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Example of procedure in calculation of control hinge moments

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THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item which supersedes ESDU Aero C.04.01.09, was monitored and guided by the Aerodynamics Committee. This Committee first met in 1942 and now has the following membership:

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EXAMPLE OF PROCEDURE IN CALCULATION OF CONTROL HINGE MOMENTS

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EXAMPLE OF PROCEDURE IN CALCULATION OF CONTROL HINGE MOMENTS

1. NOTATION AND UNITS (see Sketch 1.1)

		SI	British
A	aspect ratio of wing		
A_h	aspect ratio of horn		
a_1, a_2	rates of change of lift coefficient with angle of attack and control deflection respectively	rad ⁻¹	rad ⁻¹
B	increase in balance due to horn, see Table 2.3		
b_1, b_2, b_3	rates of change of hinge-moment coefficient with angle of attack, control deflection and tab deflection respectively, $b_1 = \partial C_H / \partial a$, $b_2 = \partial C_H / \partial \delta$, $b_3 = \partial C_H / \partial \delta_{tab}$	rad ⁻¹	rad ⁻¹
$\Delta b_{1h}, \Delta b_{2h}$	increments in b_1, b_2 due to horn	rad ⁻¹	rad ⁻¹
C_H	hinge-moment coefficient, $C_H = H / (\frac{1}{2} \rho V^2 c_f^2)$ for two-dimensional sections $= H / (\frac{1}{2} \rho V^2 \bar{c}_f^2 s_f)$ for wings $= H / (\frac{1}{2} \rho V^2 S_f \bar{c}_f)$ for increments due to horns and tabs		
C_L	wing lift coefficient		
c	wing chord	m	ft
$(c)_h$	wing chord at mid-span of horn	m	ft
$(c)_{tab}$	wing chord at mid-span of tab hinge line	m	ft
$\bar{c}$	geometric mean chord of wing	m	ft
c_b	control chord forward of hinge line,	m	ft
$(c_b)_h$	value of c_b (without horn) at mid-span of horn	m	ft
$(c_b)_{tab}$	value of c_b at mid-span of tab hinge line	m	ft
c_f	control chord aft of hinge line	m	ft
$(c_f)_{tab}$	value of c_f at mid-span of tab hinge line	m	ft

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$\bar{c}_f$	geometric mean chord of control aft of hinge line $\bar{c}_f = \int c_f d\eta$	m	ft
$\bar{\bar{c}}_f$	aerodynamic mean chord of control aft of hinge line, $\bar{\bar{c}}_f = \int c_f^2 d\eta / \bar{c}_f$	m	ft
c_h	horn chord forward of hinge line at mid-span of horn	m	ft
c_{tab}	tab chord aft of tab hinge line at mid-span of tab hinge line	m	ft
F	factor used in calculating effect of tab (Item No. Aero C.04.01.08 ¹)		
F_1, F_2	factors used in calculating effect of horn (Item No. 88003 ⁹)		
F_B	factor used in calculating b_1 and b_2 for control on wing (Item No. 89009 ¹⁰)		
G	factor used in calculating effect of tab (Item No. Aero C.04.01.08 ¹)		
G_1, G_2, G_3	factors used in calculating b_1 and b_2 for control on wing (Item No. 89009 ¹⁰)	rad ⁻¹	rad ⁻¹
H	hinge moment measured about hinge line	N m	lbf ft
K	factor used in calculating effect of horn (Item No. 88003 ⁹)		
M	Mach number		
N	factor used in calculating effect of horn (Item No. 88003 ⁹)		
R	Reynolds number based on c		
S_f	control area aft of hinge line	m ²	ft ²
s	wing semispan	m	ft
s_f	control span, $(\eta_o - \eta_i)s$	m	ft
s_h	horn span	m	ft
s_{tab}	tab span	m	ft
t	maximum section thickness	m	ft
$(t/c)_h$	thickness to chord ratio of wing at mid-span of horn		
t_h	section thickness at control hinge line	m	ft

V	free-stream velocity	m/s	ft/s
x_h	distance of horn leading-edge from control trailing-edge at mid-span of horn, as fraction of local wing chord		
x_{tr}	position of boundary layer transition aft of leading edge as fraction of local wing chord		
α	angle of attack	rad	rad
β	compressibility parameter, $(1 - M^2)^{1/2}$		
δ	control deflection angle, measured in streamwise plane	rad	rad
δ_{tab}	tab deflection angle relative to control surface	rad	rad
η	spanwise distance from wing centre-line as fraction of semispan		
η_i, η_o	value of η at inboard, outboard ends of control at hinge line		
Λ_h	sweepback of tab hinge line	deg	deg
$\Lambda_{h\ tab}$	sweepback of tab hinge line	deg	deg
Λ_m	sweepback of m 'th chord line	deg	deg
λ	ratio of wing tip chord to wing centre-line chord		
ρ	density of air	kg/m ³	slug/ft ³
τ	section trailing-edge angle	deg	deg
τ_h	trailing-edge angle at mid-span of horn	deg	deg
τ_{tab}	trailing-edge angle at mid-span of tab hinge line	deg	deg

Subscripts

0	as in $(a_1)_0$ or H_0 denotes value in two-dimensional incompressible flow
h	denotes horn or, in Λ_h and $\Lambda_{h\ tab}$, hinge line
tab	denotes tab
T	as in $(a_1)_{0T}$ denotes theoretical value
Bal	denotes value for a balanced control section
$Plain$	denotes value for a plain control section

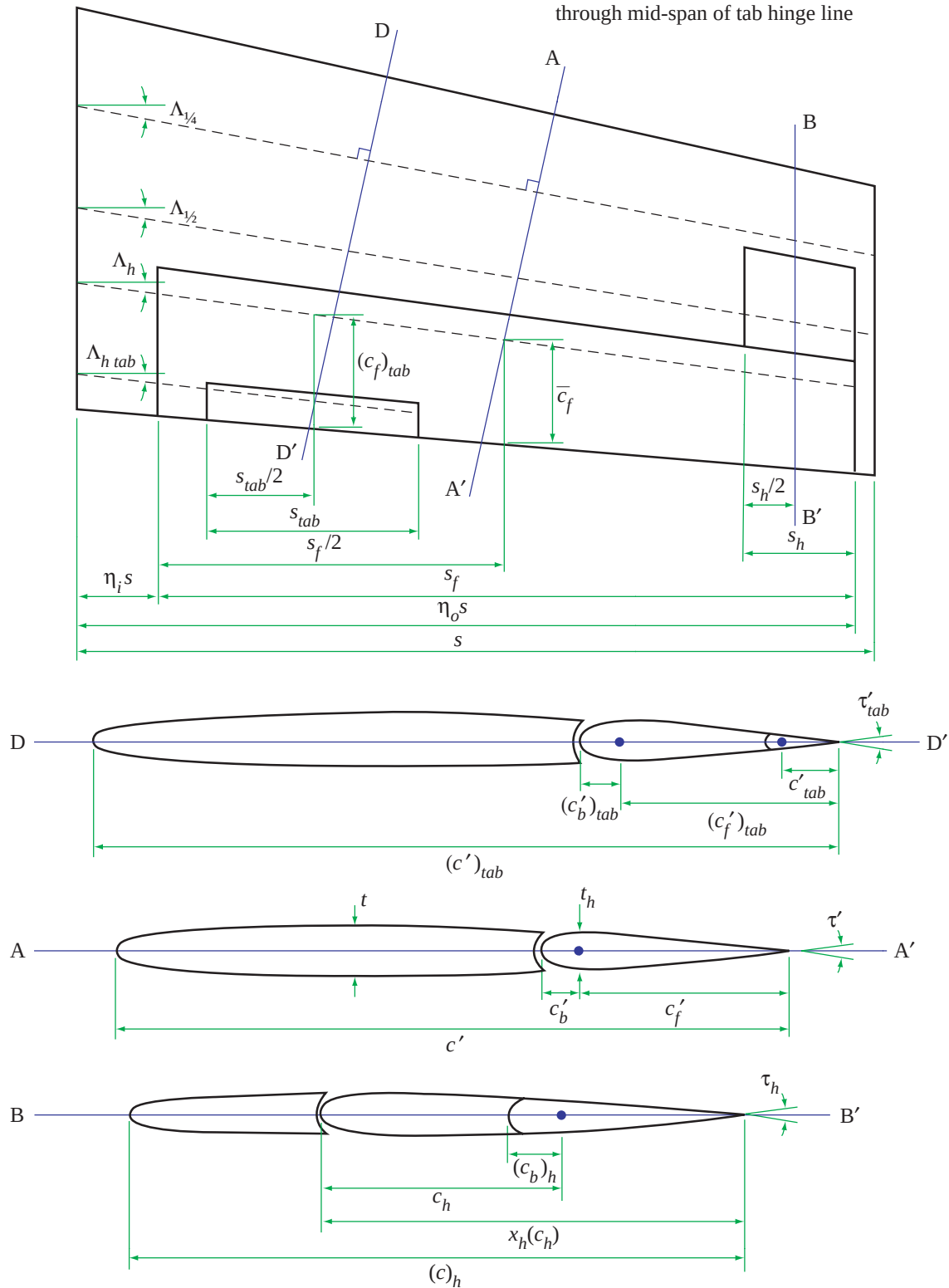
Superscripts

- * asterisks as in $(a_1)_0^*$ denote values for a 'standard' section with $\tan \frac{1}{2}\tau = t/c$
- ' primes as in c' denote quantities measured in planes normal to the wing quarter-chord line, or as in δ' and δ'_{tab} angles of deflection measured about their hinge lines. In both cases the primes provide a distinction from measurements in a streamwise plane. The hinge moment coefficient derivatives b'_2 and b'_3 denote $\partial C_H / \partial \delta'$ and $\partial C_H / \partial \delta'_{tab}$, respectively.

AA' normal to quarter-chord line and
passing through mid-span of control

BB' streamwise through mid-span of horn

DD' normal to quarter-chord line and passing
through mid-span of tab hinge line



Sketch 1.1

2. INTRODUCTION

This Item provides calculation charts for use when estimating the control hinge-moment coefficient derivatives for trailing-edge controls fitted to a wing, tailplane or fin, possibly with horn balance or tab. It uses the methods of Derivations 1 to 10, and the limitations on applicability quoted in those Items apply.

Table 2.1 provides the routine to determine the two-dimensional characteristics needed in subsequent calculations.

Table 2.2 provides the routine to determine b_1 and b_2 for the control without horn or tab balance.

Table 2.3 provides the routine to determine the additional contribution of a horn balance.

Table 2.4 provides the routine to determine the effect of a tab.

Table 2.5 summarises the results.

Blank tables are provided in this Section and may be duplicated for the user's own calculations.

A worked example is given in Section 4 for a nose-balanced control fitted with a shielded horn and a tab, and demonstrates how the Tables would be filled in during a calculation.