Engineering Notes

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Cylinder/Splitter-Plate Data Illustrating High α Support Interference

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Introduction

To obtain aerodynamic measurements over a large angle-of-attack range will, in general, require a variety of support systems. Figure 1 shows the type of support combinations that might be used in traversing an angle-of-attack range of 0-180 deg for a slender body of revolution. Each support system shown in this figure will, in some way, alter the aerodynamic characteristics of the model being tested. The extent of the interference is usually assessed by comparing aerodynamic measurements for different support systems. If the mismatch in the measured force and moment coefficients at corresponding angles of attack is small, then the data are assumed to be relatively free of support interference. There are, however, flow regimes where support interference can be quite significant. From an examination of high angle-of-attack data, the most prevalent interference seems to be associated with strut-supported models for subsonic Mach numbers.[1]

The mechanism by which the support interferes with the aerodynamic characteristics of the model is not clearly understood. It appears that the sting support acts as an extension of the body, causing a slight increase in the measured normal force coefficient. On the other hand, at large angles of attack, the strut support may act in a manner similar to a wake splitter plate. The major interference associated with the strut is a modification of the local wake characteristics. This change in wake behavior manifests itself in reduced crossflow drag contributions, which, in turn, result in a modification of the measured normal force and pitching moment coefficients.

Various experiments have been performed in the past to examine the influence of wake splitter plates on the pressure drag coefficient of two-dimensional cylinders.[2-6] These investigations have shown that a splitter plate placed parallel to the cylinder axis and the freestream could obstruct the vortex formation and also eliminate the extreme reduction in pressure in the wake. The splitter plate was found to reduce the drag coefficient of the cylinder by as much as 30% for subcritical Reynolds number flows.

The purpose of this paper is to discuss some of the results from additional two-dimensional experiments of a cylinder/plate combination. Although these experiments were performed at relatively low speeds and Reynolds numbers compared to the large wind tunnel facilities, it was felt that the data from these experiments would provide some insight into the influence of strut interference at large angles of attack.

Discussion of Results

Pressure distributions, pressure drag coefficients, and wake flow visualization data for various cylinder/splitter plate combinations were obtained for subcritical Reynolds numbers in Notre Dame's low-turbulence subsonic wind tunnel. Figure 2 is a sketch of the experimental setup. A 2-in. (5.08-cm-) diameter cylindrical pressure model was tested in combination with three different splitter plates. The dimensions of the plates were ¼ × 1 in. (0.64 × 2.54 cm), ¼ × 2.25 in.

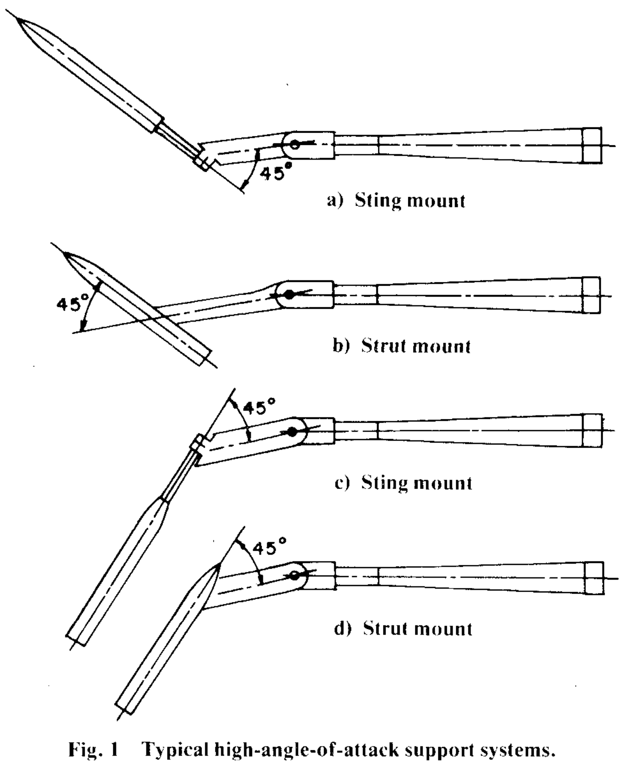

Fig. 1 Typical high-angle-of-attack support systems.

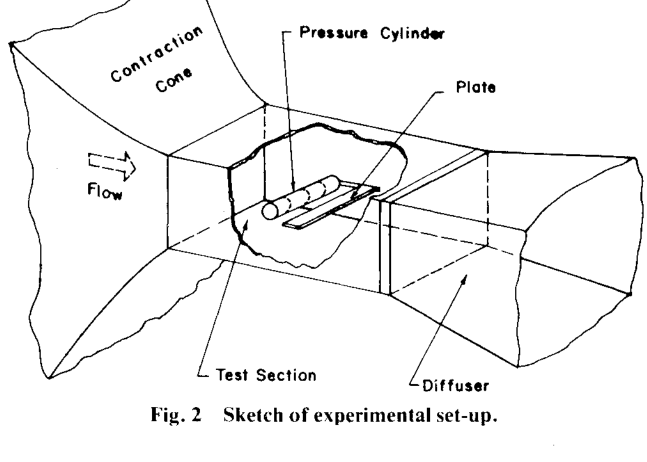

Fig. 2 Sketch of experimental set-up.

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Index categories: Jets, Wakes, and Viscid-Inviscid Flow Interactions; Subsonic Flow.

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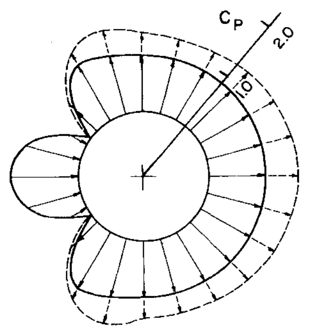
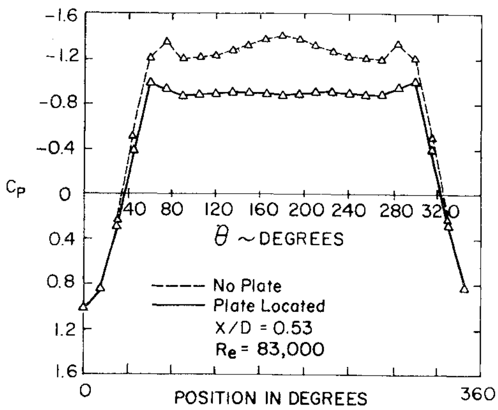


a) Surface pressure distribution



b) Pressure coefficient vs angular position

Fig. 3 Pressure distribution around the cylinder (with and without a splitter plate).

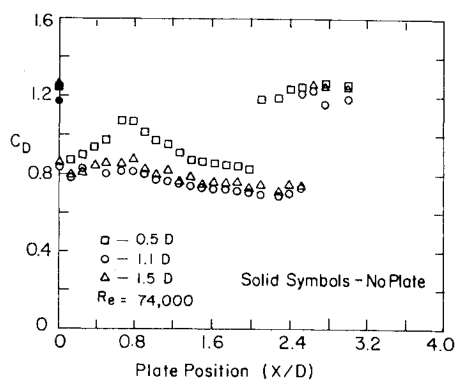
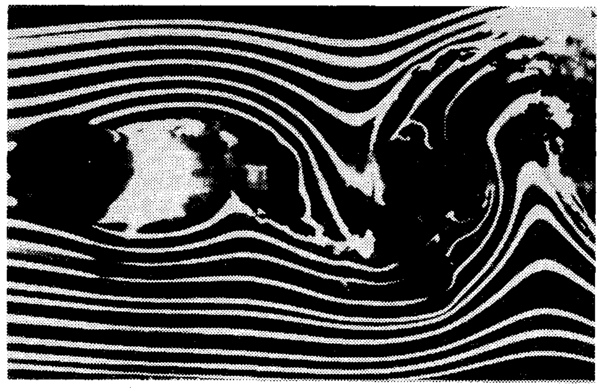
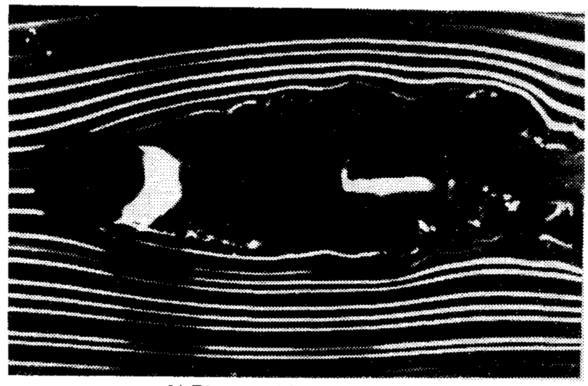


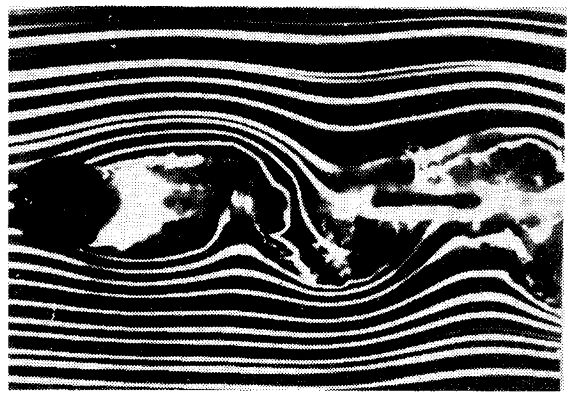
Fig. 4 Pressure drag coefficient vs plate position in the wake ($Re = 74{,}000$).



a) No plate



b) Plate position $X/D = 2.5$



c) Plate position $X/D = 3.0$

Fig. 5 Smoke photographs of wake patterns ($Re = 45{,}000$).

(0.64×5.72 cm), ¼×3 in. (0.64 cm×7.62 cm) which correspond to plate lengths in terms of the cylinder diameter of $0.5D$, $1.1D$, and $1.5D$, respectively. The cylinder and plates were designed to span the tunnel. Additional information on the models and test procedure can be found in Ref. 7 and 8.

Figure 3 shows the pressure distribution in terms of the local pressure coefficient for a cylinder with and without a splitter plate present in the wake. These figures show a significant change in the leeward pressure coefficient as compared to the no-plate condition. The splitter plate acts to lessen the extreme pressure reduction in the wake, which results in a drag reduction. For this particular case, the drag coefficient is reduced from 1.174 to 0.84, or approximately 28%.

Figure 4 shows the effect of varying the plate position. All three plates show a pronounced drop in the drag coefficient once the plate is introduced and abutted on to the cylinder. With each plate size a distinct region was found where the plate became ineffective in reducing the cylinder drag coefficient. Near this critical point a slight variation in plate position can cause the flow regime to switch from the low-drag profile to the high-drag profile, or vice versa. For the two larger plates ($1.1D$ and $1.5D$), the drag coefficient decreases as the plate is moved downstream of the cylinder until the plate reaches a position of approximately 2.5 diameters. At this point, the drag suddenly returns to a value similar to that of the cylinder without a splitter plate. The smaller plate exhibits a somewhat different trend. For this case, the drag coefficient increases as the plate is moved away from the cylinder until it reaches a position of approximately 0.6 diameter downstream. Then, the drag coefficient decreases until the plate reaches an X/D of 2.0. Further movement of the plate results in a drag ccoefficient similar to that of the cylinder without a splitter plate.

The influence of the splitter plate on the cylinder pressure drag coefficient was found to vary only slightly over the range of Reynolds numbers tested, 45,000-83,000. Higher Reynolds numbers were tested; however flutter problems developed with the splitter plate. The data for Reynolds number of 150,000 exhibited a smiliar trend with plate position until the onset of flutter.

The reduction in the drag coefficient is a direct result of the vortex wake pattern being inhibited. This is shown clearly in the smoke photographs comprising Fig. 5. The first photograph shows the wake pattern for a cylinder without a splitter plate, and the next two show the wake pattern for various splitter plate locations. With the plate located immediately behind the cylinder, the vortex shedding is clearly inhibited. It appears that the plate is effectively streamlining the cylinder. Note that, as the plate is moved beyond 2.5 diameters, the vortex pattern re-establishes itself immediately behind the cylinder as though the plate were not present. Once the wake pattern is re-established, the pressure drag coefficient returns to a value very similar to that of a plain cylinder.

Conclusions

In summary, the results of this investigation showed that the wake splitter plate could cause substantial reductions in the pressure drag coefficient. The magnitude of the drag reduction was found to be both a function of plate size and its downstream location in the wake.

Although the data presented in this paper were obtained from two-dimensional experiments, the results do provide some insight into the complicated interactions that may be present for strut-supported models at high angles of attack.

Acknowledgments

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