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Increments in aerofoil lift coefficient at zero angle of attack and in maximum lift coefficient due to deployment of a plain trailing-edge flap, with or without a leading-edge high-lift device, at low speeds

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THE PREPARATION OF THIS DATA ITEM

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INCREMENTS IN AEROFOIL LIFT COEFFICIENT AT ZERO ANGLE OF ATTACK AND IN MAXIMUM LIFT COEFFICIENT DUE TO DEPLOYMENT OF A PLAIN TRAILING-EDGE FLAP, WITH OR WITHOUT A LEADING-EDGE HIGH-LIFT DEVICE, AT LOW SPEEDS

CONTENTS

	Page
1. NOTATION AND UNITS	1
2. INTRODUCTION	3
2.1 Scope of the Item	3
2.2 Application of Data to Calculation of Total Lift Coefficient Values C_{L0} and C_{Lm}	3
3. LIFT COEFFICIENT INCREMENTS Δ_{CL0} AND Δ_{CLm}	3
4. LIFT COEFFICIENT INCREMENTS $\Delta C'_{L0t}$ AND $\Delta C'_{Lmt}$	4
4.1 Increment in Lift Coefficient at Zero Angle of Attack	5
4.2 Increment in Maximum Lift Coefficient	5
5. APPLICABILITY AND ACCURACY	7
5.1 Applicability	7
5.2 Accuracy	8
6. DERIVATION AND REFERENCE	10
6.1 Derivation	10
6.2 Reference	10
7. EXAMPLES	11
7.1 Example 1: Plain trailing-edge Flap	11
FIGURES 1 & 2	16 & 17

INCREMENTS IN AEROFOIL LIFT COEFFICIENT AT ZERO ANGLE OF ATTACK AND IN MAXIMUM LIFT COEFFICIENT DUE TO DEPLOYMENT OF A PLAIN TRAILING-EDGE FLAP, WITH OR WITHOUT A LEADING-EDGE HIGH-LIFT DEVICE, AT LOW SPEEDS

1. NOTATION AND UNITS

		SI	British
A	parameter in equation for T , Equation (4.14)		
a_t	theoretical rate of change of lift coefficient with trailing-edge flap deflection, Equation (4.2)	rad^{-1}	rad^{-1}
B	parameter in equation for T , Equation (4.15)		
C	parameter in equation for T , Equation (4.16)		
C_{Lm}	maximum lift coefficient of aerofoil with high-lift devices deployed, based on c		
C_{L0}	lift coefficient at zero angle of attack for aerofoil with high-lift devices deployed, based on c		
ΔC_{Lm}	increment in maximum lift coefficient due to deployment of high-lift devices, based on c , Equation (3.2)		
ΔC_{Lml}	increment in maximum lift coefficient due to deployment of leading-edge high-lift device, based on c , Equation (3.2)		
ΔC_{Lmt}	increment in maximum lift coefficient due to deployment of trailing-edge flap, based on c , Equation (3.5)		
$\Delta C'_{Lmt}$	increment in maximum lift coefficient due to deployment of trailing-edge flap, based on c' , Equation (4.8), at datum Reynolds number $R_c = 3.5 \times 10^6$		
ΔC_{L0}	increment in lift coefficient at zero angle of attack due to deployment of high-lift devices, based on c , Equation (3.1)		
ΔC_{L0l}	increment in lift coefficient at zero angle of attack due to deployment of leading-edge high-lift device, based on c , Equation (3.1)		
ΔC_{L0t}	increment in lift coefficient at zero angle of attack due to deployment of trailing-edge flap, based on c , Equation (3.4)		
$\Delta C'_{L0t}$	increment in lift coefficient at zero angle of attack due to deployment of trailing-edge flap, based on c' , Equation (4.5)		
c	basic (plain) aerofoil chord (<i>i.e.</i> chord with high-lift devices undeployed), see Sketch 4.1	m	ft

Issued December 1994 – 17 pages

c'	extended aerofoil chord (<i>i.e.</i> chord with high-lift devices deployed), see Sketch 4.1	m	ft
c_{el}	effective chord of leading-edge device, see Item No. 94027	m	ft
c_t	chord of trailing-edge flap, see Sketch 4.1	m	ft
Δc_l	chord extension due to deployment of leading-edge device, see Sketch 4.1	m	ft
Δc_t	chord extension due to deployment of trailing-edge flap, Equation (4.6); $\Delta c_t = 0$ for plain flap	m	ft
F_R	factor for effect of Reynolds number on ΔC_{Lml} and ΔC_{Lmt} , Equation (3.3)		
J_p	correlation factor (efficiency factor) for plain flap in Equation (4.5), Figure 1		
K_G	correlation factor for aerofoil geometry in Equation (4.8), Equation (4.9)		
K_t	correlation factor for flap deflection in Equation (4.8); $K_t = 0.8$ for plain flap		
M	free-stream Mach number		
R_c	Reynolds number based on free-stream conditions and aerofoil chord c		
T	theoretical value of $\Delta C'_{Lmt}/\Delta C'_{L0t}$, Equation (4.11) or (4.13) or Figure 2		
t	maximum thickness of aerofoil	m	ft
x'_s	chordwise location of boundary-layer separation measured from leading edge of extended chord, Equation (4.12)	m	ft
δ_t, δ_t°	deflection of trailing-edge flap, positive trailing edge down, see Sketch 4.1	rad, deg	rad, deg
θ_s	angular parameter related to location of separation, Equation (4.12)	rad	rad
θ_t	angular parameter related to trailing-edge flap chord, Equation (4.3)	rad	rad
ρ_l	leading-edge radius of basic (plain) aerofoil, see Sketch 4.1	m	ft
ϕ_t°	angle between aerofoil datum and tangent to upper surface at trailing edge, see Sketch 4.1	deg	deg

Subscripts

()_{expt} denotes experimental value

()_{pred} denotes predicted value

2. INTRODUCTION

2.1 Scope of the Item

This Item provides semi-empirical methods for estimating the incremental effects on aerofoil lift at zero angle of attack and on maximum lift due to the deployment of plain trailing-edge flaps, with or without the deployment of leading-edge high-lift devices, at low speeds.

Section 3 summarises the equations relating the contributions to the total lift increments at zero angle of attack and at maximum lift arising from the deployment of leading-edge high-lift devices and trailing-edge flaps. The contributions from leading-edge high-lift devices are obtainable from Derivation 8. Section 4 presents methods whereby the contributions from plain trailing-edge flaps are obtained.

Section 5 concerns applicability and accuracy, Section 6 gives the Derivation and References and Section 7 presents two detailed examples illustrating the use of the methods.

2.2 Application of Data to Calculation of Total Lift Coefficient Values C_{L0} and C_{Lm}

In order to use the data obtained from the present Item in the wider context in which the total lift coefficient at zero angle of attack, C_{L0} , and at maximum lift, C_{Lm} , are required for an aerofoil with high-lift devices deployed, it is necessary to refer to Item No. 94026 (Reference 9). That Item acts as an introduction to, and a link between, the Items in the complete series dealing with the incremental effects of high-lift device deployment on aerofoil lift at zero angle of attack and on maximum lift. It describes how the incremental effects are summed and added to the contributions from the basic (*i.e.* plain) aerofoil to give the total values C_{L0} and C_{Lm} .

3. LIFT COEFFICIENT INCREMENTS ΔC_{L0} AND ΔC_{Lm}

The increments in the lift coefficient at zero angle of attack, ΔC_{L0} , and at maximum lift, ΔC_{Lm} , due to the deployment of a leading-edge high-lift device and a trailing-edge flap on an aerofoil are given by the sum of the individual increments, *i.e.*

$$\Delta C_{L0} = \Delta C_{L0l} + \Delta C_{L0t} \quad (3.1)$$

$$\text{and} \quad \Delta C_{Lm} = \Delta C_{Lml} + \Delta C_{Lmt} \quad (3.2)$$

The increments in Equations (3.1) and (3.2) are based on the chord, c , of the basic aerofoil.

The values of ΔC_{L0l} and ΔC_{Lml} for various leading-edge high-lift devices are obtainable from Item No. 94027 (Derivation 8).

For correlation purposes it is more convenient to present the right-hand sides of Equations (3.1) and (3.2) in terms of increments based on the aerofoil extended chord c' . Also, whereas values of ΔC_{L0l} and ΔC_{L0t} can be taken to be independent of Reynolds number, values of ΔC_{Lml} and ΔC_{Lmt} are influenced by Reynolds number. Analysis of data in derivations 5 and 7 showed that if the increments in maximum lift coefficient were correlated at a datum Reynolds number, taken here as $R_c = 3.5 \times 10^6$ (see Section 5), then all the Reynolds number dependency could be allowed for through a factor F_R , given by

$$F_R = 0.153 \log_{10} R_c, \quad (3.3)$$

which is unity at the datum.

Therefore, the terms related to the trailing-edge flap on the right-hand sides of Equations (3.1) and (3.2) become

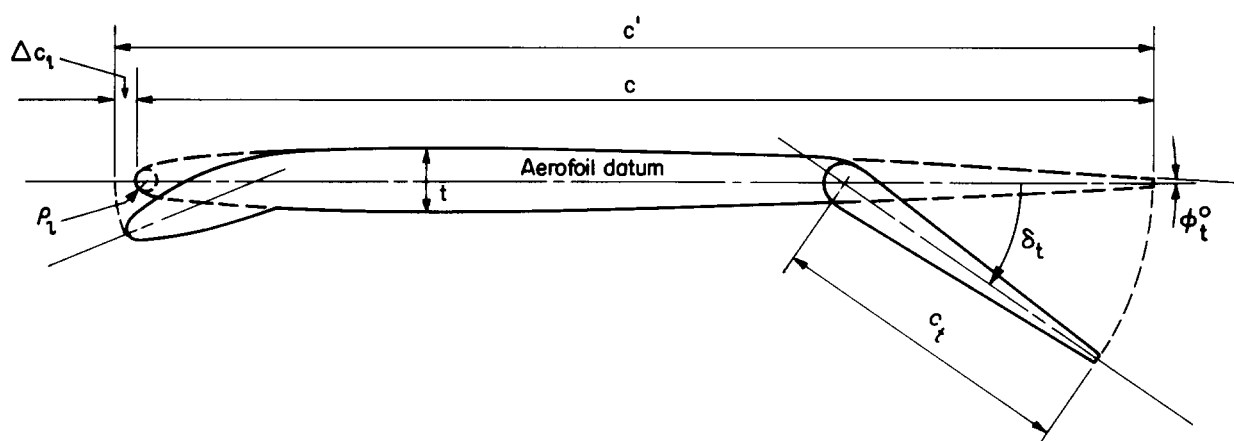
$$\Delta C_{L0t} = \frac{c'}{c} \Delta C'_{L0t} \quad (3.4)$$

$$\text{and} \quad \Delta C_{Lmt} = F_R \frac{c'}{c} \Delta C'_{Lmt}. \quad (3.5)$$

The values of $\Delta C'_{L0t}$ and $\Delta C'_{Lmt}$ in Equations (3.4) and (3.5) for plain trailing-edge flaps are determined by the methods of Section 4.

4. LIFT COEFFICIENT INCREMENTS $\Delta C'_{L0t}$ AND $\Delta C'_{Lmt}$

First approximations to the lift coefficient increments due to the deployment of trailing-edge flaps can be obtained from the theory for an equivalent thin hinged plate with empirical correlation factors to account for the geometry of practical aerofoils and flaps. To make some allowance for the effects of chord extension in the theory the flap chord ratio and the lift coefficient increments are based on the aerofoil extended chord. This approach was used in Derivation 6 and is the basis for the methods developed for this Item, see Sections 4.1 and 4.2.



Sketch 4.1 Plain trailing-edge flap with typical leading-edge high-lift device (leading-edge droop)