PROGRAM FOR CALCULATION OF AILERON ROLLING MOMENT AND YAWING MOMENT COEFFICIENTS AT SUBSONIC SPEEDS

The program has been written in "STRICT" Microsoft FORTRAN 77 for use on machines using PC/MS DOS. A diskette containing files for the source code, worked examples and an information file is provided in the Aerodynamics Software Volume and a CD-Rom. Guidance on copying, compilation and running the program is given in the "Introduction to ESDUpacs" in that volume. However, if any difficulty is experienced in using the program please contact ESDU International and we will do all we can to assist in overcoming the problem.

Every reasonable effort has been made to ensure that the program performs the intended calculations satisfactorily. However, in common with all providers of software, ESDU International cannot guarantee the suitability or fitness of the program for any particular purpose and no liability for any loss occasioned by any person as a direct or indirect result of use of the program, whether arising from negligence or otherwise, can be accepted. In no event shall ESDU International or any individuals associated with the development of the program be liable for any damage, including loss of profit or consequential loss, arising out of or in connection with the program.

1. NOTATION AND UNITS

(Only that notation required to define the input and output is detailed. For more information see Item Nos 88013 and 88029.)

		SI	*British*
A	aspect ratio		
b	wing span	m	ft
C_L	lift coefficient of wing and flap system with ailerons undeflected, $L/½\rho V^2 S$		
ΔC_{Lf}	component of lift coefficient due to deployment of trailing-edge flaps		
C_l	rolling moment coefficient due to ailerons, $\mathscr{L}/½\rho V^2 Sb$		
C_n	yawing moment coefficient due to ailerons, $\mathscr{N}/½\rho V^2 Sb$		
c_f/c	ratio of aileron chord aft of hinge line to local wing chord at mid-span of aileron		
J_f	empirical factor for converting ΔC_{Lf} into effective twist angle, see Equation (2.3) in Item No. 88029. Taken as 18.0 degrees	degree	degree
J_δ	empirical factor applied to δ_t, see Equation (2.3) in Item No. 88029. Taken as 1.4		
L	lift	N	lbf
$\mathscr{L}$	rolling moment, positive starboard wing down	N m	lbf ft

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$L_{\xi'}$	rolling moment derivative with respect to ξ', $\partial C_l/\partial \xi'$	rad^{-1}	rad^{-1}
M	Mach number		
$\mathscr{N}$	yawing moment, positive nose to starboard	N m	lbf ft
R	Reynolds number based on wing mean chord		
S	wing planform area	m^2	ft^2
s	wing semispan	m	ft
t/c	section thickness-to-chord ratio of wing at mid-span of aileron		
V	free-stream velocity	m/s	ft/s
γ'	angle between chord line of aerofoil section and line joining mid-thickness point at hinge line to trailing edge of undeflected aileron, in plane normal to hinge line, see Sketch 1.1	degree	degree
δ_t	geometric twist angle of wing tip relative to root chord, positive leading-edge up	degree	degree
η	spanwise distance from wing centre-line as fraction of semispan		
η_i	value of η at inboard limit of aileron at hinge line		
η_o	value of η at outboard limit of aileron at hinge line		
$\bar{\eta}$	$(\eta_i + \eta_o)/2$		
λ	wing taper, ratio of tip chord to centre-line chord		
Λ_h	sweepback of aileron hinge line	degree	degree
$\Lambda_{1/2}$	sweepback of wing half-chord line	degree	degree
ξ'	aileron deflection angle measured in plane normal to hinge line, arithmetic mean of deflection angles of port and starboard ailerons, positive for starboard aileron down and port aileron up, $\tfrac{1}{2}(\xi'_p + \xi'_s)/57.3$	radian	radian
ξ'_p	deflection of port aileron, measured in plane normal to hinge line, positive trailing-edge up	degree	degree
ξ'_s	deflection of starboard aileron, measured in plane normal to hinge line, positive trailing-edge down	degree	degree
ρ	free stream density of air	kg/m^3	slug/ft^3
τ	section trailing-edge angle at mid-span of aileron	degree	degree

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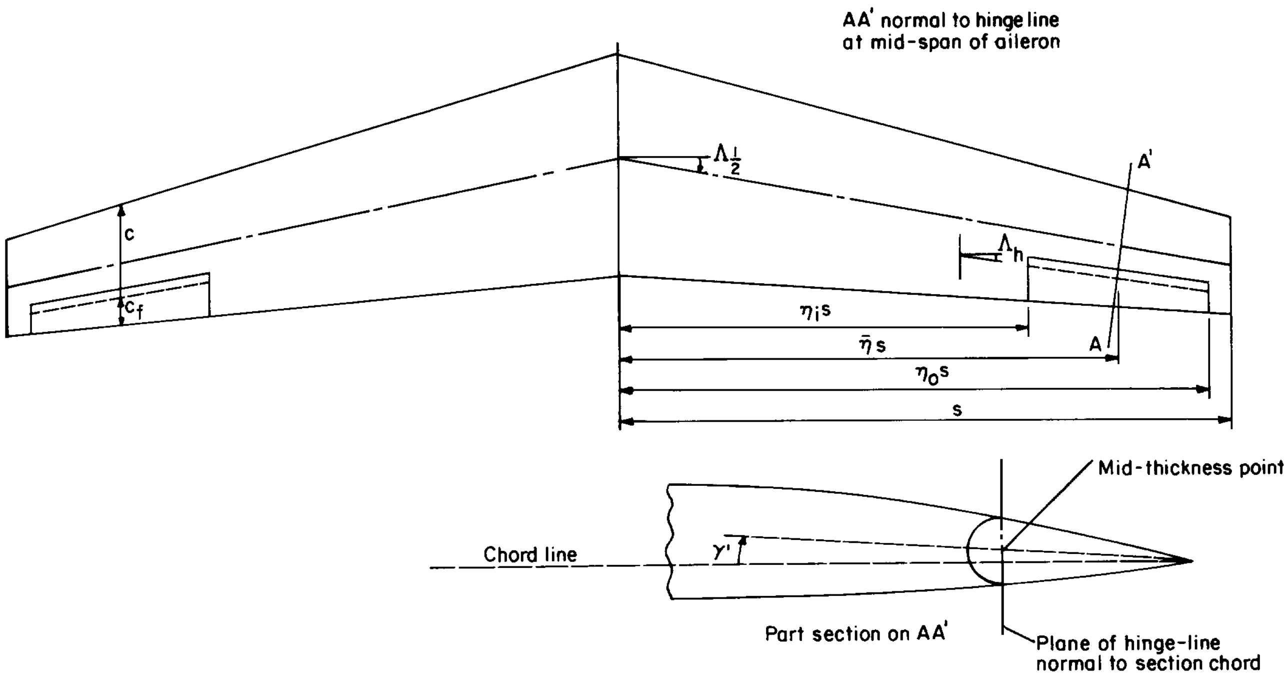

Sketch 1.1 Wing and aileron geometry

2. INTRODUCTION

A computer program, called ESDUpac A8840, has been written by the Computer Products Group of ESDU International to determine aircraft aileron rolling moment and yawing moment coefficients at subsonic speeds. It is based on the methods of Item Nos 88013 and 88029 (Derivations 1 and 2), the graphical data of those Items being held in digitised form.

For full details of the methods used Item Nos 88013 and 88029 should be consulted.

Table 2.1 lists the input parameters for the program. It gives their program name and their notation in Item Nos 88013 and 88029 (unless they are control variables of integer type in the program). The first three lines of the input are reserved for the user to input text to identify a particular run.

Section 4 poses a problem that illustrates the input to and ouput from the program. This includes the worked examples of Item Nos 88013 and 88029 but is more general. Section 4.1 gives the required input file. The output that results is shown in Section 4.2. There is firstly an echo of the input data, then for each chosen pair of aileron angles the rolling moment coefficient C_l and the yawing moment coefficient C_n are given as functions of C_L, the total lift coefficient, and ΔC_{Lf}, the lift coefficient component due to trailing-edge flap deployment. The rolling moment coefficient derivative (per radian), for aileron angles measured about the hinge line, is given separately and for a given configuration is a constant that is independent of aileron setting. Small differences in magnitude between the computer output and the values in the worked examples are due to the approximate curve fitting in the program.

TABLE 2.1 INPUT PARAMETERS

Variable name in program	*Notation in Item (or integer in program)*	*Comments*
CHAR 1 CHAR 2 CHAR 3	– – –	The first 3 lines of the input data file are read as text and are written on the output file. Each line may contain 72 characters and must end with a carriage return. A blank line must be entered if no text is available.
R M	R M	Reynolds number based on wing mean chord, $(10^6 \leq R \leq 10^8)$. Free-stream Mach number.
AR LAMBDA LAMHLF LAMH	A λ $\Lambda_{½}$ Λ_h	Planform properties. See Sketch 1.1
CFC TC TAU	c_f/c t/c τ	Values for streamwise section through mid-span of aileron. See Sketch 1.1. $50(t/c) \leq \tau \leq 150(t/c)$.
GAM1	γ'	Defined for section AA' that passes normally through mid-span of aileron hinge line. See Sketch 1.1.
ETAI ETAO	η_i η_o	Inboard limit of aileron at hinge line. Outboard limit of aileron at hinge line.
JD JF	J_δ J_f	1.4 These values should be input unless the user is modelling known experimental results, when the effect of small changes can be studied, see Section 3.1 of Item No. 88029 18.0 deg
DELT	δ_t	Twist of wing tip relative to root, positive leading-edge up, in degrees.
N3 CL(1) . . CL(N3)	INTEGER C_L . . C_L	Number of C_L values. (≤ 20) Values of total C_L (with or without trailing-edge flap deployment). The method should be used only within the range where C_L varies linearly with angle of attack.
N1 DCLF(1) . . DCLF(N3)	INTEGER ΔC_{Lf} . . ΔC_{Lf}	Number of ΔC_{Lf} values. (≤ 10) Components of C_L due to deployment of trailing-edge flaps.
N2 XI1P(1) XI1S(1) . . . . XI1P(N2) XI1S(N2)	INTEGER ξ'_p ξ'_s . . . . ξ'_p ξ'_s	Number of aileron deflection settings. (≤ 10) Aileron deflection angles, in degrees, measured in plane normal to hinge line, port then starboard. Port positive trailing-edge up, starboard positive trailing-edge down.

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3. DERIVATION

1. ESDU — Rolling moment derivative L_ξ for plain ailerons at subsonic speeds. ESDU International, Item No. 88013, 1988.

2. ESDU — Yawing moment coefficient for plain ailerons at subsonic speeds. ESDU International, Item No. 88029, 1988.

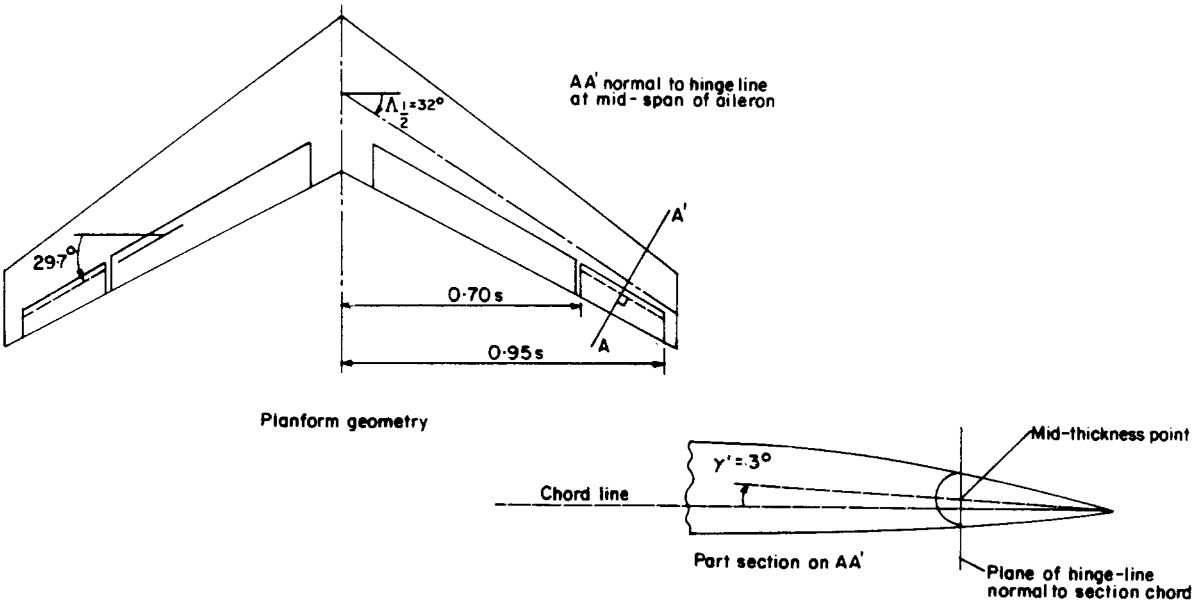
4. EXAMPLES OF INPUT AND OUTPUT

Find the rolling moment and yawing moment coefficients as a function of lift coefficient for the plain sealed ailerons of the wing shown in Sketch 4.1 for a Mach number $M = 0.4$ and a Reynolds number $R = 7 \times 10^6$. Also determine the effect of deployment of trailing-edge flaps inboard of the ailerons to give a lift coefficient component ΔC_{Lf} of 0.6.

The aileron settings (ξ'_p, ξ'_s) to be considered are (0,0), (5.5° up, 4.5° down) and (11.0° up, 9.0° down).

The wing has an aspect ratio $A = 6$, a sweep $\Lambda_{½} = 32°$ and a taper $\lambda = 0.5$. The ailerons extend from $\eta_i = 0.70$ to $\eta_o = 0.95$. At the mid-span of the aileron the control-to-wing chord ratio is $c_f/c = 0.25$, and the wing section has a thickness to chord ratio $t/c = 0.085$ and a trailing edge angle $\tau = 10.0°$. The aileron hinge line sweep is $\Lambda_h = 29.7°$. The angle γ' between the chord line of the aerofoil section and the line joining the mid-thickness point at the hinge line to the trailing edge of the undeflected aileron, measured at the mid-span of the aileron in the plane normal to the hinge line is 3.0°, see Sketch 4.1.

Summary of geometric parameters for wing			
ξ'_p	= 0, + 5.5°, + 11.0°	A	= 6.0
ξ'_s	= 0, + 4.5°, + 9.0°	λ	= 0.5
γ'	= 3.0°	η_i	= 0.70
$\Lambda_{½}$	= 32.0°	η_o	= 0.95
Λ_h	= 29.7°	$\bar{\eta}$	= 0.825
δ_t	= –2.0°	c_f/c	= 0.25



Sketch 4.1

4.1 INPUT

Guided by Table 2.1, the following input file is constructed with C_L set to increase from 0 to 1.6 in steps of 0.2, with ΔC_{Lf} of 0 or 0.6.

```
EXAMPLE 1 IN ITEM 88040, ( INPUT FILE I01A8840, OUTPUT FILE R01A8840 )
DATA FOR INPUT IN EXAMPLE 1
( COMPARE WITH HAND-WORKED CALCULATIONS IN ITEM NOS 88013 AND 88029 )
7e6
0.4
6
0.5
32
29.7
0.25
0.085
10
3.0
0.7
0.95
1.4
18.0
-2.0
9
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
2
0.0
0.6
```

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```
3
0.0 0.0
5.5 4.5
11 9
```

4.2 OUTPUT

The output produced by the program has the following form.

```
-----------------------------------------------------------------------------
ESDU International plc

PROGRAM A8840

ESDUpac Number:   A8840
ESDUpac Title:    Yawing moment and rolling moment coefficients
                  for plain ailerons at subsonic speeds
Data Item Number: 88040
Data Item Title:  Program for calculation of aileron rolling moment and
                  yawing moment coefficients at subsonic speeds
ESDUpac Version:  3.0  Issued April 1999, Data Item 88040
(See Data Item for full input/output specification and interpretation)
-----------------------------------------------------------------------------

EXAMPLE 1 IN ITEM 88040, ( INPUT FILE I01A8840, OUTPUT FILE R01A8840 )
DATA FOR INPUT IN EXAMPLE 1
( COMPARE WITH HAND-WORKED CALCULATIONS IN ITEM NOS 88013 AND 88029 )



INPUT DATA
==========

REYNOLDS NUMBER                                      =    .7E+07
MACH NUMBER                                          =    .400
ASPECT RATIO                                         =   6.000
WING TAPER                                           =    .500
SWEEPBACK OF WING QUARTER-CHORD LINE                 =  34.232
SWEEPBACK OF WING MID-CHORD LINE                     =  32.000
SWEEPBACK OF AILERON HINGE LINE                      =  29.700
AILERON/WING CHORD RATIO AT MID AILERON SPAN         =    .250
THICKNESS TO CHORD RATIO AT MID AILERON SPAN         =    .085
SECTION TRAILING-EDGE ANGLE AT MID-SPAN OF AILERON  =  10.000
ANGLE GAMMA PRIME, SEE SKETCH 1.1 OF ITEM NO. 88029 =   3.000
ETA AT INBOARD LIMIT OF AILERON                      =    .700
ETA AT OUTBOARD LIMIT OF AILERON                     =    .950
JD                                                   =   1.400
JF                                                   =  18.000
DELT                                                 =  -2.000

NUMBER OF CL =  9
CL( 1 )     .000
CL( 2 )     .200
CL( 3 )     .400
CL( 4 )     .600
CL( 5 )     .800
CL( 6 )   1.000
CL( 7 )   1.200
CL( 8 )   1.400
CL( 9 )   1.600
```

```
NUMBER OF DCLF =   2
DCLF( 1 )    .000
DCLF( 2 )    .600

NUMBER OF AILERON DEFLECTIONS =  3

          PORT     STARBOARD
1          .000         .000
2         5.500        4.500
3        11.000        9.000


OUTPUT DATA
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AILERON DEFLECTION: PORT =   .0 STARBOARD =   .0 MEAN =   .0000(deg)
ROLLING MOMENT COEFFICIENT DERIVATIVE (rad-1) =  -.092

 CL          DCLF          Cl          Cn
 .0000       .0000       .0000       .0000
 .2000       .0000       .0000       .0000
 .4000       .0000       .0000       .0000
 .6000       .0000       .0000       .0000
 .8000       .0000       .0000       .0000
1.0000       .0000       .0000       .0000
1.2000       .0000       .0000       .0000
1.4000       .0000       .0000       .0000
1.6000       .0000       .0000       .0000

=============================================================================



AILERON DEFLECTION: PORT =  5.5 STARBOARD =  4.5 MEAN =  5.0000(deg)
ROLLING MOMENT COEFFICIENT DERIVATIVE (rad-1) =  -.092

 CL          DCLF          Cl          Cn
 .0000       .0000      -.0080      -.0003
 .2000       .0000      -.0080       .0001
 .4000       .0000      -.0080       .0004
 .6000       .0000      -.0080       .0007
 .8000       .0000      -.0080       .0011
1.0000       .0000      -.0080       .0014
1.2000       .0000      -.0080       .0017
1.4000       .0000      -.0080       .0021
1.6000       .0000      -.0080       .0024

=============================================================================



AILERON DEFLECTION: PORT = 11.0 STARBOARD =  9.0 MEAN = 10.0000(deg)
ROLLING MOMENT COEFFICIENT DERIVATIVE (rad-1) =  -.092

 CL          DCLF          Cl          Cn
 .0000       .0000      -.0160      -.0007
 .2000       .0000      -.0160       .0000
```

.4000	.0000	-.0160	.0007
.6000	.0000	-.0160	.0013
.8000	.0000	-.0160	.0020
1.0000	.0000	-.0160	.0027
1.2000	.0000	-.0160	.0033
1.4000	.0000	-.0160	.0040
1.6000	.0000	-.0160	.0047

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AILERON DEFLECTION: PORT = .0 STARBOARD = .0 MEAN = .0000(deg)
ROLLING MOMENT COEFFICIENT DERIVATIVE (rad-1) = -.092

CL	DCLF	Cl	Cn
.0000	.6000	.0000	.0000
.2000	.6000	.0000	.0000
.4000	.6000	.0000	.0000
.6000	.6000	.0000	.0000
.8000	.6000	.0000	.0000
1.0000	.6000	.0000	.0000
1.2000	.6000	.0000	.0000
1.4000	.6000	.0000	.0000
1.6000	.6000	.0000	.0000

==

AILERON DEFLECTION: PORT = 5.5 STARBOARD = 4.5 MEAN = 5.0000(deg)
ROLLING MOMENT COEFFICIENT DERIVATIVE (rad-1) = -.092

CL	DCLF	Cl	Cn
.0000	.6000	-.0080	-.0015
.2000	.6000	-.0080	-.0012
.4000	.6000	-.0080	-.0008
.6000	.6000	-.0080	-.0005
.8000	.6000	-.0080	-.0002
1.0000	.6000	-.0080	.0002
1.2000	.6000	-.0080	.0005
1.4000	.6000	-.0080	.0008
1.6000	.6000	-.0080	.0012

==

AILERON DEFLECTION: PORT = 11.0 STARBOARD = 9.0 MEAN = 10.0000(deg)
ROLLING MOMENT COEFFICIENT DERIVATIVE (rad-1) = -.092

CL	DCLF	Cl	Cn
.0000	.6000	-.0160	-.0031
.2000	.6000	-.0160	-.0024
.4000	.6000	-.0160	-.0018
.6000	.6000	-.0160	-.0011
.8000	.6000	-.0160	-.0004
1.0000	.6000	-.0160	.0002
1.2000	.6000	-.0160	.0009
1.4000	.6000	-.0160	.0016

1.6000	.6000	-.0160	.0022

==

THE PREPARATION OF THIS DATA ITEM

The work on this particular Item was monitored and guided by the Aerodynamics Committee which first met in 1942 and now has the following membership.

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* Corresponding Member

The technical work in the assessment of the available information and the construction and subsequent development of the Data Item was carried out by

Mr R.W. Gilbey – Senior Engineer.