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"Dynamic Ground Effects Flight Test of the NASA F-15 Airp

Table of Contents

Navigating Around the Workshop:

[Workshop Home] [Session Agenda] [Submit Response / Read Responses]

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CONTENTS:

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Dynamic Ground Effects Flight Test of an F-15 Aircraft

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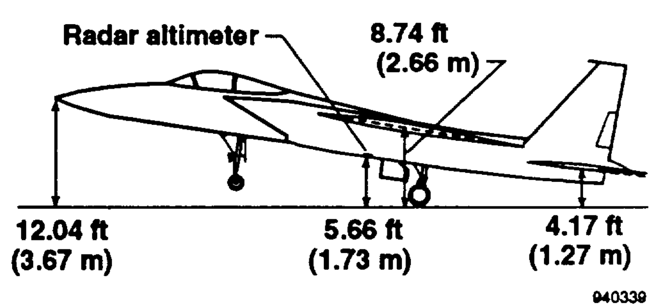
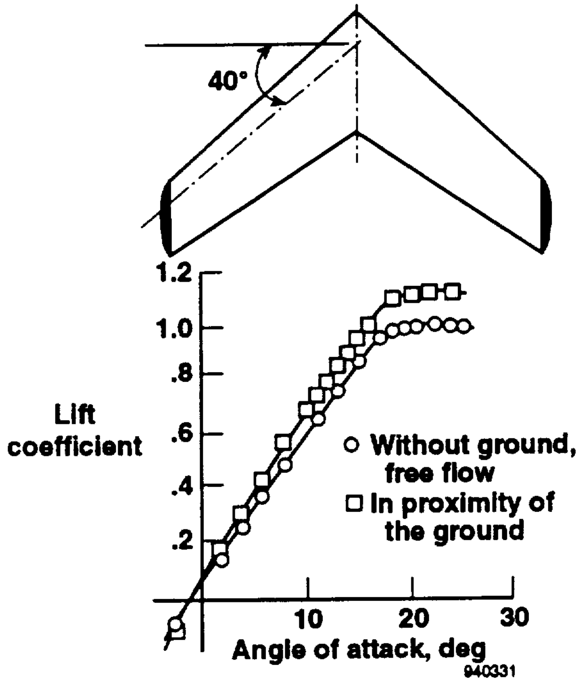
Abstract

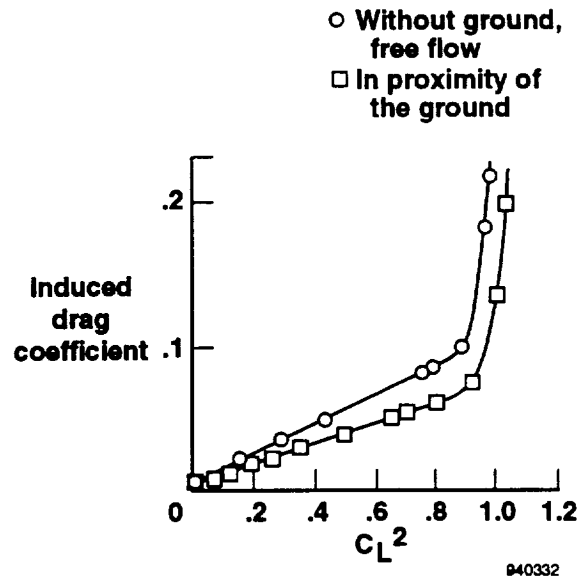
Aerodynamic characteristics of an aircraft may significantly differ when flying close to the ground rather than when flying up and away. Recent research has also determined that dynamic effects (i.e., sink rate) influence ground effects (GE). A ground effects flight test program of the F-15 aircraft was conducted to support the propulsion controlled aircraft (PCA) program at the NASA Dryden Flight Research Center.

Flight data was collected for 24 landings on 7 test flights. Dynamic ground effects data were obtained for low- and high-sink rates, between 0.8 and 6.5 ft/sec at two approach speed and flap combinations. These combinations consisted of 150 kt with the flaps down (30° deflection) and 170 kt with the flaps up (0° deflection), both with the inlet ramps in the full-up position. The aerodynamic coefficients caused by ground effects were estimated from the flight data. These ground effects data were correlated with the aircraft speed, flap setting, and sink rate. Results are compared to previous flight test and wind-tunnel ground effects data for various wings and for complete aircraft.



F-15 at touchdown attitude





Ground Effects Background

Ground effects may be explained by the interaction of the aircraft wingtip vortices with the ground. This interaction reduces the strength of these vortices. The weakened wingtip vortices reduce the downwash which increases the lift and decreases the induced drag or the drag due to lift. These figures show this change for a 40° sweptback wing. In addition, the reduced downwash at the wing trailing edge increases the angle-of-attack of the relative wind at the elevator, resulting in a nose-down pitching moment.

Ground effects data can be obtained in the wind tunnel or in flight. In conventional wind-tunnel ground effects testing, measurements are taken for a stationary aircraft model at various fixed ground heights. The results are called static ground effects data. Unfortunately, this static data simulates the aircraft flying near the ground at a constant altitude rather than simulating the transient or dynamic effects of the aircraft descending through a given altitude, termed "dynamic" ground effects data. Note that static conditions, whether in the wind tunnel or in flight, produce significantly different ground effects on an aircraft than those produced by dynamic conditions.

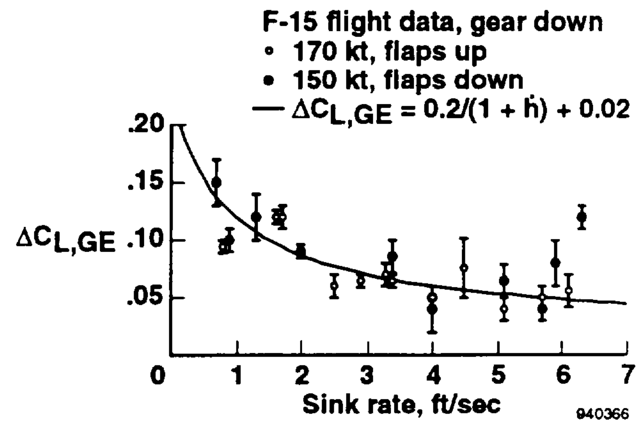
Approach Speed, Flap Setting, and Sink Rate Effects

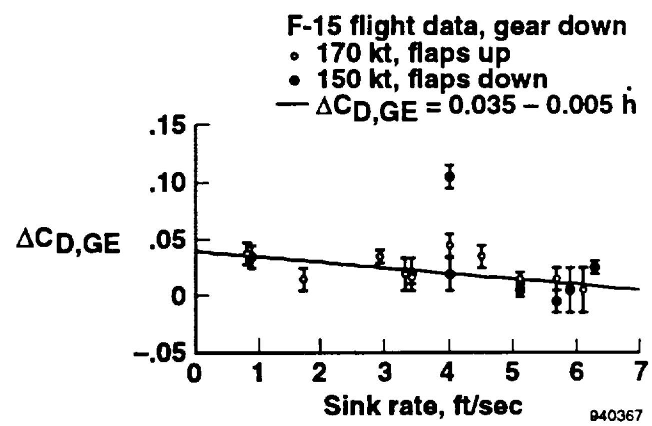
These figures show the F-15 ground effects flight data plotted versus as a function approach speed, flap setting, and sink rate. These figures show the changes due to ground effect of the lift, drag, and pitching moment coefficients as a function of sink rate. Changes in the aerodynamic coefficients were calculated at touchdown. Sink rates ranged from a low of 0.7 ft/sec (42 ft/min) to a high of 6.5 ft/sec (390 ft/min). For reference, the F-15 landing gear has a maximum sink rate capability of about 10 ft/sec (600 ft/min).

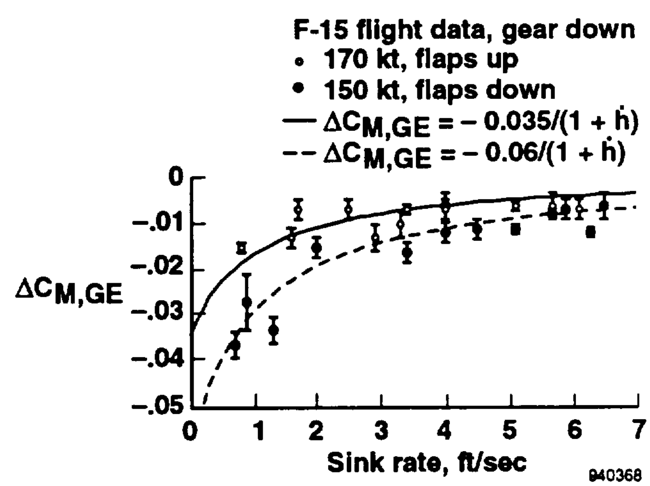
In general, these figures show that ground effect becomes more significant as sink rate decreases. The changes in the lift coefficient and the nose-down pitching moment increase with decreasing sink rate. The changes because of ground effect decrease and approach zero as the sink rate increases. These trends are not as clear for the drag coefficient.

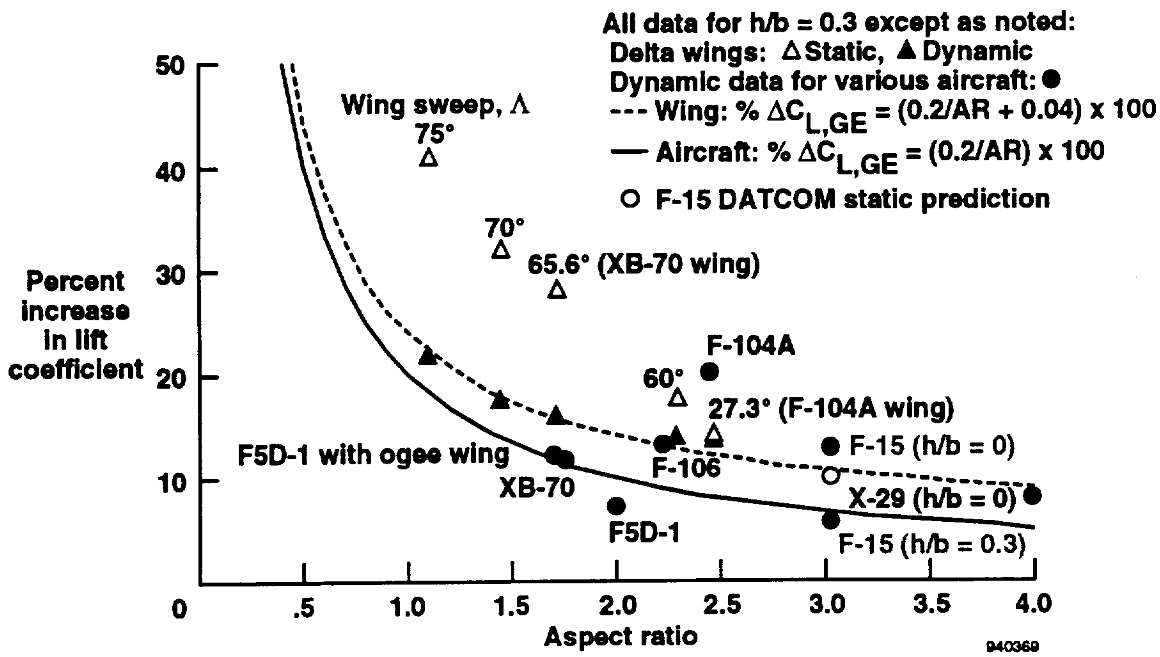
The approaches at 150 kts with the flaps down show more significant ground effects. This difference is most apparent for the pitching moment. This increase may be caused by a camber effect due to the flaps being down.

These figures show simple correlation curves that have been fit through the ground effects data. These curves give the change in lift, drag, and pitching moment coefficients because of ground effect as a function of sink rate.





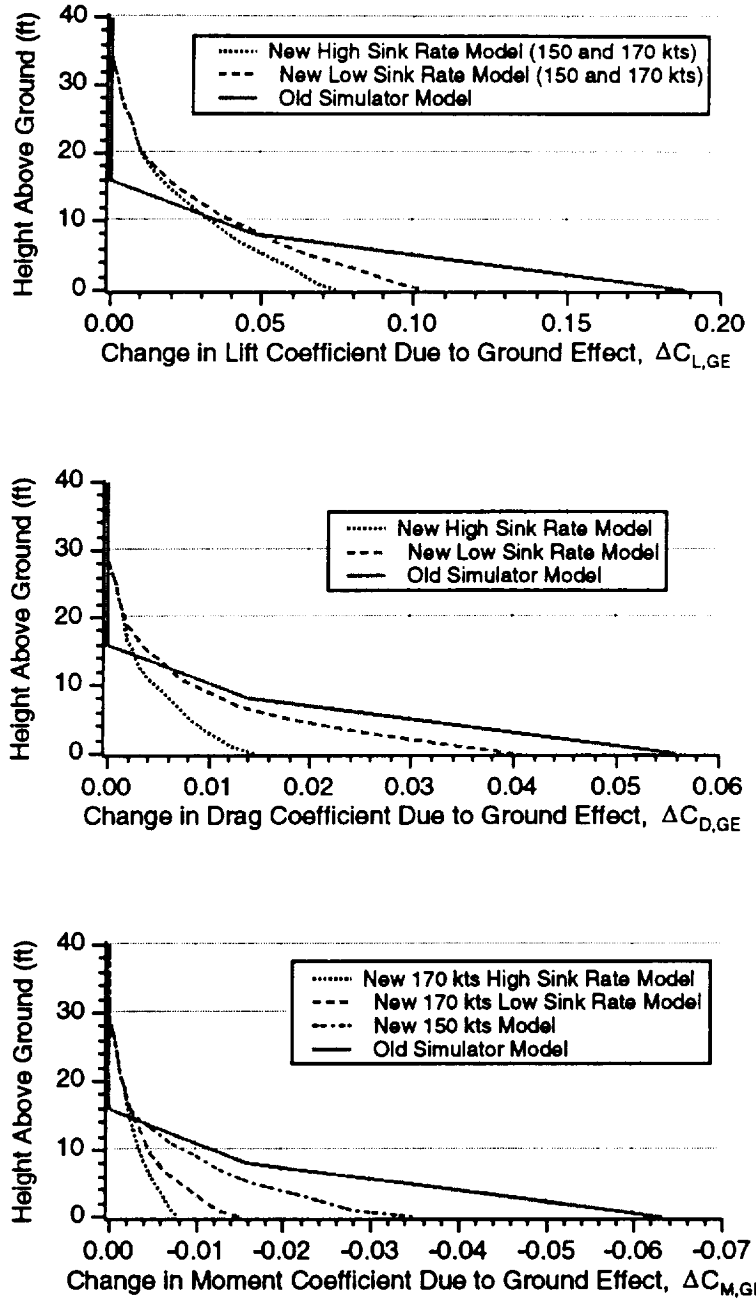




Previous Ground Effect Data Comparison

The F-15 ground effects lift data resulting from this investigation were compared to other wind tunnel and flight data for various wings and for complete aircraft. This figure shows the percent increase in the lift coefficient caused by ground effect as a function of the aspect ratio for the various wings and aircraft. The percent increase in the lift coefficient is defined as the difference between the lift coefficients in and out of ground effect divided by the out of ground effect lift coefficient. Static and dynamic data are shown. These data are for a height above the ground divided by wing span, h/b, of 0.3. The F-15 data are for the 170 kts with the flaps up configuration.

Correlation curves for the wing and for the aircraft are shown. In general, the F-15 flight data correlate well with the available aircraft dynamic ground effect data. These data show a decrease in the percent change in the lift coefficient as the aspect ratio increases. The changes in lift appear to approach nearly constant values for aspect ratios greater than about 3.



Improvement in F-15 Ground Effects Flight Simulator Model

This figure shows the improvements made to the NASA Dryden F-15 flight simulator modeling of ground effects based on the ground effects flight test data. The changes in the aerodynamic coefficients are shown as a function of height above the ground. The new ground effects model is a function of approach velocity and sink rate. The new model more closely duplicates actual flight data as seen in the results presented in the flight test paper by Burcham and Maine ("Flight Test of a Propulsion Controlled Aircraft System on the NASA F-15 Airplane").