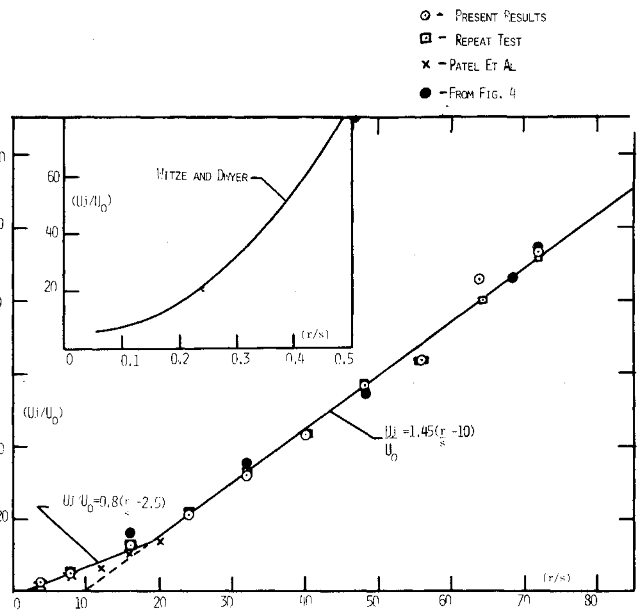

Fig. 3 Variation of centerline velocities.

high. Physically the flowfield for their impinged radial jet would be similar to the one produced by a radial free jet between two vortex rings, and boundary layer approximations will not be applicable in such a flowfield.

Conclusions

The experimental results of a turbulent radial free jet reported here show that it is possible to produce an ideal radial free jet. A necessary condition for the production of the ideal radial free jet is that the spacing between the two identical and opposing impinging jets should be quite small.

The measurements presented in this paper cover a large range of (r/s) compared to the previous investigations. From the measurements it is concluded that nondimensional mean velocity profiles within the range $4 \leq r/s \leq 72$ can be represented by an exponential function, $U/U_0 = \exp[-0.693(z/zm/2)^2]$. Furthermore, the radial jet grows linearly, with the rate of growth equal to 0.1155, and the hypothetical origin is situated on the z-axis. Also the centerline velocity varies inversely with the radial distance, i.e., $U_0 \propto 1/r$. It appears that below $r/s \simeq 18$ the variation of the centerline velocity is given by $U_j/U_0 = 0.8(r/s - 2.5)$ and above $(r/s) = 18$ it is given by $U_j/U_0 = 1.45\,(r/s - 10)$. Clearly around $(r/s) = 18$ the rate of decay of the centerline velocity changes, and this may be due to the presence of the core region and the initial boundary layers in the nozzles. The length of the nozzles appears not to have affected the measurements.

Acknowledgment

The author wishes to thank H. Halfan and A. K. Mureithi for conducting the experiments.

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Hysteresis Zone or Locus—Aerodynamic of Bulbous Based Bodies at Low Speeds

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IN Ref. 1, Ericsson and Reding discuss problems associated with measuring the one-degree-of-freedom damping in pitch $(C_{mq} + C_{m\dot{\alpha}})$ on slender axially symmetric bodies. In particular, they cite problems of hysteresis in data obtained from tests of cones with hemispherical bases shown in Figs. 5 and 6 of Ref. 1. This hystersis is a generalization of their earlier work,[2] where it is argued that interaction between the rear wake and a bulbous base causes the damping in pitch derivative to change sign and hence to have a destabilizing tendency. In these references, the idea of a hysteresis loop is introduced. The point of the presentation in Ref. 1 is to help the analyst to decide whether or not the aberration in the data is real or is facility induced. We are adding some data here which, unfortunately, compound the dilemma rather than clarifying it. The dilemma is compounded because the data suggest that a well-defined hysteresis locus does not seem to exist. Rather, if the experiment is repeated several times, the entire hysteresis region seems to fill with data rather than trace out a specific hysteresis locus. Consequently, one rather suspects that the phenomenon is governed by the whim of the fluid to separate. In this respect, the problem is rather like that reported by Lamont and Hunt.[3] Additional data show that a roughened body or a dummy sting causes a support interference that tends to reduce the hysteresis zone to a smaller, sometimes negligible region.

Figures 1 and 2 show normal force coefficient and pitching moment coefficient for a magnetically suspended bulbous base cone when a sting is near the base. The sting is either aligned with the cone axis or is 1 or 2 deg below it. The data are generally well behaved although they suggest that the linear region is relatively ill defined. Also shown on these figures is a zone where the data are not unique. This lack of uniqueness is attributed to unsteady separation from the bulbous base. Note, however, this is relatively small, extending over ½ deg or less.

Reference 4 presents data on the aerodynamic characteristics of several magnetically suspended bulbous or partially bulbous based cones. Figures 3 and 4 show that the presence of a sting caused a well-defined lift and moment coefficient curve, while in the absence of a sting a small hysteresis zone exists. The hysteresis zone is hatched in. No data were presented at the zero angle of attack point because the model motion was considered excessive. Figure 5 shows the lift coefficient again with and without a tripped boundary layer, and with no sting. The hatched hysteresis zone corresponds to that given in Fig. 3. The hysteresis zone for laminar flow is outlined by the dash-dot line. The arrows show the direction of the sequence of points, up or down. The lack of symmetry is believed due to an insufficient amount of data. Figures 6 and 7 show the same sort of effect on pitching moment and drag coefficient, although the hysteresis zones are more symmetric.

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Index categories: Jets, Wakes, and Viscid-Inviscid Flow Interactions; Aerodynamics; LV/M Dynamics and Control.

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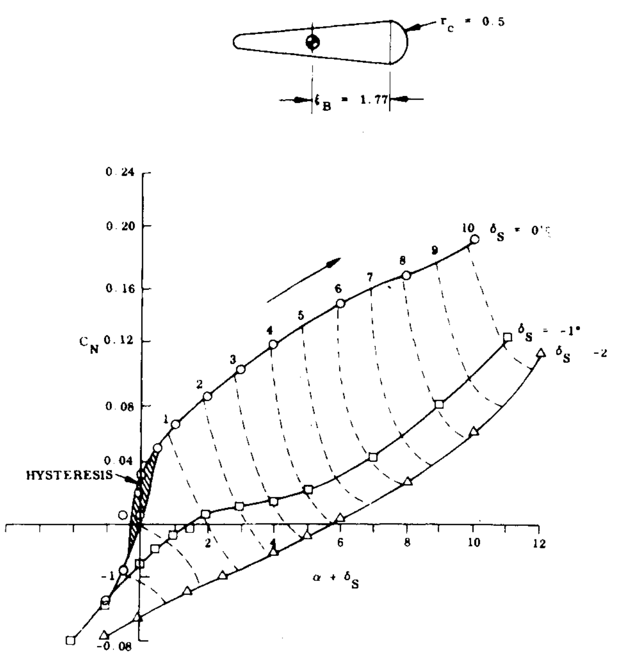

Fig. 1 Normal force coefficient for magnetically-suspended bulbous base cone with sting at angle δ_s.

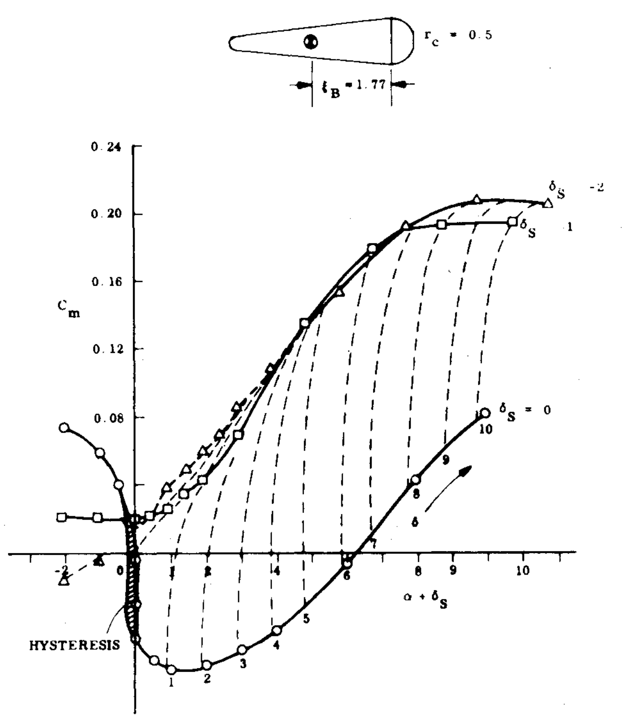

Fig. 2 Pitching moment coefficient for a magnetically-suspended bulbous base cone with sting at angle δ_s.

In retrospect, one regrets that side force and yawing moment were not recorded, for that would suggest lateral asymmetry in the separation as well, if present.

The point of this Note is to suggest that the separation locus is not present on bulbous bases even in steady flow. In a dynamic situation the separation may be coupled to the motion such that the motion is effected. Thus data obtained on an oscillating model even at low reduced frequencies may be well defined but when applied to arbitrary motion lead to less accurate results than desired.

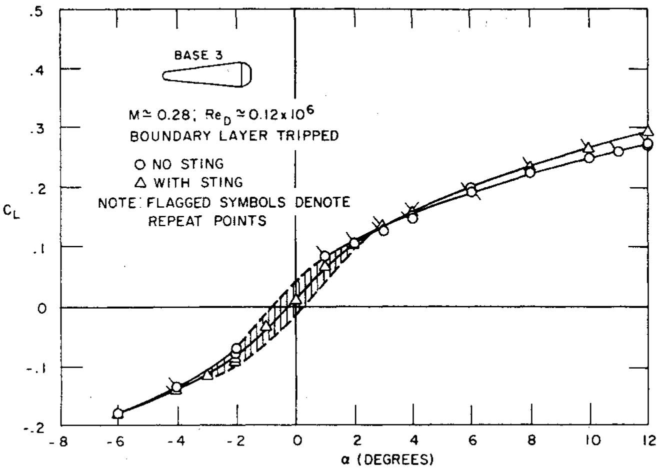

Fig. 3 Effects of sting interference on the lift coefficient vs angle of attack.

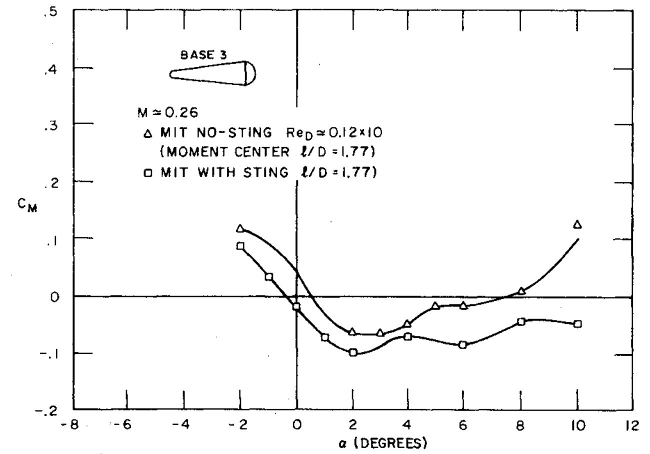

Fig. 4 Effects of sting interference on the pitching moment coefficient vs angle of attack.

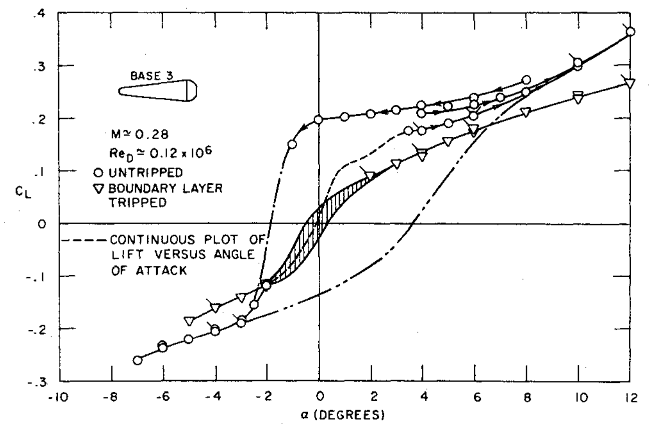

Fig. 5 Effect of boundary-layer trip and lift coefficient vs angle of attack without sting.

Acknowledgment

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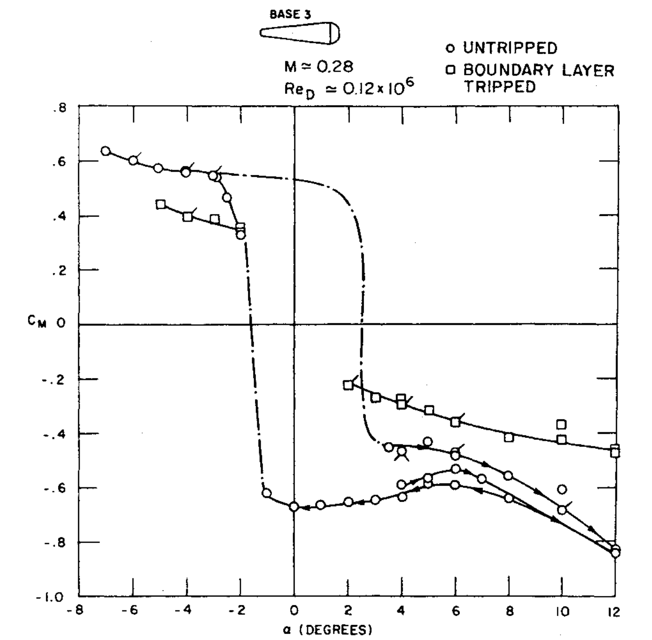

Fig. 6 Effect of boundary-layer trip on pitching moment coefficient vs angle of attack without sting.

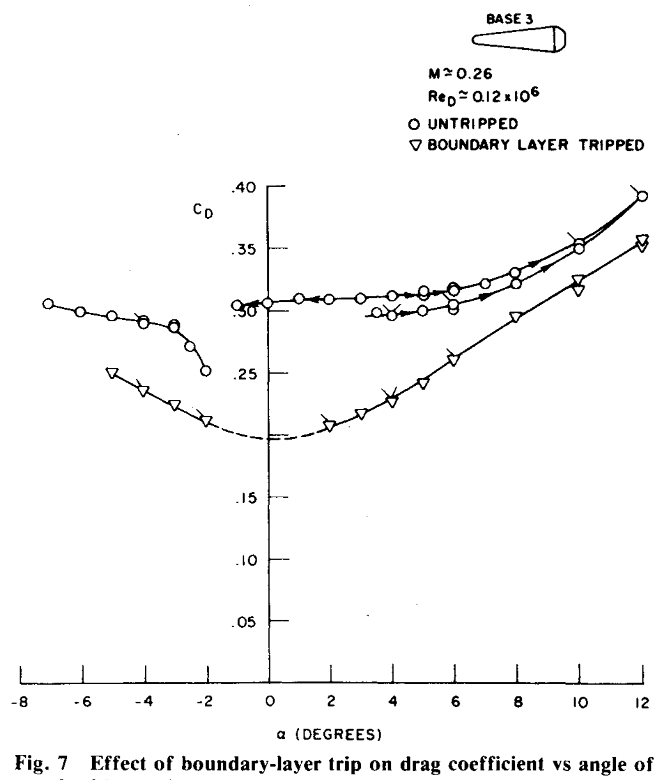

Fig. 7 Effect of boundary-layer trip on drag coefficient vs angle of attack without sting.

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Matching Procedure for Viscous-Inviscid Interactive Calculations

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Introduction

In this Note, we describe a procedure for coupling a viscous boundary-layer calculation with a solution of the Euler equations. The interaction between the viscous calculation and the rotational inviscid calculation is accomplished by means of an iterative process. An iterative approach to the subsonic interaction problem is not uncommon; several researchers have used this approach in conjunction with the displacement thickness concept[1] to obtain better approximations to flows (e.g., Refs. 2 and 3). However, the present interactive method differs from these procedures in two ways. First, the present method does not rely solely on the mechanism of a physical displacement of the outer flow streamlines by the viscous layer to achieve coupling of the viscous and inviscid calculations. The interaction takes the form of an injection at solid surfaces, but it is different from the usual equivalent source distribution technique in that this injection has a momentum and enthalpy character. Second, the viscous solution is constructed in a manner suggested by the theory of matched asymptotic expansions. In order to illustrate the operation of this procedure more clearly, we discuss the specific case where the inviscid solution is an explicit time-marching, finite-difference calculation (e.g., MacCormack's method[4]). However, the applicability of the method is not restricted to this choice.

Interactive Procedure

Consider a portion of the flowfield in the neighborhood of an impermeable wall (Fig. 1). The Euler equations for steady flow may be written in the vector form:

$$\frac{\partial F}{\partial x}+\frac{\partial G}{\partial y}=0 \tag{1}$$

where

$$F=\begin{bmatrix} \rho u \\ \rho u^2+p \\ \rho uv \\ u(e+p) \end{bmatrix} \qquad G=\begin{bmatrix} \rho v \\ \rho uv \\ \rho v^2+p \\ v(e+p) \end{bmatrix}$$

Also, the steady Navier-Stokes equations may be written in the vector form:

$$\frac{\partial f}{\partial x}+\frac{\partial g}{\partial y}=0 \tag{2}$$

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