RATE OF CHANGE OF HINGE-MOMENT COEFFICIENT WITH CONTROL DEFLECTION FOR A PLAIN CONTROL IN INCOMPRESSIBLE TWO-DIMENSIONAL FLOW, $(b_2)_0$

1. NOTATION AND UNITS

		SI	*British*
$(a_2)_0$	slope of lift coefficient increment curve with control deflection for two-dimensional aerofoil in incompressible flow	rad^{-1}	rad^{-1}
$(a_2)_{0T}$	theoretical slope of lift coefficient increment curve with control deflection for two-dimensional aerofoil in inviscid incompressible flow	rad^{-1}	rad^{-1}
$(b_2)_0$	rate of change of hinge-moment coefficient with control deflection for two-dimensional aerofoil in incompressible flow, $\partial C_{H0}/\partial\delta$	rad^{-1}	rad^{-1}
$(b_2)_{0T}$	theoretical rate of change of hinge-moment coefficient with control deflection for two-dimensional aerofoil in inviscid incompressible flow	rad^{-1}	rad^{-1}
C_{H0}	control hinge-moment coefficient for two-dimensional aerofoil in incompressible flow, $H_0/½\rho V^2 c_f^2$		
c	aerofoil chord	m	ft
c_f	control chord aft of hinge line	m	ft
H_0	control hinge moment per unit span for a two-dimensional aerofoil in incompressible flow	N m/m	lbf ft/ft
t	maximum thickness of aerofoil	m	ft
t_{90}	thickness of aerofoil at 90 per cent chord	m	ft
t_{95}	thickness of aerofoil at 95 per cent chord	m	ft
t_{99}	thickness of aerofoil at 99 per cent chord	m	ft
V	forward velocity	m/s	ft/s
δ	control deflection angle	rad	rad
ρ	density of air	kg/m^3	slug/ft^3
τ	trailing-edge angle as defined by angle between tangents to upper and lower surfaces at trailing edge	deg	deg

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τ_a	trailing-edge angle as defined by $\tan\frac{1}{2}\tau_a = (t_{90} - t_{99})/0.18c$	deg	deg
τ_b	trailing-edge angle as defined by $\tan\frac{1}{2}\tau_b = (t_{95} - t_{99})/0.08c$	deg	deg
Note:	An asterisk (*) denotes a standard series of aerofoils for which $\tan\frac{1}{2}\tau_a = \tan\frac{1}{2}\tau_b = \tan\frac{1}{2}\tau = t/c$.		

2. NOTES

The curves in this Item refer to a standard series of aerofoils for which $\tan\frac{1}{2}\tau_a = \tan\frac{1}{2}\tau_b = \tan\frac{1}{2}\tau = t/c$. In Figure 1 the theoretical rate of change of hinge moment coefficient with control deflection for a plain control in inviscid incompressible flow, $(b_2)_{0T}{}^*$, is plotted in carpet form against c_f/c and t/c . In Figure 2 the ratio $(b_2)_0{}^*/(b_2)_{0T}{}^*$ is plotted in carpet form against c_f/c and $(a_2)_0{}^*/(a_2)_{0T}{}^*$, which must be obtained from Item No. Aero C.01.01.03.

For aerofoils in general, the relationship between the thickness/chord ratio and the various trailing-edge angles differs from that for the standard series of aerofoils and a correction must be made. The values of $(b_2)_0{}^*$, $(a_2)_{0T}{}^*$ and $(a_2)_0{}^*$ are first calculated for the given t/c . The value of $(b_2)_0$ is then given by

$$(b_2)_0 = (b_2)_0{}^* + 2[(a_2)_{0T}{}^* - (a_2)_0{}^*](\tan\tfrac{1}{2}\tau_b - t/c) . \tag{2.1}$$

In the case of a control with a bevelled trailing edge, τ_b should be taken as equal to the actual angle of the bevel.

The curves apply within the linear range of the hinge moment versus incidence curve, *i.e.* in general for values of incidence and control deflection for which there is no separation of flow over the aerofoil, or control. Within these limitations an accuracy of $\pm 0.05\ \text{rad}^{-1}$ can be expected in the estimation of $(b_2)_0$.

All data refer to controls with sealed hinge gaps; they may be applied, however, if the gap is not greater than about 0.002c. For larger gaps a correction to the hinge moment may be obtained from Derivation 1.

For controls on wings of finite aspect ratio the hinge-moment coefficient must be corrected for induced effects and use may be made of the method given in Item No. 89009.

3. DERIVATION

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

1.	SEARS, R.I.	Wind tunnel data on the aerodynamic characteristics of airplane control surfaces. NACA ACR 3L08 (ARC Rep. 7986), 1943.
2.	WOODS, L.C.	The theory of aerofoils with hinged flaps in two-dimensional compressible flow. ARC CP 138, 1952.
3.	GARNER, H.C.	Charts for low-speed characteristics of two-dimensional trailing-edge flaps. ARC R&M 3174, 1957.

4. EXAMPLE

Find the rate of change of hinge-moment coefficient with control deflection in incompressible flow for a plain control on a two-dimensional aerofoil for which $c_f/c = 0.35$ and $t/c = 0.10$. The profile of the aerofoil from 80 per cent of the chord to the trailing edge is generated by two straight lines such that $\tan\frac{1}{2}\tau = 0.12$. The Reynolds number based on aerofoil chord is 10^7 and boundary-layer transition may be assumed to occur at mid-chord.

For the appropriate aerofoil in the standard series with $\tan\frac{1}{2}\tau = t/c = 0.10$.

From Item Nos Aero W.01.01.05 and C.01.01.03 with the above data

$$\frac{(a_2)_0^*}{(a_2)_{0T}^*} = 0.850 \text{ and } (a_2)_{0T}^* = 4.80 \text{ rad}^{-1} .$$

Thus $\qquad (a_2)_0^* = 0.850 \times 4.80 = 4.08 \text{ rad}^{-1}$.

From Figure 1, for the standard aerofoil with $t/c = 0.10$ and $c_f/c = 0.35$,

$$(b_2)_{0T}^* = -0.924 \text{ rad}^{-1} ,$$

and from Figure 2 with $(a_2)_0^*/(a_2)_{0T}^* = 0.850$ and $c_f/c = 0.35$,

$$(b_2)_0^*/(b_2)_{0T}^* = 0.866 .$$

Hence $\qquad (b_2)_0^* = -0.866 \times 0.924 = -0.800 \text{ rad}^{-1}$.

Since the trailing-edge profile from 80 per cent chord onwards is generated by two straight lines, for the actual aerofoil $\tan\frac{1}{2}\tau_b = \tan\frac{1}{2}\tau = 0.12$.

Hence, from Equation (2.1),

$$\begin{aligned}(b_2)_0 &= -0.800 + 2[4.80 - 4.08](0.12 - 0.10)\\ &= -0.77 \text{ rad}^{-1} .\end{aligned}$$

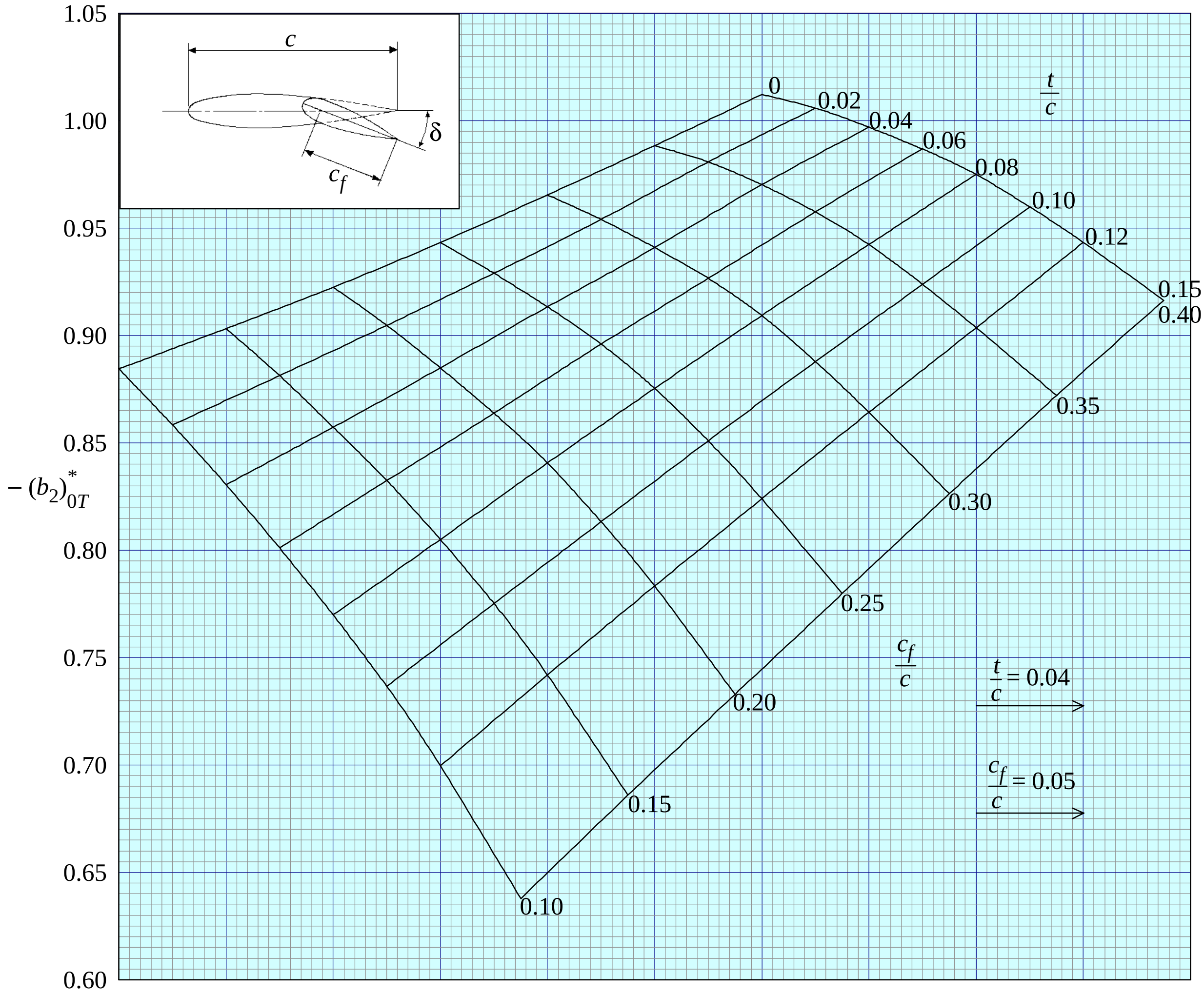

FIGURE 1

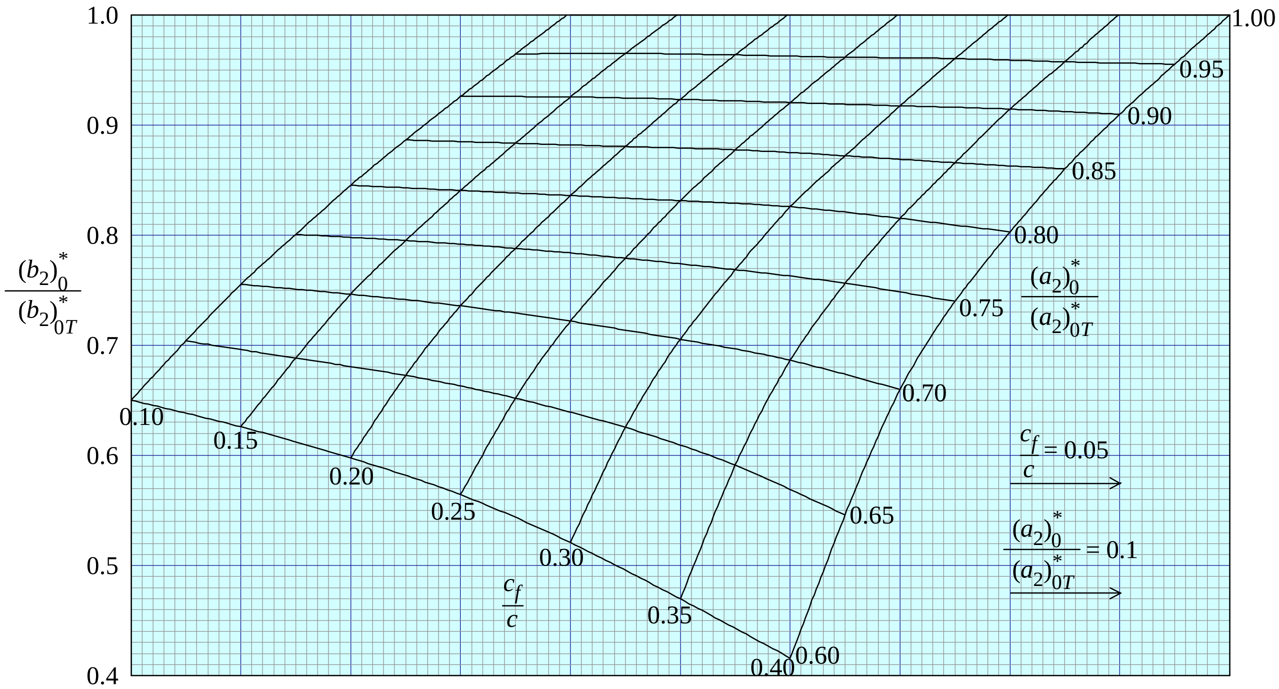

FIGURE 2