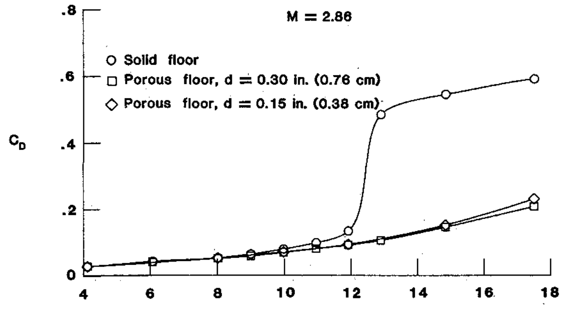

Fig. 6 Effect of porosity in forward and aft sections of cavity floor.

Results

Figure 5 shows results obtained at $M = 2.86$, which were typical of the results obtained at the other Mach numbers. The solid floor data show the typical large drag increase as the cavity flowfield switches from open to closed cavity flow at $l/h \approx 12$. In comparison, the porous floor eliminated the large drag increase for $l/h \gtrsim 12$, suggesting that the flowfield is probably typical of open cavity flow. The chamber height had no effect on the porous floor cavity drag for $l/h \lesssim 12$ and still had a minimal effect for $l/h \gtrsim 12$, although the effect is becoming greater as l/h increases.

Data were also obtained with adhesive tape covering the porous floor symmetrically about the cavity midlength to determine if the porosity near the cavity midlength had a significant effect on the cavity flowfield. Figure 6 shows data for a cavity with $l/h = 17.5$ at $M = 2.86$. The results show a steady decrease in the cavity drag as the percentage of floor area with porosity increases. The solid floor cavity drag was reduced by half when approximately 35% of the floor area was porous. When more than 50% of the floor area was porous, the additional drag reduction obtained was small. Therefore, the porosity near the cavity midlength does not significantly effect the cavity flowfield, i.e., porosity on the forward and aft sections of the cavity floor have the largest effect. This suggests the possibility that other methods (e.g., an array of tubes) could be used to transport the high-pressure air at the rear of the cavity directly to the low-pressure region at the forward part of the cavity and still obtain the same results as the porous floor.

In summary, it has been experimentally shown that a passive venting system can be employed to control cavity flowfields at supersonic speeds. Specifically, the passive venting system has been used to extend the l/h value before the onset of high drag-producing closed cavity flow.

References

[1]Stallings, R.L., Jr. and Wilcox, F.J., Jr., "Experimental Cavity Pressure Distributions at Supersonic Speeds," NASA TP-2683, June 1987.

[2]Kaufman, L.G. II, Maciulaitis, A., and Clark, R.L., "Mach 0.6 to 3.0 Flows Over Rectangular Cavities," AFWAL-TR-82-3112, 1983.

[3]Charwat, A.F., Roos, J.N., Dewey, F.L., Jr., and Hitz, J.A., "An Investigation of Separated Flows—Part I: The Pressure Field," *Journal of Aeronautical Sciences,* Vol. 28, No. 6, June 1961, pp. 457-470.

[4]McDearman, R.W., "Investigation of the Flow in a Rectangular Cavity in a Flat Plate at a Mach Number of 3.55," NASA TND-523, 1960.

[5]Blair, A.B., Jr., and Stallings, R.L., Jr., "Supersonic Axial-Force Characteristics of a Rectangular-Box Cavity with Various Length-to-Depth Ratios in a Flat Plate," NASA TM-87659, April 1986.

[6]Stallings, R.L., Jr., "Store Separations from Cavities at Supersonic Flight Speeds," *Journal of Spacecraft and Rockets,* Vol. 20, March–April 1983, pp. 129-132.

[7]Bahi, L., Ross, J.M., and Nagamatsu, H.T., "Passive Shock Wave/Boundary Layer Control for Transonic Airfoil Drag Reduction," AIAA Paper 83-0137, Jan. 1983.

[8]Nagamatsu, H.T., Orozco, R.D., and Ling, D.C., "Porosity Effect on Supercritical Airfoil Drag Reduction by Shock Wave/Boundary Layer Control," AIAA Paper 84-1682, June 1984.

Base Cavity at Angles of Incidence

Mauri Tanner*
DFVLR—Institute for Theoretical Fluid Mechanics, Göttingen, Federal Republic of Germany

I. Introduction

It is known from several investigations that a base cavity can increase the base pressure and thus decrease the base drag in axisymmetric flow (see Refs. 1-3). However, as far as the author knows, there exist no published results on the effectiveness of a base cavity at angles of incidence. By investigating the influence of tail surfaces on base pressure, some results for a base cavity at angles of incidence were also obtained. These will be given in this paper.

II. Experimental Setup

The measurements were performed in the Transonic Wind Tunnel at Göttingen, which has a test section with a square cross section of 1×1 m^2. The Mach number range is $M_\infty = 0.5$–2.2. The model was an axisymmetric cylinder with an ogival forebody. Its diameter was $D = 45$ mm and its total length $L = 13\,D = 585$ mm. The ogival nose had a length of 1.5 $D = 67.5$ mm. The length of the cylindrical part of the model was, therefore, 11.5 $D = 517.5$ mm. The model was mounted in the wind tunnel by using a sideward strut.

The base cavity used in these measurements has a depth of $T/D = 1.2$. The pressure was measured at eight orifices of 0.6-mm diameter at the bottom of the cavity. On the normal base without a cavity, the pressure was also measured at eight orifices of 0.6-mm diameter. The mean value of these local pressures was denoted as base pressure.

The measurements were performed at Mach numbers from 0.5–1.0. The Reynolds number based on the cylinder diameter was $Re_D = 3.4 \times 10^5$. The angle of incidence had values from $\alpha = 0 - 25$ deg.

III. Results

In Fig. 1, the increase of the base pressure coefficient Δc_{pB} due to the cavity is shown for all Mach numbers investigated at the angle of incidence $\alpha = 0$ deg. The quantity Δc_{pB} is defined by

$$\Delta c_{pB} = (c_{pB})_c - (c_{pB})_n \tag{1}$$

with $(c_{pB})_c$ as the base pressure coefficient for the cavity base and $(c_{pB})_n$ as the base pressure coefficient for the normal base without a cavity. One can see that the base pressure coefficient for all Mach numbers is greater for the cavity base than for the base without a cavity. At $M_\infty = 0.50$, the difference is $\Delta c_{pB} = 0.012$, or about 10% of the base pressure coefficient at the normal base. The increase of the base pressure due to the cavity is smaller for the higher Mach numbers. At $M_\infty = 1.00$, it amounts only to $\Delta c_{pB} = 0.006$, which is about 3.4%.

The investigations of Compton[1] show that the largest increase of the base pressure coefficient due to a base cavity amounts to $\Delta c_{pB} = 0.01$–0.02 at Mach numbers from $M_\infty = 0.3$–1.3. Our new results lie at the lower limit of the values given by Compton.

Morel[2] thoroughly investigated the influence of a base cavity on the base pressure at zero angle of incidence. The base cavities used by Morel had six different depths, namely $T/D = 0.10$, 0.20, 0.35, 0.50, 0.70, and 0.90 (compared with $T/D = 1.20$ as used in the present investigation). The Mach number was $M_\infty = 0.11$, and the Reynolds number based on

Received Feb. 26, 1987; revision received May 8, 1987.

*Research Scientist.

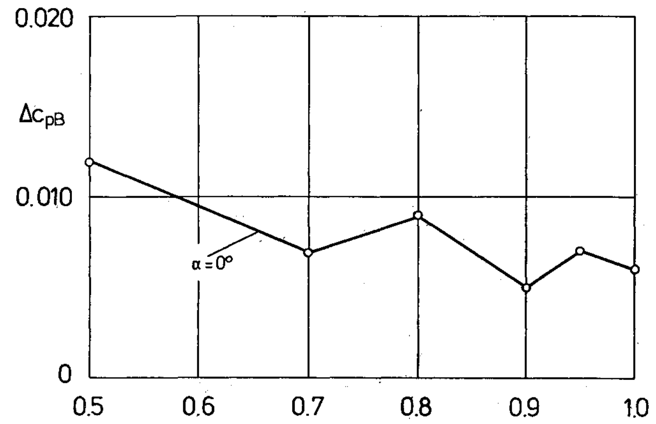

Fig. 1 The quantity Δc_{pB} as function of Mach number at $\alpha = 0$ deg.

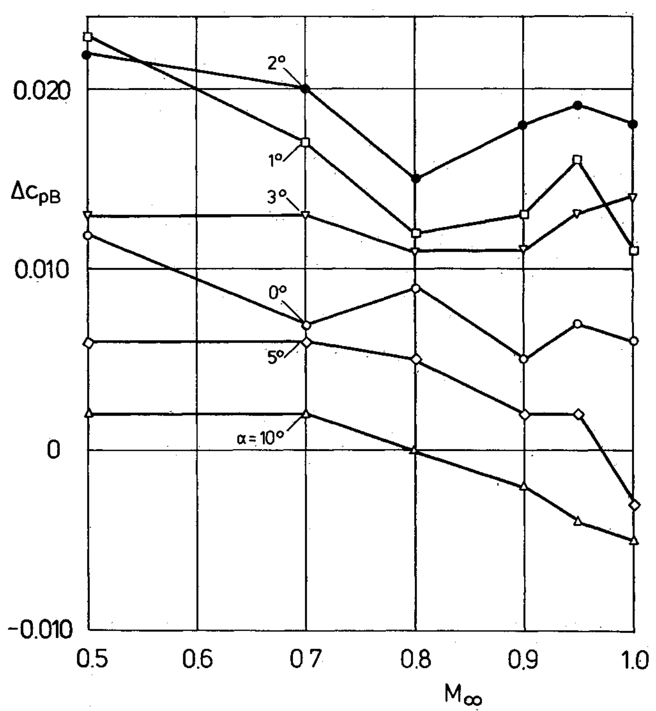

Fig. 2 The quantity Δc_{pB} as function of Mach number at several angles of incidence.

the cylinder diameter was $Re_D = 94{,}000$. The results show that Δc_{pB} depends on the depth of the cavity attaining a maximum value at $T/D \simeq 0.35$ with $\Delta c_{pB} \simeq 0.028$. The increase of the base pressure due to the cavity then decreases when T/D becomes larger. There was an approximately linear dependence between Δc_{pB} and T/D for $T/D > 0.35$. When one extrapolates the results of Morel up to $T/D = 1.20$, one gets $\Delta c_{pB} \simeq 0.014$, which agrees well with the value $\Delta c_{pB} = 0.012$, as measured by the present author for $M_\infty = 0.50$.

In Fig. 2, results are plotted for the angles of incidence $\alpha = 0$, 1, 2, 3, 5, and 10 deg. One can see that the base cavity at $\alpha = 1$ deg has a greater influence on the base pressure than at $\alpha = 0$ deg. The effect is again greatest for the Mach number $M_\infty = 0.50$ ($\Delta c_{pB} = 0.023$) and decreases with increasing Mach number. For $M_\infty = 1.00$, $\Delta c_{pB} = 0.011$ or approximately half the value at $M_\infty = 0.50$.

At the angle of incidence $\alpha = 2$ deg, the base cavity has the largest influence on the base pressure. The results in Fig. 2 show this clearly. The smallest value of Δc_{pB} ($= 0.015$) is attained at $M_\infty = 0.80$. All the other values are higher.

The results for $\alpha = 3$ deg show that the base cavity now has a smaller influence on the base pressure than for $\alpha = 2$ deg. At this angle of incidence, Δc_{pB} is practically independent of the Mach number.

At $\alpha = 5$ deg, the base cavity has only a small influence on the base pressure, which for $M_\infty = 0.50$ amounts to 3.5%. At the Mach number $M_\infty = 1.00$, the base pressure of the cavity base is smaller (and the base drag greater) than that of the normal base. The difference is very small, however, only about −1%.

For $\alpha = 10$ deg, one recognizes that at this angle of incidence, the base cavity has practically no more influence on the base pressure. This is also true for the results, which were obtained at the greater angles of incidence $\alpha = 15$, 20, and 25 deg. At $\alpha = 10$ deg and $M_\infty = 1.00$, $\Delta c_{pB} = -0.005$, which means that c_{pB} is 1.7% smaller for the cavity base than for the base without a cavity.

References

[1]Compton, W.B. III, "Effect on Base Drag of Recessing the Bases of Conical Afterbodies at Supersonic and Transonic Speeds," NACA TN D-4821, 1968.

[2]Morel, T., "Effect of Base Cavities on the Aerodynamic Drag of an Axisymmetric Cylinder," *Aeronautical Quarterly*, Vol. 30, 1979, pp. 400–412.

[3]Viswanath, P.R., "Investigation of Passive Devices for Axisymmetric Base Drag Reduction at Transonic Speeds," TM AE 8506, National Aeronautical Laboratory, Bangalore, India, 1985.

New Approach to the Analysis and Control of Large Space Structures

G. Adomian*
General Analytics Corporation, Roswell, Georgia

Introduction

THE development of orbiting space stations will present very difficult problems of thermal and structural analysis because of the severe requirements posed by large sizes, low weight, high stiffness, and minimum mechanical and thermal distortion. Such distortions must be kept within very close tolerances of the order of millimeters.

The equations involved depend, of course, upon the particular designs, orbital positioning thrusts, atmospheric drag, gravity force, vibration, and heating and cooling from the sun, Earth, and electronic equipment. They will be nonlinear and, generally, stochastic as well because of uncertainties and thermally and mechanically induced vibrations. Usual solution methods leave much to be desired, as is well known. Recent work,[1–4] however, provides methods that can show analytic dependences, minimize computation, and provide physically realistic solutions not obtainable by usual methods, and are applicable to algebraic ordinary or partial differential and integrodifferential equation systems with composite nonlinearities, stochastic parameters, retarded effects, and complex initial-boundary conditions that can be nonlinear, stochastic, or even coupled. Applications to multidimensional nonlinear stochastic control problems relevant to large structures in orbit are being considered.

Our objective is realistic solution of the nonlinear systems of equations that arise in the modeling of such problems. Realistic solution means solution of the problem *as it is*, rather than changing the problem to make it easily solvable. Thus, perturbation, linearization, assumptions of weak nonlinearity, small

Received Oct. 3, 1986.

*Senior Research Scientist.