was found that the extension of the uniform freestream solution procedures mentioned above was sufficient to treat a wide range of nonuniform flowfields. However, the method is currently limited to flowfields which are axisymmetric with respect to the spherical nose. The nonuniform nature of the freestream has a significant influence on the surface properties, and thus both stability and boundary-layer studies must account for the flow nonuniformity.

References

[1] Lomax, H. and Inouye, M., "Numerical Analysis of Flow Properties about Blunt Bodies Moving at Supersonic Speeds in an Equilibrium Gas," TR R-204, 1964, NASA.

[2] Inouye, M., Rakich, J. V., and Lomax, H., "A Description of Numerical Methods and Computer Programs for Two-Dimensional and Axisymmetric Supersonic Flow over Blunt-Nosed and Flared Bodies," TN D-2970, Aug. 1965, NASA.

[3] Rakich, J. V., "A Method of Characteristics for Steady Three-Dimensional Supersonic Flow with Application to Inclined Bodies of Revolution," TN-D5341, 1969, NASA.