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Determination of Reversal Speed of a Wing with a Partial-Span Flap and Inset Aileron

By

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Summary.—Control reversal due to deformation of a wing with a partial-span flap and inset aileron is considered theoretically for the particular case of a flap held at the root end. The semi-rigid method is used.

An investigation is made for a particular aircraft. The calculated reversal speed is found to be considerably lower than for the straight-forward wing-aileron case. The effect of variation of the degrees of wing and flap constraint is also considered. It is concluded that an increase in reversal speed is best obtained by an increase in flap root stiffness.

1. *Introduction.*—Aileron reversal has been extensively studied by several authors[1, 2, 3, 4] for the simple case involving only the wing and the aileron. Aileron reversal with the effect of a flap taken into account, however, does not appear to have been investigated. This lack of attention to the wing-flap-aileron system may be due to the fact that it is not a very common practice for the aileron to be carried on an intermediate surface to the wing. Nevertheless this practice is occasionally followed (as a device for increasing wing lift or providing trim change on a tailless aircraft) and for the specific case considered here, the importance of considering the three-degree problem is demonstrated since the reversal speed obtained is so low as to necessitate a speed restriction on the aircraft. If the flap is considered as integral with the wing and the problem treated as a two-degree case the speed obtained is higher than the maximum design speed.

This report gives a theoretical approach to the problem in which the semi-rigid method of treatment is adopted. The flap is considered to be torsionally constrained to the wing at the flap-root end, and while this is possibly the most adverse type of attachment from the reversal viewpoint it is not intended to imply that the reversal characteristics when the flap has a distributed hinge attachment can automatically be disregarded.

2. *Assumptions for the Wing-Flap-Aileron System.*—The following assumptions are made.

(*a*) The wing is encastré at the aircraft centre-line. This assumption is justified since the rolling moment and rolling velocity are considered to be zero at the reversal speed.

(*b*) The wing flexural axis is straight and lies at a distance aft of the wing quarter-chord.

(*c*) The torsional modes of deformation of the wing and flap are linear.

(*d*) The reference sections for the wing and the flap are at the mid-span of the aileron.

(*e*) All torsion loads in the flap are transferred to the wing at the root end of the flap.

(*f*) The flap and aileron extend to the wing tip.

(*g*) The aileron is torsionally rigid.

* R.A.E. Tech. Note Structures 23, received 18th August, 1950.

3. *Derivation of the Reversal Equation.*—Strip theory is adopted and the aerodynamic forces on a strip are expressed in terms of the local incidence and chord. It is assumed that the aerodynamic derivatives are constant along the span, the derivatives being defined as follows:—

$$a_1 = \frac{\partial C_L}{\partial \alpha}\ ; \qquad b_1 = \frac{\partial C_H}{\partial \alpha}\ ; \qquad m_1 = \frac{\partial C_M}{\partial \alpha}\ ;$$

$$a_2 = \frac{\partial C_L}{\partial \xi}\ ; \qquad b_2 = \frac{\partial C_H}{\partial \xi}\ ; \qquad m_2 = \frac{\partial C_M}{\partial \xi}\ ;$$

$$a_3 = \frac{\partial C_L}{\partial \beta}\ ; \qquad b_3 = \frac{\partial C_H}{\partial \beta}\ ; \qquad m_3 = \frac{\partial C_M}{\partial \beta}\ ;$$

where a is the wing lift derivative, b is the flap hinge-moment derivative and m is the wing pitching-moment derivative as measured about the wing quarter-chord. Suffixes $_1$, $_2$ and $_3$ and angles α, ξ and β refer to the wing, flap and aileron respectively.

Consider the forces on the application of aileron on a strip of width dy at a distance of y from the wing root.

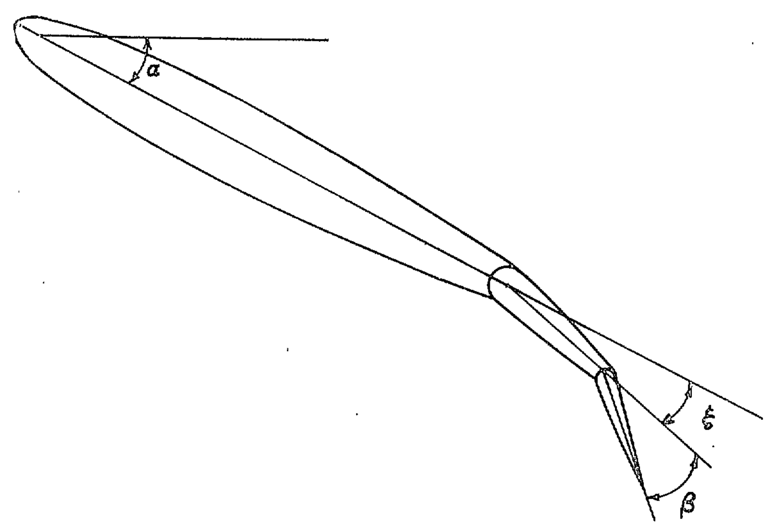

FIG. 1.

$$dL = qc\,dy\,(a_1\alpha + a_2\xi + a_3\beta) \quad \ldots \quad (1)$$

where L represents the lift force, q the dynamic pressure, c the wing chord, α the local increment of wing incidence, ξ the local flap angle, β the local aileron angle.

Also

$$dM = qc^2\,dy\,\{(m_1 + ea_1)\alpha + (m_2ea_2)\xi + (m_3 + ea_3)\beta\} \quad \ldots \quad (2)$$

where M represents the moment about the wing flexural axis, ec is the distance of the flexural axis aft of the wing quarter-chord.

$$dH = qc^2\,dy\,(b_1\alpha + b_2\xi + b_3\beta) \quad \ldots \quad (3)$$

where H represents the moment about the flap hinge.

Rewriting these equations in non-dimensional form :—

$$\left.\begin{aligned} dL &= qsc\, d\eta\, (a_1\alpha + a_2\xi + a_3\beta) \\ dM &= qsc^2\, d\eta\, \{(m_1 + ea_1)\alpha + (m_2 + ea_2)\xi + (m_3 + ea_3)\beta\} \\ dH &= qsc^2\, d\eta\, (b_1\alpha + b_2\xi + b_3\beta) \end{aligned}\right\} \quad \ldots \quad \ldots \quad (4)$$

where $\eta = y/s$ and s is the wing semi-span.

The angles α, ξ and β are now expressed in terms of the reference section and flap root angles.

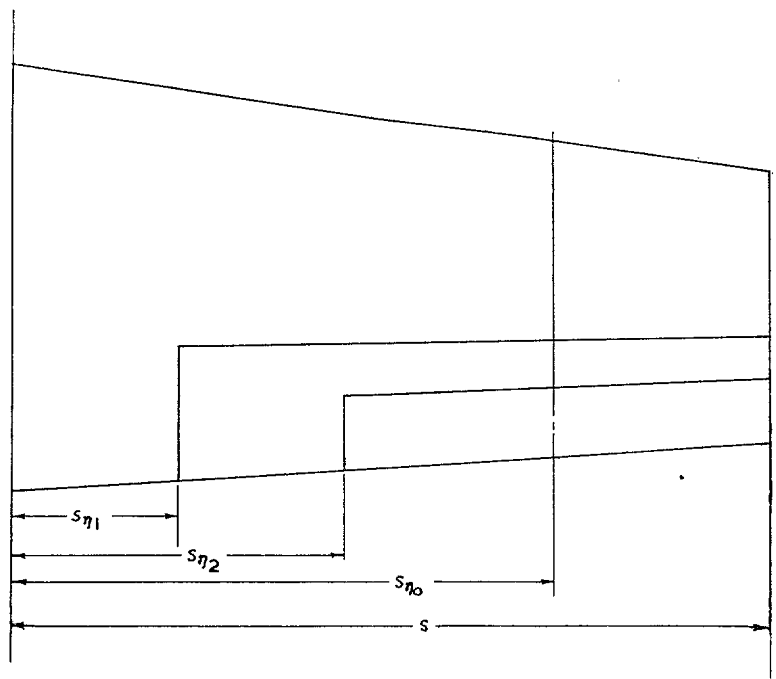

FIG. 2.

At the flap root let the flap angle relative to the wing be γ and let the wing twist be α_1. At the current section let the twist of the flap relative to the flap root be ψ and let the wing twist be α. The distortions γ, ψ, α arise from antisymmetrical application of aileron.

Then the local flap angle ξ may be expressed as

$$\xi = \gamma + \psi - \alpha + \alpha_1 . \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

The modes of the wing and flap are assumed to be linear *i.e.*,

$$\left.\begin{aligned} \alpha &= \frac{\eta}{\eta_0}\, \alpha_0 \\ \psi &= \frac{(\eta - n_1)}{(\eta_0 - \eta_1)}\, \psi_0 \end{aligned}\right\} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

where suffix $_0$ refers to the reference section.

Substituting in equation (5)

$$\xi = \gamma + \frac{(\eta - \eta_1)}{(\eta_0 - \eta_1)}\, \psi_0 - \frac{(\eta - \eta_1)}{\eta_0}\, \alpha_0 . \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

In a similar manner the expression for the local aileron angle is

$$\beta = \beta_0 + \frac{(\eta_0 - \eta)}{(\eta_0 - \eta_1)} \psi_0 \,. \qquad (8)$$

Substituting (6), (7) and (8) in equation (4)

$$dL = qsc\,d\eta \left[\left\{ a_1 \frac{\eta}{\eta_0} - a_2 \frac{(\eta - \eta_1)}{\eta_0} \right\} \alpha_0 + a_2\gamma + a_2 \left\{ \frac{(\eta - \eta_1)}{(\eta_0 - \eta_1)} + a_3 \frac{(\eta_0 - \eta)}{(\eta_0 - \eta_1)} \right\} \psi_0 + a_3\beta_0 \right] \qquad (9)$$

$$dM = qsc^2\,dn \left[\left\{ (m_1 + ea_1) \frac{\eta}{\eta_0} - (m_2 + ea_2) \frac{(\eta - \eta_1)}{\eta_0} \right\} \alpha_0 + (m_2 + ea_2)\gamma + \left\{ (m_2 + ea_2) \frac{(\eta - \eta_1)}{(\eta_0 - \eta_1)} + (m_3 + ea_3) \frac{(\eta_0 - \eta)}{(\eta_0 - \eta_1)} \right\} \psi_0 + (m_3 + ea_3)\beta_0 \right] \qquad (10)$$

$$dH = qsc^2\,d\eta \left[\left\{ b_1 \frac{\eta}{\eta_0} - b_2 \frac{(\eta - \eta_1)}{\eta_0} \right\} \alpha_0 + b_2\gamma + \left\{ b_2 \frac{(\eta - \eta_1)}{(\eta_0 - \eta_1)} + b_3 \frac{(\eta_0 - \eta)}{(\eta_0 - \eta_1)} \right\} \psi_0 + b_3\beta_0 \right]. \qquad (11)$$

At the reversal speed the total rolling moment is zero.

i.e.,

$$\int_0^1 \eta\, dL = 0\,.$$

Therefore, from equation (9).

$$0 = \left\{ \frac{a_1}{\eta_0} \int_0^1 c\eta^2\, d\eta - \frac{a_2}{\eta_0} \int_{\eta 1}^1 c(\eta - \eta_1)\eta\, d\eta \right\} \alpha_0 + a_2 \int_{\eta 1}^1 c\eta\, d\eta\, \gamma + \left\{ \frac{a_2}{(\eta_0 - \eta_1)} \int_{\eta 1}^1 c(\eta - \eta_1)\eta\, d\eta + \frac{a_3}{(\eta_0 - \eta_1)} \int_{\eta 2}^1 c(\eta_0 - \eta)\eta\, d\eta \right\} \psi_0 + a_3 \int_{\eta 2}^1 c\eta\, d\eta\, \beta_0\,.$$

From which we obtain

$$\beta_0 = A_1\alpha_0 + A_2\psi_0 + A_3\gamma \qquad (12)$$

where

$$A_1 = -\left\{ \frac{\dfrac{a_1}{\eta_0} \displaystyle\int_0^1 c\eta^2\, d\eta - \dfrac{a_2}{\eta_0} \displaystyle\int_{\eta 1}^1 c(\eta - \eta_1)\eta\, d\eta}{a_3 \displaystyle\int_{\eta 2}^1 c\eta\, d\eta} \right\}$$

$$A_2 = -\left\{ \frac{\dfrac{a_2}{(\eta_0 - \eta_1)} \displaystyle\int_{\eta 1}^1 c(\eta - \eta_1)\eta\, d\eta + \dfrac{a_3}{(\eta_0 - \eta_1)} \displaystyle\int_{\eta 2}^1 c(\eta_0 - \eta)\eta\, d\eta}{a_3 \displaystyle\int_{\eta 2}^1 c\eta\, d\eta} \right\}$$

$$A_3 = -\frac{a_2 \displaystyle\int_{\eta 1}^1 c\eta\, d\eta}{a_3 \displaystyle\int_{\eta 2}^1 c\eta\, d\eta}\,.$$

The aerodynamic moment on the flap is now considered. The total flap hinge moment is the integral of equation (11) and is expressed, after substituting (12), in the form :—

$$H = q\,[B_1\alpha_0 + B_2\psi_0 + B_3\gamma] \qquad \qquad (13)$$

where

$$B_1 = s\left[\frac{b_1}{\eta_0}\int_0^1 c^2\eta\, d\eta - \frac{b_2}{\eta_0}\int_{\eta 1}^1 c^2(\eta - \eta_1)d\eta + b_3A_1\int_{\eta 2}^1 c^2\, d\eta\right]$$

$$B_2 = s\left[\frac{b_2}{(\eta_0 - \eta_1)}\int_{\eta 1}^1 c^2(\eta - \eta_1)\, d\eta + b_3\int_{\eta 2}^1 c^2\left\{A_2 + \frac{(\eta_0 - \eta)}{(\eta_0 - \eta_1)}\right\} d\eta\right]$$

$$B_3 = s\left[b_2\int_{\eta 1}^1 c^2\, d\eta + b_3A_3\int_{\eta 2}^1 c^2\, d\eta\right].$$

This moment is reacted at the root end of the flap.

Therefore,

$$H = m_\gamma\gamma \qquad \qquad (14)$$

where m_γ is the elastic torsional stiffness of the flap root constraint.

Now consider the aerodynamic moment on the wing. The moment given by equation (10) is transferred by the principle of work to an equivalent moment at the wing reference section, using the relation

$$dM' = \frac{\eta}{\eta_0}\, dM. \qquad \qquad (15)$$

On integration and substituting (12) an equation for M' is obtained and is expressed in the form :—

$$M' = q[C_1\alpha_0 + C_2\psi_0 + C_3\gamma] \qquad \qquad (16)$$

where

$$C_1 = s\left[\frac{(m_1 + ea_1)}{\eta_0^{\,2}}\int_0^1 c^2\eta^2\, d\eta - \frac{(m_2 + ea_2)}{\eta_0^{\,2}}\int_{\eta 1}^1 c^2(\eta - \eta_1)\eta\, d\eta + \frac{(m_3 + ea_3)}{\eta_0} A_1\int_{\eta 2}^1 c^2\eta^2\, d\eta\right]$$

$$C_2 = s\left[\frac{(m_2 + ea_2)}{\eta_0(\eta_0 - \eta_1)}\int_{\eta 1}^1 c^2(\eta - \eta_1)\eta\, d\eta + \frac{(m_3 + ea_3)}{\eta_0}\int_{\eta 2}^1 c^2\left\{A_2 + \frac{(\eta_0 - \eta)}{(\eta_0 - \eta_1)}\,\eta\right\} d\eta\right]$$

$$C_3 = s\left[\frac{(m_2 + ea_2)}{\eta_0}\int_{\eta 1}^1 c^2\eta\, d\eta + \frac{(m_3 + ea_3)}{\eta_0} A_3\int_{\eta 2}^1 c^2\eta\, d\eta\right].$$

The total flap hinge moment acts upon the wing at the flap root section and this moment is transferred by the principle of work to an equivalent torque at the wing reference section,

i.e.,

$$H' = \frac{\eta_1}{\eta_0}\, m_\gamma\,\gamma. \qquad \qquad (17)$$

The total equivalent torque at the wing reference section is reacted by the wing elastic torsional stiffness. Therefore,

$$m_\theta\alpha_0 = M' + H' \qquad \qquad (18)$$

where m_θ is the elastic torsional stiffness of the wing as measured at the reference section.

In Appendix I a relationship is derived between γ and ψ_0 in terms of the elastic stiffnesses of the flap and of the flap root constraint. For the particular load distribution assumed in the appendix the relationship is

$$\gamma = 4\frac{(1+h+h^2)}{(3h^2+2h+1)}\frac{(\eta_0-\eta_1)}{(1-\eta_1)}\frac{m_\psi}{m_\gamma}\psi_0 . \qquad (19)$$

Where m_ψ is the flap torsional stiffness as measured at the flap reference section, h is the taper ratio of the flap.

Combining equations (14), (18) and (19) to eliminate α_0, ψ_0 and γ a quadratic equation in q is obtained. In general this equation will give two real speeds the lower corresponding to the speed for reversal of aileron control and the higher to the speed at which the system deforms so that direct aileron control is once again obtained.

4. *Application to a Specified Aircraft.*—The necessary details of the wing of a specific aircraft are given in Table 1. The following derivative values are used in the calculation.

$$a_1 = 3\cdot90/\text{radian}, \quad b_1 = -0\cdot476/\text{radian}, \quad m_1 = 0/\text{radian}$$
$$a_2 = 3\cdot22 \quad ,, \;, \quad b_2 = -0\cdot682 \quad ,, \;, \quad m_2 = -0\cdot498 \quad ,,$$
$$a_3 = 2\cdot24 \quad ,, \;, \quad b_3 = -1\cdot049 \quad ,, \;, \quad m_3 = -0\cdot642 \quad ,,$$

These are the theoretical values obtained from R. & M. 1171[5] multiplied by the following factors

a derivatives by $0\cdot90$

b derivatives by $0\cdot80$

m derivatives are the full theoretical values.

These factors have been determined from a comparison of practical values for a_1, a_3 and b_3, as obtained from Ref. 6, with the theoretical values of R. & M. 1171.

From the above data the reversal equation is obtained and expressed in terms of the elastic stiffnesses.

$$q^2\left(1\cdot57+1\cdot36\frac{m_\psi}{m_\gamma}\right)10^4 - q\left(1\cdot67m_\theta+2\cdot67m_\psi+2\cdot45m_\theta\frac{m_\psi}{m_\gamma}\right)10^2 + 1\cdot732m_\psi m_\theta = 0. \qquad (20)$$

The appropriate stiffness values are

$$m_\theta = 6\cdot42 \times 10^4 \text{ lb ft/radn}$$
$$m_\psi = 5\cdot63 \times 10^4 \text{ lb ft/radn}$$
$$m_\gamma = 4\cdot80 \times 10^4 \text{ lb ft/radn} .$$

The stiffnesses m_θ and m_ψ are directly measured values and the value of m_γ has been deduced from a measurement of the overall stiffness of the wing and flap.

With these stiffness values the reversal speed obtained is 220 knots (370 ft/sec). A safety margin of about 15 per cent in speed is normally required for a theoretical estimate of this nature and the aircraft can, therefore, be cleared to a speed of 185 knots. This implies a speed restriction since the design diving speed for the aircraft is 220 knots. Considering the wing-aileron system in which the flap is integral with the wing but contributes nothing to the wing stiffness (*i.e.*, $m_\theta = 6\cdot42 \times 10^4$ lb ft/radn) a reversal speed of 265 knots is obtained. In this case the 'safe' speed is higher than the maximum design speed of the aircraft.

An investigation has been made of the effect of varying in turn each of the three stiffnesses, wing, flap and flap root constraint (m_θ, m_ψ and m_γ respectively), and the results are presented in graphical form in Fig. 3. It is apparent that the stiffness most powerfully affecting the reversal speed is that of the flap root constraint, and that for any practical increase variation in wing stiffness has the least powerful effect.

5. *Conclusions.*—The theoretical treatment of this note provides a means for determining the reversal speed of a wing-flap-aileron system. The reversal speed for the wing-flap-aileron system of the specific aircraft considered bears no relation to the reversal speed of the wing-aileron system in which the flap is considered integral with the wing. An increase in reversal speed is best obtained by an increase in the stiffness of the flap root constraint. For this particular case an increase in wing stiffness has the least powerful effect in raising the reversal speed, but this is not necessarily true in general, and each case must be considered separately.

6. *Acknowledgement.*—Acknowledgements are due to Mr. P. J. Cutt of Structures Department, Royal Aircraft Establishment, for assistance given in the analytical and experimental work.

REFERENCES

No.	*Author*	*Title, etc.*
1	D. M. Hirst	Calculation of the Critical Reversal Speed of Wings. R. & M. 1568. September, 1933.
2	Mary Victory	The Calculation of Aileron Reversal Speed. R. & M. 2059. January, 1944.
3	A. R. Collar and E. G. Broadbent	The Rolling Power of an Elastic Wing. R. & M. 2186. October, 1945.
4	E. G. Broadbent and Ola Mansfield	Aileron Reversal and Wing Divergence of Swept Wings. R.A.E. Report Structures 9. September, 1947. A.R.C. 11,148.
5	W. G. A. Perring	The Theoretical Relationships for an Aerofoil with a Multiple Hinged Flap System. R. & M. 1171. April, 1928.
6	W. S. D. Marshall and P. J. Powter	Wind-Tunnel Tests on a Double Slotted Flap and Inset Aileron Fitted to a Semi-Low-Drag Wing Section—Youngman High-Lift Wing. R.A.E. Report Aero. 2158. November, 1946. A.R.C. 10,231.

APPENDIX I

The Relation between ψ_0 and γ

1. *Introduction.*—It is apparent that provided the torque distribution and mode of distortion of the flap are known, then a definite relationship may be determined between the twist of the flap at the reference section relative to the flap root ψ_0, and the twist of the flap root relative to the wing, γ. In what follows the relationship is determined for a torque distribution proportional to the square of the flap chord and a linear mode of distortion.

2. *Determination of the Relationship.*—

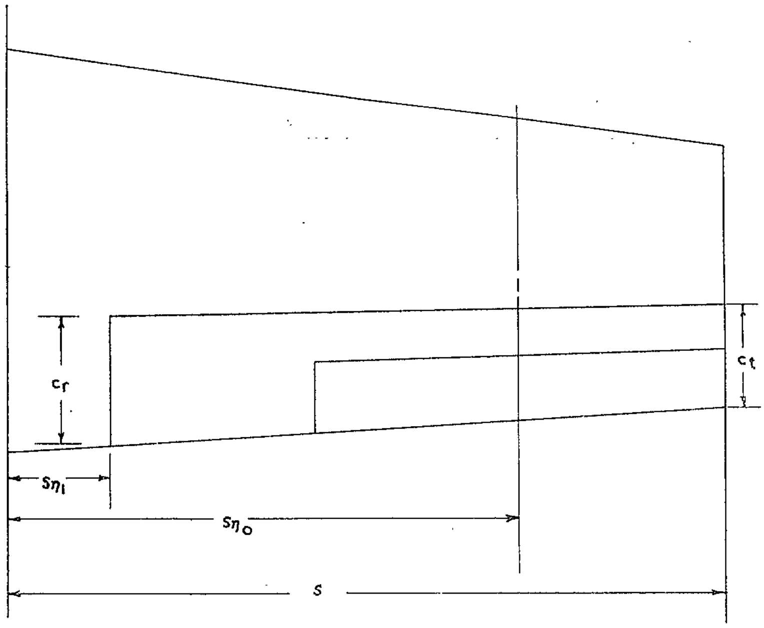

FIG. 3.

Let the taper ratio of the flap, $c_t/c_r = h$. Let the torque per unit length at the flap root be unity. Therefore, since the torque distribution is proportional to the square of the flap chord, at the current section the torque dT is given by

$$dT = s\left\{\frac{(h-1)\eta + 1 - h\eta_1}{(1-\eta_1)}\right\}^2 d\eta \,. \qquad \text{(A.1)}$$

Integrating to give the total flap torque

$$T = \frac{s(1-\eta_1)(1+h+h^2)}{3} \,. \qquad \text{(A.2)}$$

This torque is reacted by the elastic stiffness of the root constraint. Therefore

$$m_\gamma \gamma = \frac{s(1-\eta_1)(1+h+h^2)}{3} \qquad \text{(A.3)}$$

where m_γ is the torsional stiffness of the flap root constraint.

The mode of twist of the flap is linear, namely

$$\psi = \left(\frac{\eta - \eta_1}{\eta_0 - \eta_1}\right)\psi_0 \,.$$

The torque dT is now transferred by the principle of work to an equivalent torque at the reference section,

i.e., $$dT' = \left(\frac{\eta - \eta_1}{\eta_0 - \eta_1}\right) dT \,. \qquad \text{(A.4)}$$

Substituting equation (A.1) and integrating we obtain

$$T' = \frac{s(1 - \eta_1)^2(3h^2 + 2h + 1)}{12(\eta_0 - \eta_1)} \,. \qquad \text{(A.5)}$$

This torque is reacted by the flap torsional stiffness. Therefore

$$m_\psi \psi_0 = \frac{s(1 - \eta_1)^2(3h^2 + 2h + 1)}{12(\eta_0 - \eta_1)} \,, \qquad \text{(A.6)}$$

where m_ψ is the torsional stiffness of the flap relative to the root as measured at the reference section. Combining equations (A.3) and (A.6) the desired relation between ψ_0 and γ is obtained.

TABLE 1

Details of the Wing of the Specific Aircraft

Wing span (centre-line to tip)	$s = 16$ ft
Aspect ratio	$A = 5 \cdot 5$
Wing taper ratio	$\left(\frac{\text{tip chord}}{\text{root chord}}\right) = 0 \cdot 75$
Flap taper ratio	$h = 0 \cdot 75$
$\left(\frac{\text{Flap + aileron chord}}{\text{Root chord}}\right)$	$E_1 = 0 \cdot 50$
$\left(\frac{\text{Aileron chord}}{\text{Root chord}}\right)$	$E_2 = 0 \cdot 21$
Distance from centre-line to flap root constraint	$s\eta_1 = 0 \cdot 7$ ft
Distance from centre-line to aileron root end	$s\eta_2 = 10 \cdot 0$ ft
Distance from centre-line to reference section	$s\eta_0 = 12 \cdot 0$ ft

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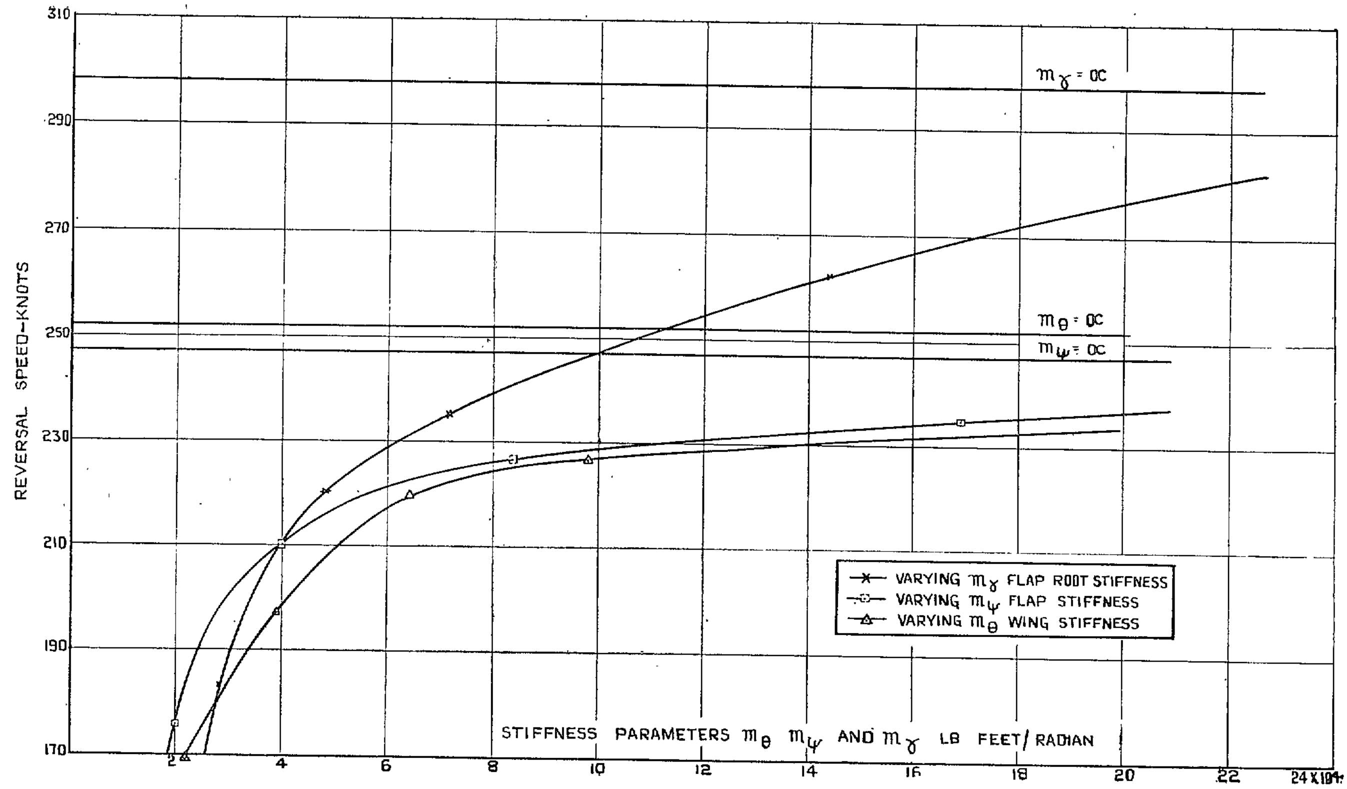

FIG. 4. The effect of variation of wing, flap and flap root stiffness on the reversal speed.

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