If one inserts Eq. (10) into Eq. (2) and then Eqs. (2) and (5b) into Eq. (1), one sees that the pressure is almost the pressure for an axisymmetric configuration with shock $\sigma \pm \alpha$, except that the curvature used in this pressure equation is no longer the curvature K of the original shock. The curvature of this equivalent axisymmetric shock is

$$\hat{K} = K(dw/dw_1) \tag{11}$$

It would have been surprising indeed if the shock for a general body of revolution at an angle of attack α_g would be of the same shape as the axisymmetric shock of this body turned by an angle $\eta = \alpha_g - \alpha$ (that is, at an angle α), as is the case for the cone. By coordinating the shock characterized by σ and K at angle of attack α to a body at angle α_g, a more complex relationship would be expected. The relationship indicated by Eq. (11) says that the curvature on the wind side is smaller by 1− corr (corr proportional to α) than the curvature K, and the curvature on the shadowside is correspondingly larger by 1+ corr, but otherwise the equation for the pressure is the same as that for a shock $\sigma \pm \alpha$ in axisymmetric flow. If the shock of a sphere cone with cone half angle $\theta + \alpha_g$ is compared to that of a sphere cone with cone half angle θ, both in axisymmetric flow, it is seen that the curvature of the larger sphere cone is indeed smaller.

The result of the present investigation is not a solution of the problem but a suggestion to replace the problem by an axisymmetric one with a body $\theta \pm \alpha_e$. The whole investigation is restricted to small α, and, if the afterbody is conical, it is suggested that the conical relation between the effective and the geometrical angles of attack be used [see Eq. (8) in Ref. 3].

Comparison of measurements for sphere cones at angle of attack with such measurements for equivalent sphere cones at zero angle of attack shows excellent agreement with each other and with numerical calculations according to Eqs. (1–11), if based on the axisymmetric shock of the equivalent body.

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Approximate Determination of the Incompressible Flow Region in Front of a Blunt Body in Hypersonic Flow

M. A. RAHMAN*
Douglas Aircraft Company, Santa Monica, Calif.

Nomenclature

M = Mach number
μ = strength of doublet
K = ratio of specific heats
R = gas constant
T = absolute temperature

Subscripts

1 = ahead of shock
2 = behind shock

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* Associate Engineer, Missiles and Space Division.

In the case of hypersonic flow, a shock wave stands in front of the blunt body and forms a region of nearly incompressible flow around the stagnation region; the flow, behind the shock and in the vicinity of the x axis (see Fig. 1), may be assumed to be nearly uniform. In this paper an attempt is made to determine the extent of the incompressible flow region in front of a hemispherical body (two-dimensional case). The shock-detachment distance δ^{*1} is assumed to be known.

In the field of hydrodynamics,[2] popular use is made of the method of combining two flow patterns (namely, the source in a uniform flow) and of interpreting the results as the flow past a rigid body. Here a similar approach is adapted to find the flow characteristics on the cylindrical curvature of the body. Therefore, a uniform flow is superimposed on a doublet at O (see Fig. 1), and either the potential function or the stream function can be used for the solution. The author's preference is to use the stream function here.

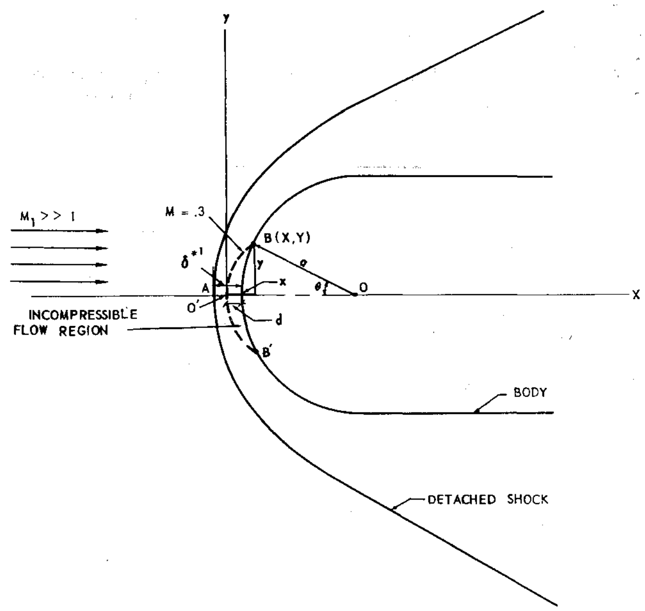

Fig. 1 Axially symmetric flow

The stream function for the combination of a doublet and a uniform flow with velocity u_2 in the positive x direction is

$$\psi = u_2 y - \mu/2\pi r^2 \cdot y \tag{1}$$

Writing $\mu = 2\pi a^2 u_2$, the stream function becomes

$$\psi = u_2 y[1 - (a^2/r^2)] = u_2[r - (a^2/r)] \sin\theta \tag{2}$$

The velocity at any point is expressed most conveniently in polar coordinates, and the radial and circumferential components are, respectively,

$$u_r = (1/r)(\partial\psi/\partial\theta) = u_2[1 - (a^2/r^2)] \cos\theta \tag{3}$$

$$u_\theta = -\partial\psi/\partial r = -u_2[1 + (a^2/r^2)] \sin\theta \tag{4}$$

On the cylindrical surface $r = a$, u_r vanishes, and the circumferential component becomes

$$u_\theta = -2u_2 \sin\theta \tag{5}$$

The equation of a circle with its center at point (r,O') and radius r is

$$(x - r)^2 + y^2 = r^2 \tag{6}$$

Now, relating the shock detachment distance δ^* with the distance d of the point O' on the x axis, where $M = 0.3$, by the empirical relation

$$\delta^*/d \approx u_2/u_2' \quad (7)$$

The sonic velocity c at O' is approximately equal to $(kgRT_2)^{1/2}$, and the Mach number is

$$M = 0.3 = u_2'/c \quad (8)$$

Using Eq. (8), the velocity u_2' is obtained, and in Eq. (7), δ^* is known and the velocity u_2 (downstream of the shock) is obtained from normal-shock relationships.[3] Thus the point O' is established by the distance d of Eq. (7). For $M = 0.3$, u_2' is equal to u_θ of Eq. (5). By use of Eq. (5), angle θ is found. Thus point $B(x,y)$ on the body is established.

In Eq. (6), the values of X and Y are known for point B. Thus the radius r of the circle through points B,O', and B', and with the center on the x axis, is found from Eq. (6).

The arc $BO'B'$ is the required line of $M = 0.3$.

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Correlation of Hypersonic Static-Stability Data from Blunt Slender Cones

JACK D. WHITFIELD* AND W. WOLNY†
ARO Inc., Arnold Air Force Station, Tenn.

CORRELATIONS of experimental hypersonic static-stability data from blunted slender cones have been obtained using simple Newtonian theory.[1] The basis for the correlation is developed in Ref. 1, and the purpose of this note is to present hypersonic static-stability data from blunt slender cones in a correlated manner suitable for use in obtaining quick, reasonably accurate predictions.

The nomenclature used is noted in Fig. 1, and the correlations of normal-force coefficients and pitching-moment coefficients are presented in Figs. 2 and 3, respectively. The correlations are based on the parametric dependence developed in Ref. 1, that is,

$$C_N \propto \alpha[2 + (\alpha/\theta_C)](1 - \xi^2)$$

and

$$C_m \propto C_N\{(2/3\theta_C)[(1 - \xi^3)/(1 - \xi^2)] - \xi[(1 - \theta_C)/\theta_C]\}$$

The correlations contain experimental data[1,2] covering a Mach number range from 8 to 22 and a bluntness ratio range from 0 (sharp) to 0.5. The Mach number "independence" of these essentially inviscid data is evident. Apparently for these cases Mach number 8 is sufficiently high to establish the limiting hypersonic static stability for these simple shapes.

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* Assistant Manager, Hypervelocity Branch, von Kármán Gas Dynamics Facility.

† Project Engineer, Hypervelocity Branch, von Kármán Gas Dynamics Facility.

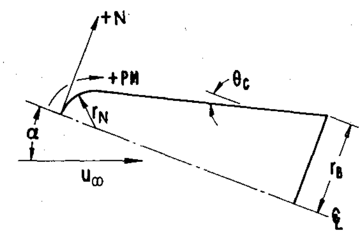

Fig. 1 Cone nomenclature

$$C_N = \frac{N}{(1/2)\,\rho_\infty U_\infty^2 S_B}$$

$$C_m = \frac{PM}{(1/2)\,\rho_\infty U_\infty^2 S_B d_B}$$

$$\xi = r_N/r_B$$

$$S_B = \pi r_B^2$$

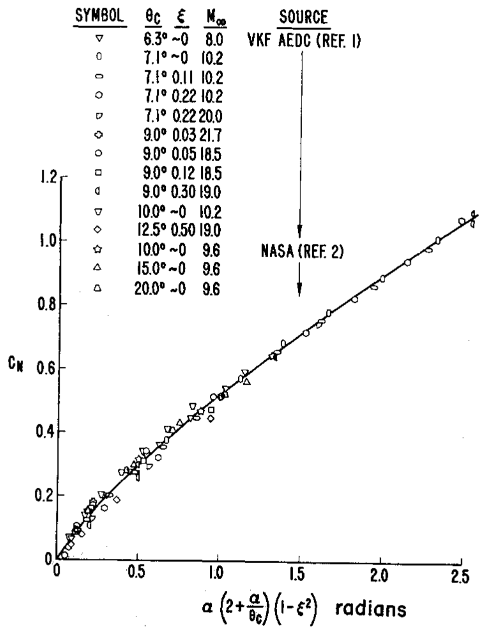

Fig. 2 Correlation of normal-force coefficients from blunt slender cones

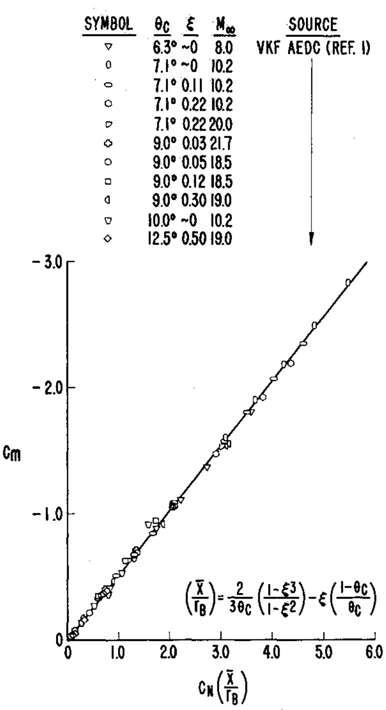

Fig. 3 Correlation of pitching-moment coefficients from blunt slender cones