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Measurement of Lift, Pitching Moment and Hinge Moment on a Two-Dimensional Cusped RAE 102 Aerofoil

by

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Measurement of Lift, Pitching Moment and Hinge Moment on a Two-dimensional Cusped RAE.102 Aerofoil.

-By-

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SUMMARY

The charts given in R. & M. 2730 for estimating two-dimensional control derivatives at low speeds was drawn mostly from data obtained on aerofoils of 15 per cent thickness. Further data have since been obtained on two aerofoils of 10 percent thickness. Results for the RAE 102 aerofoils with a trailing edge angle of 10.9 deg are reported in C.P. 191, and those for a modified RAE 102 aerofoil with a cusped trailing-edge are described here.

The aerofoil was fitted with 20 per cent and 40 percent plain round-nosed control surfaces. Lift, pitching moment and hinge moment were determined from balance measurements. The usual care was taken in observing or fixing with wires the positions of boundary-layer transition.

In general, the derivatives vary only a little with position of transition and the lift and pitching moment are in satisfactory agreement with the charts of R. & M. 2730. Some revision of the charts for hinge moment seems desirable.

1. Introduction - Ref. 1 (1953) describes experiments on a symmetrical 10 per cent RAE 102 section which were carried out in order to amplify the results of earlier work by Bryant, Halliday and Batson[2] (1950). Ref. 2 provides charts for estimating the low-speed steady two-dimensional derivative coefficients of lift, pitching moment and hinge moment on aerofoils with plain round-nosed control surfaces. These charts were largely based on data for aerofoils of 15 per cent thickness. The results for the thinner section in Ref. 1 suggest that fairly small adjustments to the charts are necessary. Since trailing-edge angle is an important parameter, the rear 39 per cent of the RAE 102 section has been modified to give a cusped trailing-edge. The resulting aerofoil, designated RAE 102C or NPL 290 (Ref. 3), has been tested with 20 per cent and with 40 per cent control surfaces and the results are given in the present report.

2./

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2. Description of Model and Scope of Tests - The ordinates of the RAE 102C section are given in Table 1. The model was mounted in the 7 ft. No.3 square tunnel and the method of measuring the forces was precisely the same as that given in §3 of Ref. 4. The working portion of the aerofoil, finished with a black smooth surface, was of 5 ft span and 30 in. chord and was fitted with alternative plain controls of 6 in. chord (E = 0.2) and 12 in. chord (E = 0.4). There was no apparent distortion of the model under maximum load and deflection due to bending of the supporting rod was negligible.

The scope of the experiments is given fully in Table 2. Lift, pitching moment and hinge moment were obtained from measurements on the roof-balances of the tunnel. The results were obtained to a fair degree of accuracy, the maximum departure from the mean curves being about 0.004 for C_L, 0.0005 for C_m about the quarter-chord axis and 0.0008 for C_H.

3. Control of Transition - The diameters of the wires used in fixing transition were 0.022 in. at chordwise positions x_t= 0.1c, 0.028 in. at x_t = 0.3c and 0.032 in. at x_t = 0.5c as recommended in §3.1 of Ref. 5 (Bryant and Garner 1950). These were satisfactory in practice provided that natural transition had not occurred farther forward.

The position of natural transition was measured on the upper surface by the paraffin-evaporation method and the results are shown by the curves of Fig 1. All the points plotted in Fig. 1 refer to the RAE 102 section with trailing-edge angle 10.9 deg.; a comparison of the points and the curves reveals that cusping the section has but little effect on transition. Control chord, however, has a greater effect presumably on account of the presence of the hinge-gap and its position along the chord. Transition was consistently farther forward for the larger control, and was found to remain near the hinge-gap for all incidences α below 1 deg. Between 1.5 and 3 deg transition rushed rapidly forward from x_t = 0.5c to 0.1c approximately. Thus the range of incidence for a backward transition on both surfaces at the same time is approximately between ±1.5 deg. For α = 0, transition remained at a roughly constant position, x_t = 0.6c, when either control was deflected from η = -5 to +5 deg.

4. Balance Measurements - Coefficients of lift, pitching moment and hinge moment, uncorrected for tunnel blockage and interference due to the tunnel walls, are given in Table 3 for E = 0.2 and in Table 4 for E = 0.4. Provided that there is little or no change in transition (§3) these coefficients plotted against α or η form well-defined straight lines within the accuracy stated in § 2.

Experiments were also carried out at some angles of incidence and control settings by varying the position of transition on the upper surface only by means of a wire. Comparision with the results for RAE 102 in Fig. 2a of Ref. 1 reveals that for the cusped control the variations of lift and pitching moment are smaller. Comparison also reveals that the incremental coefficients of pitching moment and hinge moment have changed sign.

5. Derivatives - The uncorrected derivatives with respect to incidence and control setting have been obtained from the slopes of curves of the experimental coefficients given in Tables 3 and 4. These slopes were obtained for symmetrically fixed transition x_t = 0.1c, 0.3c and 0.5c and with natural transition at about 0.6c on both surfaces; the ranges of angles

were /

were limited by the considerations of § 3. After applying a blockage correction from equation (1) of Ref. 4, § 7, the slopes thus obtained were corrected for tunnel interference by using equations (3) and (4) of Ref. 4.

The derivatives are defined in Table 5, where their theoretical and corrected experimental values are set out. They are plotted against x_t/c for both controls in Figs 2 & 3. There is difficulty owing to the lack of alignment of certain points for natural transition, especially in the case b_1 (Fig. 2). However, straight lines have been drawn over the range $0.1c < x_t < 0.5c$; and these indicate a small reduction in the values of a_1, a_2, $-m_2$, $-b_2$ and a small increase in $-m_1$ as transition moves forward. When transition is precipitated artificially, $-b_1$ increases as x_t decreases. Nevertheless, $-b_1$ is greatest when transition occurs naturally at about 0.6c. For each derivative the magnitude of the change in value with movement of transition is smaller for the cusped aerofoil than for the RAE 102.

6. Discussion of Results - Apart from a change in transition due to the gap at the nose of the control, the values of a_1 and m_1 should be the same for the two controls. As E is changed from 0.4 to 0.2, there is, within the accuracy of the experiments, little alteration in a_1 but there is a small movement in the aerodynamic centre h of about 0.003.

The results in Table 5 may be analysed by considering ratios of experimental derivatives to their theoretical values, which are denoted by the suffix T. In Table 6 such ratios are compared with corresponding quantities deduced from Ref 2. The experimental values of $a_1/(a_1)_T$ have been taken as a basis for estimating the quantities from the charts specified in Table 6. In these calculations the trailing-edge angle has been taken to be

$$\tau = 2 \tan^{-1} \frac{y_{0.95} - y_{0.99}}{0.04c} = 3.5 \text{ deg.}$$

Except for $b_1/(b_1)_T$ and $b_2/(b_2)_T$, the estimated ratios are substantiated by the experiments. The greatest discrepancy in Table 6 is for E = 0.2, when the estimated $(b_1/a_1)/(b_1/a_1)_T$ is as much as 25 per cent greater than the appropriate experimental value.

Previous experiments on the 1541d section, also with a cusped trailing-edge, gave values of $b_1/(b_1)_T$ and $b_2/(b_2)_T$ greater than unity (Ref 2), the effect of transition being unusual as the values were largest for a forward position of transition. These results are set out in Table 7 together with corresponding results of the present experiments for comparison. It is seen that, for the cusped RAE 102 aerofoil, the values are all smaller especially for $b_1/(b_1)_T$ and that the marked reversed effect of transition for the thicker aerofoil is not present.

For RAE 102 (§8 and Table 10 of Ref. 1), the estimated $(b_1/a_1)/(b_1/a_1)_T$ for E = 0.2 was about 60 per cent above experiment. For both RAE 102 and 102C aerofoils the estimated $(b_2/a_1)/(b_2/a_1)_T$ is in fair agreement with the experimental results for E = 0.2. For E = 0.4, however, $(b_1/a_1)/(b_1/a_1)_T$ and $(b_2/a_1)/(b_2/a_1)_T$ for both aerofoils are very roughly 10 per cent greater than the corresponding experimental values.

It/

It is concluded that some revision of the charts for b_1 and b_2 is necessary. This forms the subject of a separate report.

7. Acknowledgments - The author wishes to acknowledge the assistance of H. L. Nixon, W. C. Skelton and Miss A. K. Kernaghan on the tunnel and in working out the results.

References

No.	Author(s)	
1	A. S. Batson	Measurements of lift, pitching moment, and hinge moment on a two-dimensional RAE 102 aerofoil. C.P.191. November, 1953.
2	L. W. Bryant, A. S. Halliday and A. S. Batson	Two-dimensional control characteristics. R.& M.2730. March, 1950.
3	R. C. Pankhurst	N.P.L. aerofoil catalogue and bibliography. C.P.81. July, 1951.
4	H. C. Garner and A. S. Batson	Measurement of lift, pitching moment and hinge moment on a two-dimensional cambered aerofoil to assist the estimation of camber derivatives. R. & M. 2946. December, 1952.
5	L. W. Bryant and H. C. Garner	Control testing in wind tunnels. R. & M. 2881. January, 1951.

Table/

Table 1

Ordinates of Symmetrical Aerofoil NPL 290.

Modified 102 with cusp (RAE 102C).
Maximum thickness 0.10c at x = 0.35c
Leading edge radius of curvature = 0.00686c
Aerofoil chord = c = 30 inches.

$\frac{x}{c}$	$100\frac{y}{c}$
0	0
0.005	0.8253
0.0075	1.009
0.0125	1.299
0.025	1.821
0.05	2.529
0.075	3.041
0.1	3.445
0.15	4.051
0.2	4.473
0.25	4.759
0.3	4.932
0.35	4.999
0.4	4.953
0.45	4.770
0.5	4.492
0.55	4.147
0.6	3.751
0.65	3.312
0.7	2.803
0.75	2.220
0.8	1.596
0.85	0.990_3
0.9	0.476_3
0.925	0.276_7
0.95	0.126_0
0.975	0.032_3
0.9875	0.008
1.0	0

For $\frac{x}{c} \leqslant 0.61$, the ordinates are those of RAE 102.

For $\frac{x}{c} \geqslant 0.61$, $\frac{y}{c} = 1.14460 - 7.20796\,\frac{x}{c} + 18.71080\left(\frac{x}{c}\right)^4$

$$- 23.80782\left(\frac{x}{c}\right)^3 + 14.59208\left(\frac{x}{c}\right)^4 - 3.43170\left(\frac{x}{c}\right)^5.$$

Table 2/

Table 2

Scope of Experiments

Balance Measurements of Lift, Pitching Moment and Hinge Moment
Wind Speed = 60 ft/sec*

η = 0 deg.	Range of α(deg.) from no-lift angle Incidence settings α(deg.) = 0 ± 0.5 ± 1 ± 1.5 ± 2 ± 3 ± 5	
	Model, E = 0.2	Model, E = 0.4
Smooth Wing	−5 to + 5	−5 to + 5
Wires at x_u and x_l = 0.1c	−5 to + 5	−5 to + 5
= 0.3c	−5 to + 5	−5 to + 5
= 0.5c	−5 to + 5	−5 to + 5
Wire at x_u = 0.1c	−1, 0, + 1	
= 0.3c	−1, 0, + 1	
= 0.5c	−1, 0, + 1	
Wire at x_u = 0.3c		−1, 0, + 1
(Wire at x_l = 0.1c) = 0.5c		−1, 0, + 1
	Control settings, η (deg) = 0 ± 1 ± 3 ± 5 ± 10	
α = 0 deg		
Smooth Wing	−10 to + 10	−10 to + 10
Wires at x_u and x_l = 0.1c	− 5 to + 5	− 5 to + 5
= 0.3c	− 5 to + 5	− 5 to + 5
= 0.5c	− 5 to + 5	− 5 to + 5
Wire at x_u = 0.1c	− 3, −1, 0, + 1, + 3	
= 0.3c	− 3, −1, 0, + 1, + 3	
= 0.5c	− 3, −1 0, + 1, + 3	
Wire at x_u = 0.3c (Wire at x_l = 0.1c)		−3, −1, 0, +1, +3
= 0.5c		−3, −1, 0, +1, +3
α = −2 deg.		
Smooth Wing	− 5 to + 5	− 5 to + 5
Wires at x_u and x_l = 0.1c	− 5 to + 5	− 5 to + 5
α = + 2 deg		
Smooth Wing	− 5 to + 5	− 5 to + 5
Wires at x_u and x_l = 0.1c	− 5 to + 5	− 5 to + 5

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* Actual V = 63.45 ft/sec.

Table 3/

Table 3

Uncorrected Coefficients from Balance Measurements

(a) $E = 0.2$: $\eta = 0$ deg, varying α

α (deg)	C_L	C_m	C_H	C_L	C_m	C_H
	Smooth wing			Wires at 0.1c		
-5	-0.523	-0.0016	0.0367	-0.518	-0.0020_5	0.0349
-3	-0.310	-0.0040_5	0.0215	-0.312_5	-0.0038_5	0.0195
-2	-0.200_5	-0.0050	0.0142	-0.204	-0.0051_5	0.0114
-1.5	-0.153	-0.0054_5	0.0106	-0.151_5	-0.0055	0.0080
-1.0	-0.103	-0.0062	0.0059	-0.098_5	-0.0057_5	0.0048
-0.5	-0.048_5	-0.0059_5	0.0029	-0.052	-0.0059_5	0.0016
0	-0.001	-0.0064_5	-0.0007	-0.000_5	-0.0064_5	-0.0023
+0.5	$+0.054_5$	-0.0058_5	-0.0043	+0.050	-0.0063	-0.0050
1.0	0.102_5	-0.0071_5	-0.0083	0.104_5	-0.0071	-0.0093
1.5	0.156	-0.0075	-0.0121	0.153	-0.0076	-0.0129
2	0.206	-0.0074_5	-0.0162	0.206	-0.0083	-0.0166
3	0.312_5	-0.0087_5	-0.0255	0.310	-0.0081_5	-0.0234
5	0.527	-0.0099	-0.0400	0.520	-0.0099_5	-0.0390
	Wires at 0.5c			Wires at 0.3c		
-5	-0.524	-0.0023_5	0.0355	-0.524_5	-0.0015	0.0365
-3	-0.313	-0.0035	0.0215	-0.312_5	-0.0045	0.0198
-2	-0.207	-0.0057	0.0124	-0.202_5	-0.0055	0.0112
-1.5	-0.154	-0.0055	0.0089_5	-0.150_5	-0.0061	0.0077
-1.0	-0.100_5	-0.0061	0.0049_5	-0.095	-0.0061	0.0045
-0.5	-0.056	-0.0059	0.0023	-0.046	-0.0064_5	0.0011_5
0	+0.003	-0.0066	-0.0017	$+0.004_5$	-0.0066	-0.0019
+0.5	0.056	-0.0068	-0.0045_5	0.059_5	-0.0070_5	-0.0059
1.0	0.105_5	-0.0064	-0.0075	0.109_5	-0.0071_5	-0.0089
1.5	0.158	-0.0077_5	-0.0118	0.163	-0.0074_5	-0.0121
2	0.214	-0.0083	-0.0162	0.209	-0.0077_5	-0.0152
3	0.320	-0.0090	-0.0254	0.316_5	-0.0087	-0.0236
5	0.524_5	-0.0097	-0.0388	0.522	-0.0094_5	-0.0381

Continued /

Table 3 (Continued)

(b) E = 0.2 : α = 0 deg, varying η

η(deg)	C_L	C_m	C_H	C_L	C_m	C_H
	Smooth wing			Wires at 0.1c		
−10	-0.495_5	0.0944	0.1265	–	–	–
− 5	-0.254_5	0.0456	0.0656	−0.244	0.0431	0.0615
− 3	-0.153_5	0.0249	0.0392	−0.145	0.0229	0.0357
− 1	-0.048_5	0.0040	0.0121	−0.050	0.0031	0.0101
0	−0.001	-0.0064_5	−0.0007	-0.000_5	-0.0064_5	−0.0023
1	$+0.052_5$	−0.0170	−0.0146	$+0.045_5$	−0.0156	−0.0144
3	0.156_5	−0.0377	−0.0413	0.151	−0.0359	−0.0418
5	0.263	−0.0582	−0.0663	0.247	−0.0551	−0.0649
10	0.509_5	−0.1076	−0.1329	–	–	–
	Wires at 0.5c			Wires at 0.3c		
− 5	-0.252_5	0.0448	0.0653	-0.237_5	0.0434	0.0622
− 3	−0.147	0.0241	0.0395	-0.136_5	0.0227	0.0367
− 1	−0.044	0.0032	0.0116	-0.041_5	0.0030	0.0111
0	+0.003	−0.0066	−0.0017	$+0.004_5$	−0.0066	−0.0019
1	0.052_5	−0.0167	−0.0145	0.053	−0.0164	−0.0147
3	0.156	−0.0379	−0.0409	0.156	−0.0375	−0.0416
5	0.262	−0.0586	−0.0668	0.258	−0.0569	−0.0661

(c) E = 0.2 : α + −2, + 2 deg. varying η

η (deg)	C_L	C_m	C_H	C_L	C_m	C_H
	Smooth wing			Wires at 0.1c		
	α = −2 deg			α = −2 deg		
− 5	−0.452	0.0457	0.0783	-0.447_5	0.0430	0.0741
− 3	−0.353	0.0259	0.0537	−0.351	0.0243	0.0502
− 1	-0.248_5	0.0052	0.0283	-0.254_5	0.0049	0.0261
0	-0.200_5	−0.0050	0.0142	−0.204	-0.0051_5	0.0114
1	−0.145	−0.0157	−0.0005	-0.156_5	−0.0146	−0.0011
3	−0.048	−0.0365	−0.0275	−0.061	−0.0336	−0.0269
5	$+0.054_5$	−0.0569	−0.0532	$+0.033_5$	−0.0532	−0.0516
	α = +2 deg			α = +2 deg		
− 5	-0.052_5	0.0453	0.0528	−0.041	0.0418	0.0492
− 3	+0.056	0.0235	0.0034	+0.060	0.0208	0.0230
− 1	0.152_5	0.0035	−0.0015	0.153	0.0017	−0.0037
0	0.206	-0.0074_5	−0.0162	0.206	−0.0083	−0.0166
1	0.256_5	−0.0181	−0.0302	0.250_5	−0.0176	−0.0294
3	0.355	−0.0375	−0.0552	0.351_5	−0.0377	−0.0549
5	0.454	−0.0573	−0.0795	0.460_5	−0.0580	−0.0807

Table 4/

Table 4

Uncorrected Coefficients from Balance Measurements

(a) E = 0.4 : n = 0 deg. varying a

a(deg)	C_L	C_m	C_H	C_L	C_m	C_H
	Smooth wing			Wires at 0.1c		
- 5	-0.511_5	+0.0028	0.0542	-0.506	$+0.0022_5$	0.0524
- 3	-0.306_5	0.0018	0.0335	-0.294_5	-0.0004_5	0.0294
- 2	-0.204_5	0.0009	0.0233	-0.192_5	-0.0013_5	0.0189
-1.5	-0.151_5	0.0003	0.0173	-0.140	-0.0014_5	0.0138
-1.0	-0.098	-0.0003	0.0118	-0.088_5	-0.0020	0.0083
-0.5	-0.048_5	-0.0004_5	0.0067	-0.038	-0.0021	0.0040
0	+0.005	-0.0012	0.0009	$+0.012_5$	-0.0025	-0.0013
+0.5	0.058	-0.0015	-0.0048	0.061_5	-0.0029_5	-0.0063
1	0.110_5	-0.0021	-0.0103	0.113	-0.0035	-0.0117
1.5	0.164	-0.0025_5	-0.0154	0.167	-0.0041	-0.0173
2	0.213	-0.0032_5	-0.0215	0.220	-0.0045	-0.0226
3	0.316	-0.0040	-0.0324	0.326	-0.0054_5	-0.0336
5	0.522	-0.0054	-0.0538	0.530	-0.0063_5	-0.0546
	Wires at 0.5c			Wires at 0.3c		
- 5	-0.503	+0.0022	0.0524	-0.504_5	$+0.0024_5$	0.0524
- 3	-0.292	0.0002_5	0.0313	-0.297_5	0.0003_5	0.0307
- 2	-0.188	-0.0012	0.0197	-0.192_5	-0.0011_5	0.0194
-1.5	-0.138	-0.0018	0.0141	-0.142_5	-0.0014	0.0143
- 1	-0.085	-0.0023	0.0082	-0.092	-0.0017_5	0.0094
-0.5	-0.036	-0.0028	0.0033	-0.040_5	-0.0021	0.0044
0	$+0.014_5$	-0.0031	-0.0015	$+0.012_5$	-0.0025	-0.0013
+0.5	0.067	-0.0033	-0.0064	0.062_5	-0.0028_5	-0.0060
1	0.118_5	-0.0038	-0.0117	0.114_5	-0.0033_5	-0.0113
1.5	0.170_5	-0.0042_5	-0.0175	0.165_5	-0.0036	-0.0164
2	0.222_5	-0.0050_5	-0.0235	0.220	-0.0041	-0.0220
3	0.326	-0.0062	-0.0346	0.323	-0.0053_5	-0.0333
5	0.530	-0.0077_5	-0.0561	0.530_5	-0.0066_5	-0.0549

continued/

Table 4 (continued)

(b) E = 0.4: α = 0 deg, varying η

η (deg)	C_L	C_m	C_H	C_L	C_m	C_H
	Smooth Wing			**Wires at 0.1c**		
-10	-0.723	0.1016	0.1502	-	-	-
- 5	-0.367_5	0.0514_5	0.0748	-0.353	0.0501	0.0736
- 3	-0.216_5	0.0299	0.0440	-0.212	0.0287	0.0433
- 1	-0.066_5	0.0087	0.0149	-0.057_5	0.0073_5	0.0127
0	0.005	-0.0012	0.0009	0.012_5	-0.0025	-0.0013
1	0.079_5	-0.0118	-0.0136	0.082_5	-0.0128	-0.0157
3	0.236_5	-0.0335	-0.0439	0.0230_5	-0.0335_5	-0.0454
5	0.380_5	-0.0541_5	-0.0738	0.367	-0.0544_5	-0.0745
10	0.736	-0.0996_5	-0.1457	-	-	-
	Wires at 0.5c			**Wires at 0.3c**		
- 5	-0.352_5	0.0494_5	0.0734	-0.357	0.0506_5	0.0736
- 3	-0.207	0.0286_5	0.0428	-0.207	0.0294_5	0.0436
- 1	-0.056	0.0072	0.0133	-0.057_5	0.0080_5	0.0127
0	0.014_5	-0.0031	-0.0015	0.012_5	-0.0025	-0.0013
1	0.087	-0.0138	-0.0165	0.083_5	-0.0129_5	-0.0160
3	0.237	-0.0354_5	-0.0467	0.228_5	-0.0337	-0.0451
5	0.384	-0.0561	-0.0761	0.383	-0.0547_5	-0.0749

(c) E = 0.4: α = -2, +2 deg varying η

	Smooth Wing			**Wires at 0.1c**		
	α = -2 deg			α = -2 deg		
- 5	-0.574_5	0.0536_5	0.0984	-0.561	0.0511_5	0.0946
- 3	-0.425	0.0326	0.0686	-0.416_5	0.0306_5	0.0646
- 1	-0.278_5	0.0118	0.0387	-0.267	0.0093	0.0342
0	-0.204_5	+0.0009	0.0233	-0.192_5	-0.0013_5	0.0189
1	-0.133	-0.0097_5	0.0088	-0.121_5	-0.0114_5	0.0049
3	$+0.013_5$	-0.0303	-0.0199	+0.019	-0.0320_5	-0.0242
5	0.166	-0.0520	-0.0491	0.166_5	-0.0526	-0.0532
	α = +2 deg			α = +2 deg		
- 5	-0.153_5	0.0499_5	0.0534	-0.137_5	0.0471_5	0.0514
- 3	-0.005_5	0.0285_5	0.0228	+0.010	0.0264	0.0211
- 1	+0.139	0.0075	-0.0064	0.138	0.0061	-0.0076
0	0.213	-0.0032_5	-0.0215	0.220	-0.0045	-0.0226
1	0.290	-0.0143	-0.0362	0.298_5	-0.0156	-0.0384
3	0.434_5	-0.0352_5	-0.0667	0.442_5	-0.0361_5	-0.0676
5	0.580	-0.0560_5	-0.0962	0.587_5	-0.0561	-0.0961

Table 5/

Table 5

Derivative	Theoretical	Smooth wing	Wire at 0.5c	Wire at 0.3c	Wire at 0.1c
			$E = 0.2$		
a_1	6.751	5.62	5.65	5.59_5	5.52_5
m_1	−0.0641	-0.007_1	$+0.008_5$	$+0.005_6$	-0.008_8
b_1	−0.406	−0.387	−0.341	−0.341	−0.365
h	0.2595	0.2513	0.2485	0.2491	0.2516
a_2	3.712	2.83_5	2.82_5	2.73	2.73
m_2	−0.6752	−0.571	−0.566	−0.555	−0.539
b_2	−0.795	−0.739	−0.734	−0.715	−0.706
m	0.6400	0.567	0.570	0.558	0.535
			$E = 0.4$		
a_1	6.751	5.64_5	5.57_5	5.59_5	5.61
m_1	−0.0641	−0.0179	−0.0110	−0.0087	−0.0219
b_1	−0.665	−0.566	−0.529	−0.531	−0.556
h	0.2595	0.2532	0.2520	0.2516	0.2539
a_2	5.048	4.11	4.04	4.01_5	3.98_5
m_2	−0.6358	−0.572	−0.577	−0.574	−0.566
b_2	−0.896	−0.799	−0.813	−0.805	−0.804
m	0.5879	0.559	0.569	0.568	0.550

$a_1 = \partial C_L/$

$m_1 = \partial C_m/$

$b_1 = \partial C_H/$

$a_2 = \partial C_L/\partial\eta$

$m_2 = \partial C_m/\partial\eta$

$b_2 = \partial C_H/\partial\eta$

$$m = -m_2 + \frac{a_2}{a_1} m_{11}$$

Table 6/

Table 6

Comparison of Experimental Derivatives and Values from Charts (Ref.2)

Modified RAE 102 with cusp

Derivative	Fig. of Ref.2	From Charts (Ref.2)				From Experiments			
		E = 0.2		E = 0.4		E = 0.2		E = 0.4	
		Transition		Transition		Transition		Transition	
		back	forward	back	forward	back	forward	back	forward
$a_1/(a_1)_T$	–	0.832*	0.818*	0.836*	0.831*	0.832	0.818	0.836	0.831
a_2/a_1	18	0.486	0.477	0.741	0.738	0.504	0.494	0.728	0.710
$(b_1/a_1)/b_1/a_1)_T$	29,30	1.34	1.45	1.097	1.10_8	1.146	1.100	1.018	1.006
$(b_2/a_1)/b_2/a_1)_T$	31,32	1.14_2	1.16_4	1.17_2	1.18_5	1.116	1.085	1.066	1.080
$b_1/(b_1)_T$	–	1.114	1.18_6	0.916	0.920	0.954	0.900	0.851	0.836
$b_2/(b_2)_T$	–	0.950	0.952	0.980	0.984	0.929	0.888	0.892	0.897
$h/(h)_T$	65	0.969	0.962	0.971	0.968	0.968	0.970	0.976	0.978
$^{**}m/(m)_T$	67	0.880	0.844	0.99_5	0.99_3	0.886	0.836	0.951	0.936

τ is taken as 3.5 deg. when estimating the chart values (§6)

*taken from experiment

$$^{**}m = -m_2 + \frac{a_2}{a_1} m_1$$

Table 7/

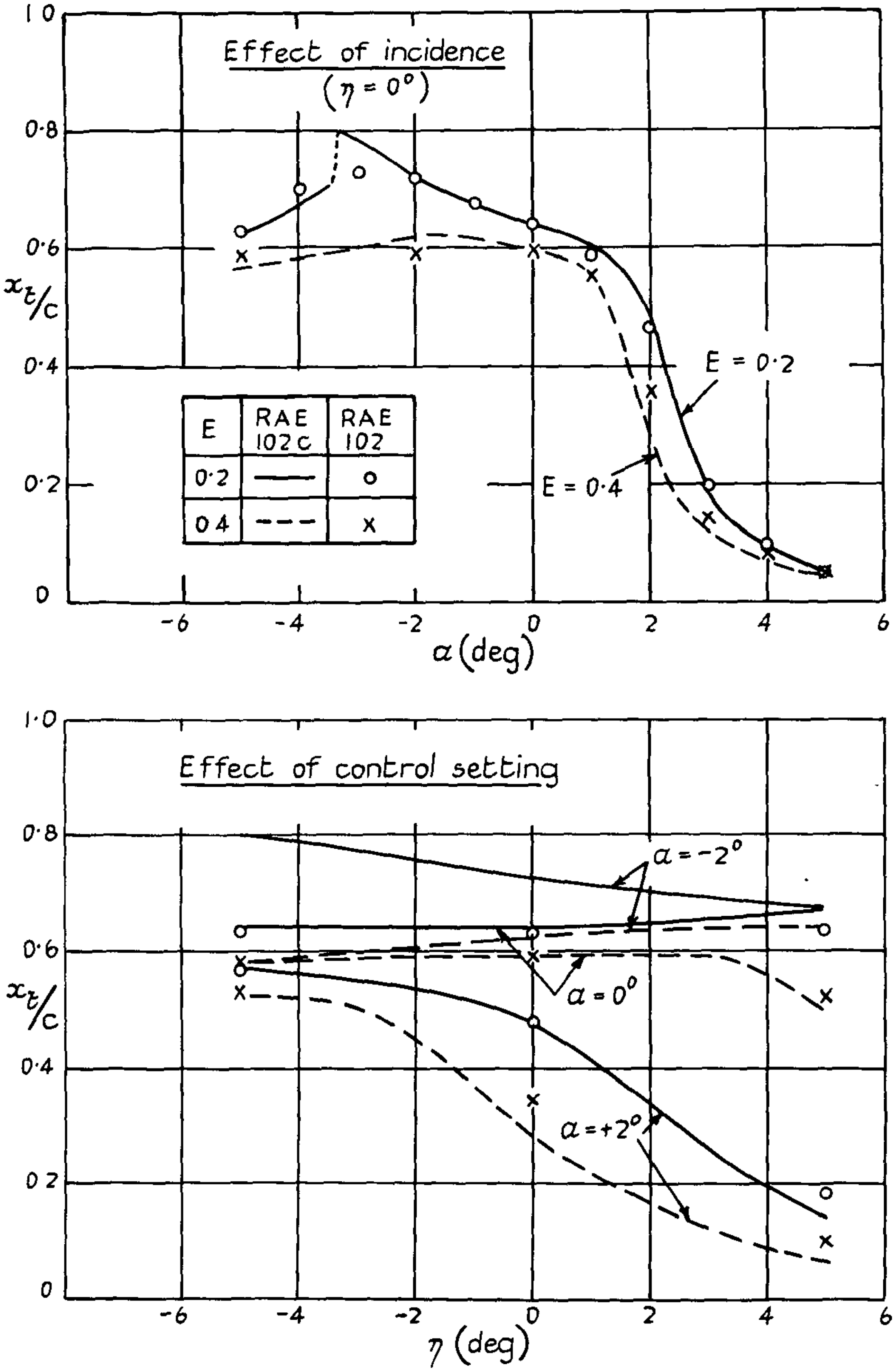
Table 7

Comparative values of $\frac{b_1}{(b_1)_T}$ and $\frac{b_2}{(b_2)_T}$

for aerofoils RAE 102C and 1541d

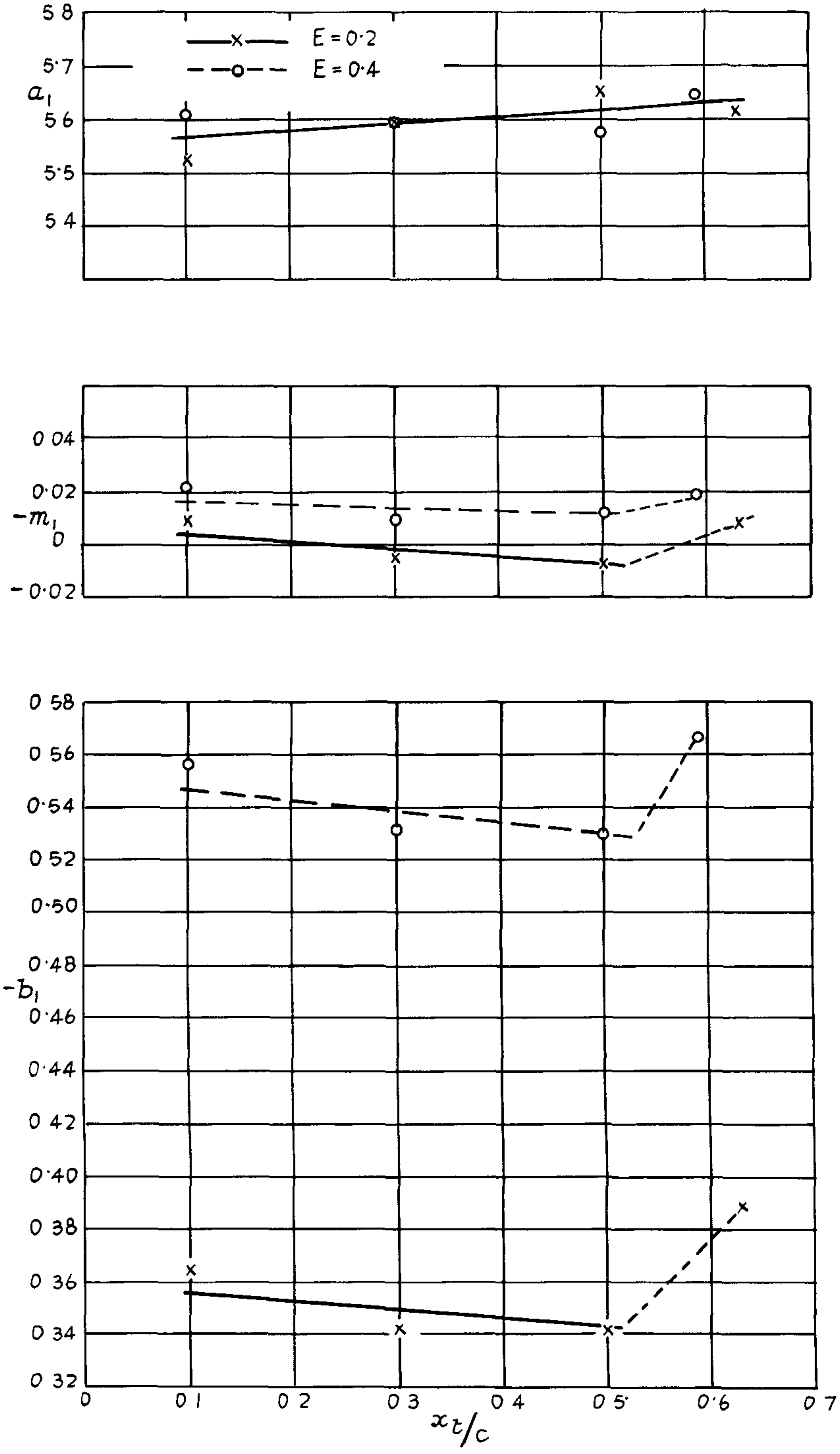
		Fig. of Ref. 2	From Experiments					
			E = 0.2			E = 0.4		
			Transition			Transition		
			back		forward	back		forward
			Natural	$\frac{x_t}{c}=0.5$	$\frac{x_t}{c}=0.1$	Natural	$\frac{x_t}{c}=0.5$	$\frac{x_t}{c}=0.1$
$b_1/(b_1)_T$	RAE 102C		0.954	0.840	0.900	0.851	0.795	0.836
	1541, cusped (1541d)	24	1.43	1.21	1.64	0.93	1.01	1.12
$b_2/(b_2)_T$	RAE 102C		0.929	0.923	0.888	0.892	0.907	0.897
	1541, cusped (1541d)	28	1.02	1.05_5	1.05_5	0.98	1.08_5	1.22_5

FIG. 1.



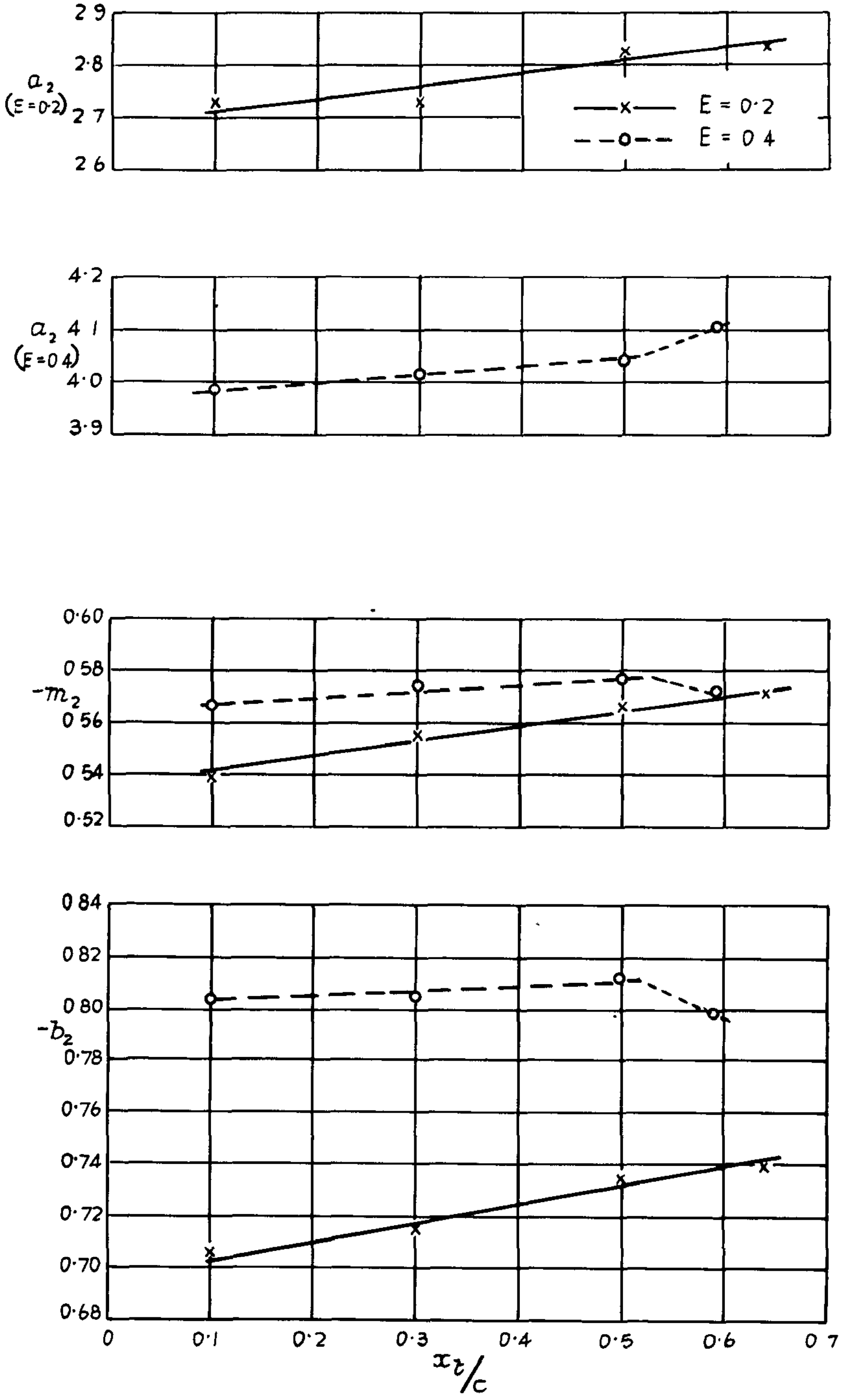
Variation of natural transition on upper surface.

FIG 2.



Experimental a_1, $-m_1$, and $-b_1$ against position of transition

FIG. 3



Experimental a_2, $-m_2$, and $-b_2$ against position of transition.

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