Engineering Notes

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Effect of Base Suction on Subsonic Drag of Bluff Bodies

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Introduction

AS a result of rising fuel costs, the subsonic base drag of bluff bodies has taken on new importance. One of the most promising techniques for reducing subsonic base drag is mass injection into the wake or base bleed. Base bleed has been studied by Wood,[1,2] Bearman,[3] Leal and Acrivos,[4] and Sykes.[5] Using base bleed, reductions in the base drag of 50% have been achieved.

Mass removal from the wake or base suction apparently would increase the drag, and thus base suction has not been carefully investigated. Tests at low suction rates conducted by Bearman[3] and Przirembel and Riddle[6] show moderate drag increases due to base suction. Cornish[7] however, has used flow visualization techniques to show that base suction can be used as a means of flow control. In his experiments, base suction was used to to trap the "shed" vortex at the base thereby preventing vortex shedding and the subsequent formation of the wake. Since as much as 90% of the base drag is due to shed vorticity in the wake,[1] sizeable reductions in base drag should result from this vortex trapping.

This Note describes a series of experiments which were conducted to determine if base suction could cause a reduction in subsonic base drag.

Experiment

The experiments were performed in a low-speed wind tunnel. The test section of the tunnel was approximately 0.4 m × 0.3 m × 0.6 m long. Maximum airspeed in the tunnel was 80 m/s, and the turbulence level was known to be less than 1%.

Two models were tested. The first (Fig. 1) was a truncated elliptical section similar to that used by Wood.[1] This model extended across the test section to produce a two-dimensional flow situation. The second model (Fig. 2) was a "quarter-football" model. This model was tested in close proximity to a ground plane installed in the tunnel. Three suction ports were cut into the base of each model. These ports were connected to a plenum chamber inside the model. The chamber then was connected to a suction pump outside the tunnel by means of a duct built into the balance system.

The balance used was specially designed to measure drag and could detect forces as small as 0.05 N. Because a drag balance was used, the drag measured included skin friction and profile drag as well as the base drag of the model.

In the experiments the drag coefficient was measured as a function of suction coefficient for constant Reynolds number. The coefficients were defined as

$$C_D = D/\tfrac{1}{2}\rho V^2 A_b \tag{1}$$

$$C_Q = Q/VA_p \tag{2}$$

$$Re = Vh/\nu \tag{3}$$

where ρ, V, and ν are the density, velocity, and kinematic viscosity in the freestream, A_b is the base area of the model, A_p is the total area of the suction ports, h is the geometric mean base height of the model, and Q is the measured volumetric flow rate through the suction ports. The suction coefficient defined by Eq. (2) is the negative of the base bleed coefficient used in Refs. 1-3.

Results

The results of the measurements are shown in Figs. 3-6. In all cases there is apparently no Reynolds number effect on the drag.

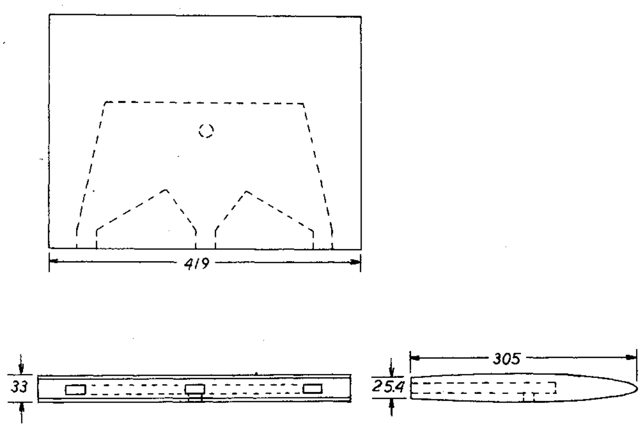

Fig. 1 Two-dimensional flow model (dimensions are in mm).

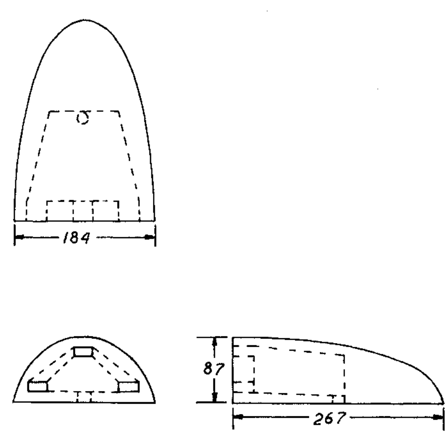

Fig. 2 Three-dimensional flow model (dimensions are in mm).

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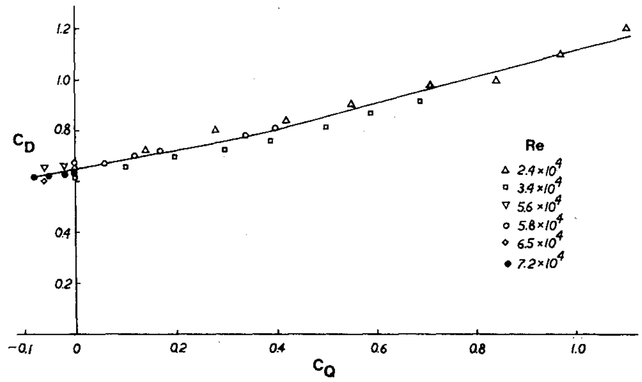

Fig. 3 Effect of suction on drag of two-dimensional model.

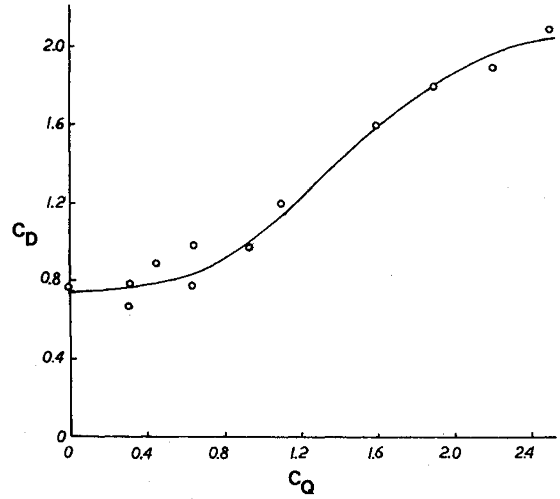

Fig. 4 Effect of high suction coefficients on two-dimensional model, $Re = 1.1 \times 10^4$.

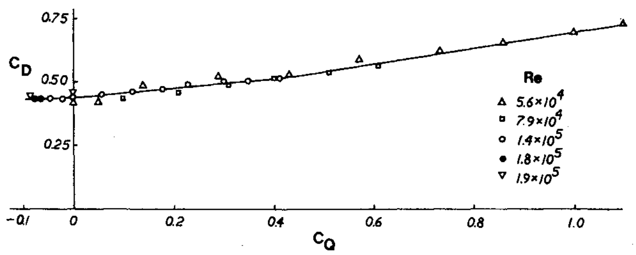

Fig. 5 Effect of suction on drag of three-dimensional model.

For the two-dimensional model, a steady increase in drag coefficient resulted as the base suction rate increased (Fig. 3). Base bleed, i.e. negative C_Q, did result in a decrease in drag, but the reduction was less than that reported by Wood. Suction coefficients larger than 1 could only be obtained for the lowest Reynolds numbers. For the two-dimensional model, the drag continues to increase for $C_Q > 1$ but at a decreasing rate (Fig. 4).

The drag coefficient for the three-dimensional model (Fig. 5) is lower than for the two-dimensional case, since the three-dimensional model has a smaller surface area relative to its base area. Thus the skin friction contribution is much less for the three-dimensional model. Again base suction causes a drag increase but at a lower rate for suction coefficients less than 1. However, for higher values of C_Q (Fig. 6) the drag increases more rapidly than for the two-dimensional model.

Conclusion

These tests show that base suction always results in a drag increase. However, at the Reynolds numbers tested, a clearly

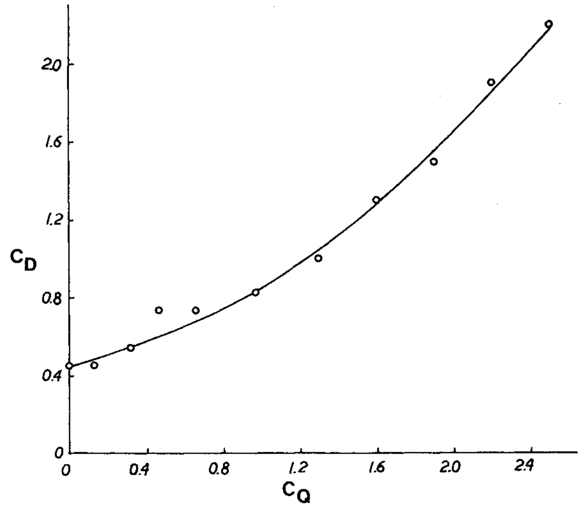

Fig. 6 Effect of high suction coefficients on three-dimensional model, $Re = 2.5 \times 10^4$.

defined shed vortex is not produced. At lower base Reynolds numbers, where a distinct Karman vortex street is present, vortex trapping by base suction may indeed produce drag reduction.

References

[1]Wood, C. J., "The Effect of Base Bleed on a Periodic Wake," *Journal of the Royal Aeronautical Society*, Vol. 68, July 1964, pp. 477-482.

[2]Wood, C. J., "Visualization of an Incompressible Wake with Base Bleed," *Journal of Fluid Mechanics*, Vol. 29, Aug. 1967, pp. 259-272.

[3]Bearman, P. W., "The Effect of Base Bleed on the Flow Behind a Two-Dimensional Model with a Blunt Trailing Edge," *Aeronautical Quarterly*, Vol. 18, Aug. 1967, pp. 207-224.

[4]Leal, L. G. and Acrivos, A., "The Effect of Base Bleed on the Steady Separated Flow Past Bluff Bodies," *Journal of Fluid Mechanics*, Vol. 39, Dec. 1969, pp. 735-752.

[5]Sykes, D. M., "The Effect of Low Flow Rate Gas Injection and Ground Proximity on Afterbody Pressure Distribution," *Proceedings of the First Symposium on Road Vehicle Aerodynamics*, London, 1969.

[6]Przirembel, C. E. G. and Riddle, R. A., "The Effect of Mass Removal from a Subsonic Axisymmetric Near-Wake," *Proceedings of the 14th Midwestern Mechanics Conference*, Norman, Oklahoma, 1975, pp. 547-562.

[7]Cornish, J. J., "Trapped Vortex Flow Control for Automobiles," *Proceedings of the Second Symposium on Aerodynamics of Sports and Competition Automobiles*, Los Angeles, 1975, pp. 111-118.

Pressure Distribution on a Symmetrical Butterfly Wing

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I. Introduction

THE mild ogee wings are the planform of the lift surfaces frequently used in aerospace vehicles flying at supersonic and hypersonic speeds. The characteristics of these wings are:

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