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Boundary-Layer Influences on the Subsonic Near-Wake of Bluff Bodies

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Introduction

MUCH attention has been given to the subject of subsonic axisymmetric bluff body wakes, however, data on nonaxisymmetric flows seem relatively sparse.[1] Previous analytical and experimental studies of bluff body flows have revealed a relationship between near-wake parameters and the state of the incoming boundary layer in both the subsonic and supersonic regimes; however, only a limited number of studies have detailed the relationship in depth, and then only for axisymmetric bluff bodies.[2,3]

A bluff body geometry of particular interest is the slanted-base, ogive-cylinder geometry which has been tested by Morel[4] and others.[5-7] The interest in this geometry is the sudden change of wake structure, with corresponding large change in drag coefficient, occurring for small changes of base slant angle, around 45 deg. The two wake types are a quasisymmetric, turbulent closure at low slant angles (blunt base), and a longitudinal vortex flow at high slant angles (slender base), as illustrated in Fig. 1.

Experimental Details

The model used in this study comprised a streamlined nosepiece with interchangeable centerbody and base components, covering a range of slant angles ("low" slant angles of 0, 40, 45 deg, and a "high" slant angle of 50 deg). The centerbody was slightly tapered (0.3-deg half-angle) with the intent of delaying boundary-layer transition to a higher Reynolds number. The length-to-base-diameter ratio (L/D) of all models is 6, measured to the most upstream point of the base. Experiments were conducted in a 4- × 3-ft, atmospheric, low-speed wind tunnel with the model mounted on a swept, slender strut attached to the nosepiece. Boundary corrections were not necessary since the model-to-test section area ratio was less than 1%. During some tests the forebody boundary layer was modified by fixing transition at one of three locations, at the leading edge, center, and near the trailing edge of the centerbody.

Experimental Results

Boundary-Layer Measurements

Boundary-layer characteristics were measured at a location 0.2-base diameters ahead of the most upstream point of the base. Boundary-layer profiles closely corresponded to classical laminar or turbulent forms. Typical momentum thicknesses, determined by integration, are shown in Fig. 2. It is thought that boundary-layer tripping did not occur at the lower Reynolds numbers, due to too small a grit size, but that natural transition reached the upstream end of the centerbody at higher Reynolds numbers.

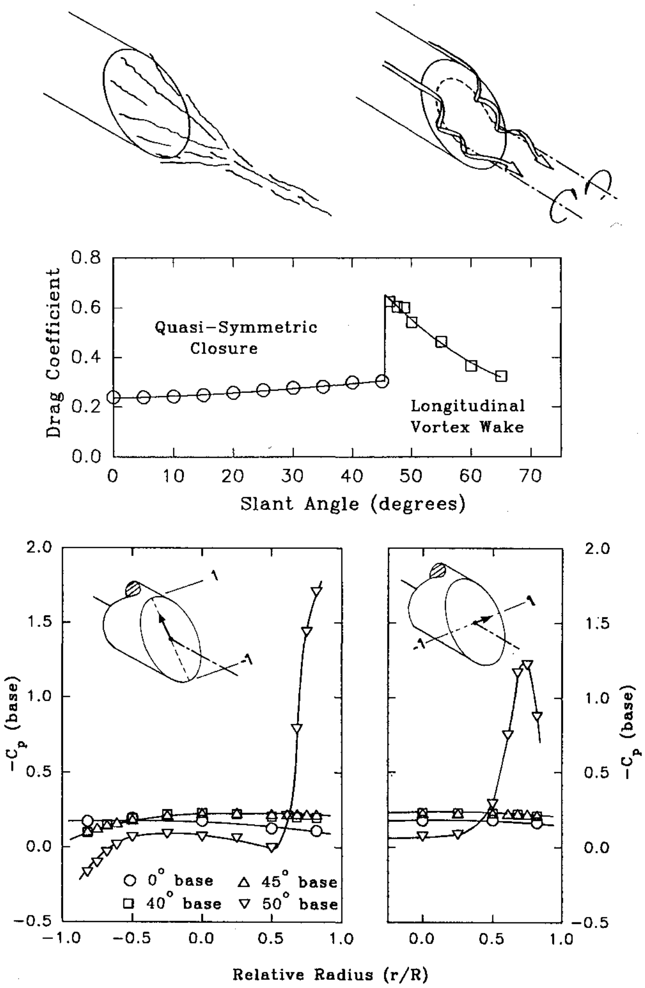

Fig. 1 Typical wake structures, drag variation, and base pressure distributions.

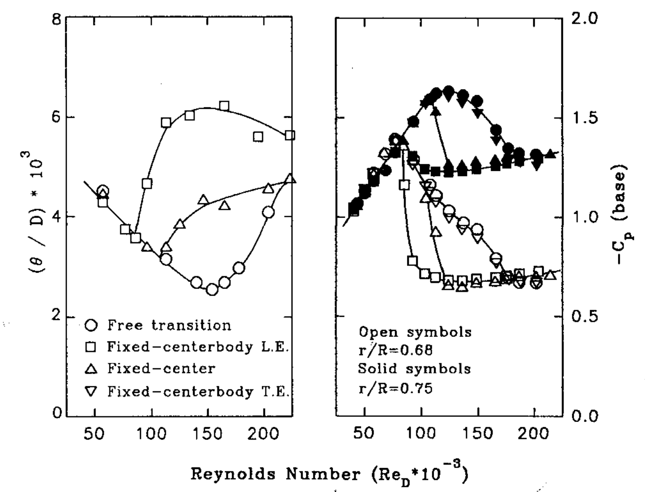

Fig. 2 Boundary-layer thickness and selected base pressures, 50-deg base.

Base Pressure Measurements

The general form of the base pressure distributions for the two types of wake flow were shown in Fig. 1. Base pressures

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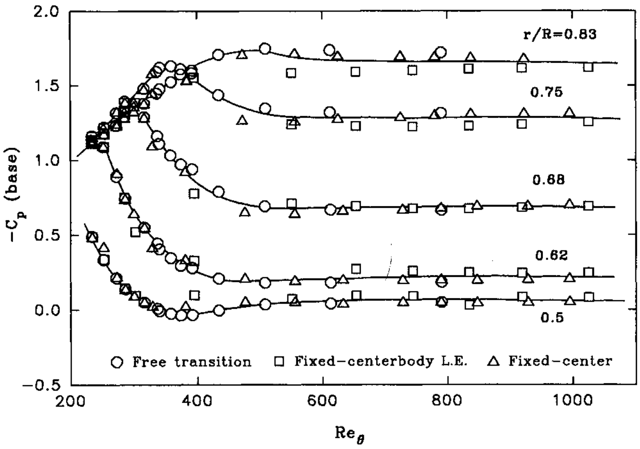

Fig. 3 Base pressure coefficients, 50-deg base.

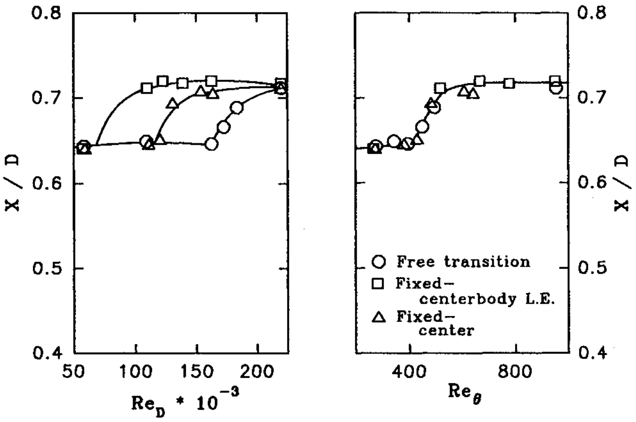

Fig. 4 Wake stagnation point locations, 40-deg base.

for low slant angles were found to vary slightly with Reynolds number, although pressure distributions remained reasonably consistent. Variations in base pressure coefficient for the 50-deg base (vortical wake) at two locations on the upstream side of the model centerline and along the symmetry plane are shown in Fig. 2. The strong variations are caused by changes in the location and strength of the longitudinal vortices. The results from Fig. 2, together with others from different stations, are shown in Fig. 3 using an appropriate nondimensional independent variable, that is the Reynolds number based on the incoming boundary-layer momentum thickness Re_θ. It is seen that free- and fixed-transition results now collapse onto single curves.

Wake Stagnation Point

The location of the wake stagnation point (the point of zero mean velocity) for low slant-angle bases (closed wake) was found to move closer to the base surface as the slant angle is increased, but away from the base at the onset of transition. Results again fall onto single curves when plotted against Re_θ, as shown in Fig. 4.

Conclusions

The wake of a family of slanted-base bluff bodies has been studied. Base pressure and wake stagnation point locations are influenced by the incoming boundary-layer momentum thickness. Similarity exists if the Reynolds number based on the Re_θ is chosen as the independent variable.

Acknowledgments

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In-Flight Velocity Measurements Using Laser Doppler Anemometry

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Introduction

LASER Doppler anemometry is a well established technique for nonintrusive measurement of flow velocities, and offers both high spatial resolution and high accuracy.[1] Although these advantages are very attractive for a wide range of aerodynamic investigations, the use of the laser Doppler anemometer (LDA) outside the controlled conditions of the laboratory has been inhibited by the size of the equipment, its power requirements, and the need to have small particles in the flow which act as scattering centers for the laser light. This is especially true for mobile applications such as in-flight or on-road velocity measurements. The recent availability of high-powered laser diodes has, however, led to newly designed LDA optical systems which are much smaller and require much less power while still offering good detection characteristics of small particles. In this study such a measurement system has been used to measure boundary-layer profiles on a twin engine Fairchild Swearingen Metro II aircraft in flight. Potentials of the technique for in-flight applications are demonstrated in this Note, and operational aspects of the present equipment are described.

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