Effects of Wing Bend on the Aerodynamic Characteristics of a Low-Aspect-Ratio Oblique Wing

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Nomenclature

b = wing span ($\Lambda = 0$)
c = wing chord
c_{av} = average wing chord
c_{root} = wing root chord ($\Lambda = 0$)
c_l = section lift coefficient
C_l = rolling moment coefficient
C_L = lift coefficient
C_m = pitching-moment coefficient about $0.4\,c_{root}(\Lambda = 0)$
M = Mach number
α = angle of attack

Theme

IN recent years,[1-3] low-aspect-ratio oblique wings have been considered for highly maneuverable aircraft, because of the low wave drag of the configuration (with the wing swept) and good landing characteristics (with the wing unswept). At a Mach number of 0.95, it was shown experimentally that an oblique winged design has about twice the maximum lift/drag ratio of that of a conventional swept wing, both having the same sweep and aspect ratio. However, at high lift coefficients, required for maneuvering flight, planar oblique wings suffer from an asymmetry of spanwise wing stalling which induces large changes in the pitching, rolling, and yawing moments. Several means of alleviating this problem with nonlinear moment curves have been considered, namely, the employment of leading-edge devices such as drooped-nose flaps or Krüger nose flaps on the downstream wing panel or the use of upward bending of both wing panels. The subject of this paper is to consider, if upward bending alone, which results in washout on the trailing wing panel and washin on the leading wing panel, is sufficient to produce more symmetrical spanwise wing stalling.

Contents

The model consisted of an oblique wing mounted on top of a Sears-Haack body of revolution as shown in Fig. 1. The wing had an aspect ratio of 6.0 ($\Lambda = 0$) and a maximum thickness that varied elliptically from $0.11c$ at the wing root to $0.06c$ at the wing tip. The airfoil perpendicular to the $0.25c$ line was the Garabedian section designed for a $c_l = 1.3$ at $M = 0.6$. The wing could be swept from 0 to 60° about a pivot located at $0.4c_{root}$ ($\Lambda = 0$). Equations for the upward bend lines are given in Fig. 2, and additional geometry details for the wing and body are given in Ref. 1.

The tests were conducted in the Ames 6- by 6-Foot Wind Tunnel throughout the Mach number range from 0.6 to 1.4. The angle-of-attack range was from -3° to 31° and the unit Reynolds number was held constant at 8.2×10^6/m. Some glass spheres were used to trip the boundary layer, confirmed by sublimation studies.

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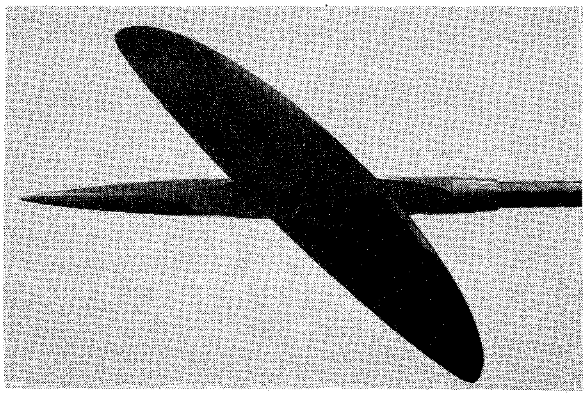

Fig. 1 Oblique wing-body combination, $\Lambda = 45°$.

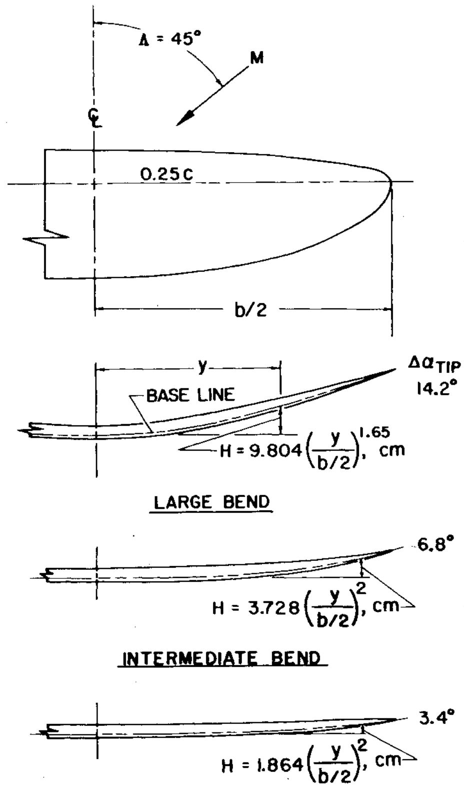

Fig. 2 Wing bends.

Predictions of the aerodynamic moments and span loadin were based on a matrix-panel method described in Ref. 2 which the wing-body combination was replaced by "Woo ward-type" lifting panels and a corresponding array of sour panels.

The calculated effect of wing bend on the spanw distribution of section lift coefficients is presented in Fig. 3. can be seen that without wing bend the downstream wi panel would be expected to stall before the upstream wi

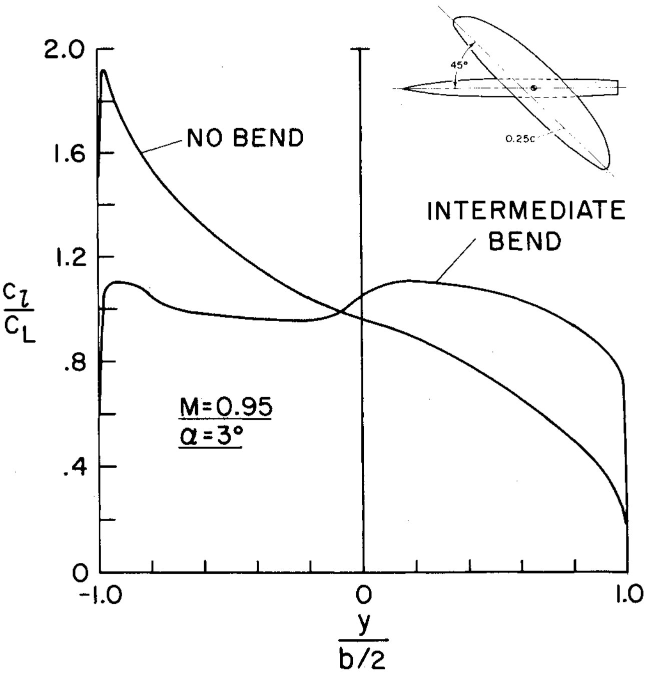

Fig. 3 Spanwise section lift distribution, $M=0.95$.

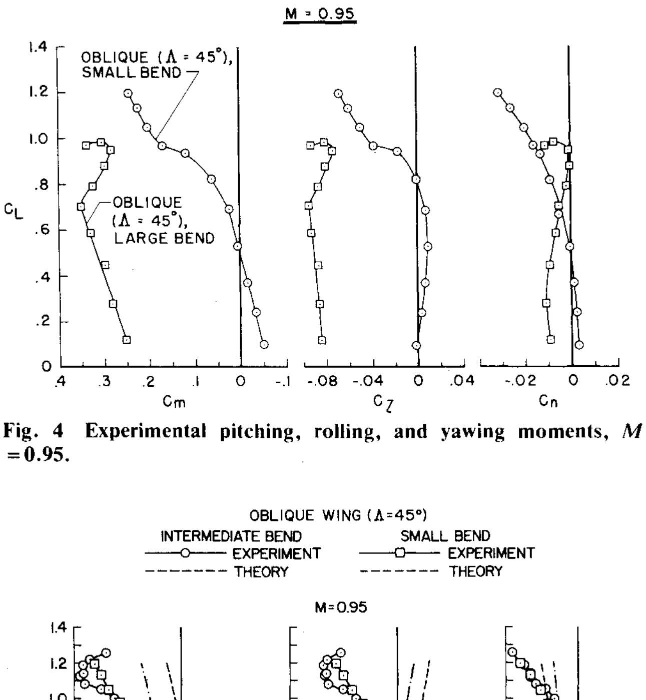

Fig. 4 Experimental pitching, rolling, and yawing moments, $M=0.95$.

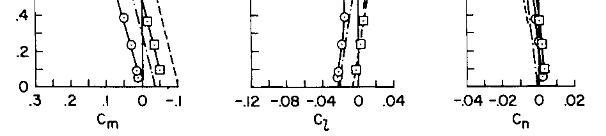

Fig. 5 Experimental and theoretical pitching, rolling, and yawing moments, $M=0.95$.

panel, thus, creating nonlinear moment curves. Evidence is given in Fig. 4 that, if sufficient bend is used (the curve marked "large bend"), the upstream wing panel can be made to stall initially, thereby producing a "pitchdown" tendency rather than a "pitchup" tendency and similar rolling- and

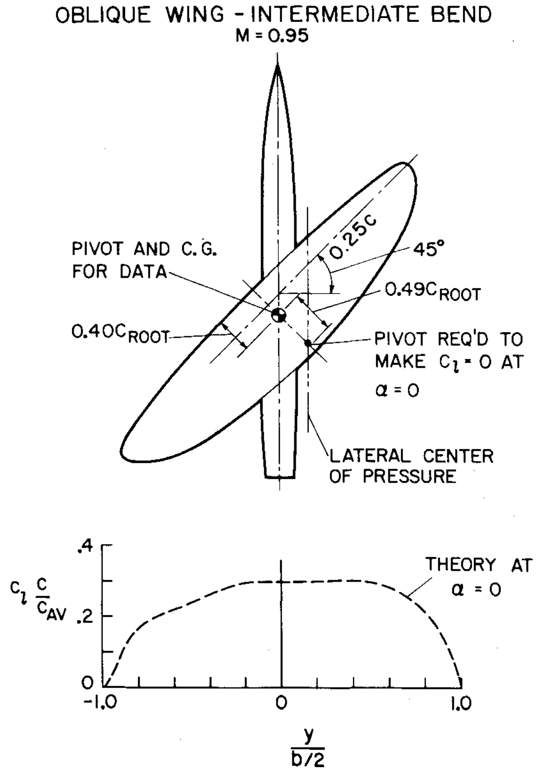

Fig. 6 Theoretical span loading, $M=0.95$.

yawing-moment results. For this reason, the wing with the "intermediate" bend was tested to determine if such a wing would have more linear moment curves. Results for such a wing bend in Fig. 5 indicate that no significant improvement in the linearity of the moment curves was produced by increasing the wing bend from small to intermediate. It is interesting to note in Fig. 5, however, that the slopes of moment curves and the moment increments due to wing bend were adequately predicted by linear theory, although the predicted pitching moments at low lift were more negative than measured.

At low lift, increasing the upward bend of the wing panels from small to intermediate, produced an increment in rolling moment (Fig. 5) which could be eliminated by moving the wing pivot rearward. The amount of rearward movement needed is calculated from experiment to be about $0.49c_{root}$ (Fig. 6) or the wing pivot would have to be at $0.89c_{root}$, an impractical location. Examination of the span loading curve (Fig. 6) indicated that at $\alpha=0$ (with the highly cambered Garabedian section and the intermediate wing bend) the right wing panel carries more load than the left wing panel, explaining the reason for the large required pivot movement.

Since it appears impractical to move the wing pivot so far rearward along the wing chord to trim out the undesirable rolling moments related to wing bend, other alternate solutions to the asymmetric spanwise wing stall must be found. Two possible solutions are presently being investigated, the use of a) leading-edge flaps, or b) designed structural bending due to load.

References

[1]Hopkins, E. J., Meriwether, F. D., and Pena, D. F., "Experimental Aerodynamic Characteristics of Low-Aspect Ratio Swept and Oblique Wings at Mach Numbers Between 0.6 and 1.4," NASA TM X-62, 317, 1973.

[2]Hopkins, E. J. and Levin, A. D., "Study of Low-Aspect-Ratio Swept and Oblique Wings," *Journal of Aircraft*, Vol. 12, Aug. 1975, pp. 648-652.

[3]Hopkins, E. J. and Nelson, E. R., "Effect of Wing Bend on the Experimental Force and Moment Characteristics of an Oblique Wing," NASA TM X-3343, 1976.