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Wing lift coefficient increment at zero angle of attack due to deployment of single-slotted flaps at low speeds

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THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item which supersedes Item No. Aero F.01.01.08, was monitored and guided by the Aerodynamics Committee. This Committee first met in 1942 and now has the following membership:

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WING LIFT COEFFICIENT INCREMENT AT ZERO ANGLE OF ATTACK DUE TO DEPLOYMENT OF SINGLE-SLOTTED FLAPS AT LOW SPEEDS

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WING LIFT COEFFICIENT INCREMENT AT ZERO ANGLE OF ATTACK DUE TO DEPLOYMENT OF SINGLE-SLOTTED FLAPS AT LOW SPEEDS

1. NOTATION AND UNITS

		SI	British
A	aspect ratio, $2s/\bar{c}$		
a_1	basic wing lift-curve slope, $dC_L/d\alpha$ (see Item No. 70011)	rad^{-1}	rad^{-1}
$(a_1)_0$	basic aerofoil lift-curve slope in incompressible flow	rad^{-1}	rad^{-1}
C_L	lift coefficient; (lift per unit span)/ qc for aerofoil, lift / qS for wing		
ΔC_{L0t}	increment in aerofoil lift coefficient at $\alpha = 0$ due to deployment of trailing-edge flap, based on c (see Item No. 94030)		
$\Delta C'_{L0t}$	increment in aerofoil lift coefficient at $\alpha = 0$ due to deployment of trailing-edge flap, based on c' (see Item No. 94030)		
ΔC_{L0tw}	increment in wing lift coefficient at $\alpha = 0$ due to deployment of trailing-edge flap, based on S		
$\Delta C'_{L1}$	increment in lift coefficient associated with deployment of single-slotted flap on aerofoil with lift-curve slope of 2π , based on c' , Figure 2 (from Item No. 94030)		
c	chord of basic aerofoil chosen to be representative of wing, <i>i.e.</i> chord at mid-span of flap panel, see Sketch 1.1	m	ft
c'	extended aerofoil chord, <i>i.e.</i> chord with trailing-edge flap deployed, see Sketch 1.2	m	ft
c_r	wing root (centre-line) chord, see Sketch 1.1	m	ft
c_{t1}	chord of single-slotted trailing-edge flap, see Sketch 1.2	m	ft
Δc_{t1}	increment in c_{t1} , see Sketch 1.2	m	ft
c'_{t1}	extended chord of single-slotted trailing-edge flap, see Sketch 1.2	m	ft
$\bar{c}$	wing geometric mean chord	m	ft
$\bar{\bar{c}}$	wing aerodynamic mean chord	m	ft

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J_{t1}	correlation factor (efficiency factor) for single-slotted trailing-edge flap, Figure 1 (from Item No. 94030)		
K_{f0}	flap-type correlation factor, see Section 4		
M	free-stream Mach number		
q	free-stream kinetic pressure	N/m ²	lbf/ft ²
$R_{\bar{c}}$	Reynolds number based on free-stream conditions and $\bar{c}$		
S	wing planform area, $2s\bar{c}$	m ²	ft ²
s	wing semi-span, see Sketch 1.1	m	ft
x	chordwise distance aft from aerofoil leading edge	m	ft
x_{ts}	chordwise location of flap-shroud trailing edge, see Sketch 1.2	m	ft
α	angle of attack (angle of incidence in Item No. 83040)	rad	rad
β	compressibility parameter, $(1 - M^2)^{1/2}$		
δ_{t1}°	deflection of single-slotted trailing-edge flap, see Sketch 1.2	deg	deg
η	spanwise distance from wing centre-line as fraction of semi-span		
η_i	value of η at inboard limit of flap, see Sketch 1.1		
η_o	value of η at outboard limit of flap, see Sketch 1.1		
$\bar{\eta}$	value of η at spanwise centre of pressure for loading due to angle of attack, see Item No. 83040		
κ	wing taper parameter in Item No. 83040; $\int_0^1 (c/\bar{c})\eta \, d\eta$, giving $(1 + 2\lambda)/[3(1 + \lambda)]$ for straight tapered wing		
Λ_h	flap hinge-line sweep angle, see Section 2 and Sketch 1.1	deg	deg
Λ_0	wing leading-edge sweep angle, see Sketch 1.1	deg	deg
$\Lambda_{1/4}$	wing quarter-chord sweep angle, see Sketch 1.1	deg	deg
$\Lambda_{1/2}$	wing mid-chord sweep angle	deg	deg
Λ_1	wing trailing-edge sweep angle, see Sketch 1.1	deg	deg
λ	wing taper ratio (tip chord/root chord)		

Φ part-span factor; lift coefficient increment due to part-span flaps extending symmetrically from wing centre-line divided by lift coefficient increment due to full-span flaps at same flap setting and wing angle of attack

Φ_i value of Φ corresponding to η_i , Figure 3

Φ_o value of Φ corresponding to η_o , Figure 3

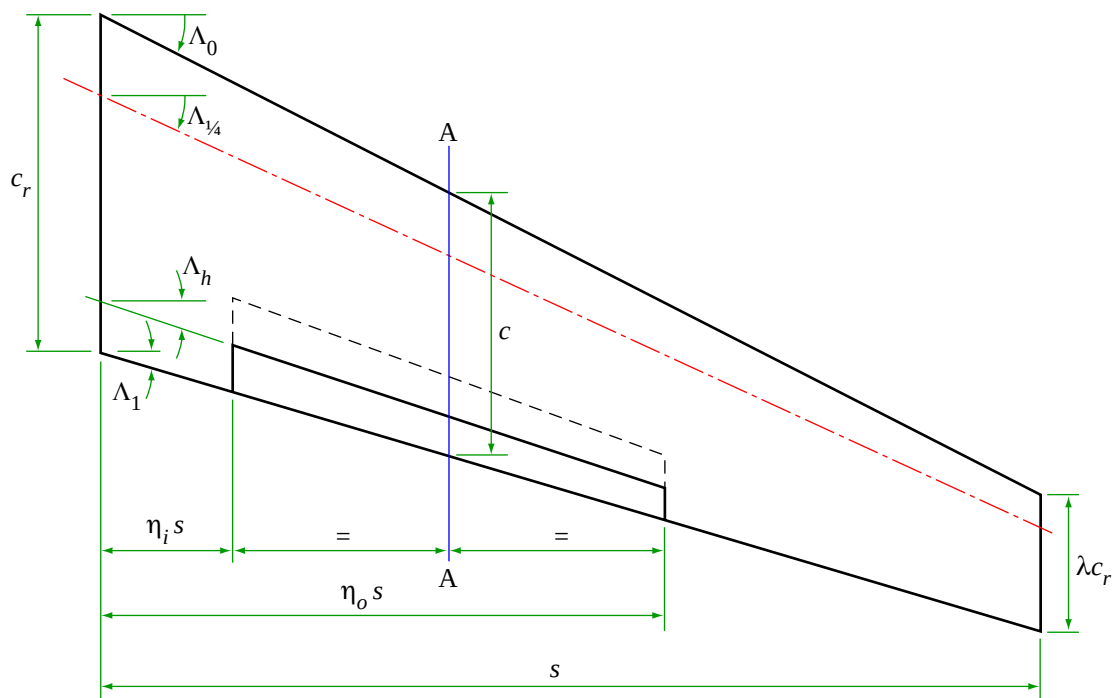
Subscripts

full-span denotes full-span flap ($\eta_i = 0$, $\eta_o = 1$)

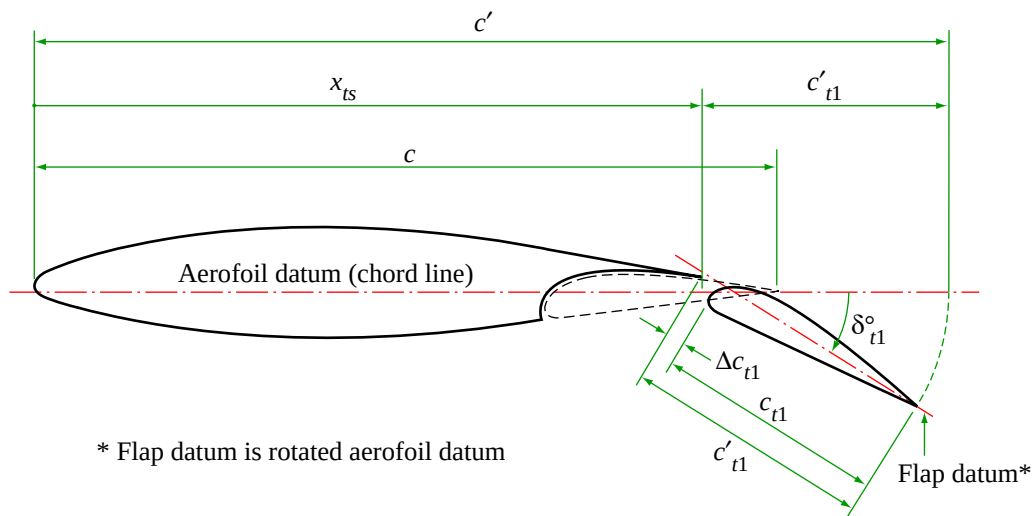
part-span denotes part-span flap ($\eta_i (\geq 0) < \eta_o \leq 1$)

$()_{expt}$ denotes experimental value

$()_{pred}$ denotes predicted value



Sketch 1.1 Wing notation (flaps undeployed)



Sketch 1.2 Deployed single-slotted flap notation (at section AA in Sketch 1.1)

2. INTRODUCTION

In this Item the increment in lift coefficient at zero angle of attack due to the deployment of trailing-edge single-slotted flaps on a wing is derived from the increment in lift coefficient due to the deployment of a trailing-edge single-slotted flap on an aerofoil section that is representative of the wing. For wings with full-span flaps a factor dependent on planform geometry is applied to allow for three-dimensional effects. For wings with part-span flaps additional factors are introduced that are dependent on the flap and wing geometry. Finally, an empirical correlation factor, dependent on flap type, is applied. Wings with double-slotted or triple-slotted flaps are dealt with in Item No. 95021 (Reference 21).

At low speeds, the increment in lift coefficient at zero angle of attack, ΔC_{L0tw} , due to the deployment of a full-span flap on a high-aspect-ratio rectangular wing is strongly dependent on the corresponding value, ΔC_{L0t} , for an aerofoil/flap combination appropriate to the mid semi-span location. The main parameters that can influence ΔC_{L0t} are the flap angle, the aerofoil shape, the change of aerofoil chord length due to flap deployment, the effective chord of the flap, the flap type, and the flow Reynolds and Mach numbers. For flaps on wings the additional parameters that can influence ΔC_{L0tw} are the wing planform geometry (aspect ratio, taper ratio and sweep), the spanwise extent of the flap and flap hinge-line sweep angle. The effects of wing planform geometry are largely accounted for in terms of their effect on the wing lift-curve slope. Note that for a simple slotted flap or a Fowler flap it is normally sufficiently accurate to take the hinge-line sweep angle, Λ_h , to be either the sweep of the leading edge of the deployed flap or the sweep of the flap-shroud trailing edge, see Sketch 1.1.

3. REQUIRED DATA ITEMS

The ESDU Data Items that may be required in the use of this Item are:

<i>Data Item No.*</i>	<i>Derivation No.</i>	<i>To Determine</i>
70011	1	Wing lift-curve slope.
76003	2	Wing planform geometry.
83040	3	Wing spanwise centre of pressure location.
94030	4	ΔC_{L0t} .

* A Location Schedule is contained in the Organisational Guide-card Section of Volume 1a. This identifies the Volume in which each Item is held.

4. PREDICTION METHOD

Reports considered in the development of the method include work by Davison, Young and Lowry and Polhamus (References 16, 17 and 18) and Item No. 94030 (Derivation 4).

The resulting method uses Item No. 94030 for the characteristics of the representative aerofoil/flap combination coupled with empirical corrections for the effects of wing planform geometry, flap type and spanwise extent.

The aerofoil/flap combination that is taken as representative of the wing/flap system is that at the mid-span of the flap panel, see Sketch 1.1. By this means the effects of any spanwise variation of either the aerofoil section or the flap chord ratio are averaged out.

This Item contains a dedicated part-span factor that is dependent, in addition to flap spanwise extent, on the spanwise position of the centre of pressure of the loading due to angle of attack for the plain wing. It should be used in preference to the factor in Item No. 74012 (Reference 20) which was derived for plain flaps, since it gives an improved correlation of the slotted flap data. The results using the present method are consistent with those of the methods in References 18 and 19.

The method requires the use of streamwise flap angles and streamwise section and flap geometries, see Sketches 1.1 and 1.2. The primary effects of wing planform geometry in terms of aspect ratio, taper ratio and sweep are realised through their influence on the wing lift-curve slope. A flap-type correlation factor K_{f0} is required for single-slotted flaps.

The general expression for the increment in wing lift coefficient at zero angle of attack due to the deployment of a single-slotted trailing-edge flap on an aerofoil is

$$\Delta C_{L0t} = (c'/c)\Delta C'_{L0t} \quad (4.1)$$

where $\Delta C'_{L0t}$ is the increment in aerofoil lift coefficient at zero angle of attack based on the extended chord length c' , and is given by Equation (4.1) of Item No. 94030, viz.

$$\Delta C'_{L0t} = J_{t1}\Delta C'_{L1}(a_1)_0/2\pi. \quad (4.2)$$