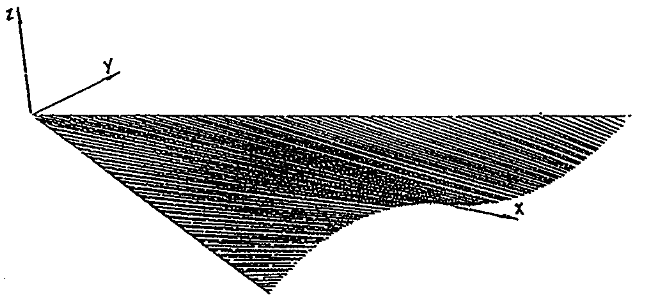


**Fig. 3 Tested thin-sheet model, deformed to represent the maximum roll-rate-induced camber.[8]**

## References

[1]Straka, W. A., and Hemsch, M. J., "Effect of a Fuselage on Delta Wing Vortex Breakdown," *Journal of Aircraft*, Vol. 31, No. 4, 1994, pp. 1002–1005.

[2]Hemsch, M. J., and Nielsen, J. N., "Equivalent Angle-of-Attack Method for Estimating Nonlinear Aerodynamics of Missile Fins," *Journal of Spacecraft and Rockets*, Vol. 20, July–Aug. 1983, pp. 356–362.

[3]Lambourne, N. C., and Bryer, D. W., "The Bursting of Leading-Edge Vortices—Some Observations and Discussion of the Phenomenon," Aeronautical Research Council, R&M 3282, London, April 1961.

[4]Ericsson, L. E., and Hanff, E. S., "Unique High-Alpha Roll Dynamics of a Sharp-Edged 65 deg Delta Wing," AIAA Paper 92-0276, Jan. 1992.

[5]Ericsson, L. E., and Hanff, E. S., "Further Analysis of High-Rate Rolling Experiments of a 65 Deg. Delta Wing," AIAA Paper 93-0620, Jan. 1993.

[6]Hanff, E. S., and Jenkins, S. B., "Large-Amplitude High-Rate Roll Experiments on a Delta and Double Delta Wing," AIAA Paper 90-0224, Jan. 1990.

[7]Ericsson, L. E., "Analysis of Wind-Tunnel Data Obtained in High-Rate Rolling Experiments with Slender Delta Wings," Inst. for Aerospace Research, IAR-CR-14, Aug. 1991.

[8]Hanff, E. S., and Huang, X. Z., "Prediction of Leading-Edge Vortex Breakdown on a Delta Wing Oscillating in Roll," AIAA Paper 92-2677, June 1992.

# 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

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

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 the aircraft shows pitch instability at c.g. positions well ahead of its neutral point. The significance of elevator position and stick force neutral points obtained from conventional flight test lies in pointing toward the reversal of stick positions and stick forces vs airspeed in steady flight. These are valuable parameters for defining acceptable handling characteristics of the aircraft.

Stick-fixed and stick-free neutral points determined at constant speed are not affected by offset thrust lines and are therefore valid references for pitch stability. They are, however, affected by the propeller normal force, which is destabilizing for tractor propellers ahead of the c.g. and stabilizing for pushers behind the c.g. All this has to be considered in establishing an aft c.g. limit.

## Conclusions

Offset thrust lines and speed variation during conventional flight tests cause elevator position neutral points to be significantly different from stick fixed neutral points determined from wind-tunnel tests or unconventional flight tests. The more accurate the data acquisition and reduction, the more clearly this difference shows. Ironically, a good agreement between the results of the two methods only proves that the data scatter, inaccuracies in the reduction methods, or other errors were large enough to hide the difference.

## References

[1]Yip, L. P., Ross, H. M., and Robelen, D. B., "Model Flight Tests of a Spin-Resistant Trainer Configuration," *Journal of Aircraft*, Vol. 29, No. 5, 1992, pp. 799–805.

[2]Solies, U. P., "Effects of Thrust Line Offset on Neutral Point Determination in Stability Flight Testing," AIAA Paper 92-4082, Aug. 1992.

[3]Solies, U. P., "Effects of Thrust Line Offset on Neutral Point Determination in Flight Testing," *Journal of Aircraft*, Vol. 31, No. 2, 1994, pp. 362–366.