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Contribution of tailplane-mounted twin fins to sideforce, yawing moment and rolling moment derivatives due to sideslip at subsonic speeds

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THE PREPARATION OF THIS DATA ITEM

The work on this particular Item, which supersedes Item No. Aero C.01.01.02, was monitored and guided by the Aerodynamics Committee which first met in 1942 and now has the following membership:

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CONTRIBUTION OF TAILPLANE-MOUNTED TWIN FINS TO SIDEFORCE, YAWING MOMENT AND ROLLING MOMENT DERIVATIVES DUE TO SIDESLIP AT SUBSONIC SPEEDS

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CONTRIBUTION OF TAILPLANE-MOUNTED TWIN FINS TO SIDEFORCE, YAWING MOMENT AND ROLLING MOMENT DERIVATIVES DUE TO SIDESLIP AT SUBSONIC SPEEDS

1. NOTATION AND UNITS

The derivative notation used is that proposed in ARC R&M 3562 (Hopkin, 1970) and described in Item No. 86021. Coefficients and aeronormalised derivatives are evaluated in aerodynamic body axes with origin at the aircraft centre of gravity with the wing span as the characteristic length. The derivatives Y_v , N_v and L_v are often written as $\partial C_Y/\partial \beta$, $\partial C_n/\partial \beta$ and $\partial C_l/\partial \beta$ or $C_{Y\beta}$, $C_{n\beta}$ and $C_{l\beta}$ in other systems of notation, but attention must be paid to the reference dimensions used and it is to be noted that a constant datum value of V is employed in the Hopkin system.

		SI	British
A_E	effective aspect ratio of each fin, allowing for endplate effect of tailplane		
A_F	geometric aspect ratio of each fin, h^2/S_F		
a_1	sideforce-curve slope for each fin in isolation, considered as a wing of aspect ratio A_E (see Section 3.1)	rad ⁻¹	rad ⁻¹
a_{1F}	average sideforce-curve slope for the individual fins allowing for body and tailplane effects	rad ⁻¹	rad ⁻¹
b	wing (reference) span	m	ft
b_T	tailplane span	m	ft
C_l	rolling moment coefficient, $\mathcal{L}/\frac{1}{2}\rho V^2 S_W b$		
C_n	yawing moment coefficient, $\mathcal{N}/\frac{1}{2}\rho V^2 S_W b$		
C_Y	sideforce coefficient, $Y/\frac{1}{2}\rho V^2 S_W$		
d	body depth at tailplane tip quarter-chord station (see Sketch 1.2)	m	ft
F	factor allowing for tailplane sweep in tailplane contribution $(L_v)_{T2F}$		
h	overall height of fin (see Sketch 1.2)	m	ft
$\mathcal{L}$	rolling moment (see Sketch 1.1)	N m	lbf ft
L_v	rolling moment derivative due to sideslip, $L_v = (\partial \mathcal{L}/\partial v)/\frac{1}{2}\rho V S_W b$		
$(L_v)_{T2F}$	twin-fin contribution to L_v in presence of body, wing and tailplane		
ΔL_v	part of $(L_v)_{T2F}$ due to loading on tailplane due to fins		

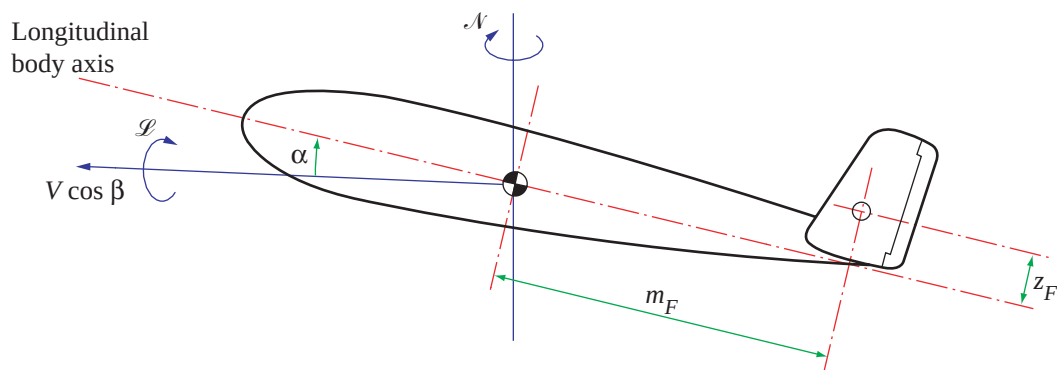
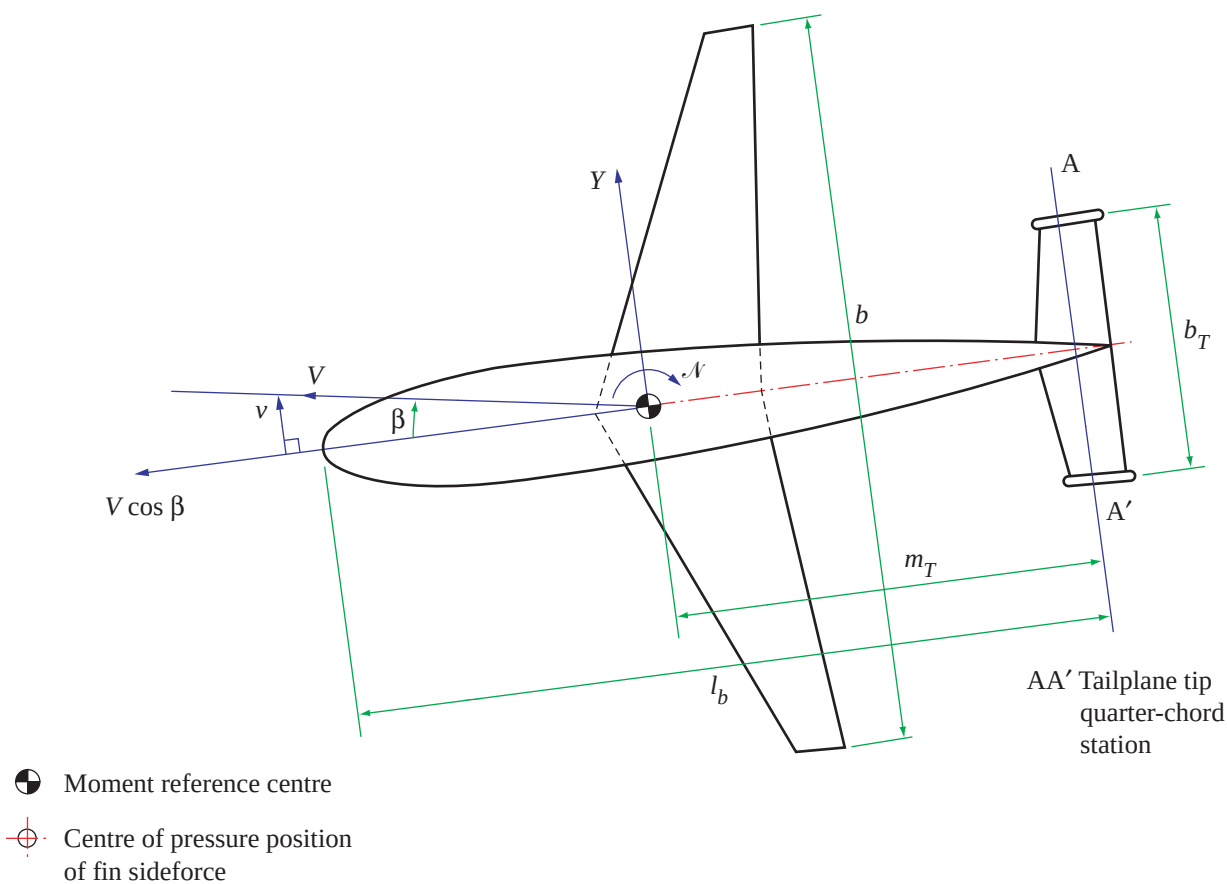
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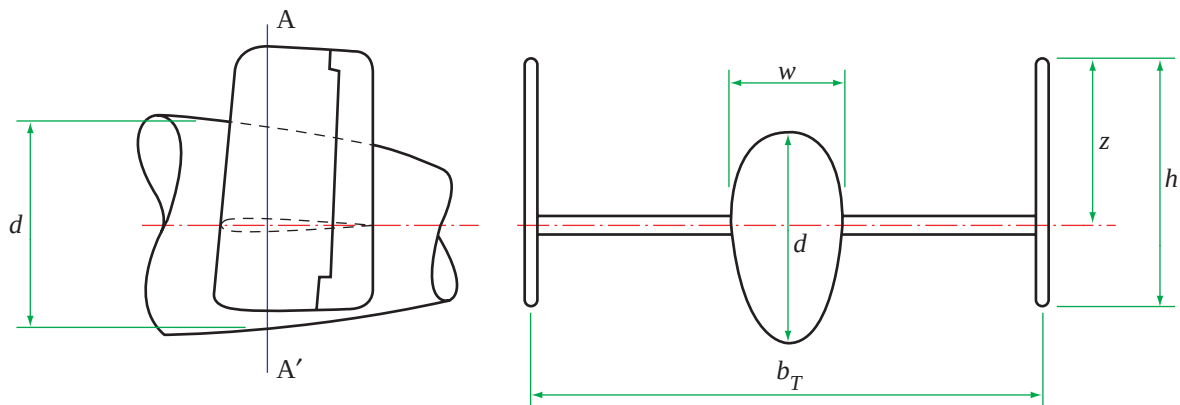
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l_B	length of body from tip of nose to tailplane tip quarter-chord station (see Sketch 1.1)	m	ft
M	free-stream Mach number		
m_F	distance of fin centre of pressure aft of moment reference centre, measured parallel to aircraft longitudinal body axis (see Sketch 1.1)	m	ft
m_T	distance of tailplane tip quarter-chord point aft of moment reference centre (see Sketch 1.1)	m	ft
$\mathcal{N}$	yawing moment (see Sketch 1.1)	N m	lbf ft
N_v	yawing moment derivative due to sideslip, $N_v = (\partial \mathcal{N} / \partial v) / \frac{1}{2} \rho V S_W b$		
$(N_v)_{T2F}$	twin-fin contribution to N_v in presence of body, wing and tailplane		
R	Reynolds number based on wing aerodynamic mean chord		
S_F	area of each fin	m ²	ft ²
S_T	area of tailplane	m ²	ft ²
S_W	wing (reference) area	m ²	ft ²
V	velocity of aircraft relative to air	m/s	ft/s
v	sideslip velocity (see Sketch 1.1)	m/s	ft/s
w	body width at tailplane tip quarter-chord station (see Sketch 1.2)	m	ft
Y	sideforce (see Sketch 1.1)	N	lbf
Y_v	sideforce derivative due to sideslip, $Y_v = (\partial Y / \partial v) / \frac{1}{2} \rho V S_W$		
$(Y_v)_{T2F}$	twin-fin contribution to Y_v in presence of body, wing and tailplane		
z	distance from tailplane tip chord line to top of fin (see Sketch 1.2)	m	ft
z_{cp}	height of centre of pressure position of load distribution on fin, measured from tailplane tip chord	m	ft
z_F	height of centre of pressure position of load distribution on fin, measured from, and normal to, longitudinal body axis	m	ft
z_T	height of tailplane tip chord above longitudinal body axis (see Sketch 3.1)	m	ft
α	angle of attack	deg	deg
β	angle of sideslip (see Sketch 1.1)	deg	deg

$\Lambda_{1/4F}$	sweepback of fin quarter-chord line	deg	deg
$\Lambda_{1/4T}$	sweepback of tailplane quarter-chord line	deg	deg
$\Lambda_{1/4TM}$	$\tan^{-1}[(\tan \Lambda_{1/4T})/(1 - M^2)^{1/2}]$	deg	deg
λ_F	taper ratio of fins		
ρ	density of air	kg/m ³	slug/ft ³



Sketch 1.1



AA' Tailplane tip quarter-chord station

Section through AA'

Sketch 1.2

2. INTRODUCTION

This Item gives a semi-empirical method for calculating $(Y_v)_{T2F}$, $(N_v)_{T2F}$ and $(L_v)_{T2F}$, the contributions of the twin vertical stabilising fins of an aircraft to the sideforce, yawing moment and rolling moment derivatives due to sideslip at subsonic speeds ($M \leq 0.7$). The method applies to twin fins of low sweep mounted at the tips of the aircraft tailplane. It was developed primarily for bodies with circular or near-circular cross-sections but may be used with caution for bodies with square or rectangular cross-sections.

The method is a modified version of that developed in Derivation 10 and was established on the basis of comparisons with wind-tunnel data in Derivations 1 to 9 and 11 to 13.

The stability derivatives are given in aero-normalised form and are for an aerodynamic-body axis system (see Reference 16).

3. METHOD

3.1 Fin Sideforce-curve Slope

The method for predicting the fin sideforce-curve slope follows the technique set out in Derivation 10 for fins of low sweep, but with some minor changes in the correlating parameters. The fins of geometric aspect ratio A_F are considered to have an effective aspect ratio A_E due to the end-plate effect of the tailplane. The ratio A_E/A_F is given in Figure 1 in terms of the vertical location, z/h , of the fins on the tailplane. To determine a_1 , the sideforce-curve slope of each fin in isolation, Figure 2 provides values of $(1 - M^2)^{1/2} a_1$, as a function of $(1 - M^2)^{1/2} A_E$ for fins of rectangular planform or with approximately elliptical spanwise loading (taken from Item No. 70011, Reference 15). A correction is applied to a_1 to allow for sidewash from the body. Figure 3 gives the ratio a_{1F}/a_1 , where a_{1F} is the lift-curve slope of each fin in the presence of the body and the tailplane. The two parameters d/h and $(1 - M^2)^{1/2} (b_T - w)/l_B$ have been used to correlate the data. The value of a_{1F} has been derived as an average of the sideforce on the individual fins, which will not be equal on account of the body. An allowance for a rudder control gap may be made by using Item No. Aero C.01.01.04 (Reference 14).