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Lift and rolling moment due to spoilers on wings with trailing-edge flaps deflected at subsonic speeds – Extension of Item No. 90030

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LIFT AND ROLLING MOMENT DUE TO SPOILERS ON WINGS WITH TRAILING-EDGE FLAPS DEFLECTED AT SUBSONIC SPEEDS – EXTENSION OF ITEM No. 90030

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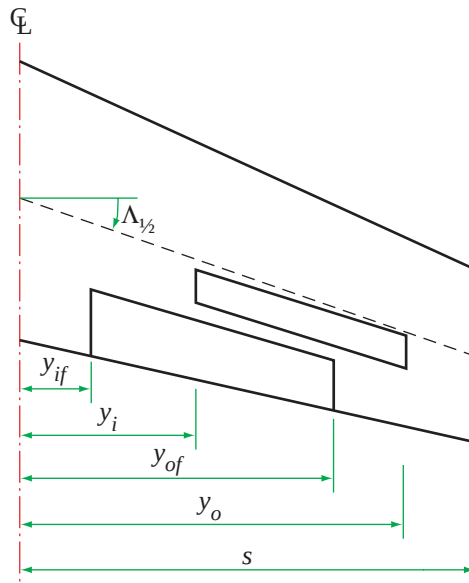
LIFT AND ROLLING MOMENT DUE TO SPOILERS ON WINGS WITH TRAILING-EDGE FLAPS DEFLECTED AT SUBSONIC SPEEDS – EXTENSION OF ITEM No. 90030

1. NOTATION AND UNITS

		<i>SI</i>	<i>British</i>
A	wing aspect ratio		
C_L	lift coefficient		
ΔC_L	total increment in lift coefficient due to spoilers on both wings, $\Delta C_{Ls} + \Delta C_{Lsf}$		
$\Delta C_{Ls\infty}$	two-dimensional value of ΔC_{Ls} , from Figure 1 of Item No. 90030		
ΔC_{Ls}	increment in lift coefficient due to spoilers on both wings, flaps undeflected, from Item No. 90030		
ΔC_{Lsf}	additional increment in lift coefficient due to spoilers on both wings when flaps are deflected (see Section 3.1)		
$dC_L/d\alpha$	wing lift-curve slope	rad^{-1}	rad^{-1}
C_l	total rolling moment coefficient due to starboard spoiler, $C_{ls} + C_{lsf}$		
C_{ls}	rolling moment coefficient due to starboard spoiler, flaps undeflected, from Item No. 90030		
C_{lsf}	additional rolling moment coefficient due to starboard spoiler when flaps are deflected (see Section 3.2)		
c	wing chord	m	ft
$\bar{c}$	wing geometric mean chord	m	ft
c_f	flap chord (see Sketch 2.1)	m	ft
c_{hs}	spoiler chord aft of hinge (see Sketch 1.3 of Item No. 90030)	m	ft
h	“height” of spoiler (see Sketches 1.2 and 1.3 of Item No. 90030)	m	ft
h_{te}	distance from trailing edge of deflected flap to chord line (see Sketch 2.1)	m	ft
k_f	flap factor (see Section 3.1 and Figure 1)		
M	free-stream Mach number		

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s	wing semi-span	m	ft
x_h	chordwise position of spoiler hinge (see Sketch 1.3 of Item No. 90030)	m	ft
y	lateral distance from wing centre-line	m	ft
y_a	moment arm for lift increment due to single spoiler, flaps undeflected (see Section 3.2.2 of Item No. 90030)	m	ft
y_{af}	moment arm for additional lift increment due to single spoiler when flaps are deflected (see Section 3.2)	m	ft
α	incidence (synonymous with angle of attack for purpose of this Item)	deg	deg
δ_f, δ_s	flap deflection, spoiler deflection in streamwise plane	deg, deg	deg, deg
η, η_a, η_{af}	$y/s, y_a/s, y_{af}/s$		
$\Delta\eta_{1f}$	moment-arm correction term for flap loading (see Section 3.2)		
$\Lambda_{1/2}$	sweepback of wing mid-chord line	deg	deg
λ	wing taper ratio, ratio of tip chord to root chord		
σ	spoiler porosity (see Item No. 90030)		
Φ	part-span correction factor for lift (see Section 3.1), from Figure 3 of Item No. 90030		
<i>Subscripts</i>			
exp	denotes experimental value		
i, o	respectively denote inboard, outboard end of spoiler (see Sketch 1.1)		
ie, oe	respectively denote effective inboard, outboard end of spoiler effect on flap		
if, of	respectively denote inboard, outboard end of flap (see Sketch 1.1)		
$pred$	denotes predicted value		



Sketch 1.1 Wing, flap and spoiler geometry

2. INTRODUCTION

Item No. 90030 (Derivation 14) presents a method for predicting the lift and rolling moment due to upper-surface spoiler deflection on wings at subsonic speeds. This Item extends that method to the effect of upper-surface spoilers when trailing-edge flaps are deflected, with comment on the effect of venting from the lower surface. Experimental data were taken from Derivations 1 to 13. Reference 15 considers the effect of spoilers, with flaps deflected, during the ground run for more limited ranges of wing, flap and spoiler geometry.

2.1 Flap Types and Flow Patterns

The main types of trailing-edge flap, *i.e.* split, plain and slotted, are shown in Sketch 2.1.

The split flap is effectively a spoiler, and will generate a separated flow for all flap deflections.

The plain flap has attached flow for low flap deflections, and is therefore more effective than the split flap in generating lift. With increase of flap deflection the flow over the flap will eventually separate, producing a flow pattern very similar to that of the split flap. Note, therefore, that when the flow over the flap is already separated the effectiveness of a spoiler (in generating a separated flow) is greatly reduced. The flap deflection for separation decreases as incidence increases.

The single- or double-slotted flap, usually used with chord extension, as in the case of the Fowler flap, retains attached flow to much larger flap deflections than a plain flap. With the double-slotted flap the separation may be staged, occurring at different flap deflections for the two flap elements.

Upper-surface spoilers used in combination with trailing-edge flaps can cause the flow over the flap to separate. Small spoiler deflections may, however, be ineffective, whilst large spoiler deflections will further increase the extent of the separation. The resulting lift increment is usually negative, *i.e.* the effect is to give a decrement in lift. A typical variation in lift decrement with spoiler deflection is shown in Sketch 2.2. Except for small spoiler deflections the lift decrement can be considered as that due to the spoiler when

trailing-edge flaps are undeflected plus an additional amount when the flaps are deflected. The additional lift decrement is a function of the type of flap (as it affects flow condition), flap chord and deflection, and incidence.

2.2 Three-dimensional Behaviour

When the trailing-edge flap is undeflected the lift decrement due to spoiler deflection on the upper surface of a wing is given by the method of Item No. 90030. When the trailing-edge flap is deflected the additional lift decrement is related to the extent that the spoiler separates the flow over the flap.

The spoiler creates an area of separated flow downstream, with some lateral spread. Insofar as the spanwise extent of the flap may be different from that of the spoiler, the effective spanwise extent of the separated flow over the flap will include only those portions of the flap within this lateral spread.

2.3 Venting from Lower Surface

Air can be vented from the lower to the upper surface either through the wing ahead of the flap or flap shroud, through the flap shroud, or by moving the shroud trailing edge as a spoiler (see Sketch 2.3). The position, width and spanwise extent of such venting relative to the spoiler may be varied, and the free passage of air may be affected by spoiler deflection. The available information is insufficient to enable a full analysis to be made, although the indications are that such venting can increase the effectiveness of spoilers, particularly for large deflections.