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BOUNDARY-LAYER MEASUREMENTS ON A HIGH REYNOLDS NUMBER THREE-ELEMENT AIRFOIL

by

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Abstract

An experimental investigation is being conducted to evaluate the boundary layer associated with a two-dimensional three-element single-flap airfoil at high Reynolds numbers. The present measurements are being made in the Langley Low-Turbulence (centerline turbulence intensity level is 0.034% at a Mach number of 0.2 and a total pressure of 60 psia) Pressure Tunnel (LTPT). The LTPT is a closed-circuit wind tunnel with a test section which is 3 ft. wide, 7.5 ft. high, and 7.5 ft. long. Operating total pressure for the LTPT varies from 10 atmospheres to near-vacuum conditions. Tests are being conducted at a Mach number of 0.2 and Reynolds numbers (based on chord length) of 5, 9, and 16 million. Measurements include boundary-layer velocity surveys at several chordwise locations and surface skin-friction measurements using Preston tubes.

A sample velocity profile is presented herein for a streamwise location of 0.45 chord lengths, obtained using a Pitot probe. Tunnel conditions included a model angle-of-attack of 4.0 deg., freestream Mach number of 0.2, and chord Reynolds number of 9 million. The velocity profile is presented in terms of nondimensional wall variables, y+ and u+, where $y^+ = y u_\tau / \nu$, $u^+ = u/u_\tau$, u_τ=wall-friction velocity= $(\tau_w/\rho)^{1/2}$, ν=kinematic viscosity, and τ_w=wall shear stress. Initially, the data were graphed in the format of a Clauser plot (see Reference 1) to facilitate the determination of the wall shear stress or alternatively, wall skin-friction coefficient, based on a curve-fit to the experimental data in the logarithmic overlap (or log-law) region (up to y+ of approximately 1000). Spalding's composite correlation (applicable to both the wall and log-law regions) was the curve-fit relation used. (see Reference 2) This formula can be written as:

$$y^+ = u^+ + e^{-KB}\left[e^{Ku^+} - 1 - Ku^+ - (Ku^+)^2/2 - (Ku^+)^3/6\right]$$

$$K = 0.4,\ B = 5.5$$

The deduced value of the wall skin-friction coefficient from the Clauser plot (0.00263) was then used to define the wall-friction velocity and the values of u+ and y+ for the experimental data. Also shown is an experimental velocity profile based on a value of the wall skin-friction coefficient of 0.00237. This is the value which is obtained from the Newtonian relationship between wall shear stress and wall velocity gradient based on experimental data points close to the wall. It is expected that wall velocity gradients calculated in this manner (at a finite distance above the wall) will result in an underestimation of the wall skin-friction coefficient, since the velocity gradient would be higher at the wall (y+=0).

The deviation of experimental data from the Spalding profile in the region 1000<y+<10000 is due to a jet effect likely caused by induced flow through the slot formed between the slat and the main airfoil element. The change in the slope of the experimental profile at y+>10000 is characteristic of the wake or outer region of the boundary layer.

References

1. Sherman, F. S., ***Viscous Flow***, McGraw-Hill, Inc., 1990.
2. White, F. M., ***Viscous Fluid Flow***, McGraw-Hill, Inc., 1991.

Multielement Airfoil (M=0.2, x/c=0.45)