Stability Coefficients of a Missile at Angles of Attack

Alfred M. Morrison*
Naval Surface Weapons Center, White Oak Laboratory, Silver Spring, Md.

and

Charles W. Ingram†
Systems Research Laboratories, Inc., Dayton, Ohio

Nomenclature

C_m = moment/Qsd, static moment coefficient
C_{m_α} = $\partial C_m/\partial\alpha$, static stability coefficient, rad^{-1}
$C_{m_q}+C_{m_{\dot\alpha}}$ = $\partial C_m/\partial(qd/2V)+\partial C_m/\partial(\dot\alpha d/2V)$, damping stability coefficient, rad^{-1}
Q = dynamic pressure, lb/ft^2
s = $\pi d^2/4$, *reference area, ft*^{2}
d = model diameter, ft
V = velocity, fps
α = angle of attack, deg

Introduction

THE current trend in maneuverable missile development has created an interest in the nonlinearity of the stability coefficients with angle of attack for high-fineness ratio, finned missiles. New wind-tunnel testing techniques[1] and flowfield analyses[2] are being undertaken. To validate these new procedures, comparisons are being made with the Basic Finner configuration.[2] The Basic Finner, Fig. 1, has been selected by the Supersonic Tunnel Association and AGARD as a standard research configuration for the evaluation of new testing and analysis techniques.

In this regard the static and damping stability coefficients for a Basic Finner model are presented as obtained from supersonic wind-tunnel tests.[3] These coefficients will supplement the currently available data.[4-8]

The stability coefficients presented in this note were determined for angles of attack from 0 to 20 degrees, at a Mach number of 1.5. The fineness ratio (length/diameter) was 10. A standard free-oscillation wind tunnel testing technique[6] was used to obtain the angular performance data. This technique employs a strut or side mount, and the model was free to oscillate in the pitch plane.

A nonlinear data analysis procedure[9] was used to extract the variation of the pitching and damping stability coefficients, C_{m_α} and $C_{m_q}+C_{m_{\dot\alpha}}$, respectively, with angle of attack.

Discussion

C_{m_α} and $C_{m_q}+C_{m_{\dot\alpha}}$ as functions of α are presented in Figs. 2 and 3. The uncertainty of C_{m_α} was $\pm 5\%$ and $C_{m_q}+C_{m_{\dot\alpha}}$ was $\pm 11\%$ as determined from the repeatability of the test data. Good agreement was obtained at low α with the ballistic range and wind-tunnel tests of Refs. 4 and 6, respectively. However, small differences do exist; this is due to the slight center of gravity variations of the various models used. The nonlinear variations of C_{m_α} and $C_{m_q}+C_{m_{\dot\alpha}}$ with α are consistent with the results of Refs. 1 and 8, i.e., C_{m_α} shows a reduction in static stability with increased α, while $C_{m_q}+C_{m_{\dot\alpha}}$ shows increased damping stability. Magnitude variations are apparent, resulting from the differences in the Mach numbers of the various tests. It is felt that this data will extend the angle-of-attack range of available stability coefficients for finned missiles, and contribute to a better understanding of missiles at high angles of attack.

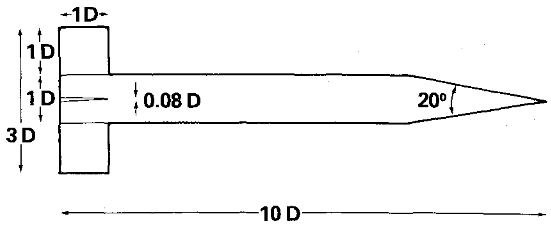

Fig.1 The Basic Finner model.

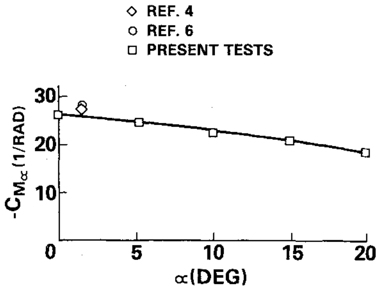

Fig.2 Static stability coefficient, C_{m_α}.

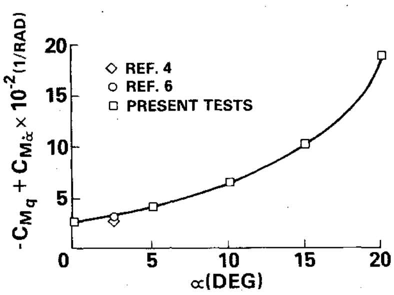

Fig.3 Damping stability coefficient, $C_{m_q}+C_{m_{\dot\alpha}}$.

Received Oct. 10, 1975; revision received Feb. 23, 1976.
Index categories: LV/M Simulation; LV/M Dynamics and Control.
*Aerospace Engineer, Experimental Aerodynamics Branch. Formerly Graduate Research Assistant, University of Notre Dame. Member AIAA.
†Senior Scientist, Aerosystems Research Division. Formerly Assistant Professor, University of Notre Dame. Member AIAA.

References

[1] Jenke, L.M., "Recently Developed Techniques for Obtaining Pitch and Roll Damping Characteristics of Missiles at High Angles of Attack," ARO, Inc., NASA/Military Industry Missile Aerodynamic Workshop, Washington, D.C., May 1975.

[2] Fidler, J.E. and Bateman, M.C., "Aerodynamic Methods for High Incidence Missle Design,"*Journal of Spacecraft and Rockets*, Vol. 12, March 1975, pp. 162-168.

[3] Morrison, A.M., "On Obtaining the Supersonic Free-Angular Motions and Nonlinear Stability Coefficients of Finned Bodies," PH.D. dissertation, June 1972, University of Notre Dame, Notre Dame, Ind.

[4] Nicolaides, J.D. and MacAllister, L.D., "A Review of Aeroballistic Range Research on Winged and/or Finned Missiles, " U.S. Navy Symposium on Aeroballistics, Laurel, Md., Oct. 1954.

[5] MacAllister, L.C., "The Aerodynamic Properties of a Simple Non-Rolling Finned Cone-Cylinder Configuration Bewteen Mach Numbers 1.0 and 2.5," Ballistic Research Laboratory, Aberdeen Proving Ground, BRL Report No. 934, Md., May 1955.

[6] Shantz, I. and Groves, R.T., "Dynamic and Static Stability Measurements of the Basic Finner at Supersonic Speeds," Naval Surface Weapons Center, White Oak Laboratory, NAVORD Report 4516, Jan. 1960.

[7] Regan, F.J., "Roll Damping Moment Measurements for the Basic Finner at Subsonic and Supersonic Speeds, "Naval Surface Weapons Center, White Oak Laboratory, NAVORD March 1964.

[8]Nicolaides, J.D., Eikenberry, R.S., Ingram, C.W., and Clare, T.A., "Flight Dynamics of the Basic Finner in Various Degrees of Freedom," Air Force Armament Laboratory, Eglin Air Force Base, Fla., AFATL-TR-68-82, July 1968.

[9]Eikenberry, R.S., "Analysis of the Angular Motion of Missiles," Sandia Labs., Albuquerque, M.M., SC-CR-70-6051, Feb. 1970.

Rear Stagnation Point Location in a Subsonic Near-Wake

R.A. Merz*
Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio
and
R.H. Page† and C.E.G. Przirembel‡
Rutgers University, New Brunswick N.J.

Nomenclature

x = axial distance from base (positive: downstream)
$x_{s.p.}$ = location of rear stagnation point
D = model diameter
d = probe diameter
M_l = approach Mach number
C_p = pressure coefficient

Introduction

NUMEROUS experimental investigations of axisymmetric near-wakes have shown that the low-pressure recirculation region associated with blunt based vehicles contributes to the total drag of the body. This contribution may be significant depending on the geometry of the vehicle and its speed. A knowledge of near-wake phenomena is essential for reentry vehicle design, since it is this region that provides the initial deceleration of the body. In addition, the near-wake structure determines the configuration of the far-wake. Information concerning both of these regions of flow is necessary for the successful deployment of any parachute and for determining its inflation-drag and -stability, drag efficiency and structural loading. All these data must be known to accomplish a soft landing.

Over the past thirty years, there have been many experimental investigations of the wakes of various axisymmetric bodies and a number of theoretical analyses. Rather complete literature reviews of the available data may be found in Refs. 1-3. From these reviews, it can be seen that there is a paucity of consistent, reliable experimental data in the subsonic speed range. It is in light of this fact that the results contained in this Note are presented.

The extent of the near-wake region is very important to the design of decelerator systems and theoretical wake analyses. One wake characteristic which is dependent on the freestream Mach number and describes the size of the near-wake is the location of the time averaged, rear stagnation point. Attempts in the past to locate this point as a function of Mach number in subsonic flows have been hampered by the presence of a sting or other model support devices and by probe interference effects. This Note presents some recent data where these effects have been eliminated.

Received Sept. 11, 1975; revision received March 2, 1976. Research jointly sponsored by the Emil Buehler Fund and Rutgers University.

Index categories: Jets, Wakes, and Viscid-Inviscid Flow Interactions; Entry Vehicle Testing; Subsonic and Transonic Flow.

*Instructor, Aero-Mechanical Engineering Department. Member AIAA.

†Professor and Chairman, Mechanical, Industrial and Aerospace Engineering Department. Associate Fellow AIAA.

‡Associate Professor, Mechanical, Industrial and Aerospace Engineering Department. Member AIAA.

Apparatus and Procedure

A series of tests were conducted in a second-generation Rutgers Axisymmetric Near-Wake Tunnel (RANT II).[1] This tunnel was designed and constructed for interference-free studies of turbulent axisymmetric near-wakes at subsonic speeds. As shown in Fig. 1, the unique feature of RANT II is an upstream sting which was designed as an integral part of the nozzle to produce uniform flow over a 1.9-cm diam cylindrical model. RANT II is an open jet, blowdown type tunnel capable of producing speeds over the entire subsonic Mach number range. The nozzle has an overall contraction ratio of 8:1 and an exit diameter of 10.16 cm. Reynolds numbers for the tests varied from 0.1×10^7 per meter to 3.1×10^7 per meter. Stagnation pressures varied from just above atmospheric pressure to 206 kPa absolute, while the stagnation temperature was 283 K $\pm$ 11 K. Velocity profiles of the boundary layer approaching the blunt base showed that it was turbulent and fully developed for all approach Mach numbers.

A stagnation point may be characterized as a point in a flowfield where the static and total pressures are equal (that is the dynamic pressure equals zero). For an axisymmetric body, one such point occurs on the centerline at the downstream limit of the near-wake. Figure 2 shows a schematic of the flow model. To locate this point, total and static pressures on the near-wake centerline were measured by extending either a pitot probe or a static probe from the blunt base through a hole in the center of the base. Both probes consisted of a straight piece of stainless steel tubing with an o.d. of 0.89 mm and an i.d. of 0.61 mm. The tip of the pitot probe was open and rounded while the static tube had a tip which was plugged and rounded. The static probe had an orifice 0.56 mm in diameter located on the side wall of the probe 0.60 cm from the tip. The location of both probes was changed by manually sliding them in or out of the base. The position of each was measured with a precision scale readable to 0.25 mm. The pressure sensed by the probes was measured with a water manometer readable to 0.13 cm of water.

In addition to the probe pressure, the base pressure was measured to monitor the basic flow. No change in base pressure was observed during the centerline surveys. This was

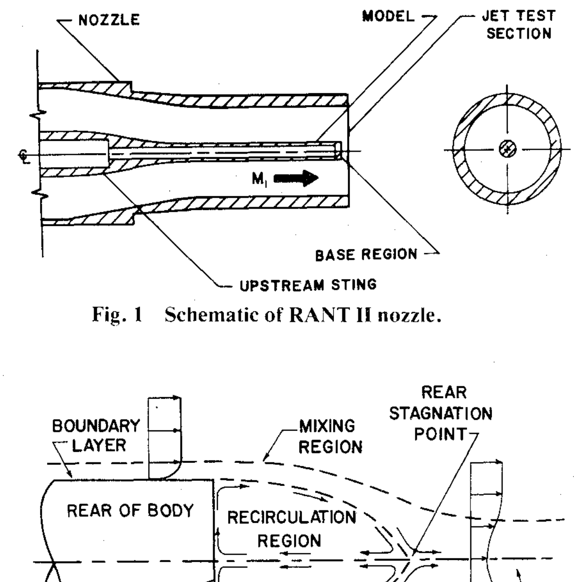

Fig. 1 Schematic of RANT II nozzle.

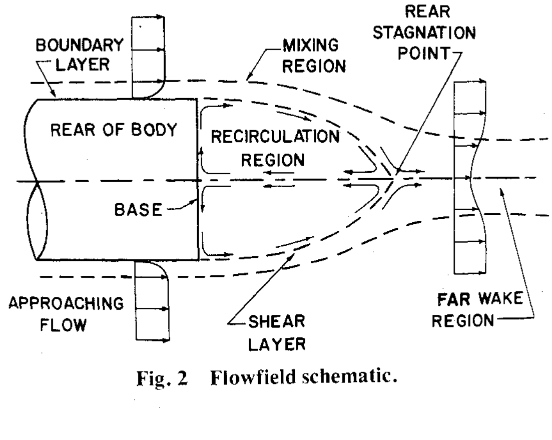

Fig. 2 Flowfield schematic.