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The roll motion of an R.T.V.2 has been analysed to determine the aileron power and roll damping of the R.T.V.2 over a range of Mach numbers. The results of this analysis together with some theoretical extrapolation of the results are presented.
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R.T.V.2 Variation of $L_{p}$ with Height and Mach Number 5
1 Introduction

In order to obtain flight measurements of the aileron power and roll damping of the R.T.V.2 ailerons, R.T.V.2 round 8 (Trial PR2/C/1, round 1) was fired with a programme of aileron deflections on two ailerons. Roll velocity and aileron angles were measured throughout the flight using the R.A.E. 465 m.c.s. sub-miniature telemetry system. The roll attitude of the vehicle was also measured, both by camera observations and the 465 m.c. roll telemetry system.

The variations of aileron deflection, roll velocity and roll attitude with time were analysed to obtain the aileron power and roll damping of the R.T.V.2 over a range of Mach numbers and the results of the analysis are presented in this paper. A more detailed account of the results of the trial, the method of analysis employed and the analysis of the trial data will be given in a future R.A.E. Technical Note.

2 Determination of Aileron Power and Roll Damping

The equation of motion of a rolling projectile is taken to be:

\[ \dot{\phi} = p \dot{\psi} = \zeta L_\phi + L_\psi + T \]

where
- \( \phi \): projectile moment of inertia in roll
- \( p \): roll angular velocity
- \( L_\phi \): roll torque per unit rate of roll
- \( \zeta \): aileron deflection
- \( L_\psi \): roll torque per unit aileron deflection
- \( L_\psi \): roll torque due to misalignments
- \( T \): total roll torque due to aileron deflection and misalignments.

Roll velocity and aileron deflection were measured continuously during flight, a programme of deflections of two ailerons being used.

The programme was:

<table>
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<th>Time</th>
<th>Aileron Deflection</th>
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<tr>
<td>0 to 0.5 sec.</td>
<td>( +2.5^\circ )</td>
</tr>
<tr>
<td>0.5 to 1.0 sec.</td>
<td>( -2.5^\circ )</td>
</tr>
<tr>
<td>1.0 to 1.5 sec.</td>
<td>( +2.0^\circ )</td>
</tr>
<tr>
<td>1.5 to 2.0 sec.</td>
<td>( -2.0^\circ )</td>
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In order to check the calibration of the rate gyroscope used to measure roll velocity, the recorded roll velocity was integrated with respect to time to give change in roll attitude. This estimate of the change in roll attitude was then compared with the roll attitude obtained from camera and roll telemetry observations. The measurements of roll attitude obtained from camera and roll telemetry observations were in good agreement with each other, and were assumed to be subject only to random, i.e. non systematic error. With this assumption, the comparison of the integral of recorded roll velocity, and the observed roll attitude enabled
a scale error ($E_F$) and zero error 1.2 rad/sec on the records of the roll velocity to be removed. This procedure allowed the scale of the records of the roll-velocity gyroscope to be obtained to an accuracy of rather better than 0.2%.

Using the corrected values of the roll velocity the following principle was used to determine the aileron power and roll damping, from records of roll velocity.

It is assumed that during a period of time, $\delta t$, say, when $\xi$ is constant, $I_F$, $L_F$, $L_0$, are also constant. With these assumptions integrating equation (1) over a finite period of time $\delta t$, we obtain

$$\int_{t}^{t+\delta t} (p_{t+\delta t} - p_t) \, dt = T \delta t$$

Thus during the period $\delta t$ plotting $p_{t+\delta t} - p_t$ against $\int p \, dt$ for different values of $\delta t$, but keeping $\delta t$ constant we obtain a straight line of slope $\frac{L_F}{A}$, and intercept $\frac{T}{A} \delta t$ when $\int p \, dt = 0$.

In practice the definite integral $\int p \, dt$ can be evaluated with sufficient accuracy by using a trapezoidal summation, providing the time interval between successive values of $p$ used in the summation is small compared with $\frac{\delta t}{I_F}$.

The values of $p$ obtained from Eq. 2 and Eq. 3, when treated in this way did in fact give good straight lines, and from these lines, $I_F$, and $T$ were obtained. As a symmetrical aileron programme was used $L_0$ could be eliminated from alternate values of $T$, and $L_F$ and $L_p$ determined.

The value of $L_0$ is equivalent to 10 of aileron deflection on two ailerons.

Figs. 2 and 3 give $\xi$ and $\phi$ as functions of Mach number, where

$$\xi = \frac{L_F}{\gamma \rho v^2 \, ds} \quad ; \quad \phi = \frac{L_p}{\gamma \rho v \, d^2 S}$$

$S$ = body maximum cross-sectional area = 1.576 ft$^2$;

$d$ = body maximum diameter = 1.417 ft.

Computed values of $L_F$ and $L_p$ obtained from the experimental data are plotted in figures 4 and 5 respectively, as functions of Mach number and height, together with the 'I.C.A.N.' standard atmosphere being used to obtain the variation of $\gamma \rho v^2$, and $\gamma \rho v$ with Mach number and height.
Discussion of Results

Considerations of the errors in the experimental data suggest that \( c_p \) and \( L_p \) are accurate to about \( \pm 7\% \) and \( \delta_p \) and \( L_p \) are accurate to about \( \pm 15\% \).

3.1 Aileron Power

In Fig. 2, the experimental values of \( c_p \), together with theoretical estimates of the values of \( c_p \) are shown.

The theoretical values were obtained by calculating the lift on the ailerons, assuming full root loss at the juncture of the ailerons with the body, but ignoring any interaction of the ailerons with each other.

Now the slender body value of the aileron power, assuming \( \delta P = \frac{\delta c}{\delta q} \)

\[
\delta P, \quad \text{for each aileron where} \quad \delta R \quad \text{is the aspect ratio of each aileron,}
\]

and an interaction between the ailerons is \( c_p = -22.5 \), whereas the corresponding value of \( c_p \) determined experimentally i.e. \( \delta R = 1 \), is 14.5. Further, the experimental values of \( c_p \) appear to tend towards the theoretical values \( \delta R = 1.4 \).

It is believed that the tendency for the experimental results to be below the theoretical results at the lower Mach numbers, but to approach them at the higher Mach numbers is due to interaction between each aileron and the wind angle at its.

It will be shown in a future R.A.E. Technical Note that such an interaction is geometrically possible at Mach numbers less than approximately 1.5. This loss of aileron power has been noted elsewhere.

3.2 Tail Dragging

The experimental variation of \( c_p \) with Mach number is shown in Fig. 3.

The R.A.E.2 wings are equipped wth wings with a root chord of 4.4", root chord of 5", and tip chord of 3.2", the leading edge being swept back 45°. It is difficult to estimate \( c_p \) theoretically for such wings for the range of Mach numbers covered by the experiment, but slender

body theory does enable us to estimate \( c_p \) for \( R = 1.0 \), the theoretical values being shown in Fig. 4. The lower value is that for the wings alone, and the upper value is for the wings and tail, assuming that the tail is 50% effective.

As can be seen from Fig. 3 the experimental values of \( c_p \) lie between these two values.

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<td>J.D. Burgess</td>
<td>Drag coefficient of k.T.V. 2 with wrap-round boosts, derived from flight measurements. Tech. Note No. GW 224, Dec. 1952</td>
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<td>Handbook of Supersonic Aerodynamic data, applicable to Guided Weapon Design. GW/Handbook/1 Section 4.2.0</td>
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FIG. 1. DIMENSIONS OF THE R.T.V. 2 AILERON.
FIG. 2. R.T.V. 2. VARIATION OF $\xi$ WITH MACH NUMBER.
(Four ailerons.)

$$\xi = \frac{F}{\frac{1}{2} \rho v^2 S d}$$

$S = 1.576$ SQ. FT.
$d = 1.417$ FT.
FIG. 3. R.T.V. 2. VARIATION OF $\ell_p$ WITH MACH NUMBER.
FIG. 4. R.T.V. 2. VARIATION OF $L_{\xi}$ WITH HEIGHT AND MACH NUMBER.

(FOUR AILÉRONS.)
FIG. 5. R.T.V. 2. VARIATION OF $L_p$ WITH HEIGHT AND MACH NUMBER.
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Record Summary: AVIA 6/1 8843
Title: Aileron power and roll damping of the RTV 2 as determined from flight measurements
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) TECH MEMO GW 213
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