

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM

No. 1206

SYSTEMATIC INVESTIGATIONS OF THE EFFECTS OF PLAN FORM AND
GAP BETWEEN THE FIXED SURFACE AND CONTROL SURFACE
ON SIMPLE FLAPPED WINGS

By Göthert and Röber

Translation of ZWB Forschungsbericht Nr. 552/4, February 1940



Washington

May 1949

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM NO. 1206

SYSTEMATIC INVESTIGATIONS OF THE EFFECTS OF PLAN FORM AND

GAP BETWEEN THE FIXED SURFACE AND CONTROL SURFACE

ON SIMPLE FLAPPED WINGS*

By Göthert and Röber

SUMMARY

Four-component measurements of 12 wings of symmetric profile having flaps with chord ratios $t_R/t_L = 0.3$ and $t_R/t_L = 0.2$ are treated in this report. As a result of the investigations, the effects of plan form and gap between fixed surface and control surface have been clarified. Lift, drag, pitching moment, and hinge moment were measured in the control-surface deflection range: $-23^\circ \leq \beta \leq 23^\circ$ and the range of angle of attack: $-20^\circ \leq \alpha \leq 20^\circ$. Six wings with flaps of small chord ($t_R/t_L < 0.1$) were investigated at large flap settings.

SYMBOLS

A	lift, kilograms
W	drag, kilograms
M	pitching moment, meter-kilograms
M_R	control-surface hinge moment, meter-kilograms
F_L	total tail-plane area, meters ²
F_R	control-surface area, meters ²
b	span of the total tail-plane surface, meters

*"Systematische Untersuchungen über den Einfluss von Umrissform und Spaltgrösse zwischen Flosse und Ruder an einfachen Klappenflügeln." Zentrale für wissenschaftliches Berichtswesen über Luftfahrtforschung (ZWB), Berlin-Adlershof, Forschungsbericht Nr. 552/4, February 10, 1940.

t_L	total tail-plane chord, meters
t_R	control-surface chord, meters
s	slot between fixed surface and control surface, meters
α	angle of attack, degrees
β	control-surface angle, degrees
v	velocity in the undisturbed flow, meters per second
ρ	air density ($\text{kg sec}^2 \text{ m}^{-4}$)
q	dynamic pressure, kilograms per meter ² $\left(\frac{1}{2}\rho v^2\right)$
d	maximum thickness of the profile, meters
Λ	aspect ratio $\left(\frac{b^2}{F_L}\right)$
c_a	lift coefficient $\left(\frac{A}{qF_L}\right)$
c_w	drag coefficient $\left(\frac{W}{qF_L}\right)$
c_m	pitching-moment coefficient $\left(\frac{M}{qF_L t_L}\right)$
c_r	hinge-moment coefficient $\left(\frac{M_R}{qF_L t_L}\right)$

The pitching moment and control-surface moment are computed as positive when the air load tends to move the trailing edge down.

I. INTRODUCTION

The present report is the concluding chapter in a very elaborate program of research on wings with hinged flaps and auxiliary flaps. In FB 552/3 the effect of the chord ratio t_R/t_L on the parameter of a control surface was investigated in a series of measurements with constant aspect ratio ($\Lambda = 3.46$). In a second series of measurements, the aspect ratio Λ varied from 3.46 to 0.6 with constant chord ratio $t_R/t_L = 0.4$. The actual experimental results for flapped wings with auxiliary flaps are compiled in FB 553. In the present report the following are investigated:

- (1) Effect of the slot width between fixed surface and control surface for two chord ratios
- (2) Effect of the plan form for two chord ratios
- (3) Rectangular wing with flaps of small chord at high flap angles

II. TEST RESULTS AND ANALYSIS

The designations and dimensions of the models tested, as well as the measured ranges of angle of attack and control-surface angle, are evident from table 1 and the sketches on page 10.

TABLE 1

Model	t_R/t_L	F_R/F_L	s/t_L	b^2/F_L	Plan form	Experimental range	
						α°	β°
S	0.3	0.3	$\left\{ \begin{array}{l} 0.004 \\ .011 \\ .023 \\ .004 \end{array} \right.$	2.5	a	$-20 \leq \alpha \leq 20$	$-23 \leq \beta \leq 23$
T	.2	.2	$\left\{ \begin{array}{l} .011 \\ .023 \end{array} \right.$	2.5	a		
U	.3	.3	.004	1.5	a		
V	.3	.289	.004	2.99	b		
W	.3	.288	.004	1.99	b		
X	.3	.280	.004	3.59	c		
Y	.3	.276	.004	2.67	c		
Z	.2	.2	.004	1.5	a		
Γ	.2	.192	.004	2.99	b		
Σ	.2	.191	.004	1.99	b		
Φ	.2	.184	.004	3.59	c		
Ω	.2	.179	.004	2.67	c		

Type and construction of the models are described in FB 552/3. The models had zero twist; the wing section (Gö 409) is symmetrical. The various plan forms were obtained by adding wing tips, which were connected to the rectangular wings with pins and straps. The plan forms of the tips can be seen in the sketches on page 10. They are obtained from two quarter ellipses. The rectangular wing is designated "plan form a"; as a result of adding the small tips "plan form b" originated; as a

consequence of adding the large tips "plan form c" resulted. With two rectangular wings of chord ratio $t_R/t_L = 0.3$ and $t_R/t_L = 0.2$ ($\Lambda = 2.5$), the slot width s was varied between $s/t_L = 0.004$ and 0.023 . In FB 552/3 measurements with flapped wings of small flap chord had already been made at large control-surface settings; this series of experiments was still being completed. The models described in FB 553 (wings with flaps and auxiliary flaps) were used for this investigation. The principal control surface was fixed at zero setting, the slot between fixed surface and control surface sealed, and the auxiliary control surface set; as a result of all this, in effect, again there was a simple flapped wing. The important dimensions of the models investigated are to be seen in table 2, likewise the experimental range of angle of attack and of control-surface angle.

TABLE 2

Model	t_R/t_L	Experimental range	
		α°	β°
A	0.1	-20 + 20	0 + 60
B	.075	-20 + 20	0 + 70
C	.05	-20 + 20	0 + 70
H	.06	-20 + 20	0 + 70
I	.3	-20 + 20	0 + 60
K	.03	-20 + 20	0 + 50

Like the earlier flapped-wing tests, the experiments were carried out in the old wind tunnel of the Technischen Hochschule, Braunschweig. (Data on the tunnel: open-jet tunnel, Göttingen type of construction, jet-diameter 1.3 meters). The airspeed was 40 meters per second; that corresponds to a Reynolds number $Re = \frac{vt_L}{\nu}$ of 6×10^5 referred to the total chord $t_L = 220$ millimeters. Lift, drag, pitching moment, and hinge moment were measured in the angular regions mentioned before. (See table 1.) The angle of attack and control-surface angle were changed at intervals of 2° or 3° so that the polar was measured at constant control-surface angle. The dimensionless coefficients are computed from the experimental results in the familiar manner:

$$c_a = \frac{A}{q_{FL}}; \quad c_w = \frac{W}{q_{FL}}; \quad c_m = \frac{M}{q_{FL} t_L}; \quad c_r = \frac{M_R}{q_{FL} t_L}$$

(c_r referred to the total tail-plane chord, see FB 552/3) α and c_w are corrected for jet-boundary effects.

The experimental results are assembled graphically, and for each model α , c_m , and c_r are plotted as functions of the lift coefficient c_a with the control-surface angle β as a parameter. (See the families of curves at end of text designated "Raw Data.") The experimental material was interpreted by the interpolation method described in FB 552/3. The essence of this interpretation method consists of ascertaining the six parameters of the following linear equations:

$$\alpha^0 = \left(\frac{\partial \alpha^0}{\partial c_a} \right) c_a + \left(\frac{\partial \alpha}{\partial \beta} \right) \beta^0 \quad (1)$$

$$c_m = \left(\frac{\partial c_m}{\partial c_a} \right) c_a + \left(\frac{\partial c_m}{\partial \beta^0} \right) \beta^0 \quad (2)$$

$$c_r = \left(\frac{\partial c_r}{\partial c_a} \right) c_a + \left(\frac{\partial c_r}{\partial \beta^0} \right) \beta^0 \quad (3)$$

If $c_r = 0$, the two most important characteristics of a tail surface with control surface free may be computed.

$$\left(\frac{d\beta^0}{dc_a} \right)_{c_r=0} = - \left(\frac{\partial c_r / \partial c_a}{\partial c_r / \partial \beta^0} \right)$$

$$\left(\frac{\partial \alpha^0}{\partial c_a} \right) - \left(\frac{d\alpha^0}{dc_a} \right)_{c_r=0} = \left(\frac{\partial \alpha}{\partial \beta} \right) \left(\frac{\partial c_r / \partial c_a}{\partial c_r / \partial \beta^0} \right)$$

Since the measurements described in the present report have only been carried out up to control-surface angle $|\beta| = 23^\circ$, accurate statements about the region with detached flow at the control surface may not be made. From the diagrams the new flow condition is already evident; however, the region is too small to permit quantitative statements about it to be made. Therefore, only the parameters for the unstalled-flow region are discussed in this report.

The drags are evident from the polars at the conclusion of the report. For the rest of the drag data, reference is made to the empirical formulas presented in FB 553 b for the increase of profile drag by flap setting.

III. DISCUSSION OF THE RESULTS

(a) Slot Effect (Compare page 12)

Since there is almost always in practice a slot between fixed surface and control surface of a tail surface, it is necessary to regulate the effect of this slot on the tail-surface characteristics. The experimental results discussed in this section afford information on the effect of the size of the slot.

The experimental results are compared with the theory of the hinged flat plate with slot. The theoretical results were obtained by the method of Kleinwächter (Lufo March 1938). By means of an iteration method, the mutual induction of fixed surface and control surface are ascertained.

(a) The well-known fact that the parameter $(\partial\alpha^0/\partial c_a)$ exhibits considerable scatter, as shown in all previous published literature dealing with investigations on simple flapped wings, is partially explained by the various slots used between fixed surface and control surface. (An additional part of this scattering is interpreted as the effect of the tail surface contour; compare page 13.) The experimental results for $(\partial\alpha^0/\partial c_a)$ differ in the range of slot width investigated $(0.004 \leq s/t_L \leq 0.023)$ by ~ 6 percent; the lift gradient becomes worse with increasing slot size. The theory likewise shows this tendency; however, the worsening of the lift gradient only amounts to ~ 2 percent here.

The parameter $(\partial\alpha/\partial\beta)$ becomes considerably smaller with increasing slot size; relative to a slot width $s/t_L = 0.004$ $(\partial\alpha/\partial\beta)$ declines by 23 percent for $s/t_L = 0.023$. Therefore, the control-surface effectiveness for large slot between fixed surface and control surface is considerably smaller than for small slot. To obtain good control-surface effectiveness, the slot between fixed surface and control surface must be held as small as possible. Comparison of experimental and theoretical results shows that the theory also gives a reduction in control-surface effectiveness with increasing slot. The decrease according to theory in $(\partial\alpha/\partial\beta)$ corresponding to the slot increment investigated amounts to about 9 percent, not as large, therefore, as the experimental results.

(c_m) The effect of the slot on the parameter $(\partial c_m/\partial c_a)$ is very small, for $(\partial c_m/\partial c_a)$ is practically constant for all slot widths; at most a very small backward travel of the center of pressure is observed with increasing slot. The theory likewise indicates just a small effect on the position of the center of pressure, a small backward travel to be exact.

Theory and experiment exhibit considerable differences over the slot effect on the parameter $(\partial c_m / \partial \beta^0)$. The experimental results indicate a large decrease of up to 15 percent in the change in pitching moment with control-surface angle for increasing slot width in the range of slot width investigated; theory, on the other hand, indicated a partial increase in the parameter $(\partial c_m / \partial \beta^0)$. In this case, therefore, theory and experiment do not agree, even in trend.

(c_r) The slot exercises only a small influence on the control-surface moment. The parameter $(\partial c_r / \partial c_a)$ remains almost perfectly constant in the slot interval investigated; with the chord ratio $t_R/t_L = 0.3$, $(\partial c_r / \partial c_a)$ increases slightly with increasing slot. The theory likewise indicates a slight tendency to increase.

The change in hinge moment with control-surface setting is hardly affected by different slot widths. On the contrary, the theory indicates a considerable increase of as much as 8 percent in the parameter $(\partial c_r / \partial \beta)$ with increasing slot width in the slot range investigated.

Control surface free. - (See page 11.) The experimental results with control surface free hardly allow a relationship between slot width and the parameter of the hinge moment to be recognized. Only for the model with the larger control-surface chord $t_R/t_L = 0.3$ is a minor effect observed on the self-setting and the unstabilizing action of the free control surface. Comparison with the theory indicates an opposite effect of the slot on the parameters of the free control surface.

Summarizing, the experimental results on the slot effect reveal that the slot should be kept as small as possible in the interests of good stabilizing action, as well as good control-surface effectiveness of the tail surfaces.

(b) Effect of Plan Form (See page 13)

In the following, the dependence of the parameter on the plan form will be discussed. The plan forms a, b, and c were defined in the introduction.

It was shown in FB 552/3 that the test points for $(\partial \alpha^0 / \partial c_a)$ may be faired out satisfactorily by means of a curve.¹ The comparison with the theoretical curve shows that the test values can be satisfactorily interpolated for all aspect ratios by affine distortion

¹The effect of aspect ratio on rectangular wings with three different chord ratios (control surfaces) is illustrated in a separate diagram (page 14) by the use of the results of FB 552/3.

of the theoretical curve; the distortion factor amounted to 1.23. This applies to rectangular wings, plan form a on the chart, and is confirmed by existing measurements. The same relationship is not observed for the wing plan forms b and c. However, the diagram clearly shows that the greater the departure from the rectangular plan form, the more $\partial\alpha^\circ/\partial c_a$ increases; that means that the stabilizing portion of the tail surface becomes essentially smaller as plan forms are employed that depart further from the rectangular plan form.

The control-surface effectiveness exhibits a definite decrease in the case of plan forms b and c compared to the rectangular wing (plan form a). The parameter $(\partial\alpha/\partial\beta)$ declines in this case with control-surface chord $t_R/t_L = 0.3$ by ~ 17 percent. With the small chord ratio $t_R/t_L = 0.2$, the difference amounts to ~ 30 percent. It would have been better for comparison to investigate the individual plan forms with the same area ratios F_R/F_L instead of constant chord ratio t_R/t_L . However, this was not feasible for experimental reasons; on the average, the differences between t_R/t_L and F_R/F_L are only small (on the average ~ 6 percent). The large deviations among plan forms through this only account for an unimportant part.

(c_m) The parameter $(\partial c_m/\partial c_a)$ is very closely related to the plan form, and, in fact, the center of pressure moves forward (up to 20 percent) with increasing deviation from the rectangular design. Still larger deviations are exhibited by $(\partial c_m/\partial\beta)$ especially with small chord ratio. For $t_R/t_L = 0.2$, the difference between plan form c and the rectangular wing amounts to as much as 35 percent.

(c_r) In FB 552/3 it had been shown that the parameter $(\partial c_r/\partial c_a)$ reverses sign from negative to positive for small aspect ratio ($\Lambda \sim 1.5$, $t_R/t_L = 0.4$). This phenomenon is confirmed by the present data. Plan forms b and c do not show any excessively large differences. For both chord ratios and plan forms investigated, $(\partial c_r/\partial c_a)$ is nearly zero; however, the following is to be mentioned especially: All previous parameters have revealed a systematic order with regard to plan forms; that is, all parameters vary in the order: plan forms a, b, and c. The only exception is $(\partial c_r/\partial c_a)$; the test data for plan form c - the model with large tips - lie between the rectangular wing (a) and plan form b. This peculiarity does not appear for $(\partial c_r/\partial\beta^\circ)$; for plan form c $(\partial c_r/\partial\beta^\circ)$ is ~ 30 percent smaller than for the rectangular wing.

Control surface free. - (See page 11.) The same phenomena occur in the case of the free control surface, as was shown already in FB 552/3 with smaller aspect ratio. The parameter $(d\beta^\circ/dc_a)_{c_r=0}$ reverses sign or lies wholly on the positive range. The expression $\left(\frac{\partial\alpha^\circ}{\partial c_a}\right) - \left(\frac{d\alpha^\circ}{dc_a}\right)_{c_r=0}$ likewise reverses sign; that is, the free control surface in this case has a

stabilizing action, not an unstabilizing one. The test data for the plan form c lie between the values for a and b . The reason for this is that the expression $\left(\frac{\partial \alpha^0}{\partial c_a}\right) - \left(\frac{d\alpha^0}{dc_a}\right)_{c_r=0}$ depends principally on the parameter $(\partial c_r / \partial c_a)$, which, as already mentioned, exhibits the same characteristics.

(c) Measurements of Wings with Small Flap Chord

In the investigations of wings with small flap chord, the parameter $(\partial \alpha^0 / \partial c_a)$ alone was evaluated. Although the flow at the control surface is detached, the most important result observed is the fact that the lift gradient $(\partial \alpha^0 / \partial c_a)$ improves up to control-surface angles of 70° , and this improvement in the lift gradient amounts to a maximum of ~ 25 percent at $\beta = 70^\circ$ with respect to $\beta = 0^\circ$. (See page 15.)

IV. SUMMARY

In the present report four-component measurements of flapped wings with various slot widths between fixed surface and control surface, and various plan forms have been discussed. In addition, flapped wings with very small flap chords at large angular settings were investigated.

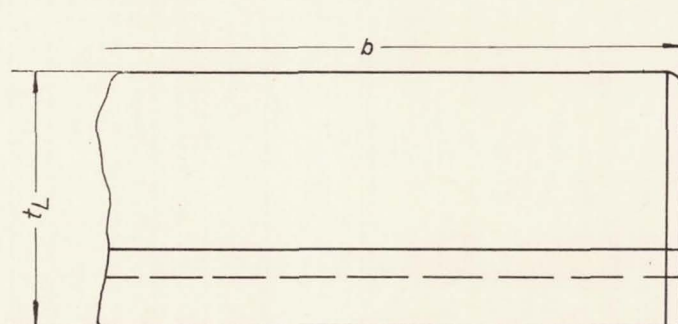
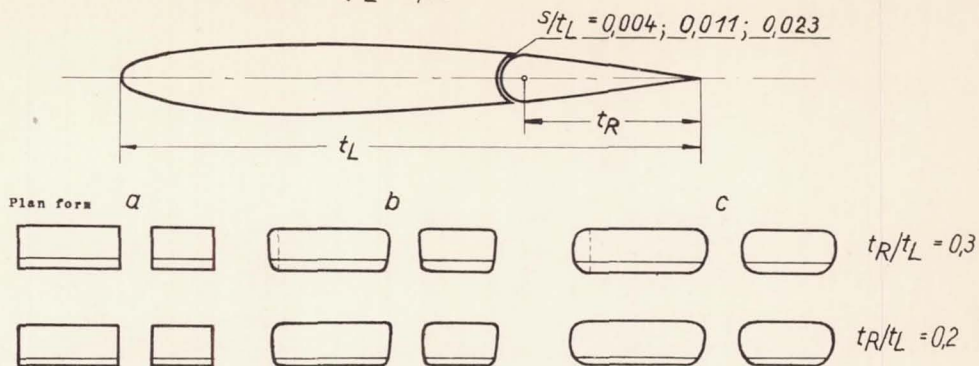
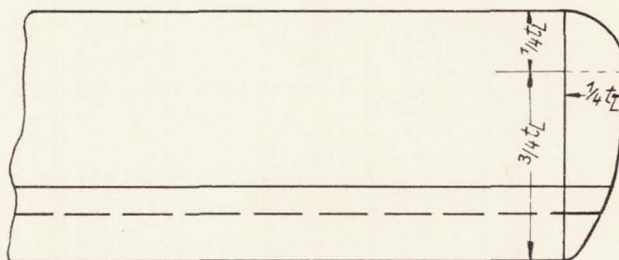
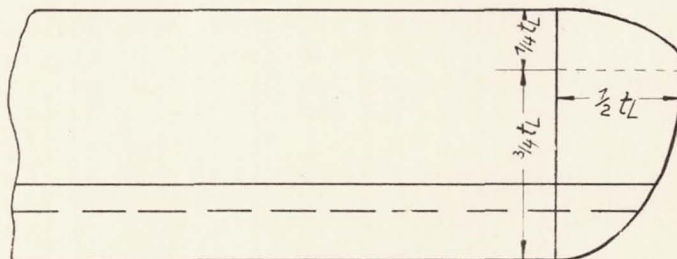
The slot between fixed surface and control surface affects $(\partial \alpha / \partial \beta)$ and $(\partial c_m / \partial \beta^0)$ first of all; that is, with increasing slot width the control-surface effectiveness and also the change in pitching moment with control-surface angle become considerably lower.

With change of plan form, it is observed that the control-surface effectiveness $(\partial \alpha / \partial \beta)$ and also $(\partial c_m / \partial \beta^0)$ and $(\partial c_r / \partial \beta^0)$ decrease considerably the more the plan form departs from the rectangular; the lift gradient $(\partial \alpha^0 / \partial c_a)$ is likewise worsened.

As a result of large settings of flaps of small chord, there is an improvement in $(\partial \alpha^0 / \partial c_a)$ in the sense of a larger aspect ratio; the increase can amount to 25 percent.

Translated by Dave Feingold
National Advisory Committee
for Aeronautics

Flapped wings with various plan forms

Profile Gö. 409 $d/t_L = 0,127$ $s/t_L = 0,004; 0,011; 0,023$ Plan form *a*Plan form *b*Plan form *c*

Braunschweig flapped wings

Control surface free

Raw data and intermediate results

Slot effect

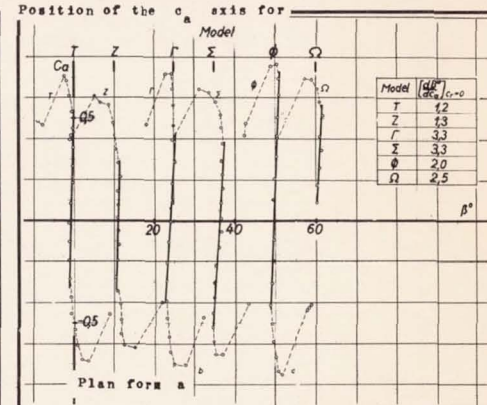
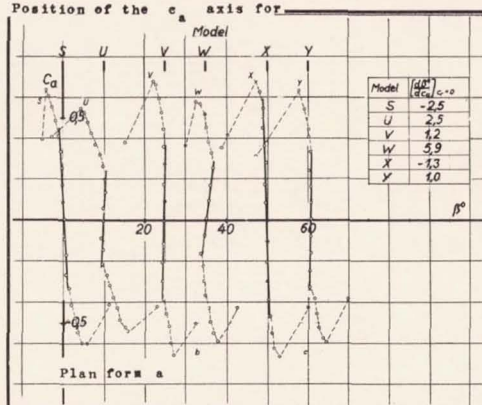
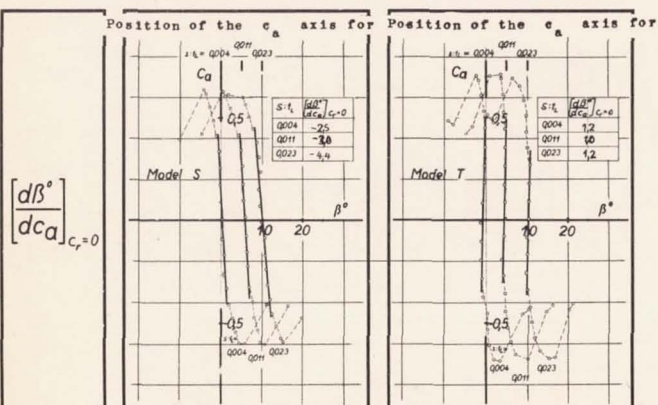
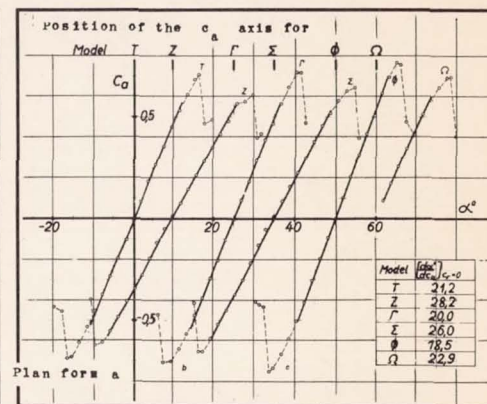
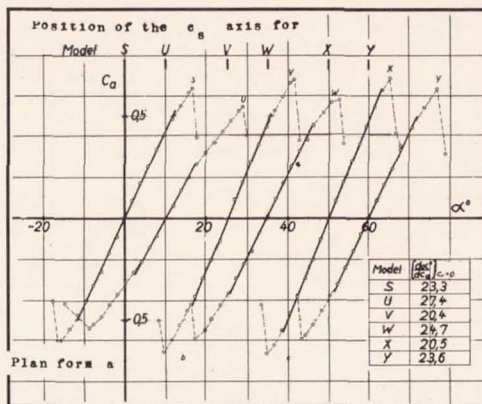
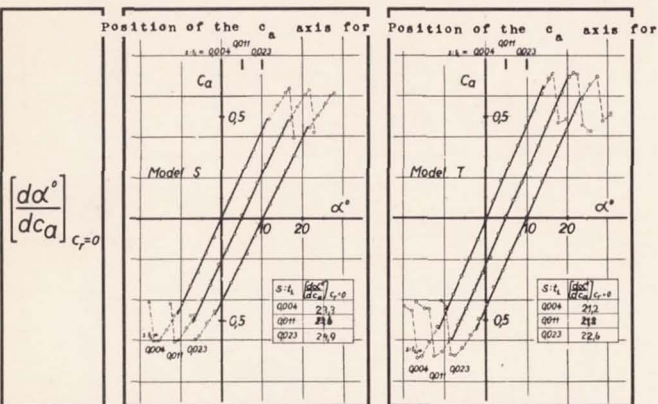
Effect of Plan form

$t_R:t_L=0.3$ $\Lambda=2.5$

$t_R:t_L=0.2$ $\Lambda=2.5$

$t_R:t_L=0.3$

$t_R:t_L=0.2$



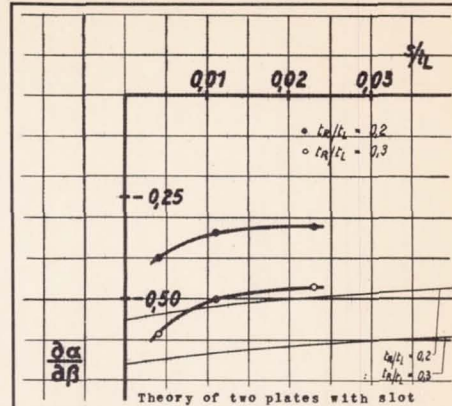
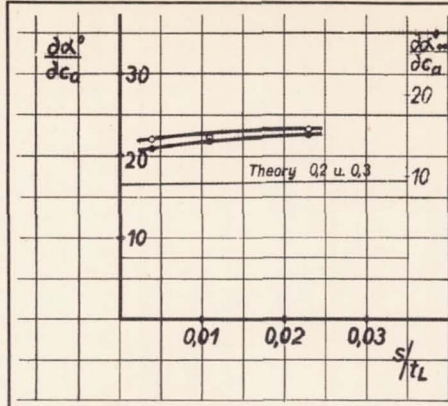
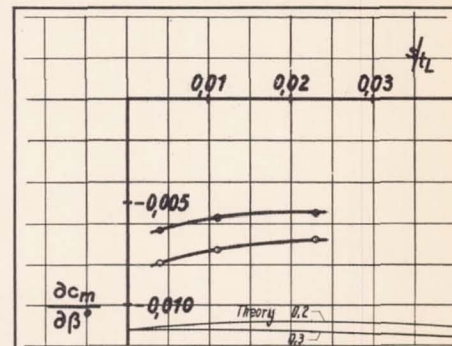
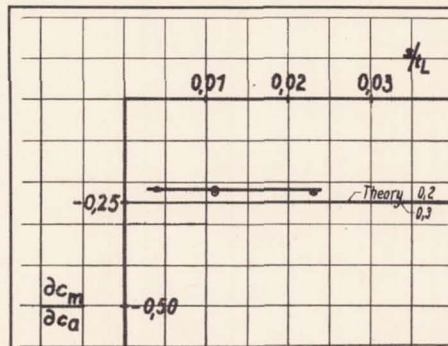
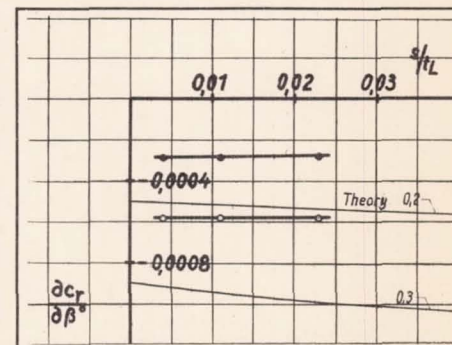
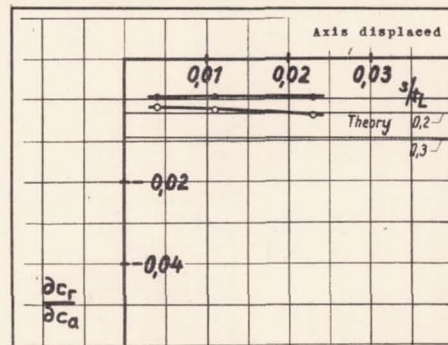
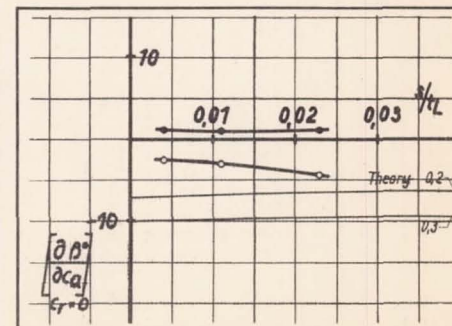
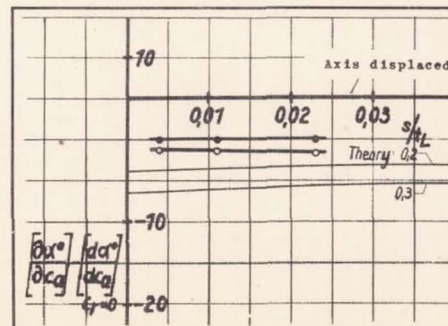
Braunschweig flapped wings

Final result

Slot effect

 $\Lambda=25$

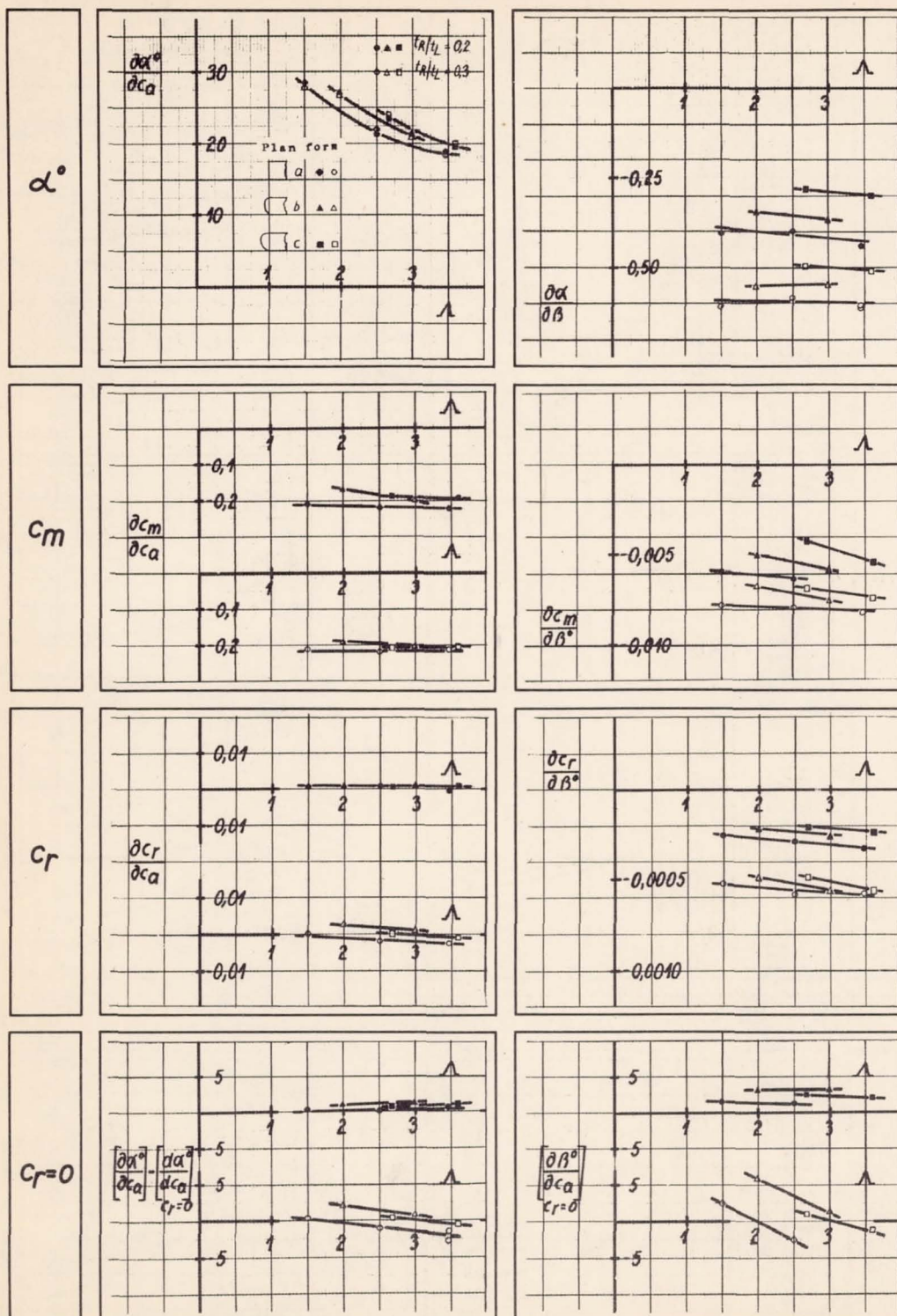
Rectangular wing

 α°  c_m  c_r  $c_r=0$ 

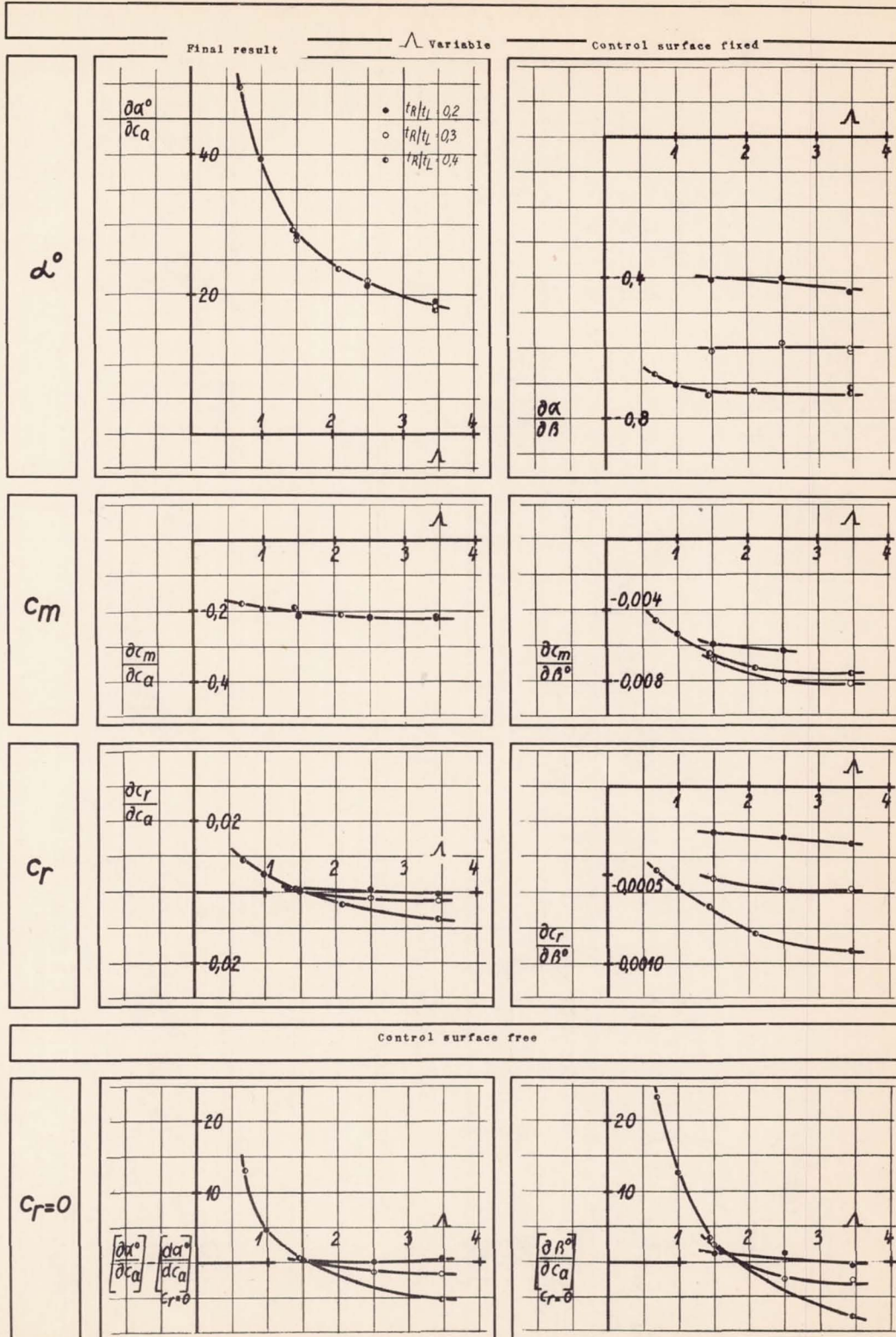
Braunschweig flapped wings

Final result

Effect of plan form



Braunschweig flapped wings

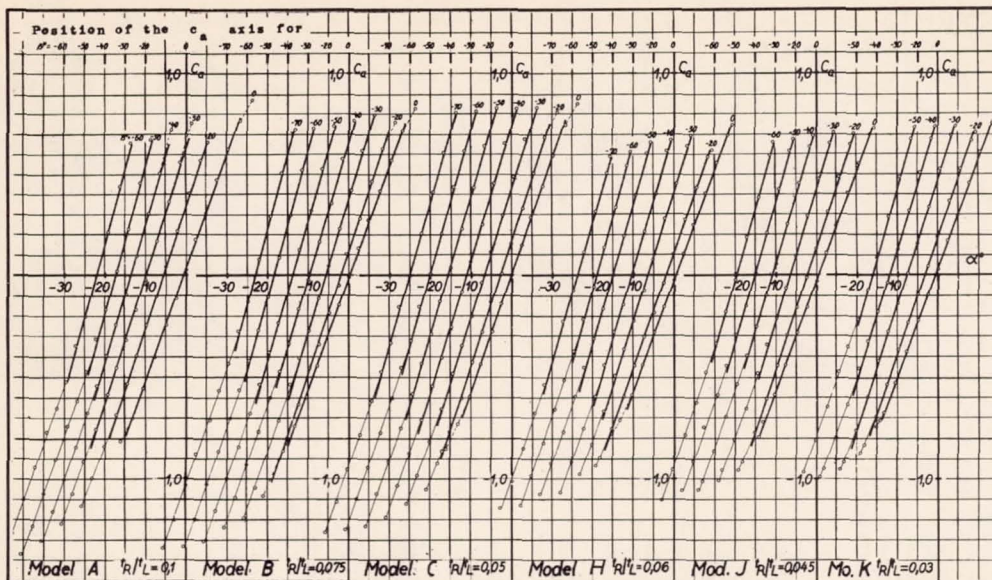


Braunschweig flapped wings

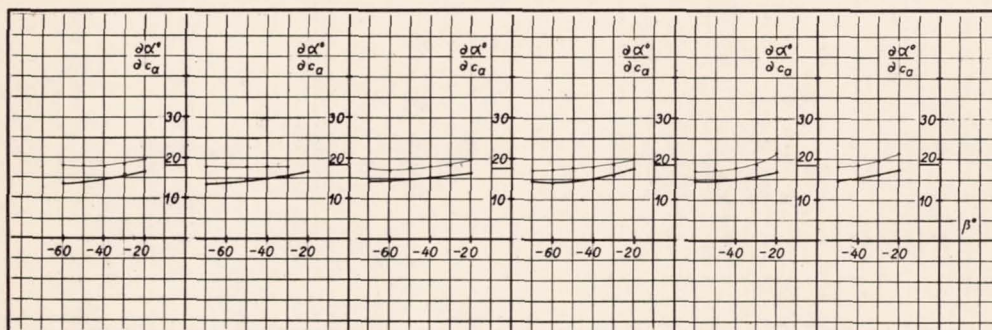
Flaps of small chord

Effect on $\frac{\partial \alpha^*}{\partial c_a}$ $\Lambda = 346$

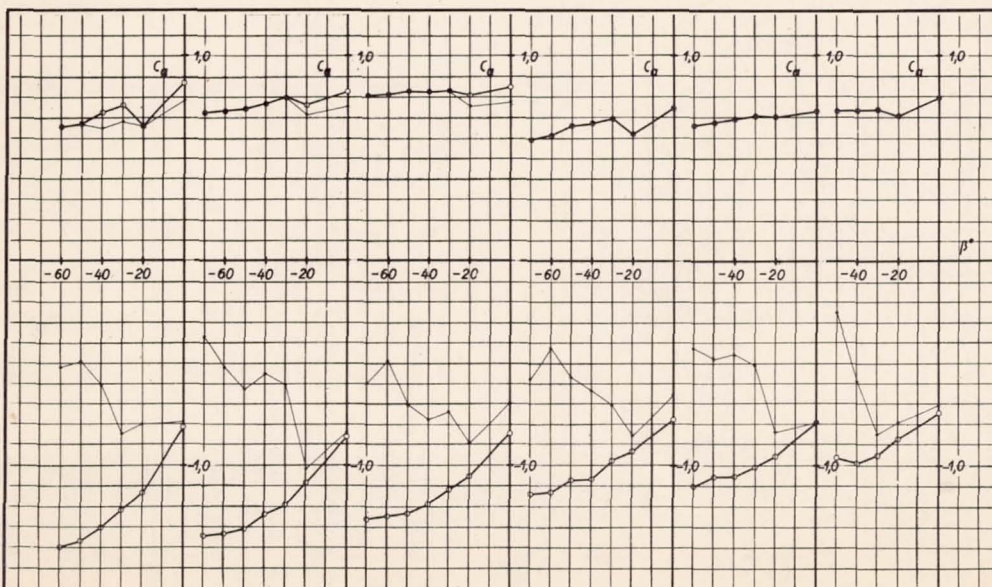
Raw data



Intermediate results



Range of validity



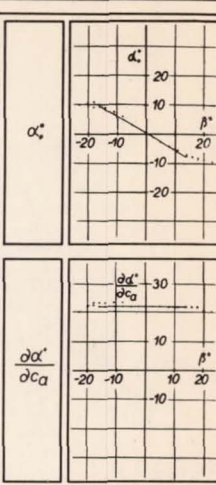
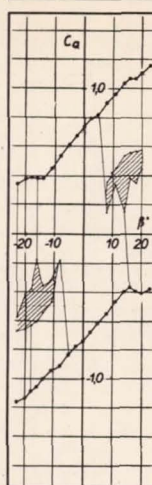
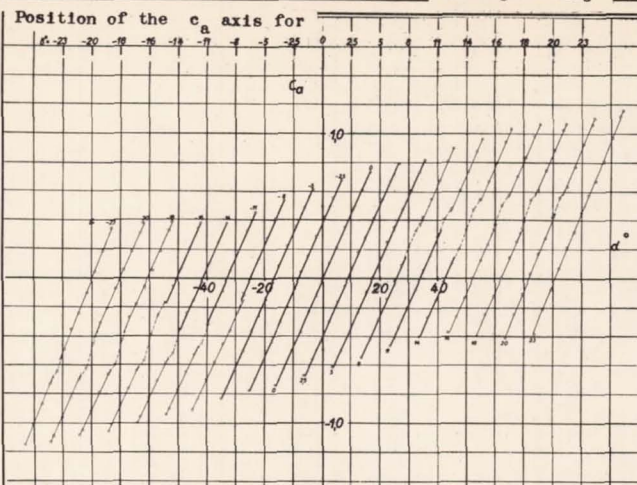
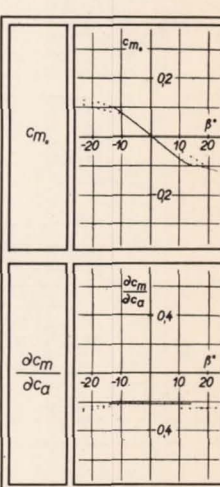
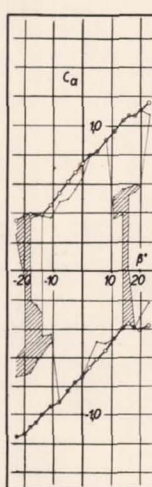
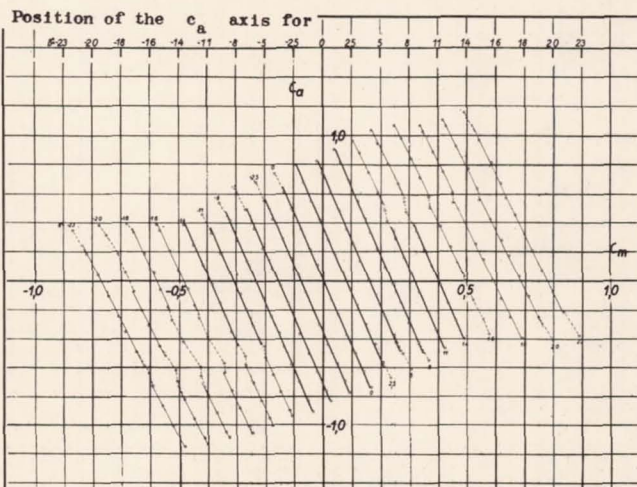
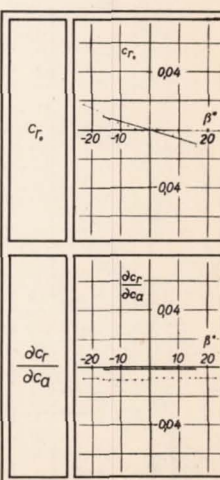
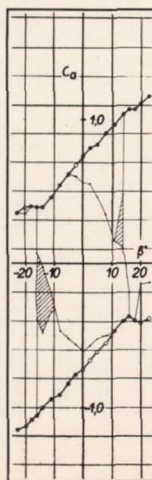
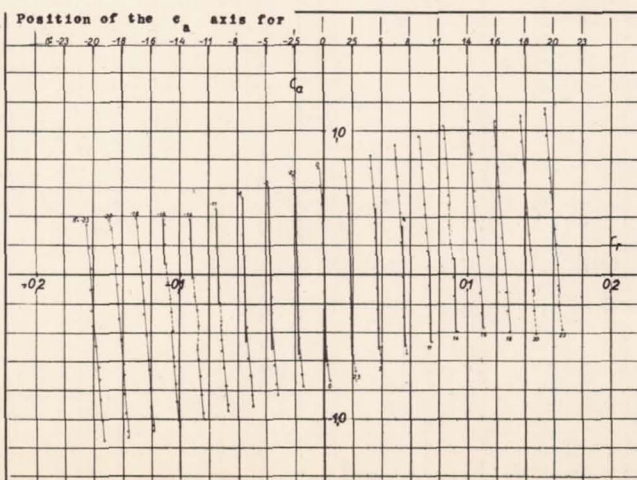
Braunschweig flapped wings

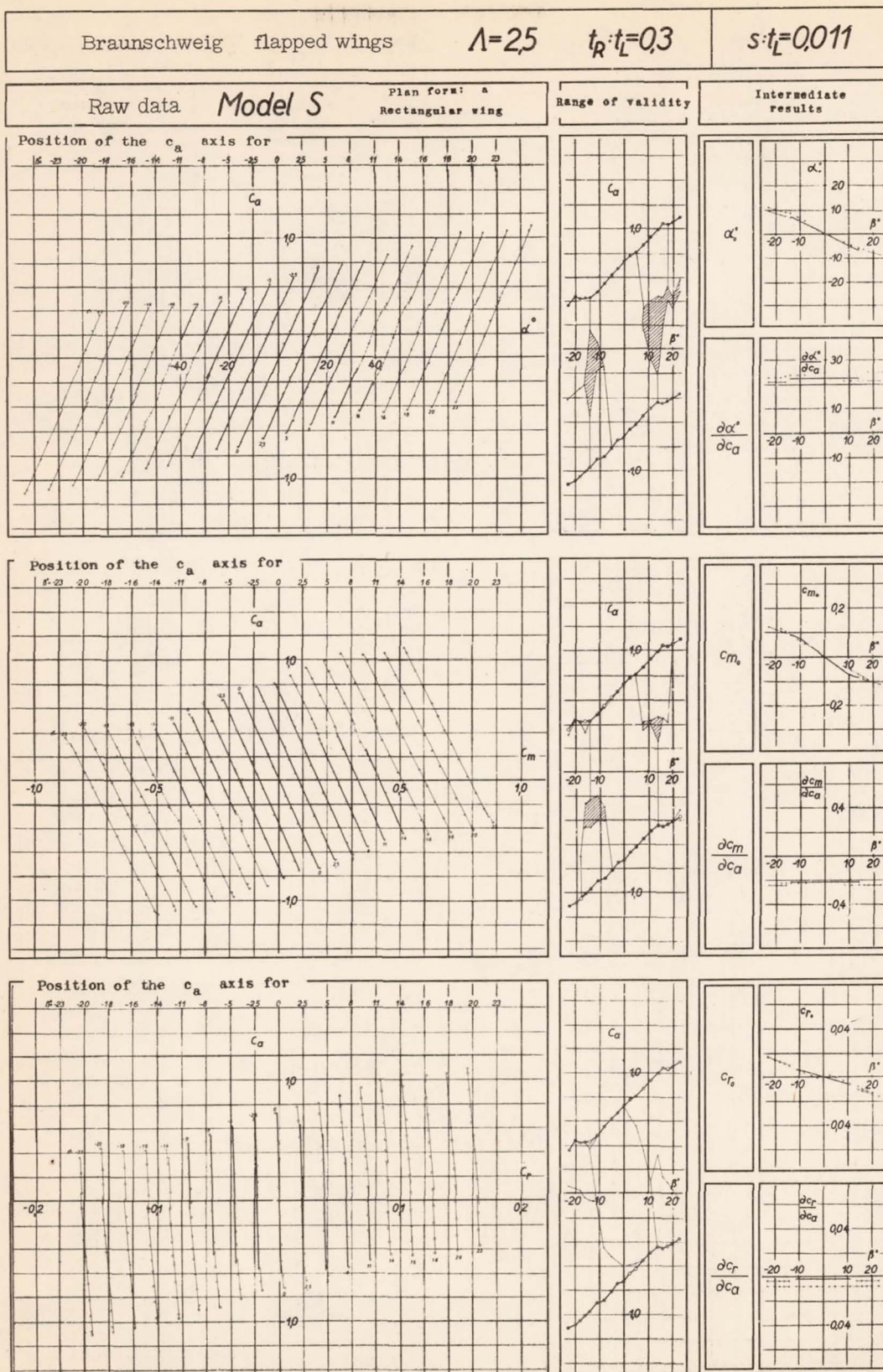
 $\Lambda=25$ $t_p:t_L=0.3$ $s:t_L=0.004$

Raw data

Model SPlan form: a
Rectangular wing

Range of validity

Intermediate
resultsPosition of the c_a axis forPosition of the c_a axis forPosition of the c_a axis for



Braunschweig flapped wings

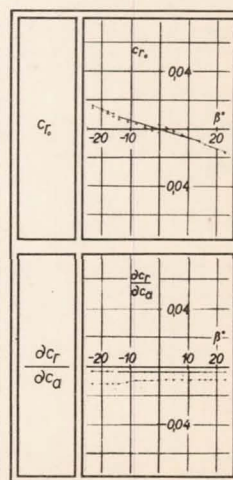
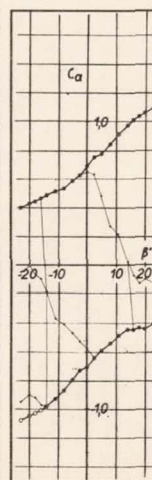
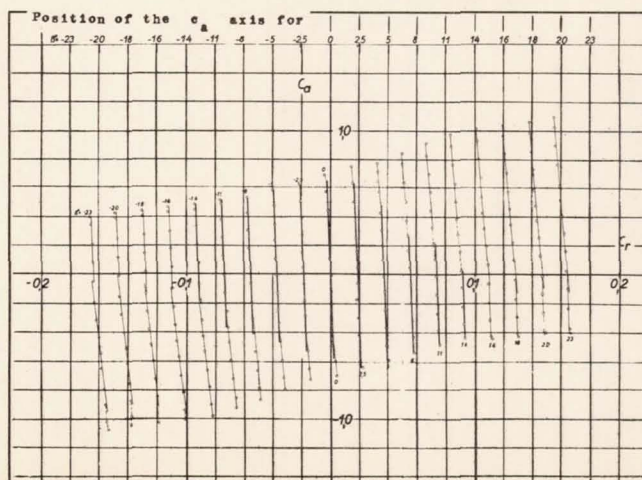
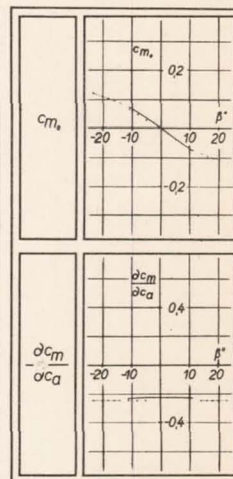
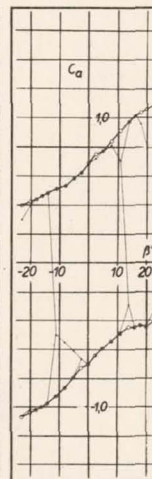
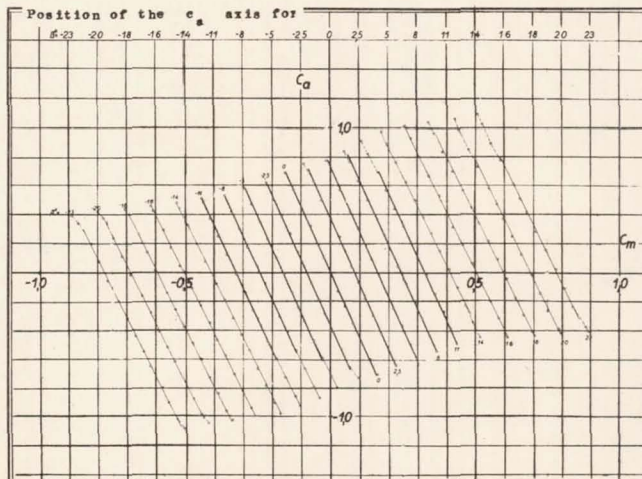
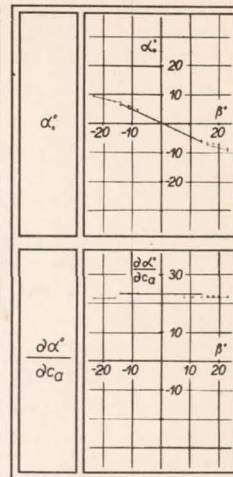
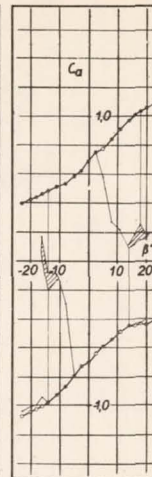
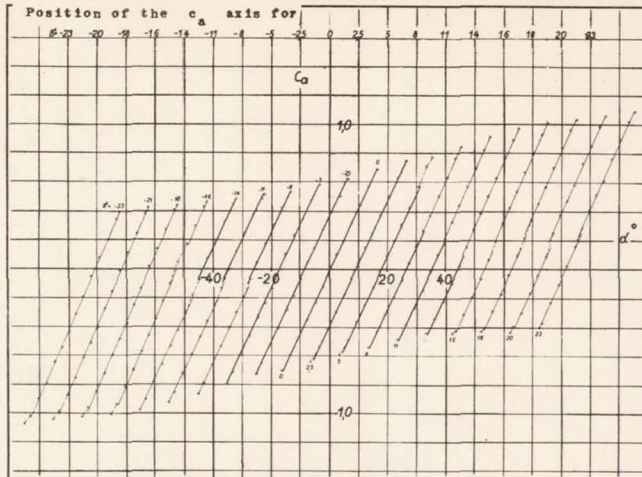
 $\Lambda=2,5$ $t_R:t_L=0,3$ $s:t_L=0,023$

Raw data

Model S

Plan form: a
Rectangular wing

Range of validity

Intermediate
results

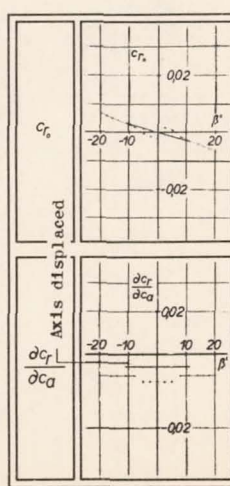
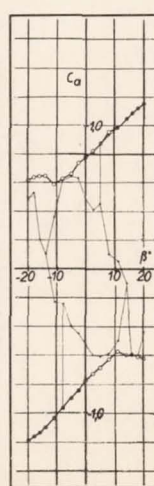
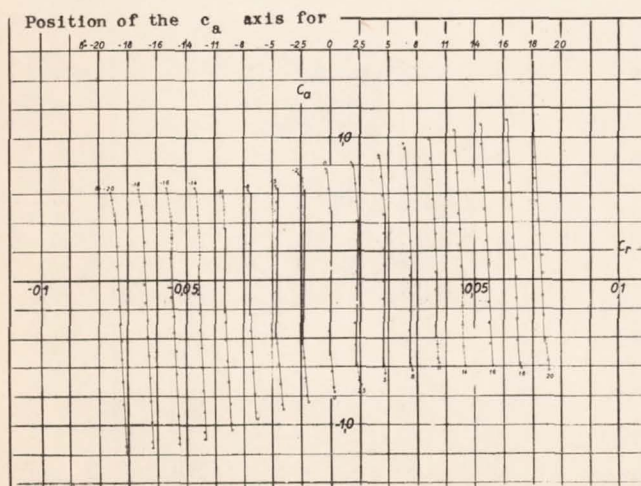
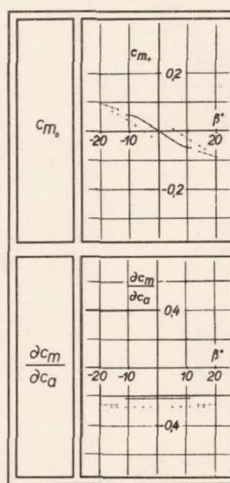
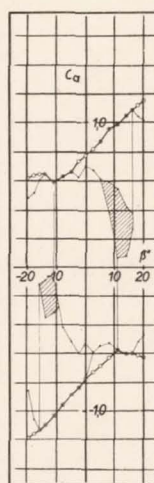
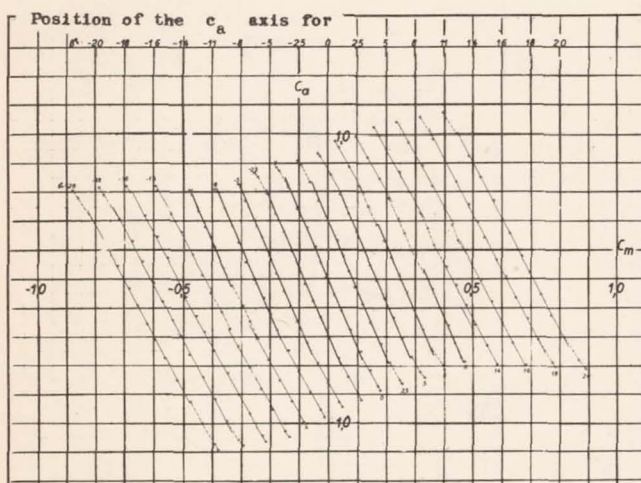
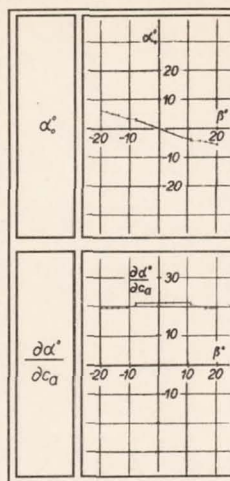
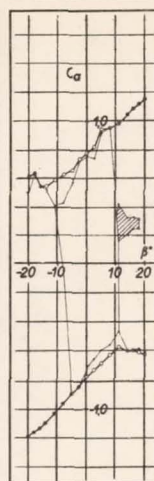
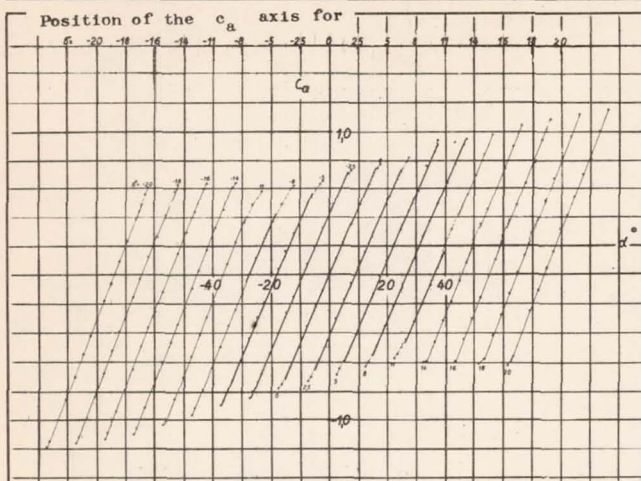
Braunschweig flapped wings

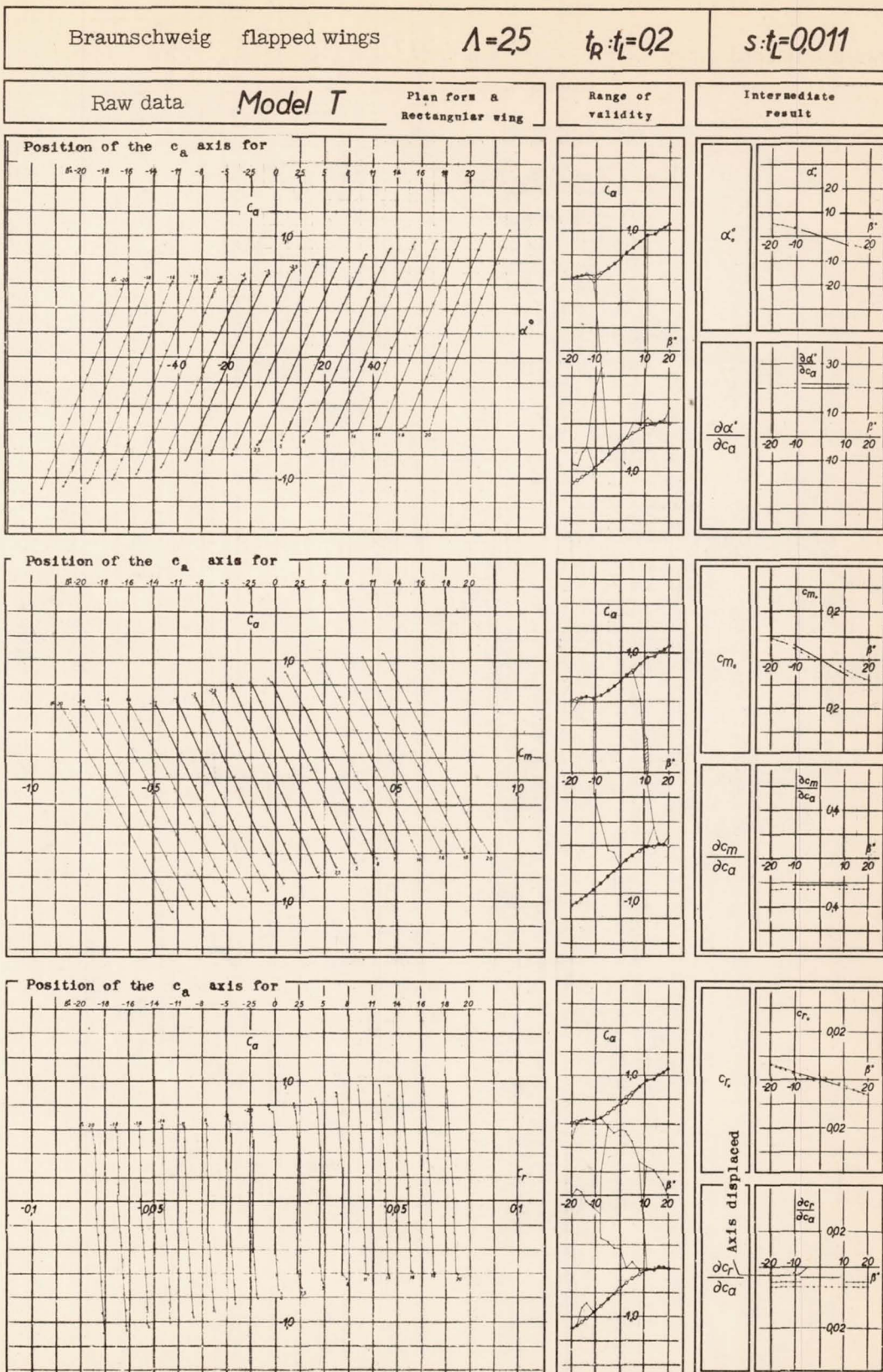
 $\Lambda=25$ $t_R:t_L=0.2$ $s:t=0.004$

Raw data

Model TPlan form a
Rectangular wing

Range of validity

Intermediate
results



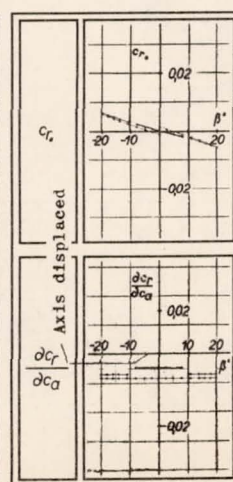
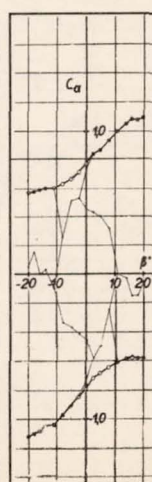
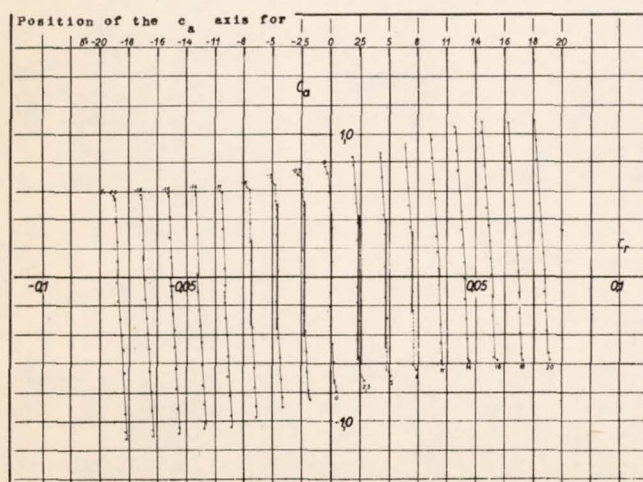
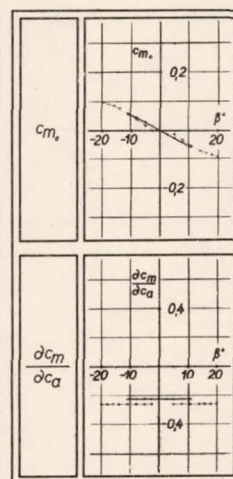
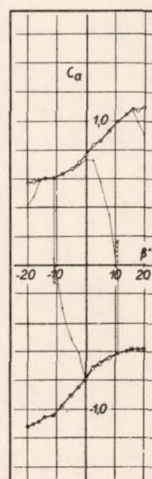
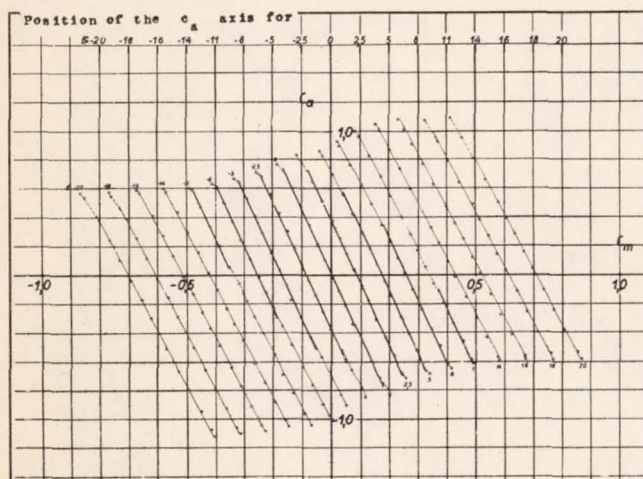
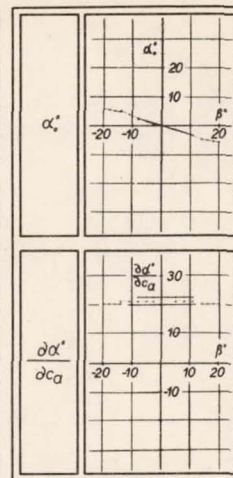
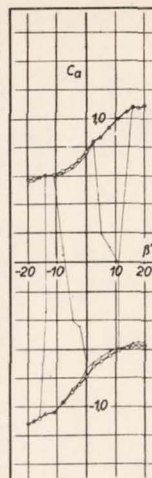
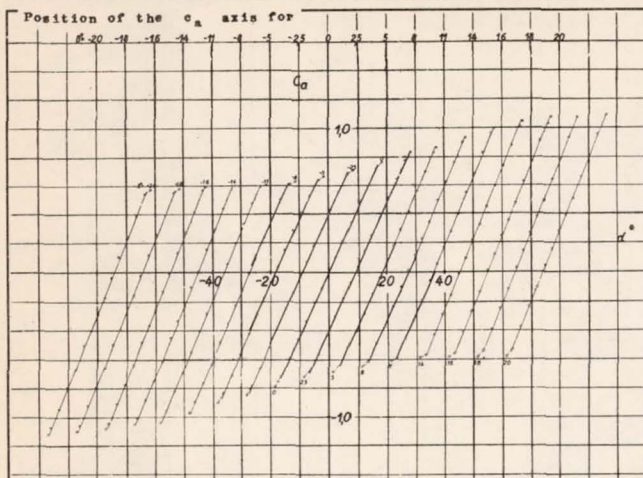
Braunschweig flapped wings

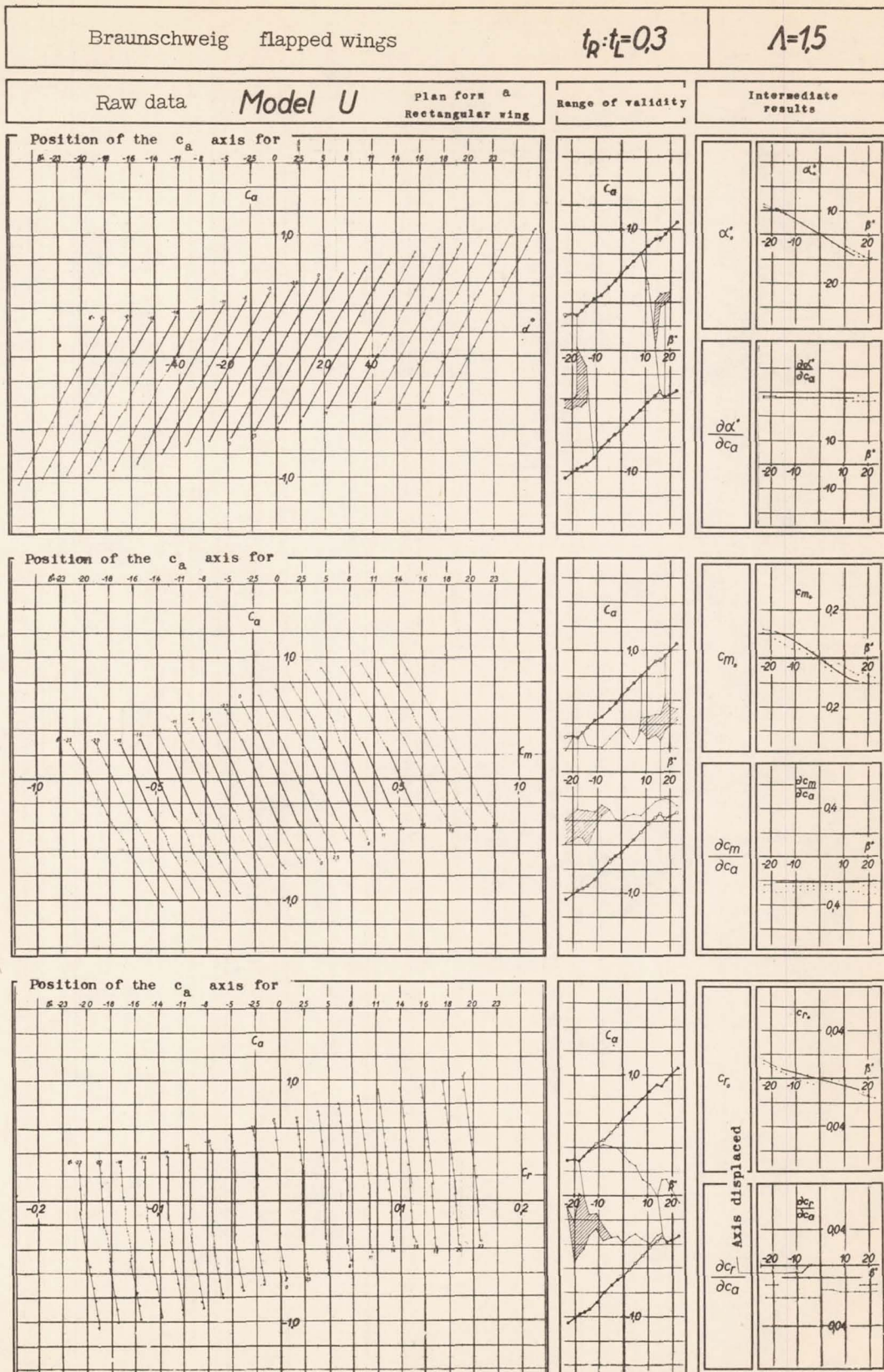
 $\Lambda=25$ $t_p:t_L=0.2$ $s:t_L=0.023$

Raw data

Model TPlan form a
Rectangular wing

Range of validity

Intermediate
results



Braunschweig flapped wings

$F_R:F_L=0.289 \quad t_R:t_L=0.3$

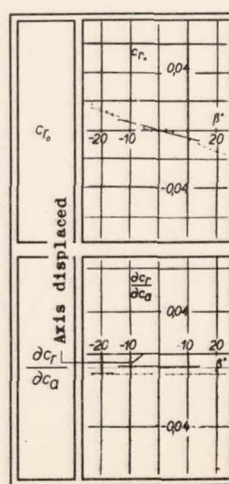
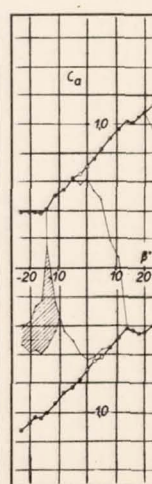
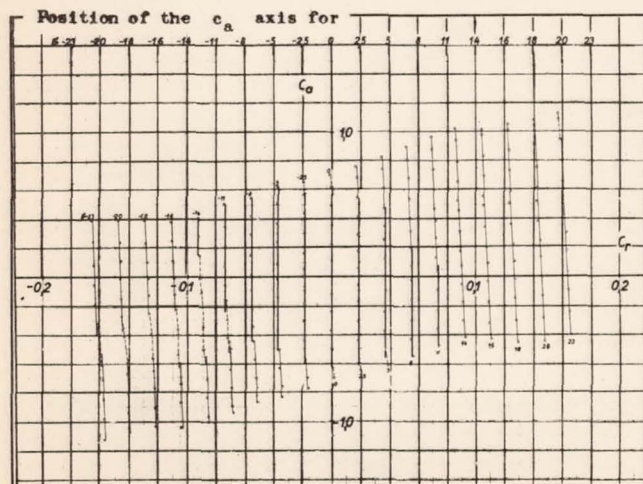
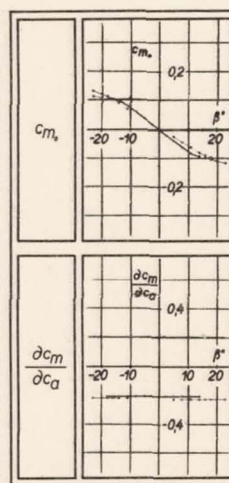
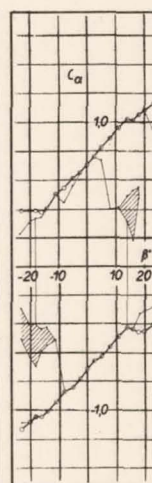
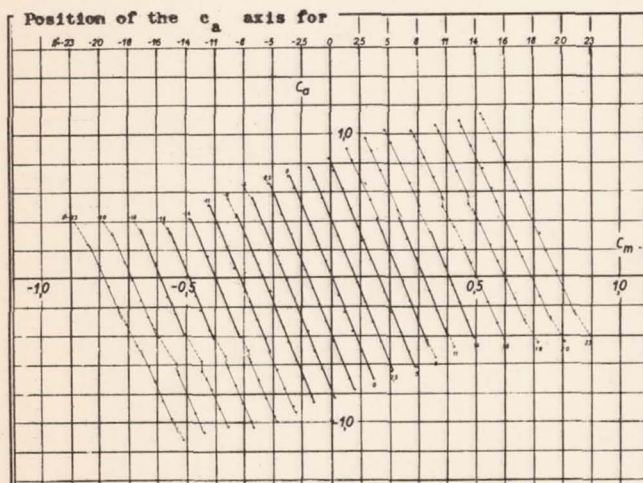
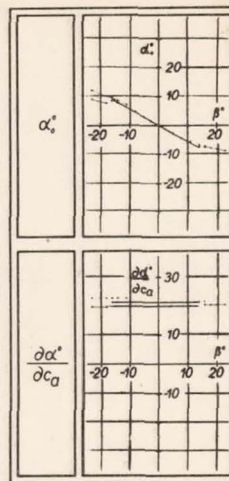
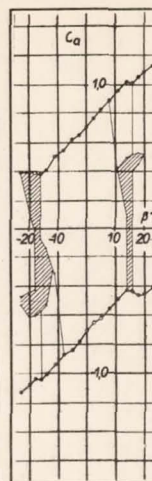
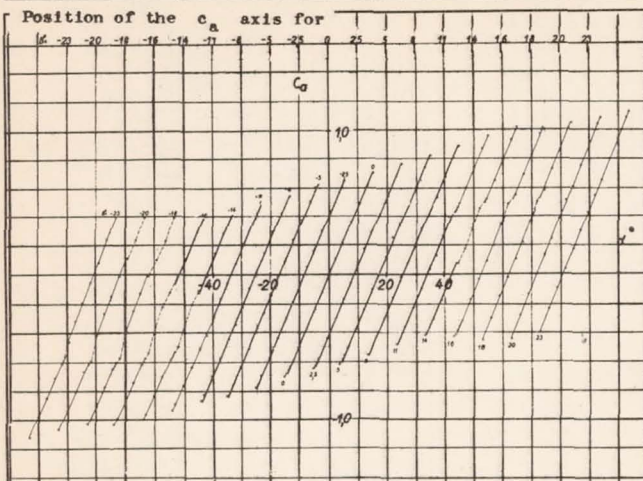
$b^2:F_L=2.99$

Raw data **Model V**

Plan form b

Range of validity

Intermediate results



Braunschweig flapped wings

$F_R:F_L=0.288 \quad t_R:t_L=0.3$

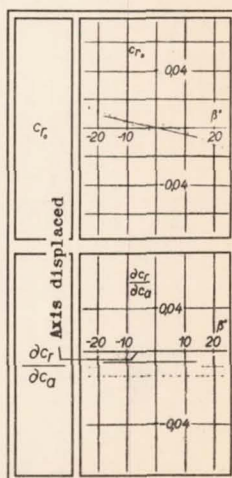
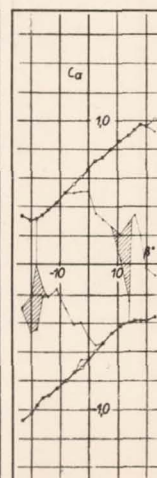
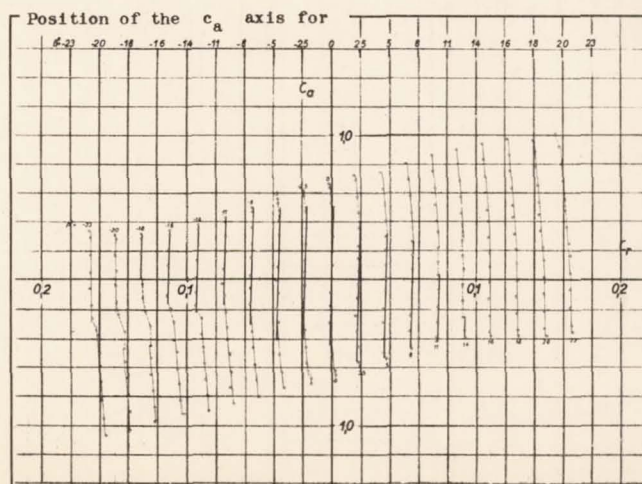
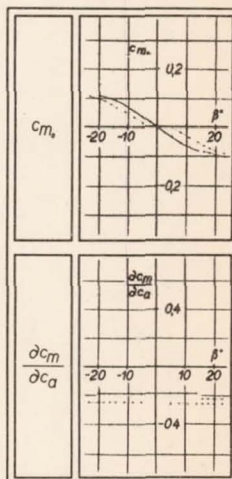
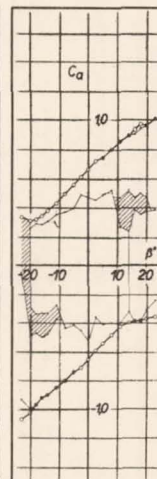
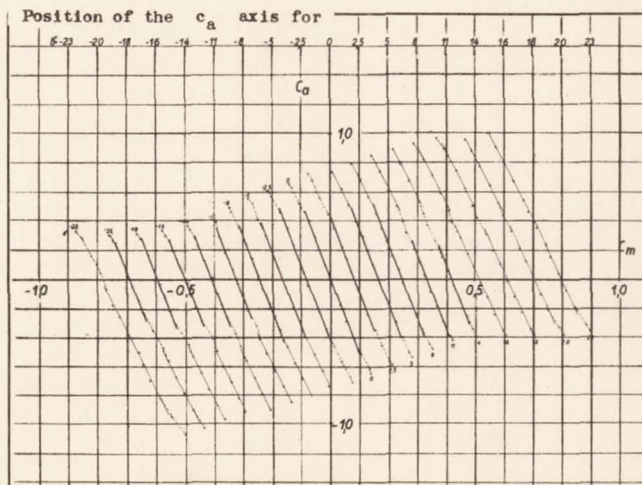
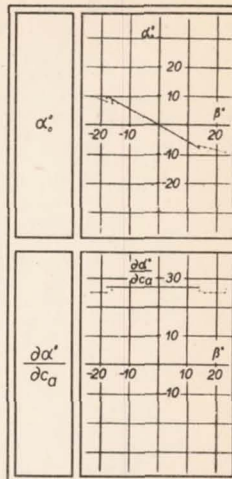
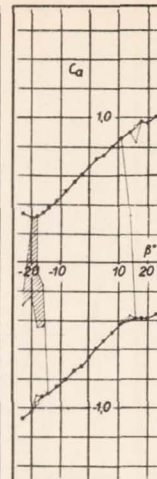
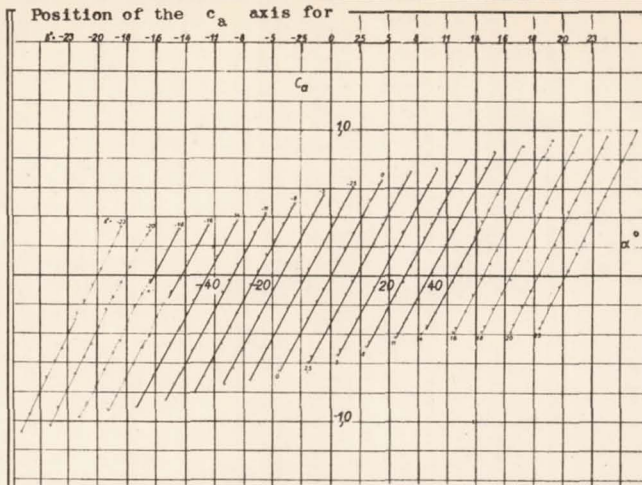
$b^2:F_L=199$

Raw data *Model W*

Plan form: b

Range of validity

Intermediate results

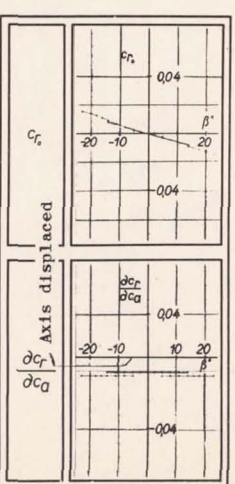
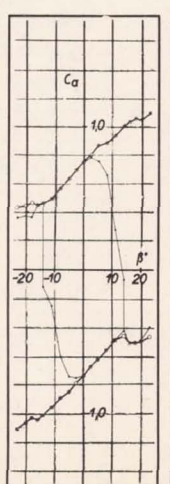
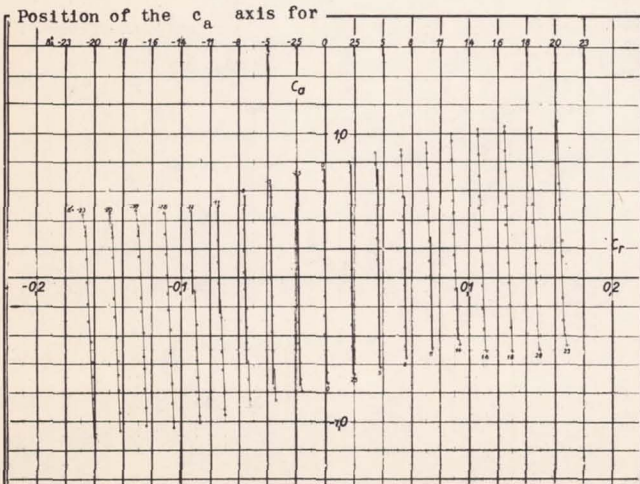
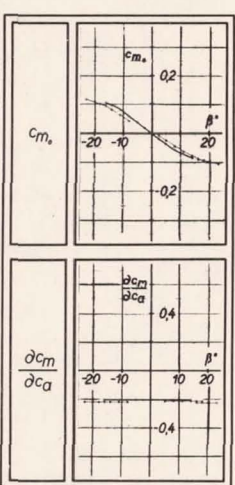
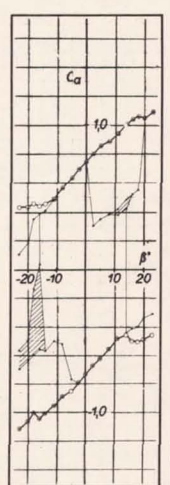
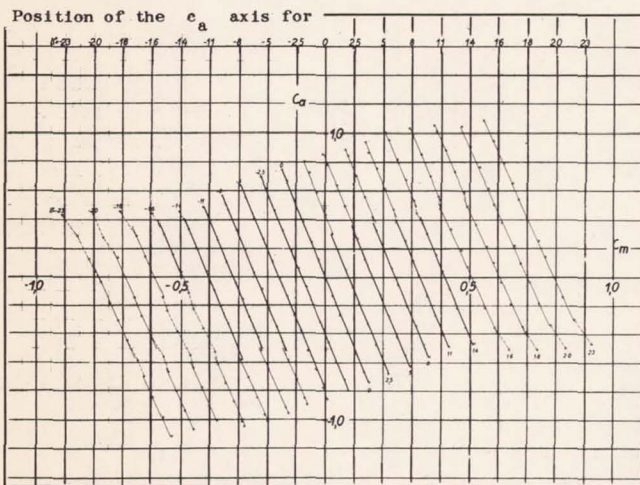
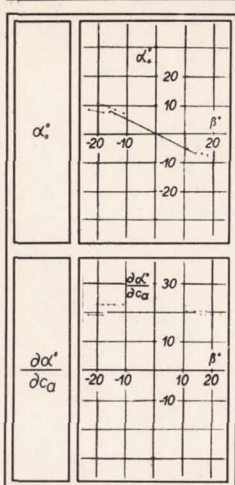
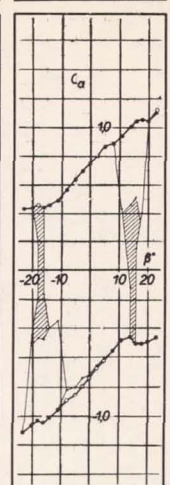
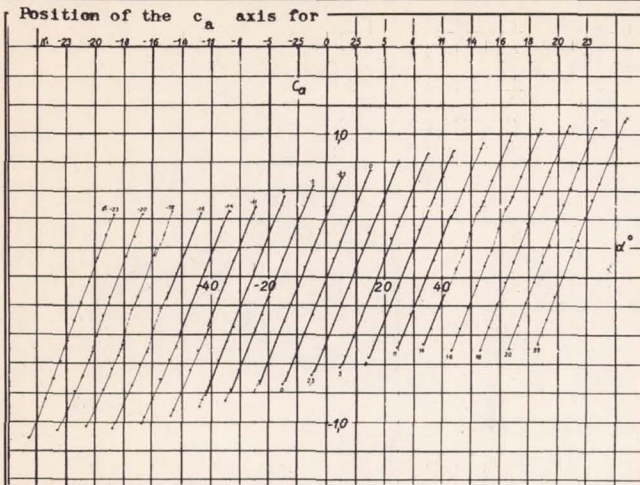


Braunschweig flapped wings $F_R:F_L=0.280$ $t_R:t_L=0.3$ $b^2:F_L=3.59$

Raw data **Model X** Plan form: c

Range of validity

Intermediate results



Braunschweig flapped wings

$$F_R:F_L=0,276 \quad t_R:t_L=0,3$$

$$b^2:F_L=2,67$$

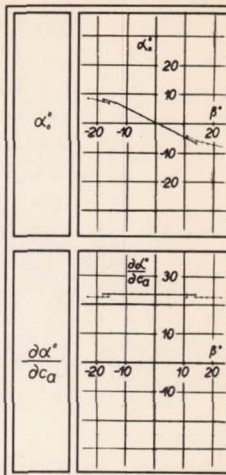
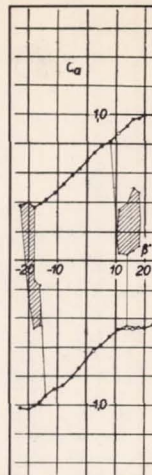
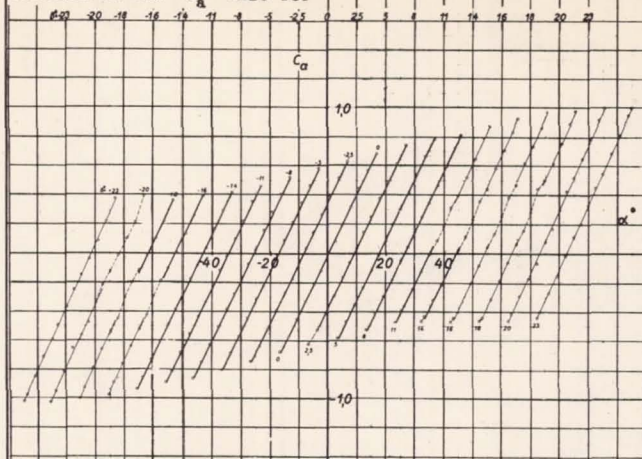
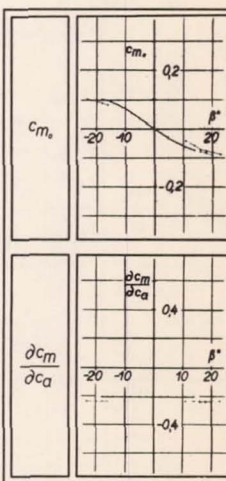
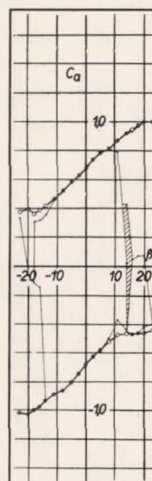
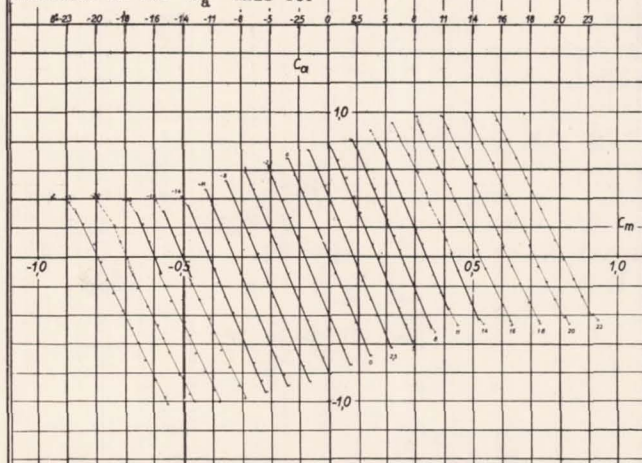
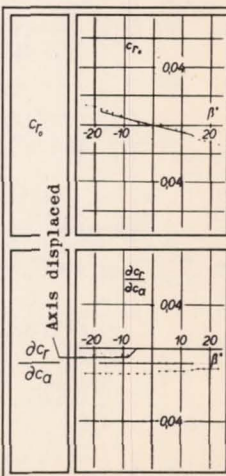
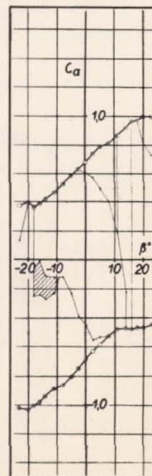
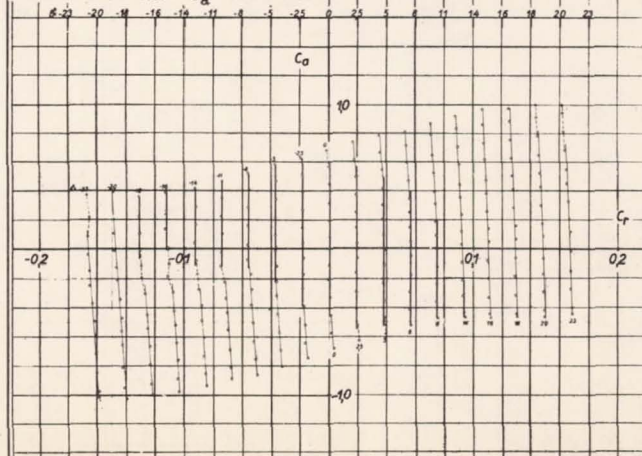
Raw data

Model Y

Plan form: c

Range of validity

Intermediate results

Position of the c_a axis forPosition of the c_a axis forPosition of the c_a axis for

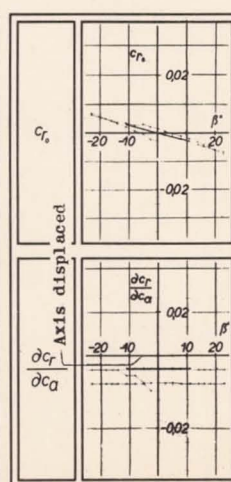
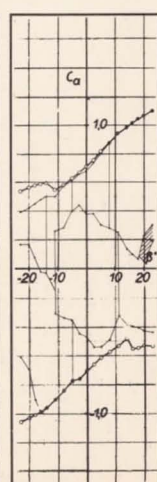
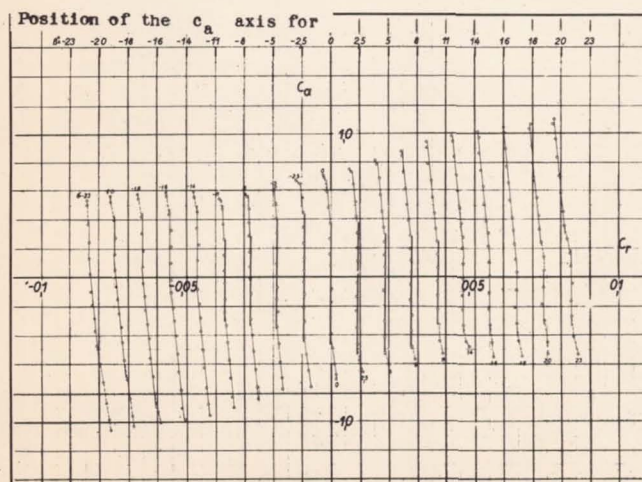
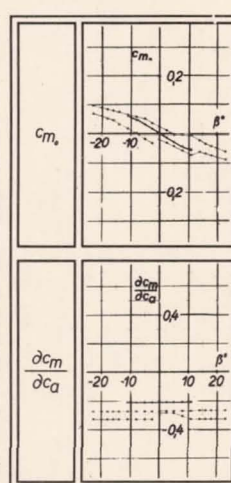
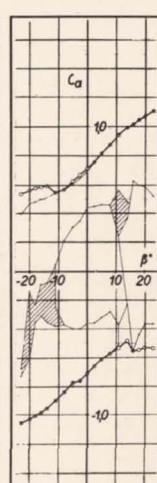
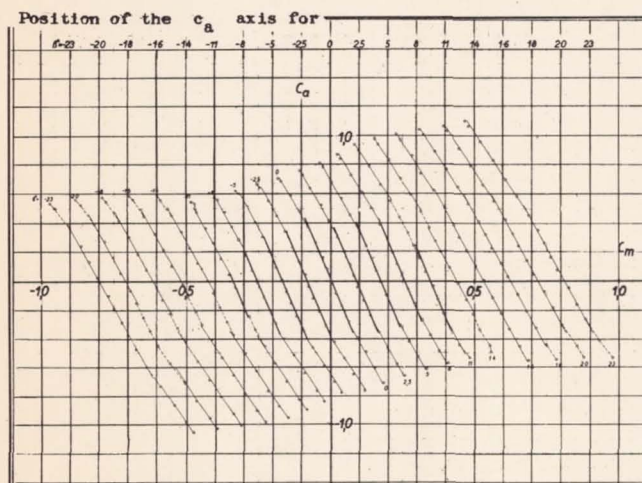
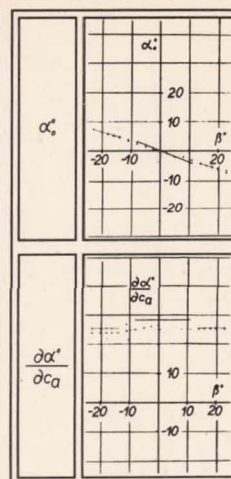
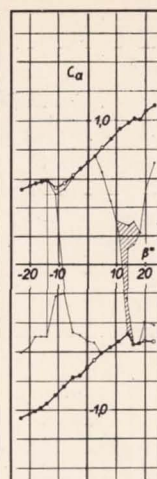
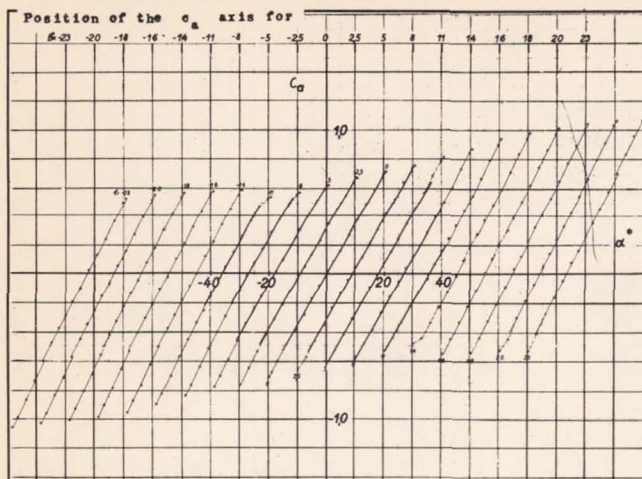
Braunschweig flapped wings

 $t_p:t_l=0.2$ $\Lambda=15$

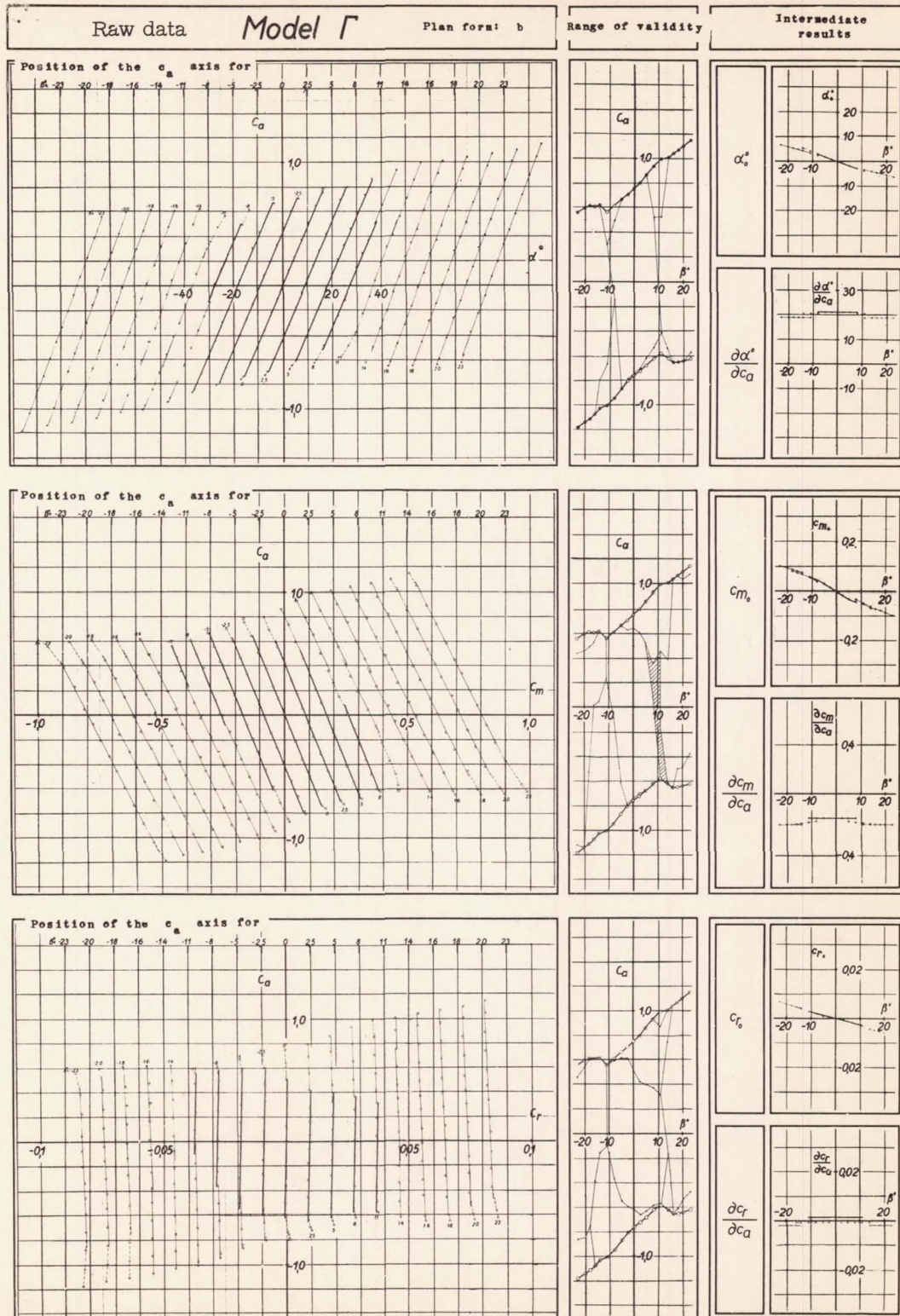
Raw data

Model ZPlan form a
Rectangular wing

Range of validity

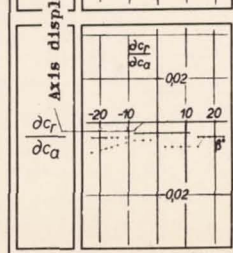
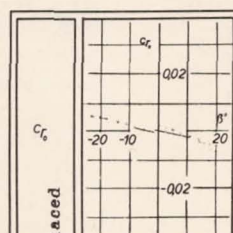
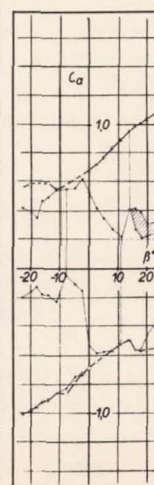
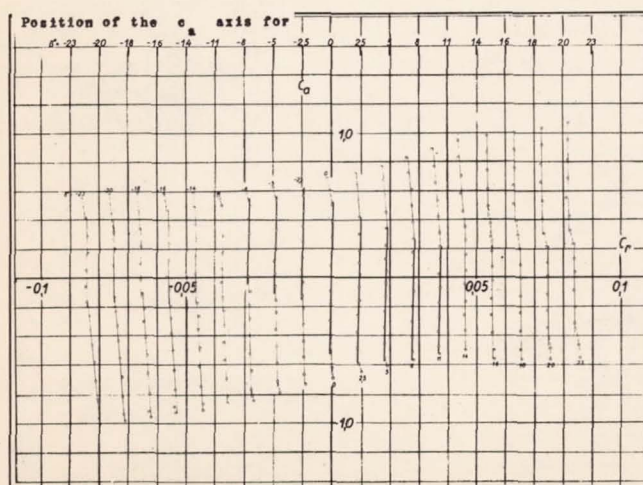
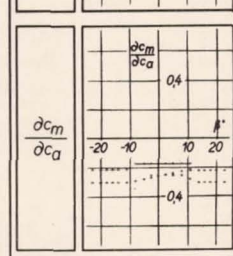
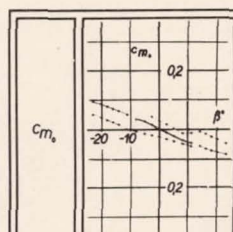
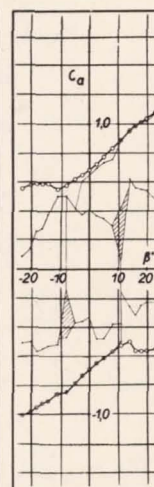
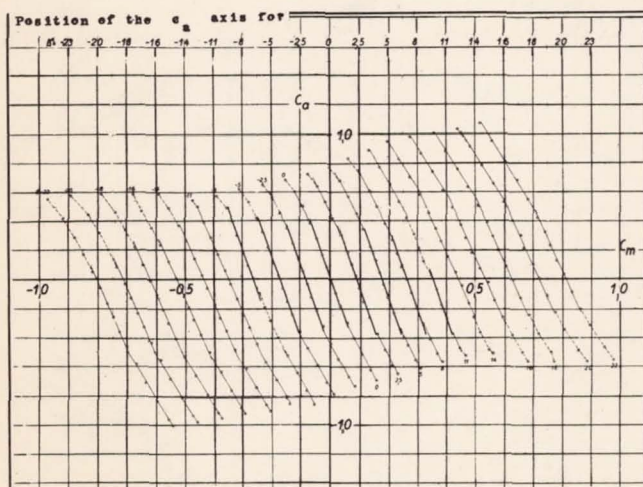
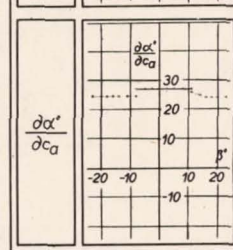
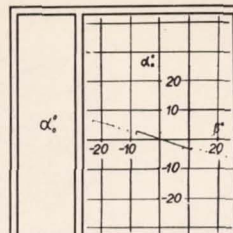
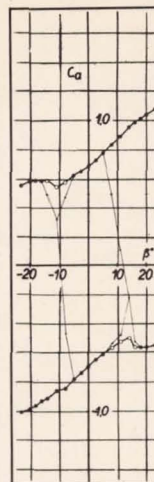
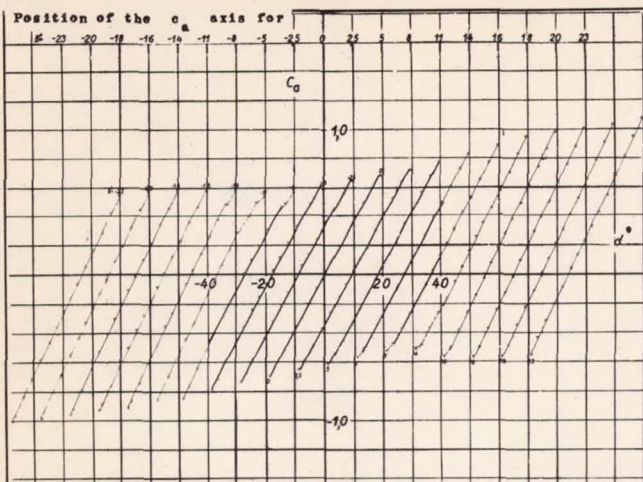
Intermediate
results

B Braunschweig flapped wings

 $F_R:F_L=0.192$ $t_R:t_L=0.2$ $b^2:F_L=2.99$ 

Braunschweig	flapped wings	$\bar{F}_R : \bar{F}_L = 0,191$	$t_R : t_L = 0,2$	$b^2 : \bar{F}_L = 199$
--------------	---------------	---------------------------------	-------------------	-------------------------

Raw data	Model Σ	Plan form : b	Range of validity	Intermediate results
----------	----------------	---------------	-------------------	----------------------



Braunschweig flapped wings

$F_R:F_L=0.184 \quad t_R:t_L=0.2$

$b^2:F_L=3.59$

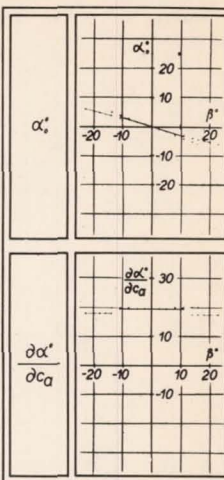
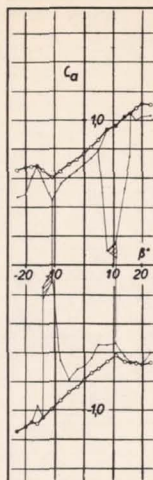
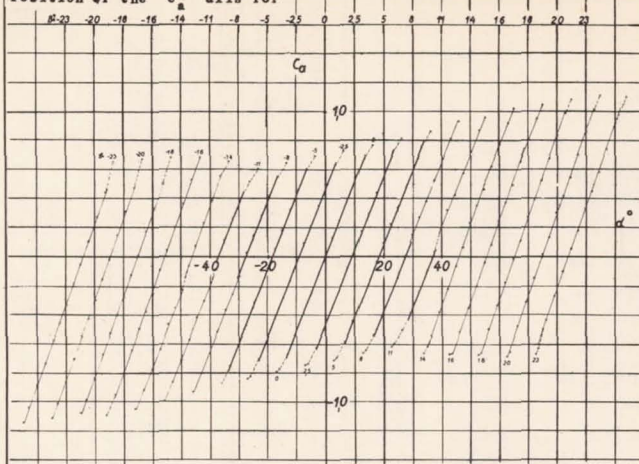
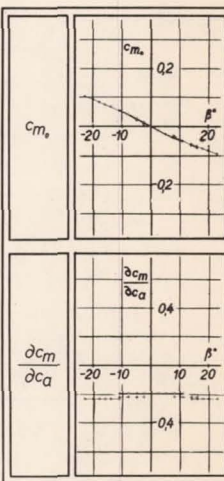
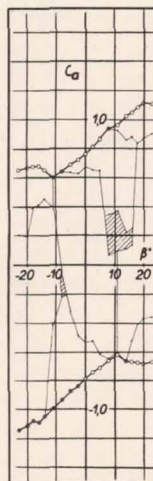
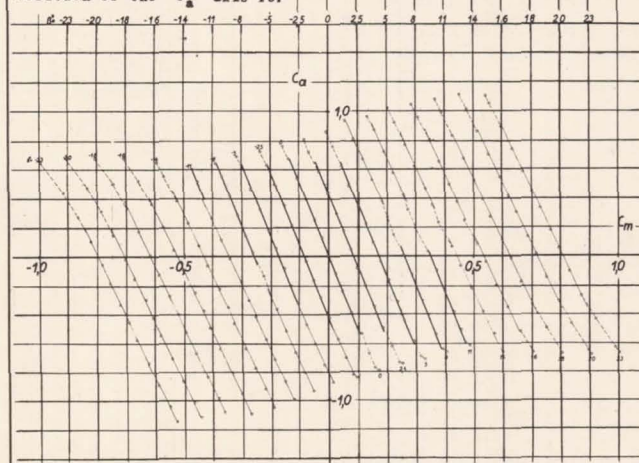
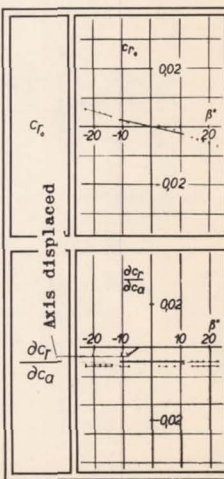
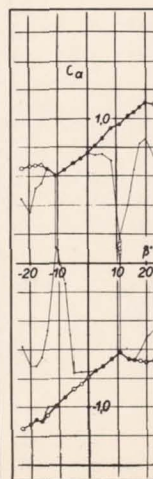
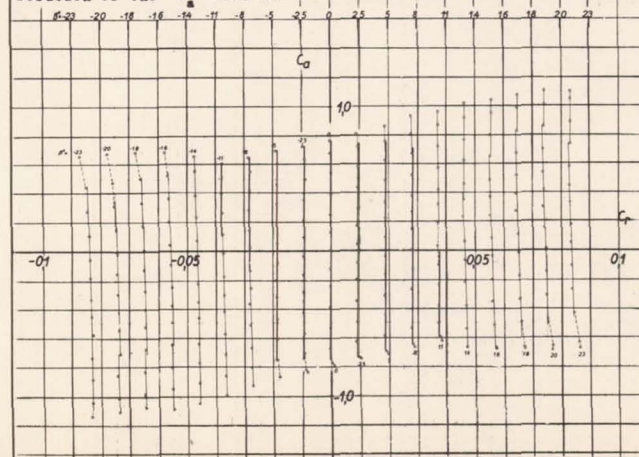
Raw data

Model ϕ

Plan form c

Range of validity

Intermediate results

Position of the e_a axis forPosition of the e_a axis forPosition of the e_a axis for

Braunschweig flapped wings

$$F_R:F_L=0.179 \quad t_R:t_L=0.2$$

$$b^2:F_L=2.67$$

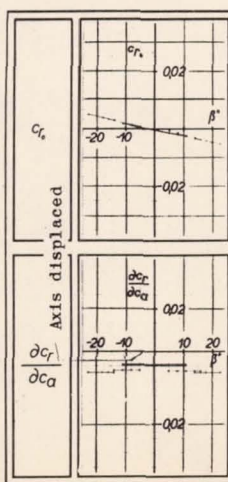
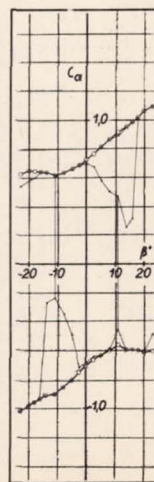
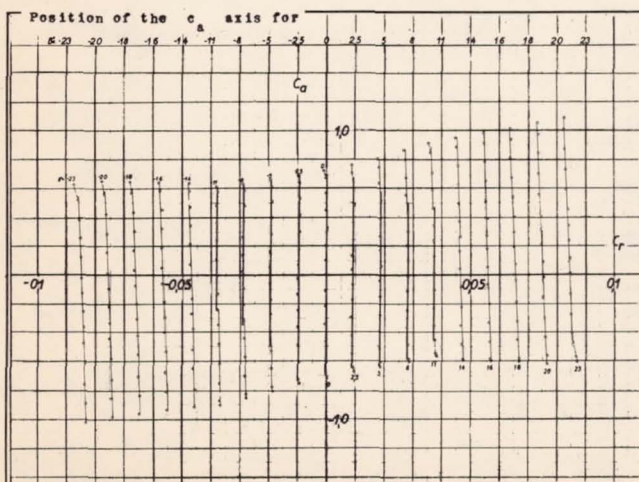
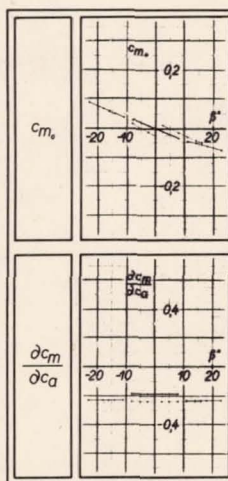
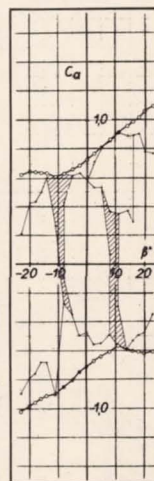
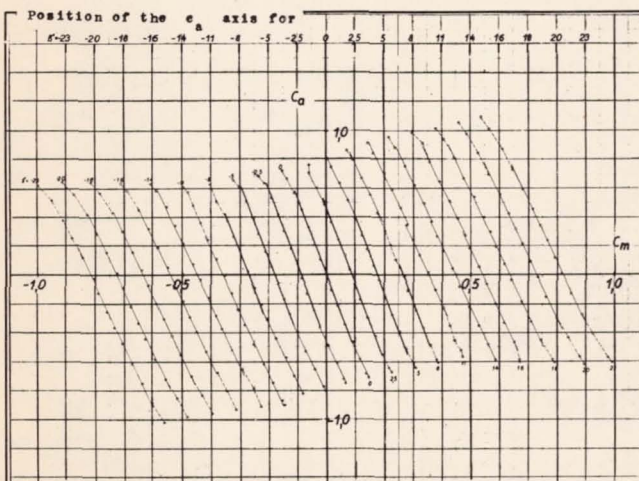
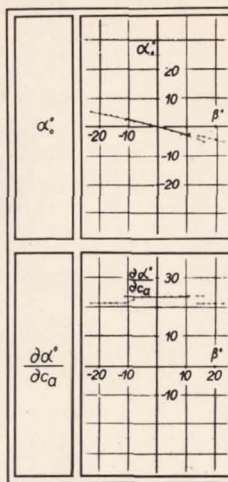
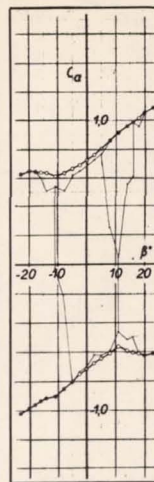
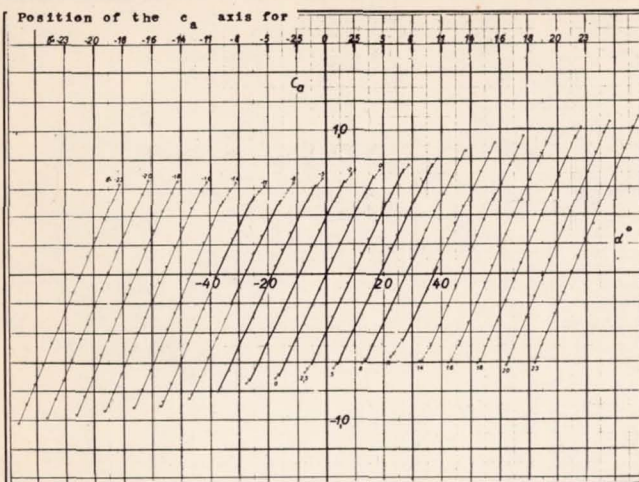
Raw data

Model Ω

Plan form : c

Range of validity

Intermediate results



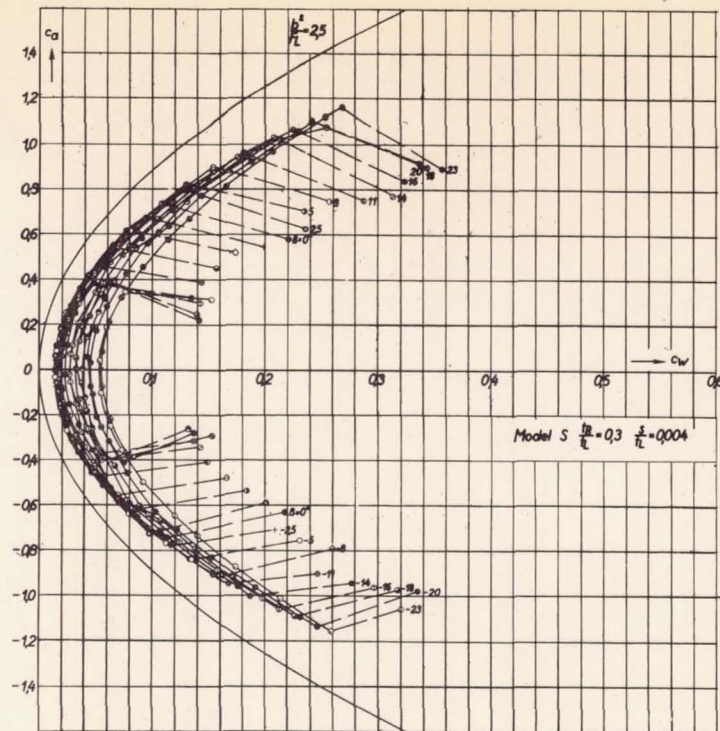


Figure 1.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form a (rectangular wing).

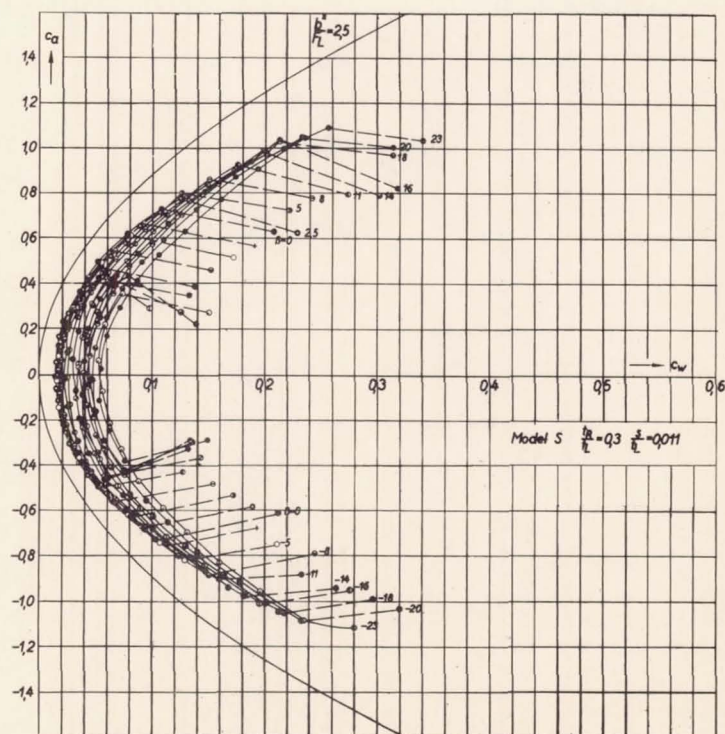


Figure 2.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form a (rectangular wing).

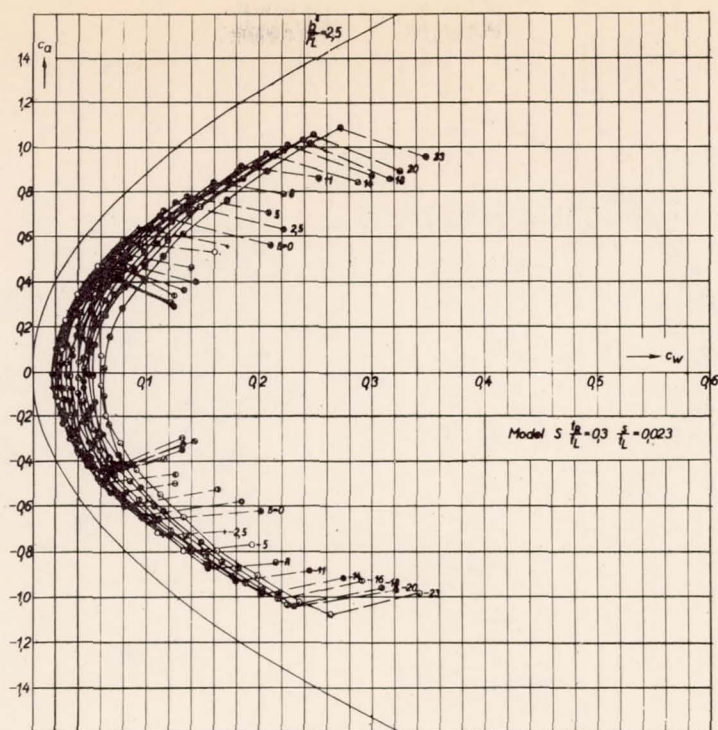


Figure 3.- Polars c_a $[c_w]$ for various control surface angles β .
Plan form a (rectangular wing).

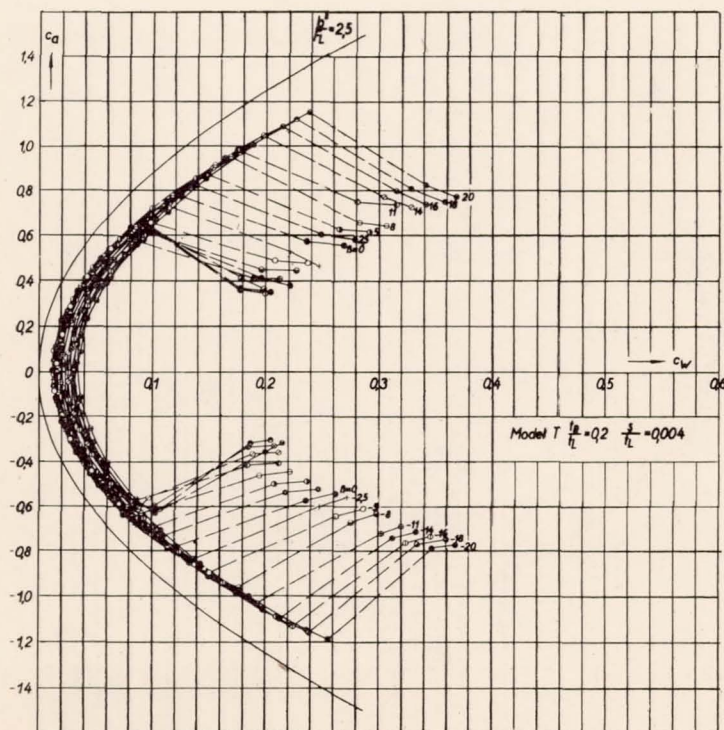


Figure 4.- Polars c_a $[c_w]$ for various control surface angles β .
Plan form a (rectangular wing).

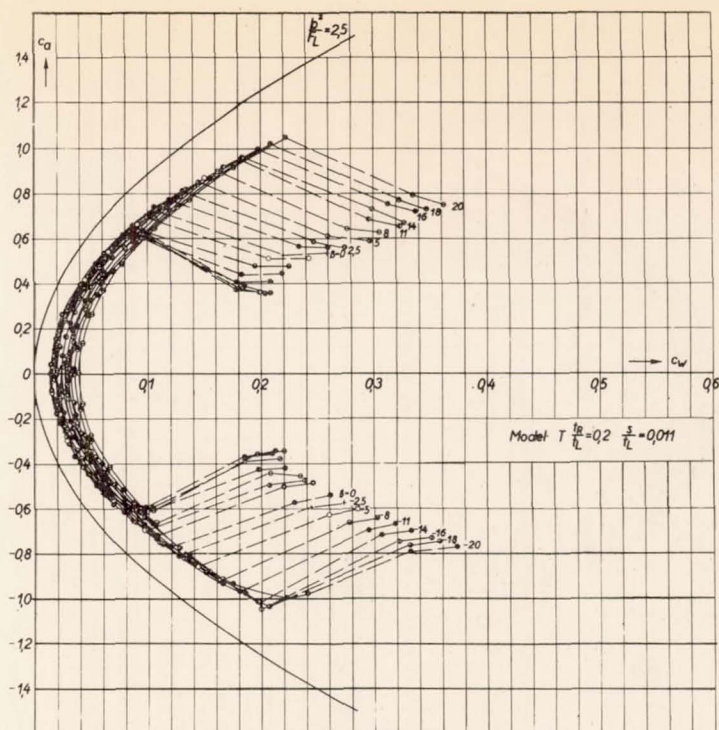


Figure 5.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form a (rectangular wing).

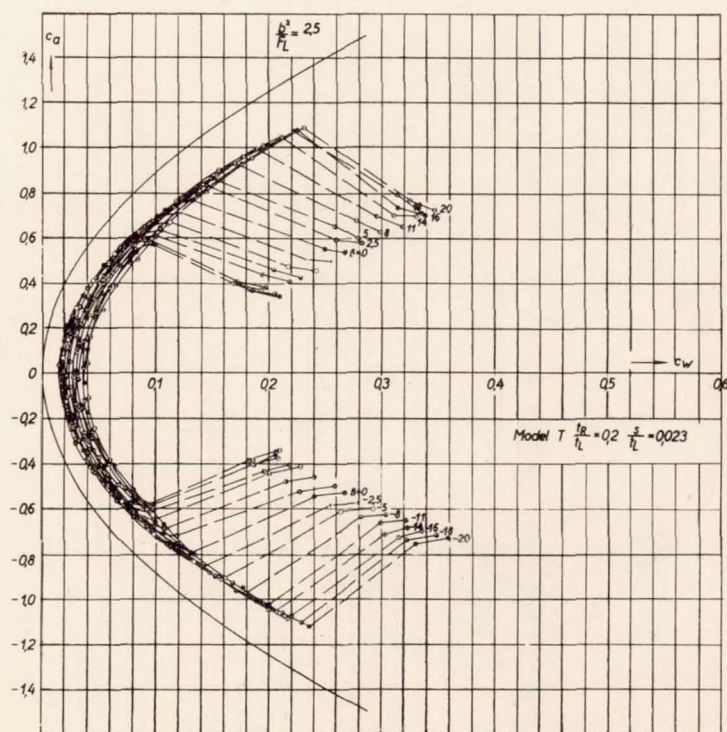


Figure 6.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form a (rectangular wing).

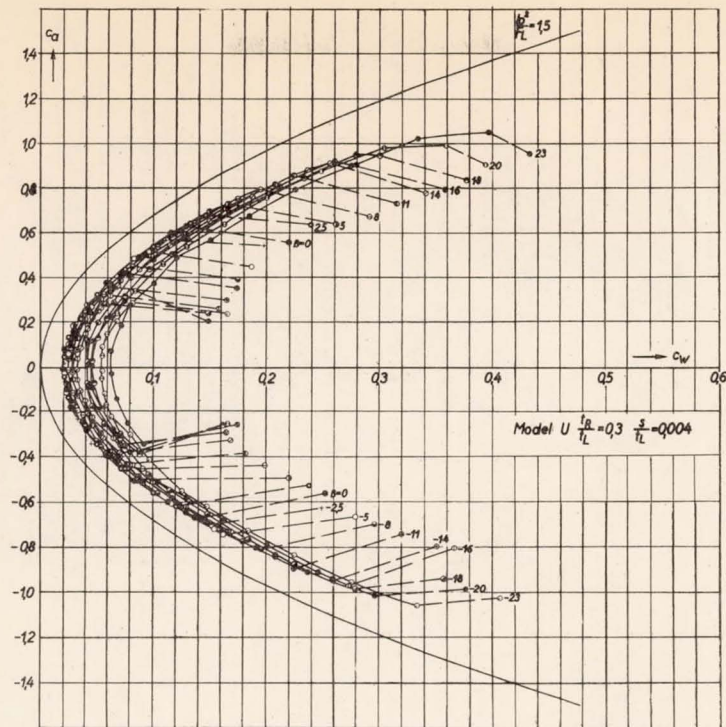


Figure 7.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form a (rectangular wing).

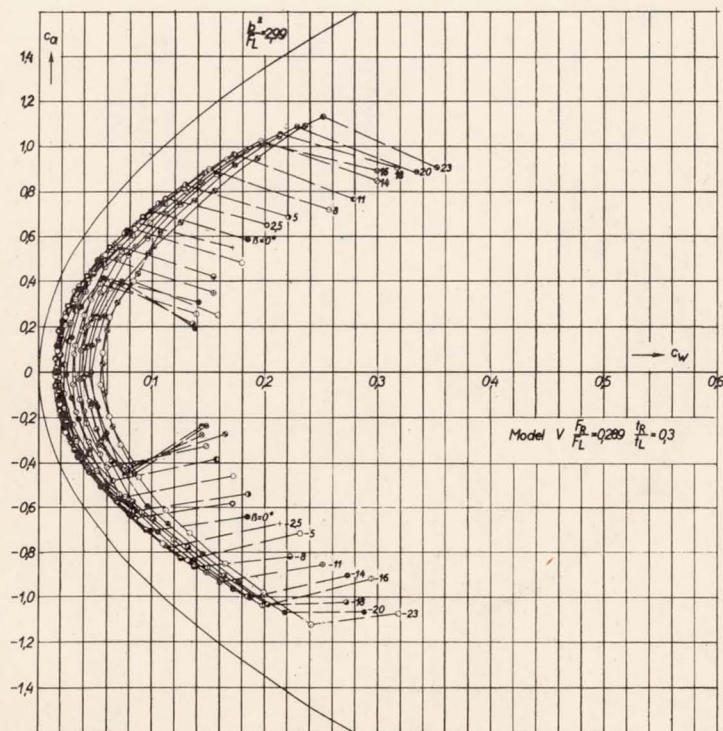


Figure 8.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form b.

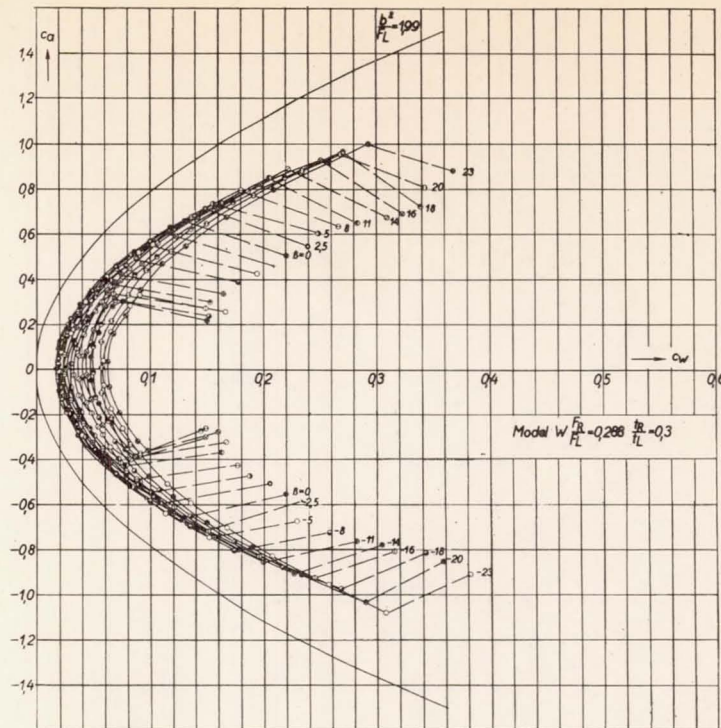


Figure 9.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form b.

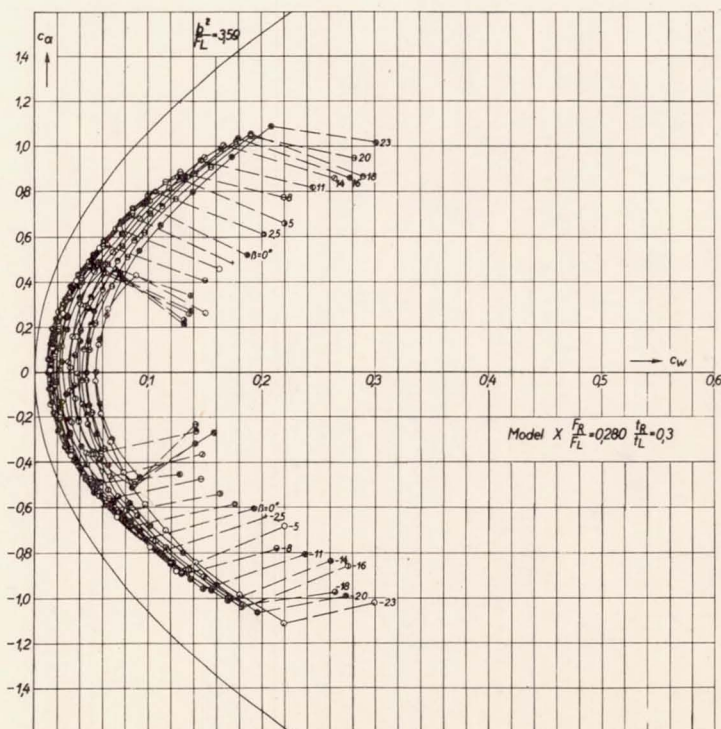


Figure 10.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form c.

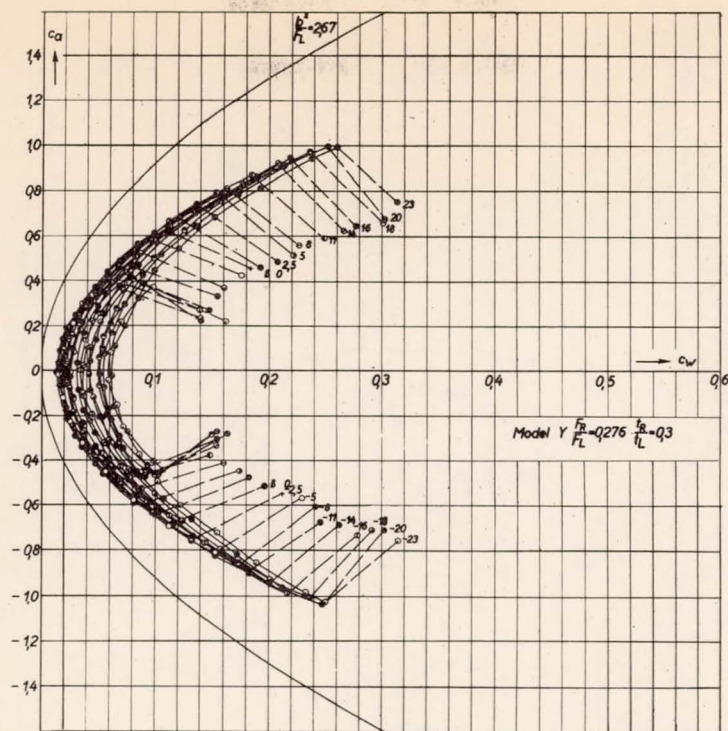


Figure 11.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form c.

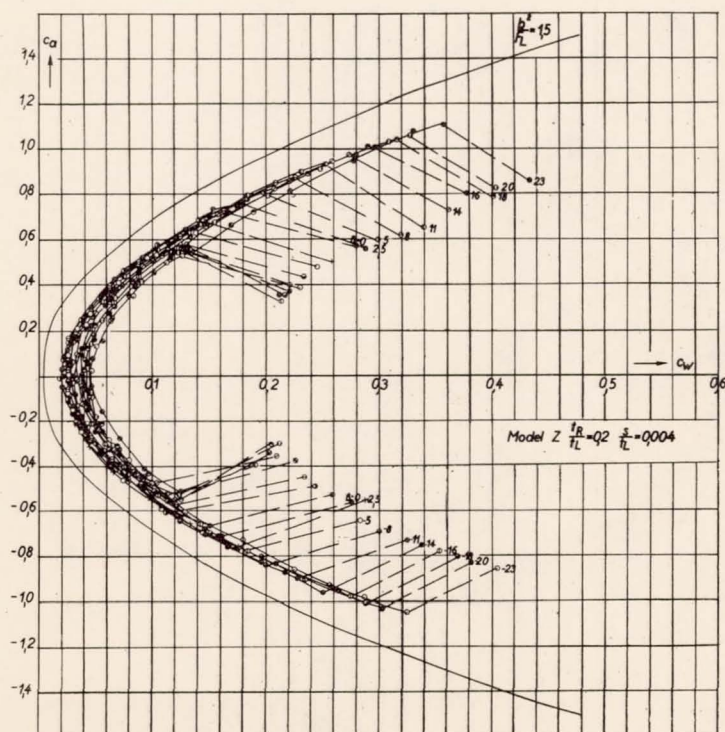


Figure 12.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form a (rectangular wing).

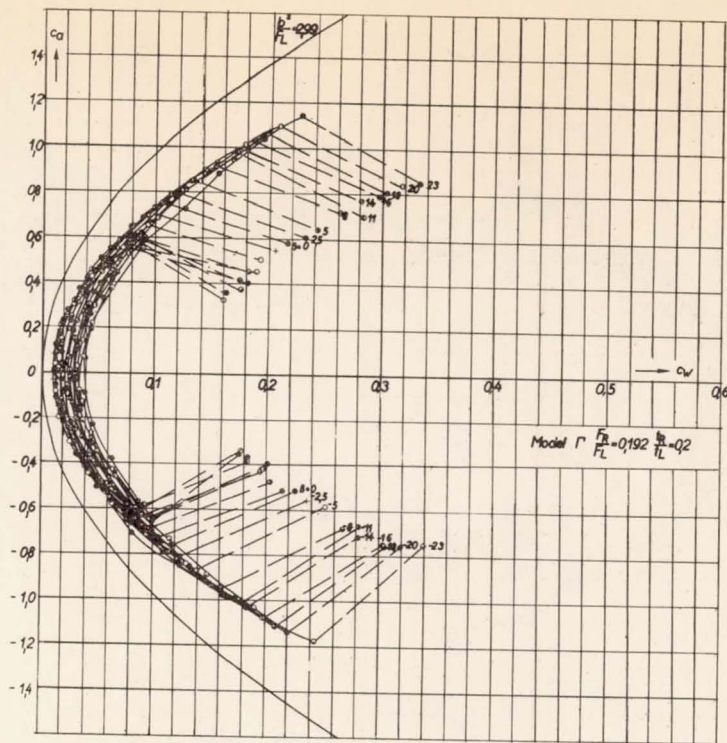


Figure 13.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form b.

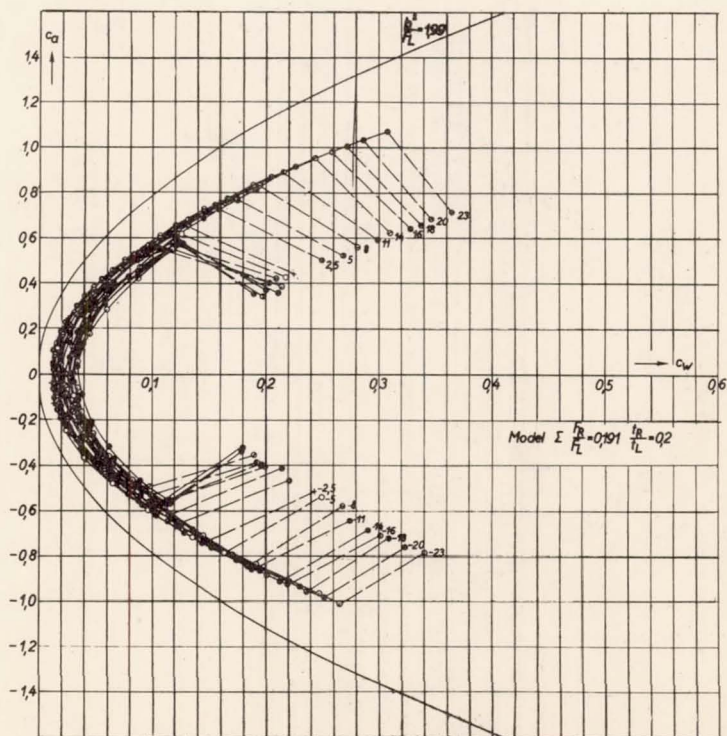


Figure 14.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form b.

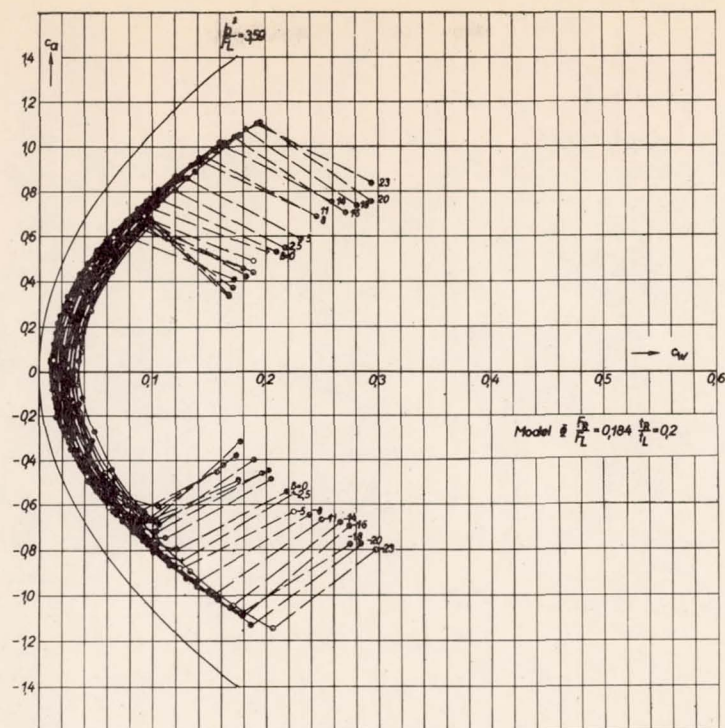


Figure 15.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form c.

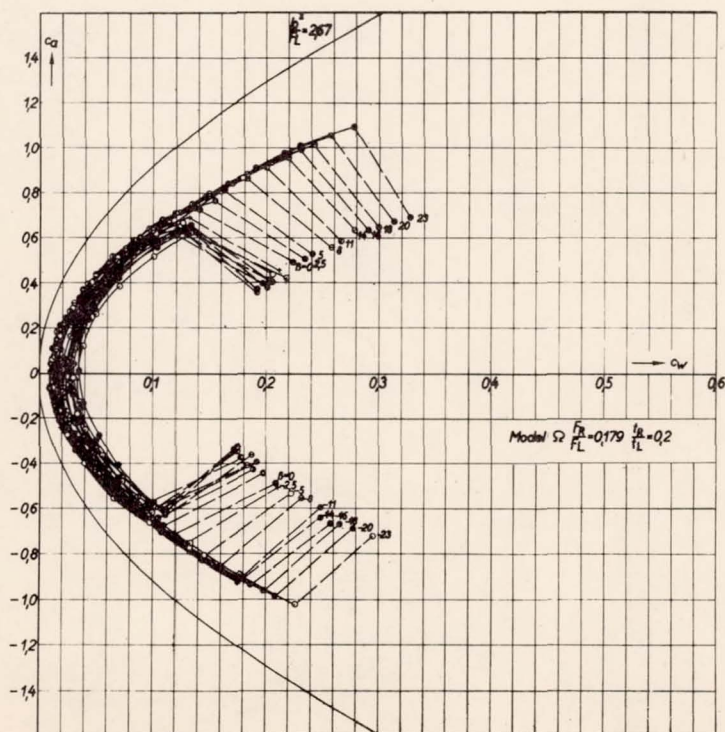


Figure 16.- Polars $c_a [c_w]$ for various control surface angles β .
Plan form c.

