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Lift and drag due to spoiler operation in the ground run

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THE PREPARATION OF THIS DATA ITEM

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LIFT AND DRAG DUE TO SPOILER OPERATION IN THE GROUND RUN

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LIFT AND DRAG DUE TO SPOILER OPERATION IN THE GROUND RUN

1. NOTATION AND UNITS

		SI	British
A	wing aspect ratio, b^2/S_{gross}		
b	wing span	m	ft
C_D	total aircraft drag coefficient on ground in ground roll attitude with slats, flaps and spoilers deployed (see Equation (5.1))		
C_D^*	aircraft drag coefficient on ground in ground roll attitude with slats and flaps deployed		
C_{D0}	aircraft zero-lift drag coefficient on ground with flaps and spoilers retracted (includes undercarriage and slat drag)		
C_{Lsl}	lift coefficient on ground in ground roll attitude with slats deployed		
C_L	net overall lift coefficient on ground in ground roll attitude with slats, flaps and spoilers deployed (see Sketch 4.1)		
$\left. \begin{matrix} c_a \\ c_b \end{matrix} \right\}$	flap chords used in determining c_f (see Sketch 3.2)	m	ft
c_f	spoiler chord at mid-span of spoiler combination under consideration, measured from hinge line (see Sketch 3.2)	m	ft
c_n	reference wing chord normal to $1/4$ -chord line (passing through $1/4$ -chord point of c_s)	m	ft
c_s	streamwise reference wing chord through mid-span of spoiler combination under consideration (see Sketch 3.2)	m	ft
F	frontal area of individual spoiler panel (see Equation (5.4))	m ²	ft ²
F_F	frontal area of those parts of flaps affected by spoilers (assumed to extend for three spoiler chords along hinge line outboard and inboard of spoiler extremities, see Section 3.3)	m ²	ft ²
F_S	total frontal area of deflected spoilers ($= \Sigma F$, see Equation (5.4))	m ²	ft ²

K	part-span factor on vortex drag due to flap deflection (taken as 0.3 for those cases in which spoilers affect only part of flap span (see Section 5.2) and as given by Item Nos Aero F.02.01.08 and 09 for those cases in which spoilers affect whole of flap span (see Section 5.3))		
S_{gross}	gross wing planform area (see Sketch 3.1)	m ²	ft ²
S_p	planform area of individual spoiler panel, measured from hinge line	m ²	ft ²
t	maximum thickness of wing reference section	m	ft
α	wing incidence	degree	degree
ΔC_{D0u}	portion of total increment in zero-lift drag coefficient due to flap deflection on ground arising from those portions of flap span unaffected by spoilers (see Section 5.2)		
ΔC_{LF}	increment in lift coefficient due to flap deflection in free air (spoilers retracted) at incidence corresponding to ground attitude, arising from those parts of flaps to be affected by spoilers (see Section 3.3)		
ΔC_{Lf}	increment in lift coefficient due to flap deflection on ground in ground roll attitude (see Sketch 4.1)		
ΔC_{Lsf}	lift coefficient increment in free air (slats and flaps retracted) at incidence corresponding to ground attitude, arising from split flaps with same geometry as spoilers and obtained from Item Nos 74009 and 74012 (see Section 3.2)		
δC_D	increment in drag coefficient on ground, in ground roll attitude with slats and flaps deployed, due to deflection of spoilers (see Equation (6.1))		
δC_{D0}	increment in C_{D0} due to deployment of flaps and spoilers on ground for those parts of flap span affected by spoilers (see Section 5.4)		
$\delta C'_{D0}$	increment in C_{D0} due to deployment of flaps and spoilers on ground for those parts of flap span affected by spoilers, based on frontal area of spoilers and those parts of flap span affected by spoilers (see Section 5.4)		
δC_L	increment in lift coefficient on ground, in ground roll attitude with slats and flaps extended, due to deflection of spoilers (see Equation (3.1))		
δC_{Lr}	net change* in lift coefficient, on ground in ground roll attitude, arising from flap and spoiler deployment (see Sketch 4.1)		
δ_ϕ	spoiler deflection angle, measured in plane normal to spoiler true hinge-line	degree	degree

η	spanwise distance from wing centre-line non-dimensionalised with respect to $b/2$		
Λ	sweep of line of constant fraction of streamwise chord	degree	degree
Λ_h	sweep of spoiler equivalent hinge-line, required for use in Item No.74009 (see Sketch 3.2)	degree	degree
λ	taper ratio of equivalent wing planform, tip chord/wing centre-line chord		
Φ	part-span factor on flap lift (Item No.74012)		
ϕ	sweep of spoiler true hinge-line (see Sketch 3.2)	degree	degree

Subscripts

i	denotes inboard station of spoiler or flap			
n	denotes quantity measured in plane normal to wing panel $\frac{1}{4}$ -chord line			
o	denotes outboard station of spoiler or flap			
s	denotes quantity measured in streamwise plane parallel to plane of symmetry			
0	pertaining to wing panel leading-edge			
$\frac{1}{4}$ $\frac{1}{2}$	<table> <tr> <td>pertaining to $\frac{1}{4}$-chord line</td> <td rowspan="2">} of equivalent wing planform or wing panel as appropriate</td> </tr> <tr> <td>pertaining to $\frac{1}{2}$-chord line</td> </tr> </table>	pertaining to $\frac{1}{4}$ -chord line	} of equivalent wing planform or wing panel as appropriate	pertaining to $\frac{1}{2}$ -chord line
pertaining to $\frac{1}{4}$ -chord line	} of equivalent wing planform or wing panel as appropriate			
pertaining to $\frac{1}{2}$ -chord line				
1	pertaining to wing panel trailing-edge			

* The sign convention adopted is that δC_{Lr} is positive for an increase and negative for a decrease.

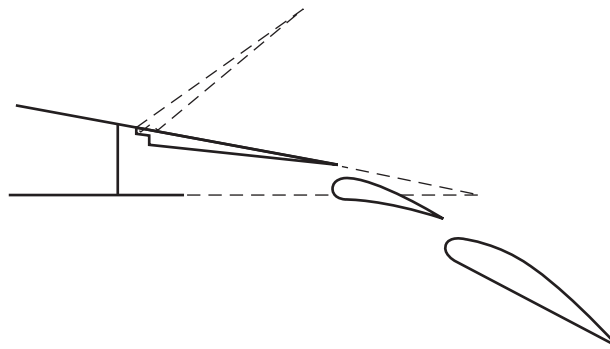
NOTE

- (i) All aerodynamic coefficients are assumed based on S_{gross} unless otherwise stated.
- (ii) All increments in aerodynamic coefficients are “untrimmed” values, *i.e.* they are pertinent to a constant elevator angle.

2. INTRODUCTION

NOTE: Before using this Item Addendum A must be consulted as it will have a direct bearing on the use of the Item. It also deals with the application to “fixed-shroud” spoilers.

One way of reducing the landing ground run of an aircraft with a given brake system is to get as much of the aircraft weight on to the wheels as quickly as possible after touch-down. In order to do this the lift has to be reduced as much as possible and an efficient way of achieving this is to reduce the flap lift drastically. This is commonly effected by deflecting upwards the rear portion of the flap shroud (see Sketch 2.1) thus spoiling the slot flow over the first flap element, thereby reducing the flap lift increment. The deflected shroud acts additionally as an upper-surface split flap providing download and drag in its own right.



Sketch 2.1

In practice, with transport aircraft, there are usually several spoiler panels extending over the full flap span, most of which are operated on the ground but some of which have other, primary, functions as airbrakes, as lateral control surfaces, or as direct lift control surfaces on the landing approach.

Throughout this Item the generic term “spoilers” will be applied to any upper-surface panel deployed on the ground. There are a number of terms ascribed to the different modes of spoiler operation. For example, spoilers operated on the ground are commonly referred to as operating in the “lift-dumping” mode in the UK whereas in the US the term “ground spoiler” mode is often used.

The intention of this Item is to provide a means of estimating the total lift and drag of an aircraft on the ground in the ground roll attitude following the deployment of deflecting-shroud spoilers. To do this it is assumed that the user has a knowledge of the aircraft lift and drag characteristics (spoilers retracted) in ground effect with and without flaps deployed. If free air values only are known Item No.72023 will be of use in estimating the effect of ground proximity.

The total aircraft lift (see Section 4) is calculated using the estimated lift decrease due to spoiler deflection (see Section 3), and the drag increase due to spoiler deflection (see Section 6) is calculated using the estimated total drag of the aircraft (see Section 5).