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Aerofoil and wing pitching moment coefficient at zero angle of attack due to deployment of trailing-edge split flaps at low speeds

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THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item which supersedes, in part, ESDU Aero F.08.01.01 and F.08.01.02, was monitored and guided by the Aerodynamics Committee. This Committee first met in 1942 and now has the following membership:

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AEROFOIL AND WING PITCHING MOMENT COEFFICIENT AT ZERO ANGLE OF ATTACK DUE TO DEPLOYMENT OF TRAILING-EDGE SPLIT FLAPS AT LOW SPEEDS

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AEROFOIL AND WING PITCHING MOMENT COEFFICIENT AT ZERO ANGLE OF ATTACK DUE TO DEPLOYMENT OF TRAILING-EDGE SPLIT FLAPS AT LOW SPEEDS

1. NOTATION AND UNITS

		SI	British
A	aspect ratio, $2s/\bar{c}$		
C_L	lift coefficient; $(lift)/qc$ for aerofoil, $](lift)/qS$ for wing		
ΔC_{L0t}	increment in lift coefficient at zero angle of attack due to deployment of trailing-edge split flap on aerofoil, based on c		
C_m	pitching moment coefficient; $(pitching\ moment)/qc^2$ for aerofoil, $(pitching\ moment)/qS\bar{c}$ for wing, referenced to $c/4$ for aerofoil and $\bar{c}/4$ for wing, see Sketch 1.1		
$\Delta C_{m\alpha 0}$	increment in pitching moment coefficient at zero angle of attack due to deployment of trailing-edge split flap on aerofoil, based on c^2 and referenced to $c/4$, see Equation (3.1)		
$\Delta C_{mtw\alpha 0}$	increment in pitching moment coefficient at zero angle of attack due to deployment of trailing-edge split flap on wing, based on $S\bar{c}$ and referenced to $\bar{c}/4$, see Equation (3.4)		
c	basic (plain) aerofoil chord (<i>i.e.</i> chord with high-lift devices undeployed), see Sketch 1.2	m	ft
$\bar{c}$	wing geometric mean chord	m	ft
$\bar{\bar{c}}$	wing aerodynamic mean chord	m	ft
c_r	wing root chord	m	ft
c_t	chord of trailing-edge split flap, see Sketch 1.2	m	ft
h_2	centre of incremental lift at zero angle of attack due to trailing-edge split flap deflection on aerofoil section expressed as fraction of chord, measured positive aft from aerofoil quarter-chord position, see Equation (3.2)		

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h_{2T}	theoretical value of h_2 , see Equation (3.3)		
K_f	flap type correlation factor		
$K_{f\Lambda}$	flap type correlation factor for sweep		
K	part-span factor; pitching moment coefficient increment due to part-span trailing-edge split flaps extending symmetrically from wing centre-line of unswept wing ($\Lambda_{1/4} = 0$) divided by pitching moment coefficient increment due to full-span trailing-edge split flaps at same deflection angle and wing angle of attack		
K_i	value of K corresponding to $\eta = \eta_i$, Figure 1		
K_o	value of K corresponding to $\eta = \eta_o$, Figure 1		
K_Λ	wing sweep factor dependent on wing taper ratio and spanwise extent of trailing-edge flap, Equation (3.5)		
$K_{\Lambda i}$	value of K_Λ corresponding to $\eta = \eta_i$, Figure 2		
$K_{\Lambda o}$	value of K_Λ corresponding to $\eta = \eta_o$, Figure 2		
M	free-stream Mach number		
q	free-stream kinetic pressure	N/m ²	lbf/ft ²
R_c	aerofoil Reynolds number based on free-stream conditions and c		
$R_{\bar{c}}$	wing Reynolds number based on free-stream conditions and $\bar{c}$		
S	wing planform area, $2s\bar{c}$	m ²	ft ²
s	wing semispan, see Sketch 1.1	m	ft
t	maximum thickness of aerofoil	m	ft
z_{lm}	lowest surface ordinate of basic aerofoil, see Sketch 1.2	m	ft
δ_t°	deflection of trailing-edge flap, positive trailing-edge down, see Sketch 1.2	deg	deg
η	spanwise distance from wing centre-line as fraction of semispan		
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		

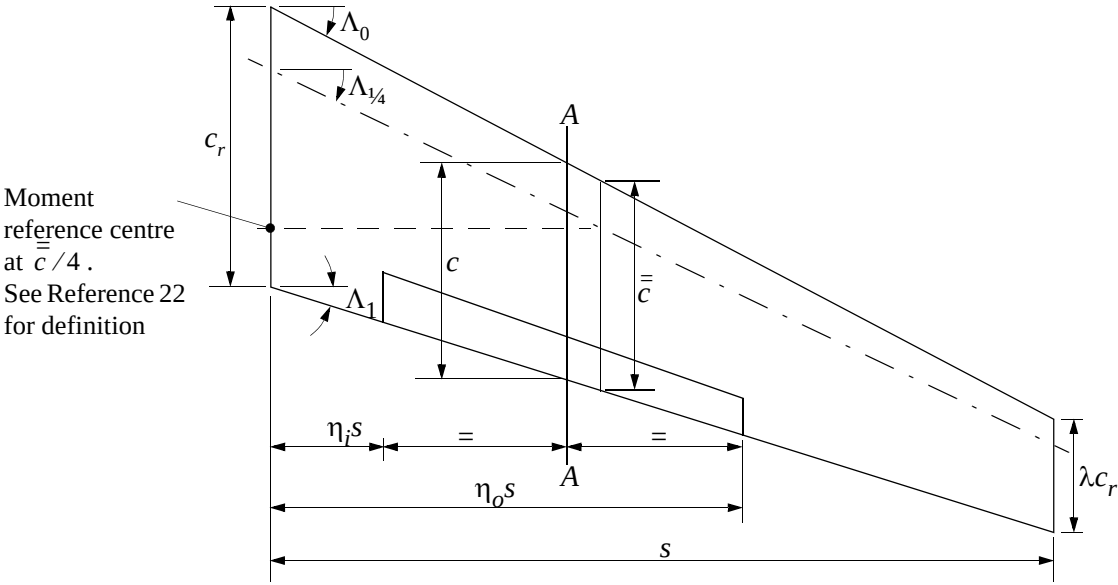
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Λ_0	wing leading-edge sweep angle, see Sketch 1.1	deg	deg
$\Lambda_{1/4}$	wing quarter-chord sweep angle, see Sketch 1.1	deg	deg
Λ_1	wing trailing-edge sweep angle, see Sketch 1.1	deg	deg
λ	wing taper ratio (tip chord/root chord)		

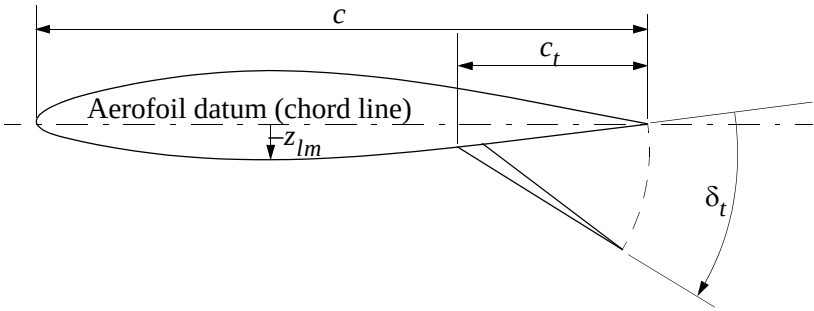
Subscripts

α_0	denotes value at zero angle of attack
$()_{expt}$	denotes experimental value
$()_{pred}$	denotes predicted value

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Sketch 1.1 Wing notation (flaps undeveloped)



Sketch 1.2 Deployed split flap notation (at Section AA)

2. INTRODUCTION

This Item provides a method to obtain the increment in pitching moment coefficient at zero angle of attack, due to deployment of trailing-edge split flaps, either on an aerofoil or on a wing.

For aerofoils the method predicts the centre of lift position, h_2 , due to split flap deployment, based on the thin aerofoil theory of Derivation 19 and modified to obtain correlation with the experimental data of Derivations 5, 6, 12 and 17. This is combined with the increment in aerofoil lift coefficient calculated from Item No. 94029 (Derivation 1) to estimate the pitching moment coefficient increment.

For wings with full-span trailing-edge split flaps, factors, dependent on planform geometry, are applied to the pitching moment coefficient increment on an aerofoil section that is representative of the wing, to allow for three-dimensional effects. For wings with part-span trailing-edge flaps, additional factors are introduced that are dependent on the wing taper ratio, aspect ratio and sweep as well as on the spanwise extent of the flap. Derivations 20 and 21 were used as the basis for three dimensional effects, with some adjustment to the simple theoretical assumptions.

Section 3 describes the prediction method and Section 4 discusses Mach number and Reynolds number effects. The accuracy and applicability of the method are addressed in Section 5. The Derivation and References are given in Section 6. Section 7 presents a worked example that illustrates the steps of the calculation.

3. PREDICTION METHOD

The method of this Item requires the use of Item No. 94029 to determine the lift increment characteristics of the aerofoil/trailing-edge split-flap combination.

For a wing the *streamwise* section and trailing-edge split flap geometries and angles at the mid-span of the flap panel are taken to be representative of the wing/split-flap system, see Sketches 1.1 and 1.2. By this means the effects of spanwise variation are averaged out. Empirical corrections allow for the effects of wing planform geometry and the spanwise extent of the flaps.

3.1 Aerofoil Pitching Moment Coefficient Increment, $\Delta C_{m\alpha 0}$

The increment in the pitching moment coefficient at zero angle of attack, for deployment of a split flap on an aerofoil is

$$\Delta C_{m\alpha 0} = -\Delta C_{L0t} h_2 \quad (3.1)$$

where ΔC_{L0t} is the increment in lift coefficient at zero angle of attack due to deployment of a split flap on an aerofoil and is obtained from the method of Item No. 94029.

The centre of the lift increment, at zero angle of attack, h_2 , derived empirically for a split flap deflected on an aerofoil section, expressed as a ratio of the chord and measured positive aft from the quarter-chord point, is given by

$$h_2 = h_{2T} - 0.025 + 0.22(c_t/c)^2 - 0.0000457(c_t/c)(\delta_t^\circ)^2 - 0.0436(c_t/c)(z_{lm}/c)\delta_t^\circ \quad (3.2)$$

where c_t/c is the ratio of the flap chord to the aerofoil chord,

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