

LIFT COEFFICIENT INCREMENT DUE TO FULL-SPAN SLOTTED FLAPS

See ESDU 97002 for introduction to Items on high-lift devices.

1. NOTATION AND UNITS

		SI	British
A	aspect ratio of wing with flap in neutral position		
a, a_6	slopes of lift curves corresponding to wings of aspect ratios A and 6, respectively	rad^{-1}	rad^{-1}
C_{LN}	lift coefficient of wing of aspect ratio A at chosen incidence, with flap in neutral position		
ΔC_L	lift coefficient increment due to slotted flap with wing at chosen incidence, based on wing chord c		
$\Delta C'_L$	lift coefficient increment due to slotted flap with wing of aspect ratio 6 at chosen incidence, based on wing chord c'		
c	wing chord	m	ft
c_f	flap chord with flap in neutral position (see sketch in Figure 1)	m	ft
c'	extended wing chord (see sketch in Figure 1)	m	ft
δ_f	flap angle, i.e. rotation of flap from neutral position	deg	deg

2. NOTES

This Item is superseded by ESDU 93019, but is temporarily retained because it is cross-referenced in other Items. However, ESDU 93019 should now always be used to calculate the flap lift increment.

The lift coefficient increment $\Delta C'_L$ for rectangular wings due to full-span slotted flaps, is plotted in Figure 1 against the flap angle δ_f for various values of the ratio of the flap chord to the extended wing chord c_f/c' for two types of slotted flaps.

Lift coefficient increments of flaps having a fixed centre of rotation are given by full lines. For comparison, lift coefficient increments obtainable with slotted flaps placed in the position giving maximum lift increments at every flap angle are shown by dotted lines.

Flaps with a fixed centre of rotation are generally designed to give as nearly as possible the maximum lift coefficient increment with the flap in the landing position (i.e. δ_f in the region of 50° to 60°). However, in meeting other requirements, such as take-off, this condition will not always be satisfied. It may also be noted that the full curves relating to this type of flap are based on an average of a great number of tests,

whereas the dotted curves are based on a single series of tests. Therefore the full curves do not coincide with the dotted curves even at the maximum $\Delta C'_L$. For flaps such as the Fowler the curves apply only when the flap is near its fully extended position and the slot is properly developed.

The increment $\Delta C'_L$ can be assumed to be independent of incidence provided that the stalling angle is not too closely approached. The increments ΔC_L and $\Delta C'_L$ are related by the equations

$$\Delta C_L = \Delta C'_L \left[\frac{c'}{c} \frac{a}{a_6} + \frac{C_{LN}}{\Delta C'_L} \left(\frac{c'}{c} - 1 \right) \right] \quad (2.1)$$

or

$$\frac{\Delta C_L}{\Delta C'_L} \frac{a_6}{a} = \frac{c'}{c} + \frac{C_{LN}}{\Delta C'_L} \frac{a_6}{a} \left(\frac{c'}{c} - 1 \right). \quad (2.2)$$

Therefore ΔC_L is dependent on the characteristics of the aerofoil and its incidence. To help in the calculation of ΔC_L from the equations, the ratio $(\Delta C_L / \Delta C'_L) (a_6 / a)$ is plotted in Figure 2 against $(C_{LN} / \Delta C'_L) (a_6 / a)$ for various values of c' / c .

For a part-span flap the factors given in ESDU 74012 may be applied.

3. DERIVATION

The Derivation lists selected sources that have assisted in the preparation of this Item.

1. WENZINGER, C.J. Wind-tunnel investigation of an NACA 23012 airfoil with various
HARRIS, T.A. arrangements of slotted flaps. NACA Rep. 664, 1939.
2. WENZINGER, C.J. Wind-tunnel investigation of an NACA 23012 airfoil with various
HARRIS, T.A. arrangements of slotted flaps. NACA Rep. 677, 1939.
3. YOUNG, A.D. The aerodynamic characteristics of flaps. ARC R&M 2622, 1953.

4. EXAMPLE

Find the lift coefficient increment due to a fixed-hinge full-span slotted flap of 0.96 m mean flap chord at a flap angle of 45°. The mean wing chord is 3.70 m, the extended mean chord is 4.00 m, and a/a_6 is 1.065. The wing with the flap in the neutral position has a lift coefficient, $C_{LN} = 1.10$.

From the dimensions given $c_f / c' = 0.96 / 4.00 = 0.240$ and from Figure 1, $\Delta C'_L = 0.90$.

Also $c' / c = 4.00 / 3.70 = 1.080$, and $(C_{LN} / \Delta C'_L) (a_6 / a) = (1.10 / 0.90) \div 1.065 = 1.15$.

Therefore $(\Delta C_L / \Delta C'_L) (a_6 / a) = 1.17$, from Figure 2, and hence $\Delta C_L = 1.17 \times 0.90 \times 1.065 = 1.12$.

For the same wing and flap arrangement, the optimum $\Delta C'_L$ that could be obtained is, from Figure 1, 0.99. The parameter $(C_{LN} / \Delta C'_L) (a_6 / a)$ is now 1.04, and from Figure 2 $(\Delta C_L / \Delta C'_L) (a_6 / a) = 1.16$ and hence $\Delta C_L = 1.16 \times 0.99 \times 1.065 = 1.22$.