Engineering Notes

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AIAA 80-0186R

Longitudinal Aerodynamic Characteristics of the ATLIT Airplane

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Nomenclature

C_D	= drag coefficient
C_L	= lift coefficient
$C_{L_{wfn}}$	= lift coefficient of airplane without horizontal tail
C_m	= pitching moment coefficient
T'_c	= total thrust coefficient
α	= angle of attack

Subscripts

max	= maximum
0	= zero-lift

Introduction

THE Advanced Technology Light Twin-Engine (ATLIT) airplane was developed by the University of Kansas as part of a general aviation program sponsored by NASA Langley Research Center.[1]

Flight test results indicated that the ATLIT, an extensively modified Piper PA-34-200 Seneca I, failed to achieve the predicted improvements in climb and cruise performance. They were not better than those of the basic Seneca at the same gross weight and with the same installed power. A full-scale wind-tunnel research program[2] was undertaken to evaluate the various advanced aerodynamic concepts and to determine the lack of performance improvements.

In Oct. 1978, a research project was started with the objective of correlating theoretical predictions of longitudinal- and lateral-directional aerodynamic characteristics with full-scale wind-tunnel data and flight-test results on the ATLIT airplane. The first phase of this project, correlation of longitudinal characteristics, is described in Ref. 3. This Note will present the main results and conclusions.

Methods used in arriving at theoretical predictions are those used in Refs. 4, 5, and 6. In addition, results obtained with a "thick-wing" lifting surface method[7] and results acquired with a "thin-wing" lifting surface method[8] were also used in the correlations. The correlations were performed on C_L, C_m, and C_D and included tail- and power-effects.

Received Jan. 8, 1980; presented as Paper 80-0186 at the AIAA 18th Aerospace Sciences Meeting, Pasadena, Calif., Jan. 14-16, 1980; revision received Oct. 6, 1980.

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Results and Discussion

Two-dimensional lift characteristics of the wing (NASA LS(1)-0417 airfoil section) were obtained from experimental results.[9] The ATLIT wing does have a parabolic twist distribution instead of the common linear twist. The calculations include this effect. In Fig. 1, the lift prediction of the wing-fuselage-nacelle combination is compared with full-scale wind-tunnel results. The discrepancy between the calculated α_0 and the experimental value is probably caused by the wing lift prediction, as is shown in Ref. 3. An additional factor is the omission of wing-nacelle interference effects in the calculations. Smetana[10] also experiences a lower predicted lift for a given angle of attack. The difference in $C_{L_{max}}$ is thought to be due to the fact that the method used to estimate the maximum lift coefficient is relatively insensitive to wing planform and configuration which affect $C_{L_{max}}$.

In Fig. 1, results obtained with three-dimensional surface panel methods are also shown. The lift predictions of both methods show better agreement with the experimental data than the calculated. It should be noted that the program of Ref. 7 is approximately a magnitude more expensive to run than the QVLM program.[8] However, QVLM does not take into account the effect of nacelles. Addition of this effect will result in a lift-curve prediction which agrees well with experimental results in the linear lift region.

Although the tail-on lift curve is not shown, similar discrepancies occur between calculated results and wind-tunnel data.

Prediction of the drag of the complete airplane and results obtained in the full-scale wind tunnel are shown in Fig. 2. In the linear lift region the calculated curve agrees well with the experimental drag polar. In order to obtain good agreement between the calculated and experimental value of C_{D_0}, the accuracy of the fuselage and nacelle wetted area estimation must be high. In this study, the wetted areas of the bodies were calculated by ways of integrating the cross-sectional circumference over the length of the body.

The pitching moment coefficient of the ATLIT airplane relative to the quarter-chord of the wing mean aerodynamic chord is shown in Fig. 3. The stability parameter, $\partial C_m/\partial C_L$, is well predicted. However, the calculated value of C_{m_0} differs

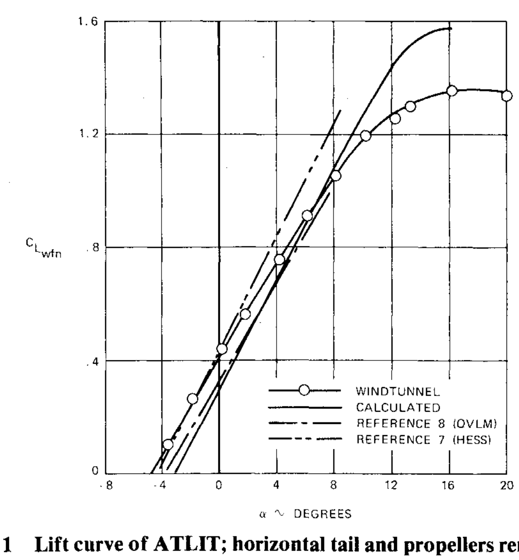

Fig. 1 Lift curve of ATLIT; horizontal tail and propellers removed.

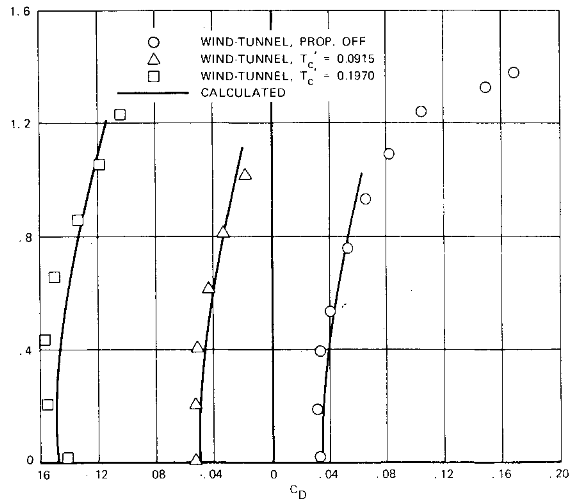

Fig. 2 Comparison of predicted drag with wind-tunnel data for different power conditions.

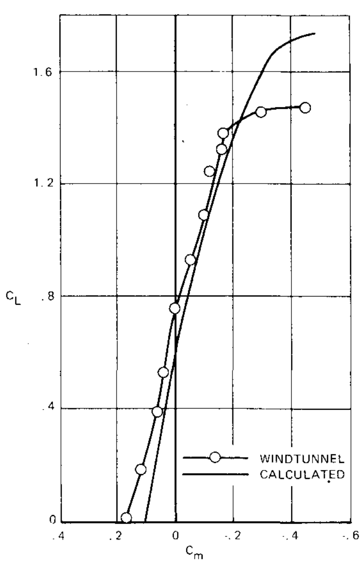

Fig. 3 Pitching moment of airplane; propellers removed and stabilizer not deflected.

from the experimental value. This is caused by the omission of the nacelle effect on C_{m0}.

The effects of power from propeller operation on lift, pitching moment, and drag were considered by the method presented in Ref. 4. In Fig. 2, the influence of power on drag is demonstrated. The effect of power on aerodynamic characteristics is well predicted by the method of Ref. 4. However, in the case of the ATLIT, opening of the engine inlets and engine cowl flaps has a considerable effect on airplane lift, pitching moment, and, especially, drag. The method used to predict power effects does not include engine cooling system effects. Changes in lift, pitching moment, and drag due to cooling system were derived from wind-tunnel data.

Conclusions

In Ref. 3, an analytical method is presented for predicting longitudinal aerodynamic characteristics of light, twin-engine, propeller driven airplanes. The method is applied to the ATLIT airplane and the calculated characteristics are compared with full-scale wind-tunnel data. The calculated lift-curve shows only fair agreement with the wind-tunnel results. Pitching moment and drag coefficient, however, are well predicted, as is the effect of power on the aerodynamic characteristics. No attempt was made to calculate the effects of engine cooling system, yet it does have a considerable effect on C_m and C_D.

Acknowledgment

This work was supported by NASA Langley Research Center under Grant NSG-1574.

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AIAA 81-4187

Spanwise Lift Distribution of Forward- and Aft-Swept Wings in Comparison to the Optimum Distribution Form

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Nomenclature

b = wing span
c = wing chord
$\bar{c}$ = mean wing chord
c_l = local lift coefficient
C_D = induced drag coefficient
C_L = lift coefficient
D = induced drag
f = scale factor, see Eq. (1)
L = lift
M = freestream Mach number
M_B = wing bending moment
s = wing semispan
S, S_w = wing area
t = wing thickness
w = weight function, see Eq. (2)
W_w = wing weight
y = spanwise distance from wing centerline
Λ_{LE} = leading-edge sweep
η = $2y/b$, nondimensional spanwise distance
$\bar{\eta}$ = auxiliary spanwise coordinate, see Eq. (5)

Subscripts

1,2,3 = quantities pertaining to wings 1, 2, or 3

Received June 18, 1980; revision received Sept. 23, 1980.

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