Experimental Investigation of Dynamic Ground Effect

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Nomenclature

b = model wing span, in.
c = model wing mean geometric chord, in.
C_D = drag coefficient at any particular ground height, drag/qS
C_{D_∞} = drag coefficient out-of-ground effect
$\Delta C_D\%$ = percent increase in drag coefficient, $(C_D - C_{D_\infty})/C_{D_\infty} \times 100$
C_L = lift coefficient at any particular ground height, lift/qS
C_{L_∞} = lift coefficient out-of-ground effect
$\Delta C_L\%$ = percent increase in lift coefficient, $(C_L - C_{L_\infty})/C_{L_\infty} \times 100$
C_m = pitching moment coefficient at any particular ground height, pitching moment/$qS\bar{c}$
H = ground height measured from the quarterchord point of $\bar{c}$, in.
$\dot{h}$ = sink rate, ft/s
q = dynamic pressure, lb/ft^2
R_N = Reynolds number based on mean geometric chord
S = model wing area, in.^{2}
V_∞ = wind-tunnel airspeed, ft/s
δ_f = flap deflection, deg (positive down)

Abstract

Models of an F-106B and an XB-70 aircraft were tested under static and dynamic conditions in ground effect in a 36 in. × 51 in. wind tunnel. Tests were made with and without flap deflections. Lift, drag, and pitching moments were measured by a movable strain gaged sting. Test results showed that the percentage increments in lift and drag coefficients in dynamic ground effect were always smaller than those measured under static conditions. The dynamic pitching moment data were masked by the system dynamics in initiating the dynamic tests.

Contents

To simulate the constant angle-of-attack flight-test technique in a wind tunnel, a test technique of moving a model toward a ground board was developed and is explained in Ref. 1. Only wing models were tested in the exploratory experiments of Ref. 1. These tests showed that the percentage increments in lift and drag coefficients $\Delta C_L\%$ and $\Delta C_D\%$ in dynamic ground effect were always smaller than those measured under static conditions for highly swept wings. In the present investigation, complete configuration models for the F-106B and XB-70 aircraft were tested to compare dynamic and static ground effects for wing-alone and wing/body combinations, with and without flap deflections. Significant results are presented for the F-106B configurations; results for the XB-70 configurations can be found in Ref. 2.

Tests were conducted in a 36 in. × 51 in. wind tunnel at Reynolds numbers of 3×10^5 to 7.5×10^5 based on the mean geometric chord. Tests were conducted under static conditions at selected heights in ground effect and under dynamic conditions in ground effect. In the dynamic tests, vibrations were set up in the sting by the initiation of the motion. Because of the strain gage positions and the electronic instrumentation used, the dynamic drag and pitching moment data contained considerable extraneous signals. The dynamic drag data were difficult to reduce; the dynamic pitching moment data were considered unusable. However, the lift data were readily reducible.

The $\Delta C_L\%$ and $\Delta C_D\%$ in ground effect for both the static and dynamic conditions are presented in Figs. 1 and 2 for the F-106B model at $\alpha = 14$ deg. The static $\Delta C_L\%$ are approximately the same for flap angles of +15, 0, and −30 deg. At an H/b of approximately 0.7, the static $\Delta C_L\%$ commences increasing much more rapidly with decreasing height. Under dy-

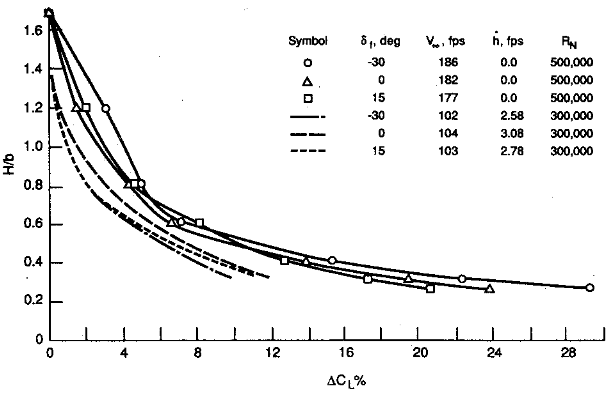

Fig. 1 Percentage lift-coefficient increments for an F-106 model with flap deflections in static and dynamic ground effect at $\alpha = 14$ deg.

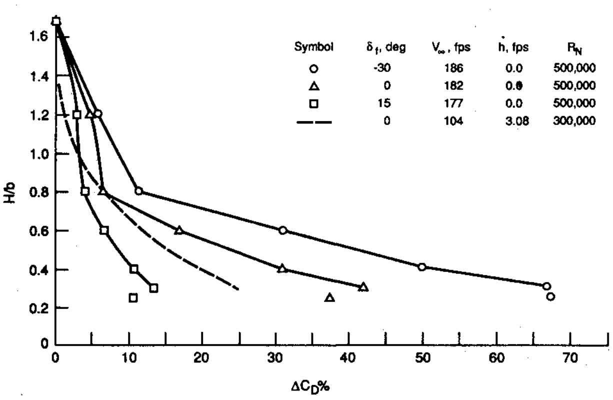

Fig. 2 Percentage drag-coefficient increments for an F-106 model with flap deflections in static and dynamic ground effect at $\alpha = 14$ deg.

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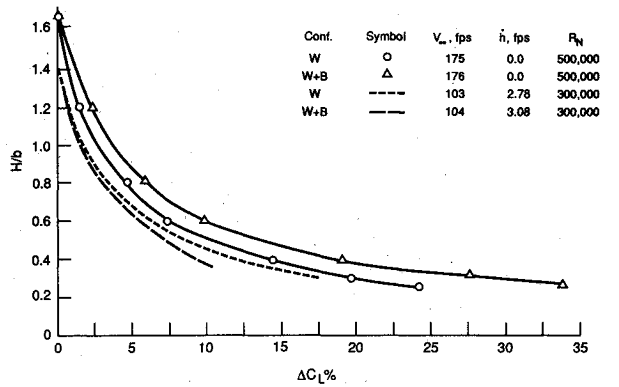

Fig. 3 Fuselage effect on lift-coefficient increments for an F-106 model in static and dynamic ground effect at $\alpha = 14$ deg.

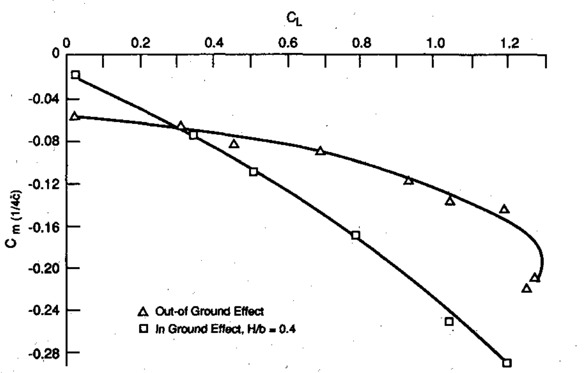

Fig 4 Pitching moment coefficients for an F-106 model in static ground effect at $H/b = 0.4$ and out-of-ground effect, $R_N = 5 \times 10.^5$

namic conditions, the percentage lift-coefficient increments are less for the +15 and −30-deg flaps than for the 0-deg position. All of these increments under dynamic conditions were less than those under corresponding static conditions.

Although for the F-106B model the static $\Delta C_L\%$ for the three flap angles was approximately the same, the static $\Delta C_D\%$ was dependent on flap deflection. The +15-deg flap deflection percentage change was much smaller than the 0-deg flap deflection; the −30-deg flap deflection percentage change was much larger. This was due to two factors: 1) the more positive the flap deflection, the larger the coefficient of drag increment as H/b decreased, and 2) the more negative the flap deflection angle the larger the reference drag coefficient C_{D_∞}. The static $\Delta C_D\%$ commenced increasing rapidly at an H/b of approximately 0.8. At the lowest H/b position plotted in Fig. 2, the wing trailing edge and rear of fuselage were closely approaching the ground board. This provided a decrease in the static drag-coefficient increments.

The percentage drag-coefficient increments under dynamic conditions were less than those under static conditions at 0 deg flap. Vortex lag is probably the contributing factor. Data at the other two flap deflections were not reduced.

The effect of the fuselage on the static and dynamic $\Delta C_L\%$ is presented in Fig. 3; $\Delta C_L\%$ of the wing-alone was always larger than that of the wing/body configuration in both static and dynamic conditions.

Similar comparisons of static and dynamic pitching moment coefficients cannot be made because the dynamic data were considered unusable. However, static ground-effect testing showed that the longitudinal stability is increased substantially by reducing ground height, as seen in Fig. 4. A possible reason for this is that in ground effect the leading-edge vortices not only become stronger but also stay more outboard. As a consequence, the tip region is more positively loaded to result in a more negative pitching moment.

Conclusions

Models of an F-106B and an XB-70 with and without flap deflections have been tested in static and dynamic ground effect. From these test data, the following conclusions can be made.

1) Percentage increments in lift and drag coefficients in dynamic ground effect were always smaller than the static values.

2) Trailing-edge flap deflection affected the percentage lift-coefficient increments due to ground effect only slightly.

3) Trailing-edge flap deflection affected the percentage drag-coefficient increments more significantly than the lift data.

4) Comparing the results with wing-alone and wing/body data, the fuselage was found to reduce the percentage lift increments in ground effect.

Acknowledgement

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References

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