

ESDU Flaps 02.01.08

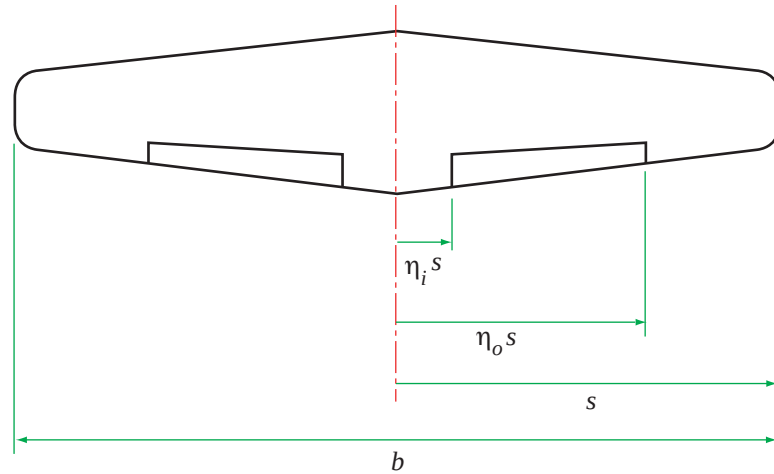
VORTEX DRAG COEFFICIENT OF WING WITH PART-SPAN FLAP AND CENTRAL CUT-OUT

1. NOTATION AND UNITS

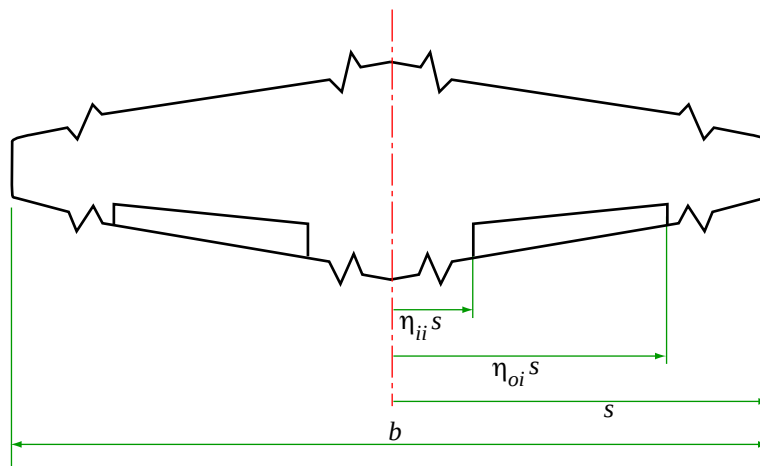
		<i>SI</i>	<i>British</i>
A	wing aspect ratio, b^2/S		
b	wing span	m	ft
C_{DV}	trailing-vortex drag coefficient at lift coefficient C_L , based on S		
C_L	total lift coefficient, based on S		
ΔC_L	lift coefficient increment due to deflection of all flaps, based on S		
ΔC_{Li}	lift coefficient increment due to deflection of i^{th} pair of flap panels, based on S		
K	correlation factor, see Equation (2.1)		
N	number of flap panels (on each half wing)		
S	wing planform (reference) area	m ²	ft ²
s	wing semi-span	m	ft
η_i, η_o	dimensionless inboard and outboard limits of single flap panel (see Sketch 1.1)		
η_{ii}, η_{oi}	dimensionless inboard and outboard limits of i^{th} flap panel (see Sketch 1.2)		

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With Amendments A to E, October 2013 – 10 pages
This page Amendment D

1



Sketch 1.1 Single pair of flap panels



Sketch 1.2 i^{th} pair of flap panels

2. INTRODUCTION

Derivation 1 contains a lifting-line analysis of the increment in trailing-vortex drag due to the symmetric deployment of part-span flaps in incompressible flow. The calculation method is greatly simplified if the wing without deployed flaps is taken to have an elliptical spanwise loading and if flap deployment is assumed to take place without chord extension. The trailing-vortex drag coefficient can then be written

$$C_{DV} = \frac{C_L^2}{\pi A} + (\Delta C_L)^2 K^2, \quad (2.1)$$

where C_L is the total lift coefficient, A the wing aspect ratio, ΔC_L the part of C_L due to flap deployment and K a correlation factor that can be evaluated directly from the lifting-line expressions that represent the spanwise loading due to incidence and flap deployment. The simplifying assumptions noted ahead of Equation (2.1) prevent the appearance of cross-coupling terms between the incidence and flap loadings and the need for iterative calculations to determine K . (Section 5.2 of ESDU 97002, Reference 2, discusses other forms for the trailing vortex drag when the simplifying assumptions do not apply.)

3. METHODS TO OBTAIN CORRELATION FACTOR K

3.1 Single Pair of Flap Panels on Wing

Figures 1a to 1d present K graphically for a single part-span flap on each half wing in terms of A and η_o for $\eta_i = 0, 0.2, 0.4$ and 0.6 , respectively. A worked example in the use of the Figures is given in Section 5.1.

It is important to note that the data for K apply directly to isolated wings. If when $\eta_i > 0$, a fuselage is present in the central cut-out between the inboard ends of the flap panels, and the gaps between the inboard ends of the panels and the fuselage side are less than $0.05s$ (say), then there will be an appreciable interference effect between the flaps and the fuselage. ESDU 97003 (Reference 3) contains a method that describes how this effect can be allowed for by adding notional extensions to the inboard end of each flap to decrease η_i .

Note that computer program ESDUpac AF218, described in Section 3.2, can be used to calculate K for the case in which there is a single pair of flap panels.

ESDU 97002 lists the Data Items that are available for calculating the lift coefficient increments of various types of flap.

3.2 Multiple Pairs of Flap Panels on Wing

A computer program, ESDUpac AF218, has been written to calculate K in the general case when there may be more than one pair of flap panels. The program can cater from one pair to ten pairs. The assumptions inherent in Equation (2.1) are maintained but the calculation does, of course, include the interactions between the lift increments associated with the different pairs of panels, since K is not formed by simple addition of the values for each separate pair.

The input file used in the program is described below. A worked example that illustrates the use of the program is given in Section 5.2.