

ESDU Controls 04.01.00

INTRODUCTION TO DATA ITEMS ON CONTROL HINGE MOMENTS

This Item provides an introduction to the group of Data Items which deal with the change in the hinge moment of a control surface due to a change in the angle of attack or to a control or tab deflection. The Items are confined to the ranges within which control moments vary linearly with angle of attack and control deflection. These ranges depend on the wing section and control geometry and on the conditions of the airflow, and cannot be accurately predicted. However, some general information on the extent of linearity to be expected is given in Section 3.

1. NOTATION AND UNITS

All relevant parameters are defined in the individual Items. To avoid the inconsistencies found in the reference literature, the following conventions have been used.

		SI	British
a_1, a_2	rates of change of lift coefficient with angle of attack and control deflection respectively	rad^{-1}	rad^{-1}
b_1, b_2, b_3	rates of change of hinge-moment coefficient with angle of attack, control deflection and tab deflection respectively, $b_1 = \partial C_H / \partial \alpha$, $b_2 = \partial C_H / \partial \delta$, $b_3 = \partial C_H / \partial \delta_{tab}$	rad^{-1}	rad^{-1}
C_H	hinge-moment coefficient, $C_H = H / (\frac{1}{2} \rho V^2 \bar{c}_f^2)$ 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	wing chord	m	ft
c_b	control chord forward of hinge line	m	ft
c_f	control chord aft of hinge line	m	ft
$\bar{c}_f$	geometric mean control chord aft of hinge line, $\bar{c}_f = \int c_f d\eta$	m	ft
$\bar{\bar{c}}_f$	aerodynamic mean control chord aft of hinge line, $\bar{\bar{c}}_f = \int c_f^2 d\eta / \bar{c}_f$	m	ft
H	hinge moment measured about hinge line	N m	lbf ft
M	Mach number		
S_f	control area aft of hinge line	m^2	ft^2
s	wing semispan	m	ft
s_f	control span	m	ft

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t	maximum section thickness	m	ft
V	free-stream velocity	m/s	ft/s
α	angle of attack	rad	rad
δ	control deflection angle measured in streamwise plane	rad	rad
δ°	δ expressed in degrees	deg	deg
δ_{tab}	tab deflection angle relative to control surface	rad	rad
η	spanwise distance from wing centre-line as fraction of semispan		
Λ_m	sweepback of m 'th chord line	deg	deg
ρ	density of air	kg/m ³	slug/ft ³
τ	section trailing-edge angle	deg	deg

Subscripts

0	as in $(a_1)_0$ or H_0 denotes value in two-dimensional incompressible flow
T	as in $(a_1)_{0T}$ denotes theoretical value

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. For a control with a sweptback hinge line the derivative $\partial C_H / \partial \delta'$ is denoted by b'_2 and $\partial C_H / \partial \delta'_{tab}$ by b'_3 .

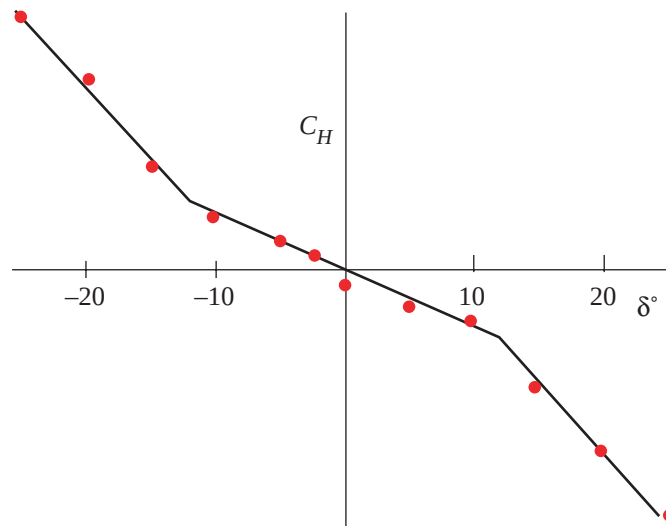
2. METHOD OF ESTIMATION OF HINGE MOMENTS

Within the linear range, the estimation of all hinge moments has been based on the coefficients for plain controls in two-dimensional flow given in Item Nos Aero C.04.01.01 and C.04.01.02 (References 10 and 11). These values must be corrected for the effects of aspect ratio, part span and aerodynamic balances. Where an aerodynamic balance extends substantially over the whole span of the control surface (as in the case of nose balance, internal balance or Frise-type balance) the balance effects are applied to the two-dimensional plain control hinge-moment coefficients before converting to three-dimensional conditions. Where the balance is essentially a part-span one (as in the case of horn or tab) the hinge-moment coefficient increment due to the balance is added to the coefficient for the control surface after it has been evaluated under three dimensional conditions. A worked example of such a combined calculation is given in Item No. 89010 (Reference 14).

3. LINEAR RANGE OF HINGE MOMENTS

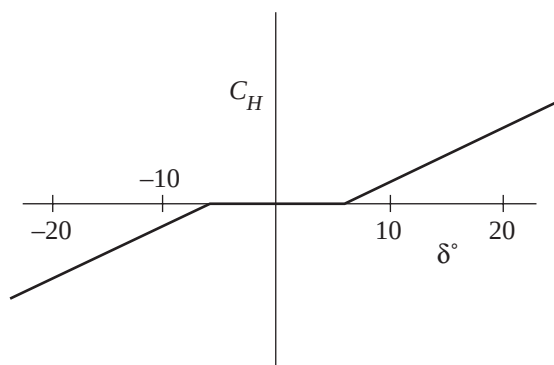
The rates of change of the hinge moment with angle of attack or control deflection only remain constant over a restricted range. Strictly speaking, the values of b_1 and b_2 given in the Items refer to the slopes of the hinge-moment curves at zero angle of attack or zero control deflection. For the purpose of estimating the hinge moment of a control at some given angle of attack and control deflection, the mean values of the rates of increase of hinge moment over the relevant ranges are required; however, it has been found that the hinge moments can generally be estimated with fair accuracy over a considerable range by assuming b_1 and b_2 , given by the Items, to be mean values.

Outside the linear range of b_1 or b_2 , where typically the flow has separated over the control surface, hinge moments increase much more rapidly. A typical curve of hinge moment plotted against control deflection is shown in Sketch 3.1.

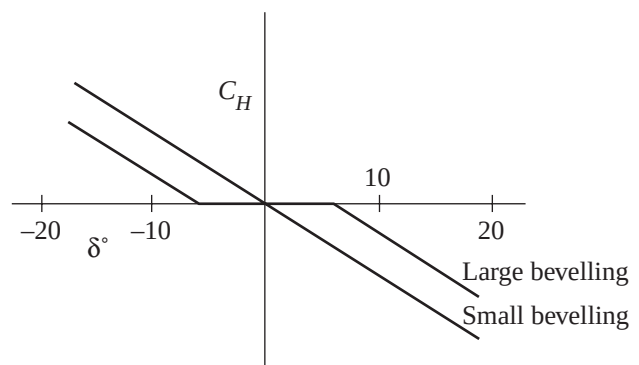


Sketch 3.1 Typical curve of hinge moment

In the case of certain control surfaces with very large nose-balance ratios (> 0.50) or very large trailing-edge angles ($> 30^\circ$) it has been found that the slope of the hinge-moment curve changes suddenly at a small control deflection, after which it remains constant again for a considerable interval. Examples of this effect are given in Sketches 3.2 and 3.3. The Items apply only to the slope in the region of zero deflection. Therefore, caution should be used when applying the data to control surfaces with very large balance or extreme bevelling



Sketch 3.2 Effect of large nose balance



Sketch 3.3 Effect of bevelled trailing-edge