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Technical Comments

Comment on "Effect of Fuselage on Delta Wing Vortex Breakdown"

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IT is shown in Ref. 1 that the presence of a fuselage significantly promotes the breakdown of delta wing leading-edge vortices. Applying the equivalent angle-of-attack concept[2] only accounted for a fraction of the measured effect of the fuselage, predicting a 17% increase of the effective angle of attack compared to the measured 45% increase. The present comment describes a flow mechanism that can explain this discrepancy, i.e., the wing-camber effect generated by the fuselage-induced upwash along the leading edge of the delta wing.

The effect of longitudinal camber on the breakdown of the leading-edge vortex on a slender delta wing is large[3] (Fig. 1). For the same maximum local angle of attack on the delta wing α_{max} a positive camber of $\Delta\alpha/\alpha_{max} = 1$ delays breakdown to occur downstream of the trailing edge, whereas a negative camber of the same magnitude, $\Delta\alpha/\alpha_{max} = -1$, causes burst to occur very close to the apex.

Obviously, for a pitching delta wing the pitch-rate-induced camber will have similarly large effects on the breakdown of leading-edge vortices. It is described in Refs. 4 and 5 how the roll-rate-induced camber effect would be very similar to the pitch-rate-induced camber effect. In both cases, it is the motion-induced change of the local angle of attack at the leading edge that matters (Fig. 2).

For the maximum reduced frequency and amplitude used in the roll oscillation test of a 65-deg, sharp-edged delta wing,[6] the roll-rate-induced camber at the trailing edge was $\Delta\alpha_{LE}/\alpha = 0.31$.[7] Following the suggestion in Ref. 7, static tests were performed with models deformed to produce the roll-rate-induced camber[8] (Fig. 3). The results were as expected[7]; i.e., the twisted-up side of the delta wing experienced later vortex breakdown than the opposite, twisted-down side, approximately at 70% chord compared to 45% chord (for zero roll angle $\phi = 0$).

It should be noted that the variation of the induced angle of attack along the leading edge is linear, proportional to the local semispan, in the examples given in Figs. 1–3, whereas the variation is nonlinear, roughly inversely proportional to the local semispan, in the case of the body-induced wing camber. However, the results in Ref. 7 serve to illustrate how large the effect of camber is on vortex breakdown.

Based upon these results one can expect that the body-induced negative wing camber along the delta wing leading edge is a very important parameter. Thus, a better approach than using any mean-alpha value for the delta wing, such as the equivalent angle of attack,[2] is to use the body angle of attack α together with the body-induced wing camber at the trailing edge $\Delta\alpha_{LE}/\alpha$, to correlate measurements of the breakdown of delta wing leading-edge vortices in the presence of a fuselage.

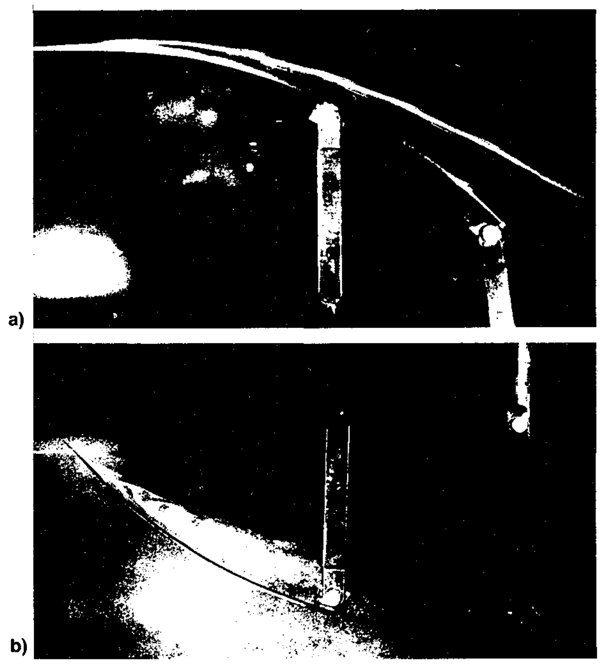

Fig. 1 Effect of longitudinal camber on vortex breakdown on an 80-deg delta wing.[3] Local incidence: a) increasing and b) decreasing with distance from apex.

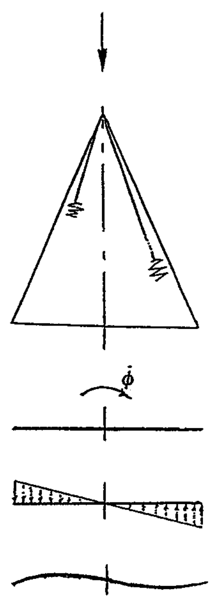

Fig. 2 Roll-rate-induced conical camber.

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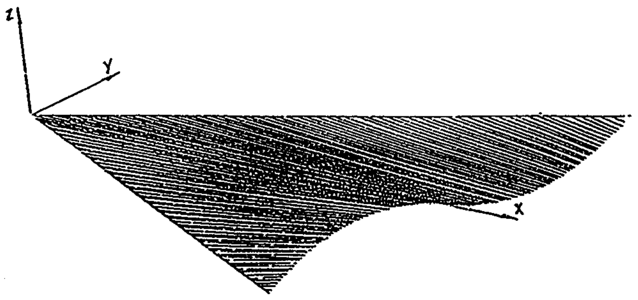

Fig. 3 Tested thin-sheet model, deformed to represent the maximum roll-rate-induced camber.[8]

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Comment on "Model Flight Tests and Neutral Point Determination"

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Introduction

IN their article on model flight tests of a spin-resistant trainer configuration, Yip et al.[1] did an excellent job in showing how a professionally conducted model flight test can demonstrate critical flight characteristics of a prototype aircraft. One small, but important part of their work was the determination of the neutral point. This Technical Comment addresses only the aircraft's high thrust line and its implications on neutral point (NP) determination.

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Neutral Points

The NP is generally understood as a critical reference point with respect to the pitch stability of the aircraft. If the center of gravity (c.g.) is moved progressively rearward, the aircraft becomes unstable in pitch as soon as the c.g. passes the NP. Therefore, NP determination is crucial for the establishment of aft c.g. limits on prototype aircraft. In wind tunnels, aircraft pitching moments are typically measured at various angles of attack at constant tunnel speed. The NP can then be determined as that reference point, where the change of pitching moments with angle of attack is zero.

In flight tests, aircraft pitching moments cannot be measured directly, therefore, NP determination has to rely on indirect methods, such as measuring elevator deflections and stick forces. These are typically measured at different airspeeds in order to get angle-of-attack variation. One method involves climbing or descending flight at constant thrust setting, whereas another one maintains level flight, requiring throttle adjustments for different speeds. This latter method was employed by the authors in flying the model parallel to the ground at stabilized speeds, recording elevator angles. The data reduction resulted in figures 14 and 15 of their paper, with a neutral point at 45% of the mean aerodynamic chord c. They comment that this was in good agreement with the wind-tunnel result of 44% c. This comment implies that the NP obtained from flight tests should be the same as the one obtained from wind-tunnel tests, and that good agreement indicates high quality of the flight test data. Unfortunately, this implication ignores the effects of offset thrust lines and leads to wrong conclusions about the physical significance of elevator position neutral points.

Thrust Effects

As was shown by this author,[2] offset thrust lines combined with speed variation during conventional flight tests cause an apparent neutral point shift, resulting in "elevator-position neutral points" that differ significantly from "stick-fixed neutral points" obtained from wind-tunnel tests or unconventional flight tests. This difference is not caused by data scatter or inaccuracies, but is a direct result of the differing methods employed. Since the model had a high thrust line ($z_{\mathrm{TH}} < 0$), the neutral point obtained from a flight test must be behind the neutral point obtained from the wind-tunnel test. Modifying equation (20) in Ref. 2 for level flight, results in a NP shift of

$$\Delta h_n = -\tfrac{3}{2}(T/W)(z_{\mathrm{TH}}/c) \approx 0.1 \pm 0.06 \tag{1}$$

i.e., 4–16% c in this case, depending on the vertical c.g. location and the power setting. In level flight, the thrust equals drag and must be adjusted at each speed. This causes the elevator deflection vs angle-of-attack data to be curves rather than straight lines, with increased values of delta at high angles of attack. This trend is clearly evident by taking a close look at the data in Yip et al.'s figure 14.

The curved trend of the data results in varying slopes vs alpha, reflecting the fact that the elevator position neutral point changes with varying thrust in level flight. Linearizing the data by a straight-line curvefit, as the authors chose to do, means to single out one particular neutral point. This choice is basically arbitrary, considering that the slope of the line depends on which data are included in the curvefit. It can be shown, e.g., that at the zero-lift angle of attack the elevator deflections converge to a single value (estimated 2 deg in fig. 14). Including this in the curvefit results in smaller slopes and a different neutral point.

The physical significance of such neutral points changes as a result of offset thrust lines: elevator position neutral points lose their meaning with regard to pitch stability. If during the flight test of a high-thrust line aircraft the test team relies on conventional methods, they will be surprised by the fact that