TECHNICAL MEMORANDUMS

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No. 586

GÖTTINGEN SIX-COMPONENT SCALE MEASUREMENTS ON A JUNKERS A 35 AIRPLANE MODEL

By Hermann Blenk

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GÖTTINGEN SIX-COMPONENT SCALE MEASUREMENTS ON A JUNKERS A 35 AIRPLANE MODEL.*

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I. Introduction

This is a report on the measurements made by the Göttingen Aerodynamic Laboratory, at the request of the D.V.L. (Deutschen Versuchsanstalt für Luftfahrt). The data are given here in condensed form.

The suggestion for these measurements, as for the previously reported measurements on dihedral, sweepback, and warping (Luftfahrtforschung, Vol. III, 1929, p. 27), was prompted by the results of spinning experiments. For the theoretical spinning investigations there was a lack of data on lateral force, yawing, and rolling moment of airplanes (aside from English and American experiments). In order to be able to compare the model tests themselves and the theoretical investigations based upon them with the flight practice, we chose a model of the well-known Junkers A 35 - low-wing type monoplane (Fig. 1). The scale of the model was 0.085, without propeller. Further tests with running propeller are to be published later.

*"Gottinger Sechskomponentenmessungen an einem Modell des Flugzeugmusters Junkers A 35." From 1930 Yearbook of the D.V.L.

II. Definitions

The following symbols are used:

α geometrical angle of attack,

γ angle of yaw,

β_Q angle of aileron deflection,

β_H angle of elevator deflection,

β_S angle of rudder deflection,

F wing area,

b wing span,

t wing chord (in center),

q static pressure,

A lift, its coefficient $c_a = \frac{A}{qF}$,

W drag, its coefficient $c_w = \frac{W}{qF}$

S cross force, its coefficient $c_s = \frac{S}{qF}$

M_h pitching moment, its coefficient $c_{mh} = \frac{M_h}{qFt}$

M_s yawing moment, its coefficient $c_{ms} = \frac{M_s}{qFt}$

M_q rolling moment, its coefficient $c_{mq} = \frac{M_q}{qFt}$

Figure 2 shows the positive angles, forces and moments. The x-axis of the coordinate system forms the usual reference line of the wing. The angle of the air flow defines the x-axis so that the wind direction falls in the x-y plane. The angle formed by wind direction and x-axis is the angle of yaw γ. The z-axis is perpendicular to the other two axes. Axes x, y, and z form a clockwise system. The angle of the mean wing chord and a line parallel to the y-axis is the angle of attack α.

Lift A, drag W, and cross-wind force S are positive in the direction of positive x, y, and z axes. The moments M_h, M_s, and M_q, are positive when turning negatively in the direction of the clockwise system of axes. The positive directions of rotation of control movements β_H, β_S, and β_Q have been chosen so that positive control movements produce positive moments.

III. Synopsis of Measurements

We made three-component scale measurements:

1) On wing alone for angle of attack ranging from $\alpha = -20^\circ$ to $+90^\circ$; angle of yaw $\gamma = 0^\circ$; and ailèron angle $\beta_Q = 0^\circ$.

2) On whole airplane for $\alpha = -20^\circ$ to $+90^\circ$; angle of yaw $\gamma = 0$; and aileron angle $\beta_Q = \beta_H = \beta_S = 0^\circ$.

3) On whole airplane for $\alpha = -6^\circ$ to $+15^\circ$; angle of yaw $\gamma = 0^\circ$; aileron angle $\beta_Q = \beta_S = 0^\circ$; $\beta_H = \pm 10^\circ$.

4) On fuselage with tail surfaces minus landing gear, for $\alpha = -10^\circ$ to $+45^\circ$; angle of yaw $\gamma = 0^\circ$; rudder angle $\beta_S = 0^\circ$; $\beta_H = 0^\circ$; and $\pm 10^\circ$.

Six-component scale measurements were made on the whole airplane for $\gamma = -7^\circ$ to $+7^\circ$, and for each four and two angles of attack, respectively; the combinations of the control angles were:

$\beta_H = -5^\circ$	$\beta_S = 0^\circ$	$\beta_Q = 0^\circ$
-5°	0°	5°
-5°	0°	15°
-5°	5°	0°
-5°	5°	5°
-5°	5°	15°
-5°	10°	0°
-5°	10°	5°
-5°	10°	15°

IV. Results of Tests

Figures 3 and 4 show the polars and the pitching moment curve for the A 35 wing at $\alpha = -20^\circ$ to $+90^\circ$ and $\gamma = 0^\circ$. The curves corresponding to the whole airplane are shown in Figures 4 and 5 with γ, β_Q, β_H, and $\beta_S = 0^\circ$. It should be noted that the curves in Figures 3 and 5 are made at a different scale from those of Figure 4. Figure 5 also contains the polars and the pitching moment curves of the whole airplane with elevator settings of -10° and $+10^\circ$, while Figure 6 gives the data for the fuselage with tail surfaces without landing gear. The c_a, c_w and c_{mh} coefficients here are plotted against the wing area and wing chord, while the angle of attack is plotted against the propeller axis. The incidence of the mean chord to the propeller axis is 3°. The longitudinal moment (for fuselage with tail, Fig. 6) is measured about the lateral axis through the intersection of thrust axis and nose of fuselage. By comparing the respective measurements on the whole airplane, on the wing alone, and on the fuselage with tail surfaces, we can draw conclusions as to the amount of downwash at the tail surface.

For known reasons the six-component scale measurements (Figs. 7-15) had to be confined to angles of yaw $\gamma = -7^{\circ}$ to $+7^{\circ}$. It was found that lift, drag and longitudinal (pitching) moment (values from usual three-component scale measurements) are independent within the measured range of γ, β_Q, and β_S. For this reason we can omit in the following, the data on c_a, c_w and c_{mh}; they can, moreover, be quite accurately determined from Figures 4 and 5. This enables us to present the six-component scale measurements more simplified.

In six-component scale measurement, the points of measurement are spread out considerably, so in order to make it as expressive as possible, we omitted the compensation curves and merely connected the points of measurement by straight lines.

Figures 7, 8, and 9 show the coefficients of the cross-wind force c_s of the whole airplane plotted against the angle of yaw γ (Fig. 7: $\beta_H = -5^{\circ}$, and $\beta_Q = 0^{\circ}$; Fig. 8: $\beta_Q = 5^{\circ}$; Fig. 9: $\beta_Q = 15^{\circ}$). As γ increases, S decreases. Hence the value $\frac{\partial c_s}{\partial \gamma}$ is negative and practically unaffected by β_Q and β_S. Even the effect of angle α on $\frac{\partial c_s}{\partial \gamma}$ is generally small. A rudder movement produces a positive cross-wind force, whose value, within the measured range of all other angles (α, γ, β_Q) is practically unaffected. This is seen in the graphs, where the corresponding curves for different cross-wind angles run parallel at the same distance (measured in the ordinate axis). Comparison with the cross-wind forces measured on the wing alone, which, within the range in question, amounts to $c_s = 0.01$, show that by far the greater part of the cross-wind force was contributed by tail surfaces and fuselage, as we expected.

Figures 10 to 12 give the coefficients of yawing moment c_{ms} plotted against γ (Fig. 10: $\beta_H = -5^\circ$, and $\beta_Q = 0^\circ$; Fig. 11: $\beta_Q = 5^\circ$; Fig. 12: $\beta_Q = 15^\circ$). The moment decreases as γ increases. The value $\partial c_{ms}/\partial \gamma$ likewise is negative and practically unaffected by β_Q and β_S. On the other hand, the effect of α on $\partial c_{ms}/\partial \gamma$ is at times quite enormous, which agrees with the previously mentioned measurements on individual wings. A rudder movement produces a positive lateral moment, but an aileron movement produces a negative lateral moment. Both controls work against each other in this respect. At $\alpha = 14.5^\circ$, for example, the effect of a $\beta_S = 10^\circ$ rudder deflection on the lateral moment is practically counterbalanced by a $\beta_Q = 5^\circ$ aileron movement. The effect of an aileron movement on the yawing moment increases with the angle of attack, in conformity with the theory of Betz and Petersohn.* A numerical comparison with the repeatedly cited measurements on individual wings shows the order of magnitude of the yawing moment to be about the same in both cases. So we conclude that a large portion of the yawing moment is contributed by the wings (in contrast with the cross-wind force).

Figures 13 to 15 contain the coefficients of the rolling moment of the whole airplane plotted against angle γ (Fig. 13: $\beta_H = -5^\circ$, and $\beta_S = 0^\circ$; Fig. 14: $\beta_S = 5^\circ$; Fig. 15: $\beta_S = 10^\circ$). While the measurements for constant aileron deflection β_Q were combined in Figures 7 to 12, each diagram here shows the measurements for constant β_S. The rolling moment increases as γ increases. But the increase in $\partial c_{mq}/\partial\gamma$ is almost negligible at small or average α, and increases to a multiple only when approaching the burbling point, a phenomenon very important for stalling flight. An aileron deflection β_Q produces a strong positive rolling moment. In our example, rolling moments produced by a $\beta_Q = 5^\circ$ aileron deflection, are larger than those occurring at $\alpha = 14.5^\circ$, $\gamma = 7^\circ$, and $\beta_Q = 0^\circ$, so that within

* A. Betz and E. Petersohn, "Zur Theorie der Querruder," Zeitschrift für angewandte Mathematik und Mechanik, Aug., 1928, Vol. VIII, pp. 253-257. (See N.A.C.A. Technical Memorandum No. 542: "Contribution to the Aileron Theory," Dec., 1929.)

C. Wieselsberger, "Theoretische Untersuchungen über die Querruderwirkung beim Tragflügel." Report of the Aeronautical Research Institute, Tokio Imperial University, Dec., 1927, No. 30, Vol. II, No. 16, pp. 421-446. (See N.A.C.A. Technical Memorandum No. 510: "Theoretical Investigation of the Effect of the Ailerons on the Wing of an Airplane," April, 1929.)

this range the control of rolling seems to be assured with the aileron. With stronger side wind, however, the conditions become less favorable. The deflection of rudder β_S has no effect on the rolling moment; Figures 13 to 15 almost correspond, as we expected. From this and from a comparison with the wing measurements we can conclude that the rolling moment is produced by the wing alone.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.

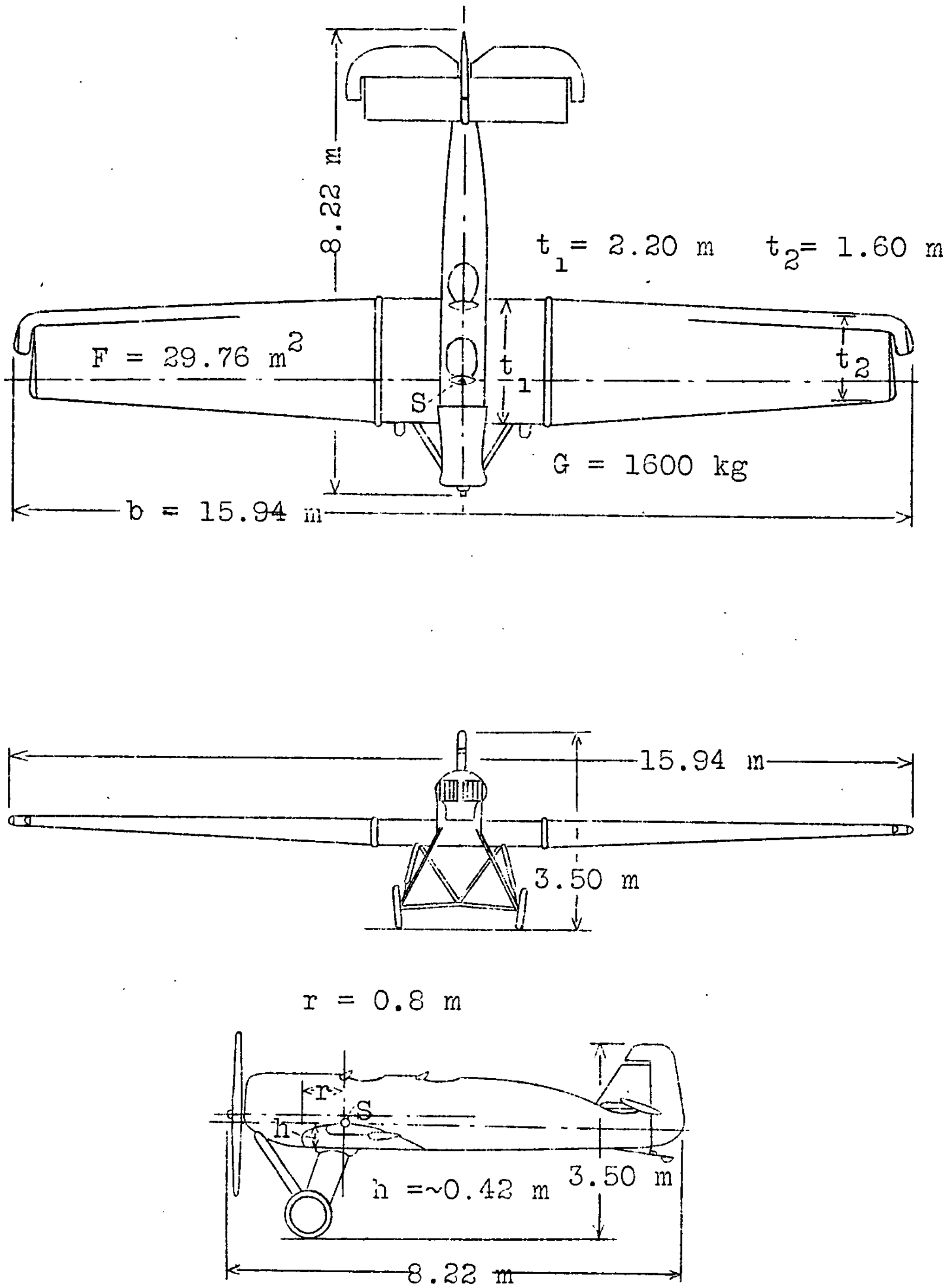

Fig.1 The Junkers A 35 airplane.

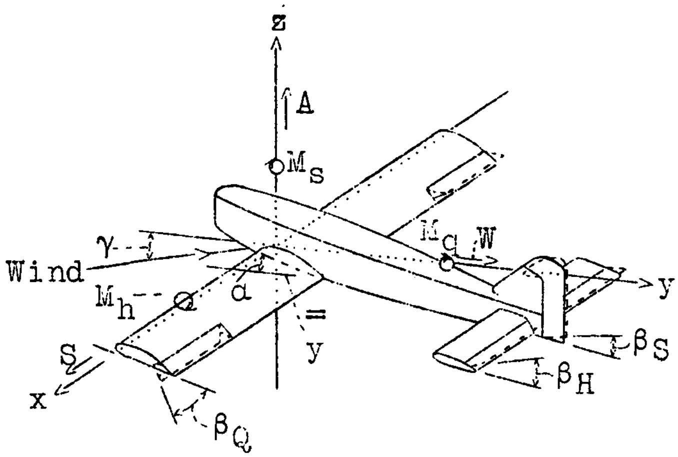
z
A
Ms
Wind
γ
α
Mh
S
x
βQ
Mq
W
y
βS
βH

Fig.2

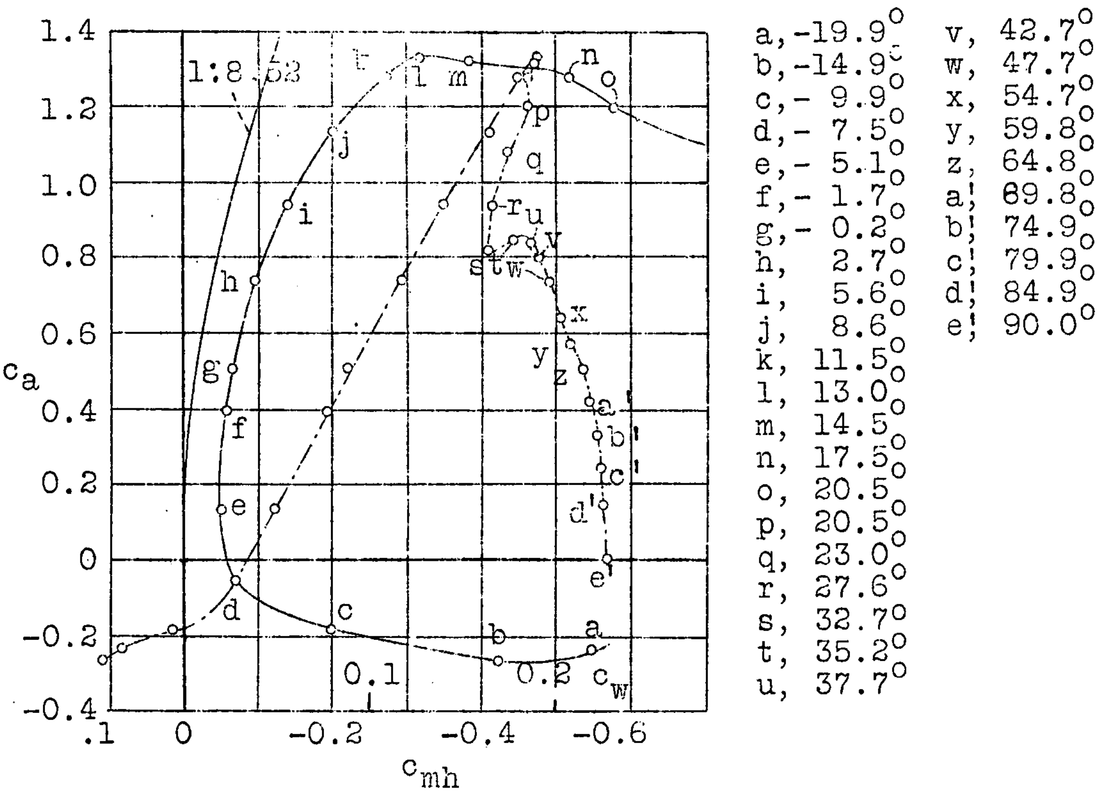
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
ca
.1
0
-0.2
-0.4
-0.6
cmh
1:8.52
0.1
0.2
cw
a, -19.9°
b, -14.9°
c, - 9.9°
d, - 7.5°
e, - 5.1°
f, - 1.7°
g, - 0.2°
h, 2.7°
i, 5.6°
j, 8.6°
k, 11.5°
l, 13.0°
m, 14.5°
n, 17.5°
o, 20.5°
p, 20.5°
q, 23.0°
r, 27.6°
s, 32.7°
t, 35.2°
u, 37.7°
v, 42.7°
w, 47.7°
x, 54.7°
y, 59.8°
z, 64.8°
a', 69.8°
b', 74.9°
c', 79.9°
d', 84.9°
e', 90.0°

Fig.3

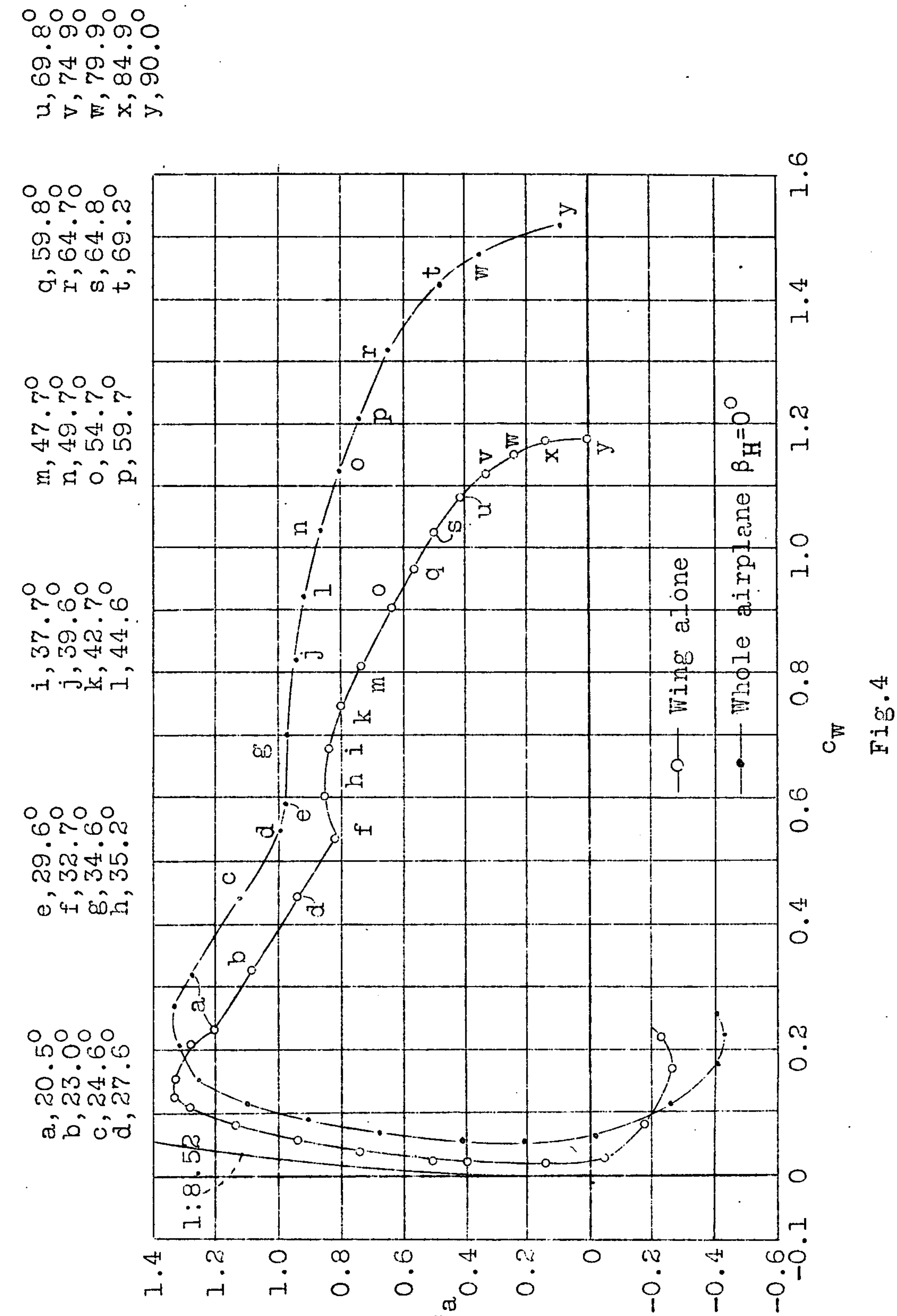
a, 20.5°
b, 23.0°
c, 24.6°
d, 27.6
e, 29.6°
f, 32.7°
g, 34.6°
h, 35.2
i, 37.7°
j, 39.6°
k, 42.7°
l, 44.6
m, 47.7°
n, 49.7°
o, 54.7°
p, 59.7
q, 59.8°
r, 64.7°
s, 64.8°
t, 69.2°
u, 69.8°
v, 74.9°
w, 79.9°
x, 84.9°
y, 90.0°
1:8.52
Wing alone
Whole airplane
$\beta_H = 0°$
c_a
c_w

Fig.4

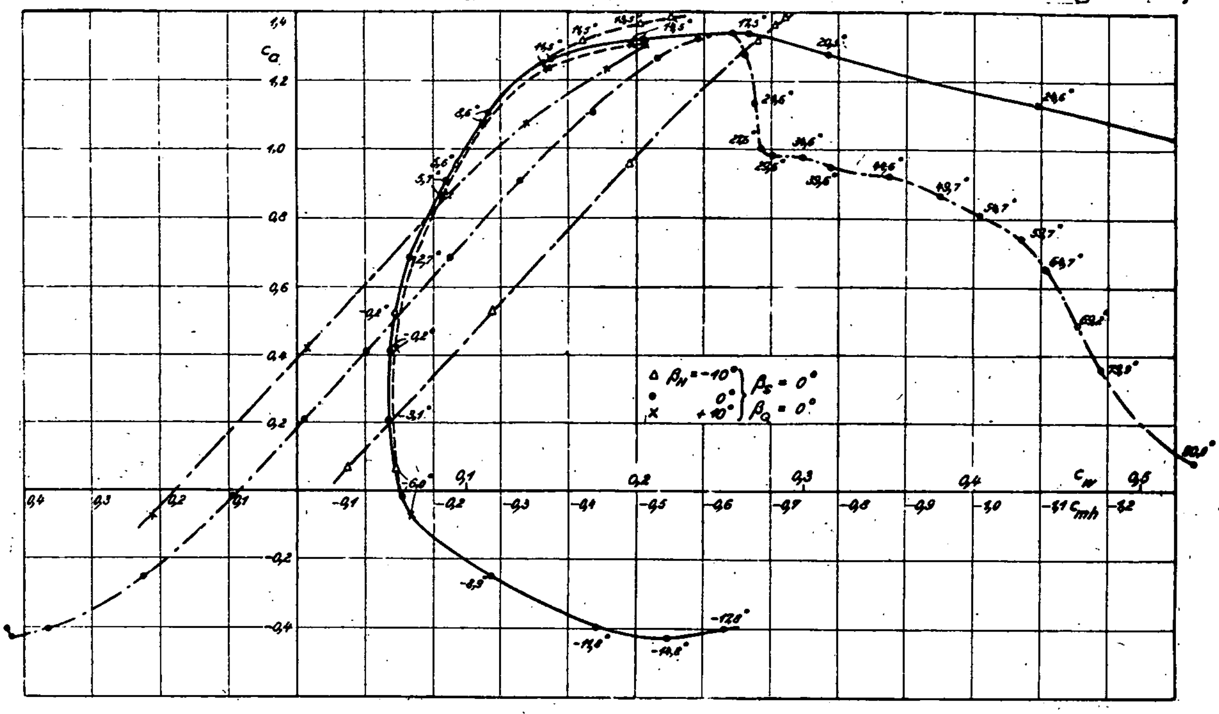

Fig.5

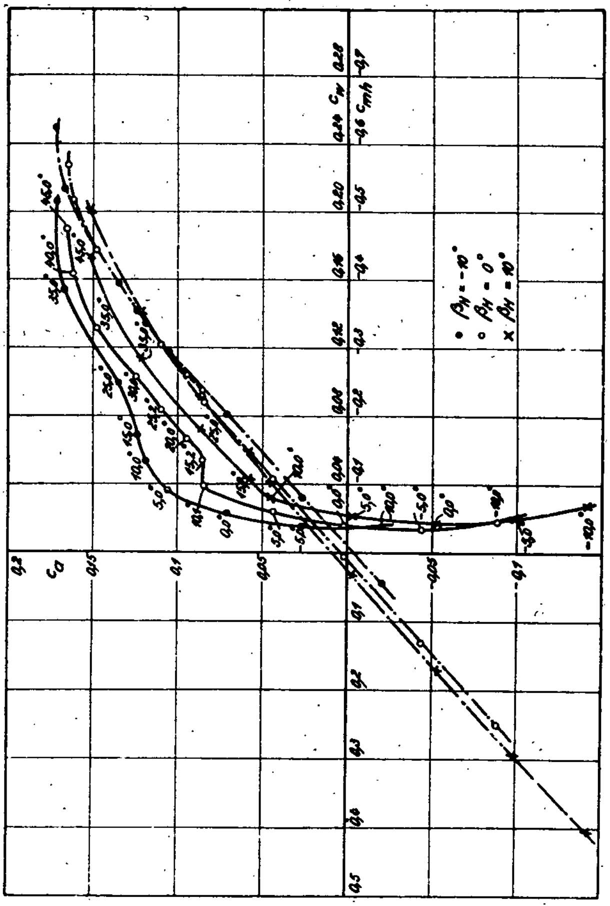

Fig.6

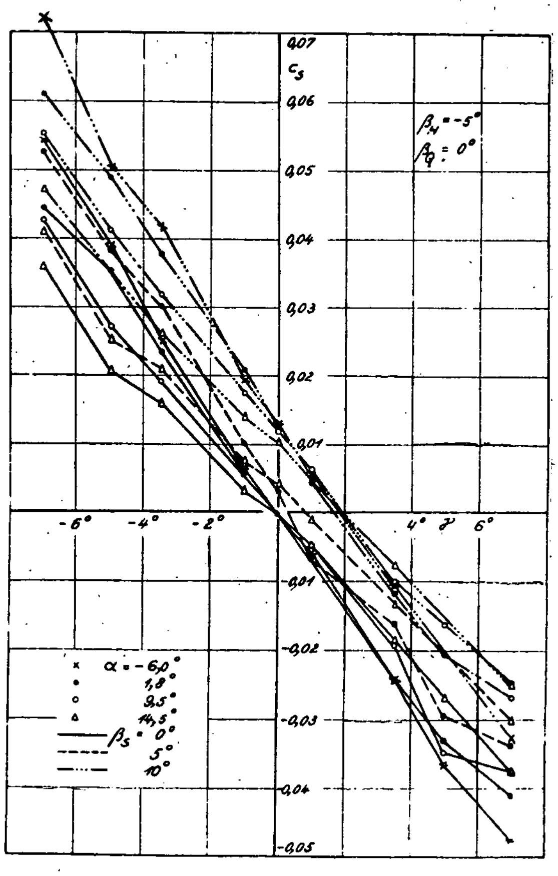

Fig.7

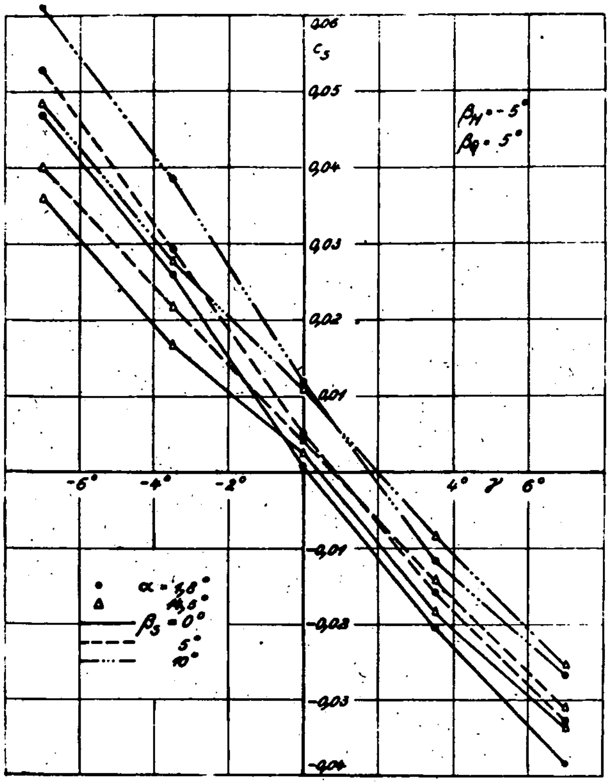

Fig.8

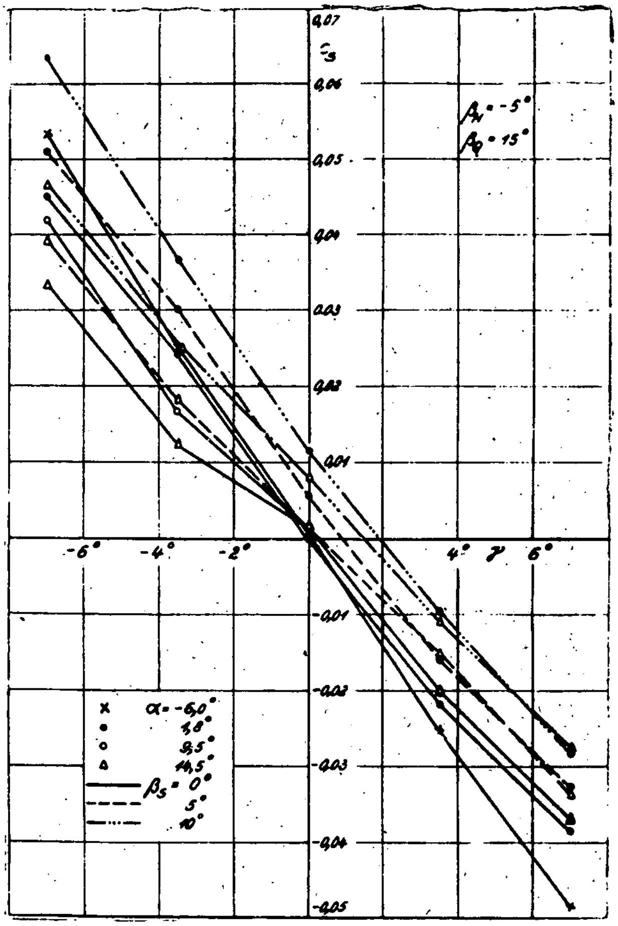

Fig.9

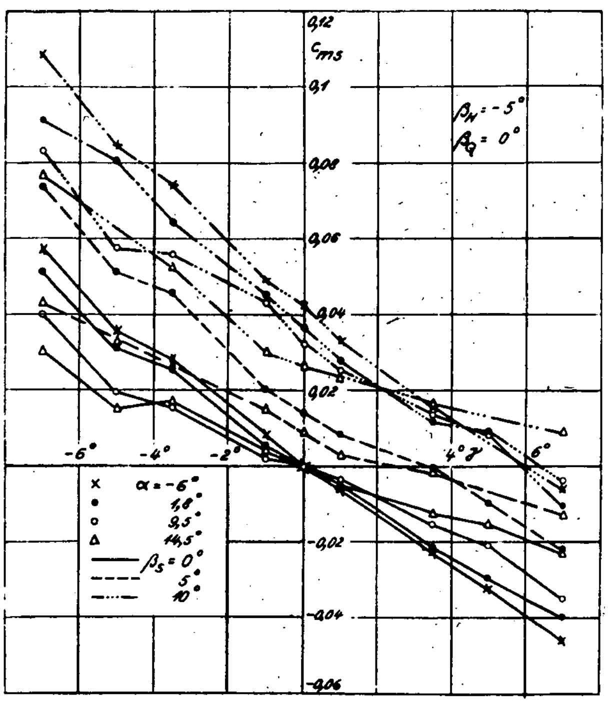

Fig.10

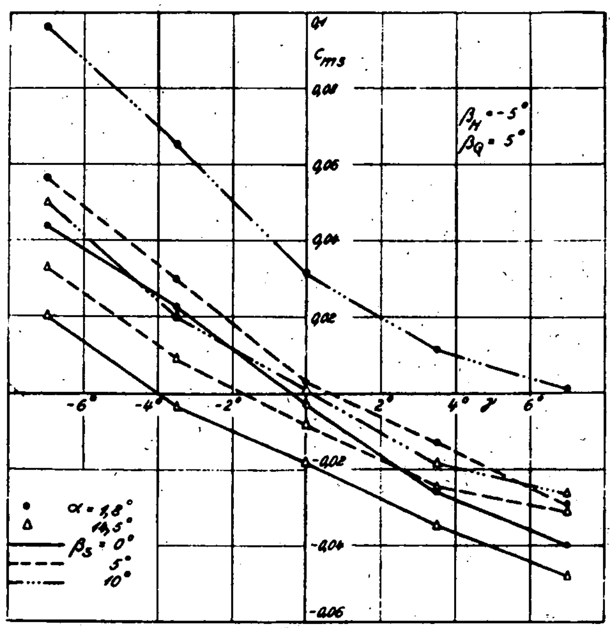

Fig.11

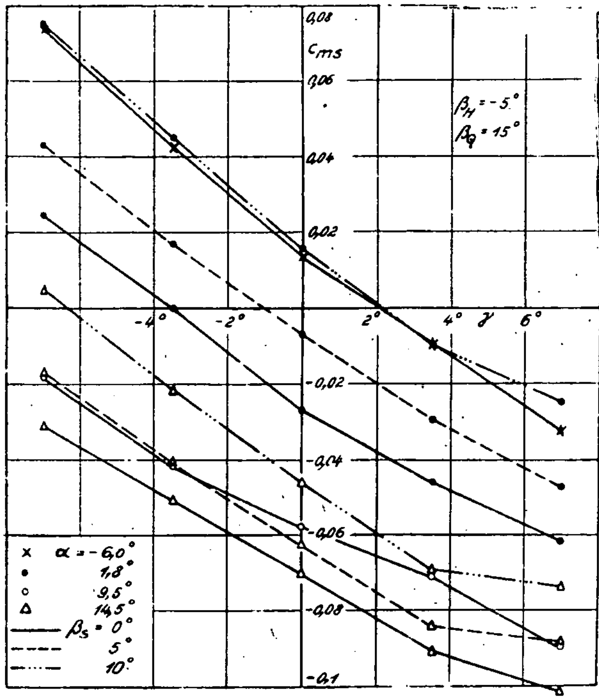

Fig.12

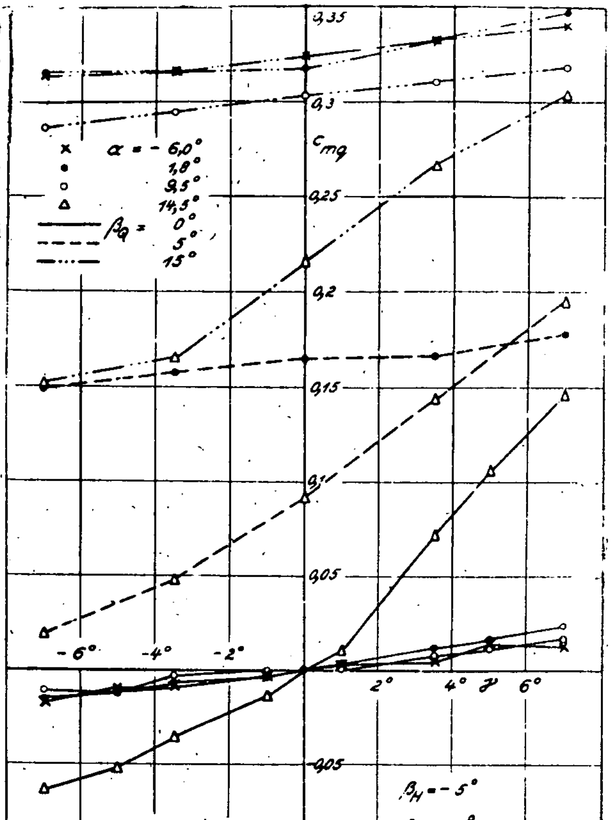

Fig.13

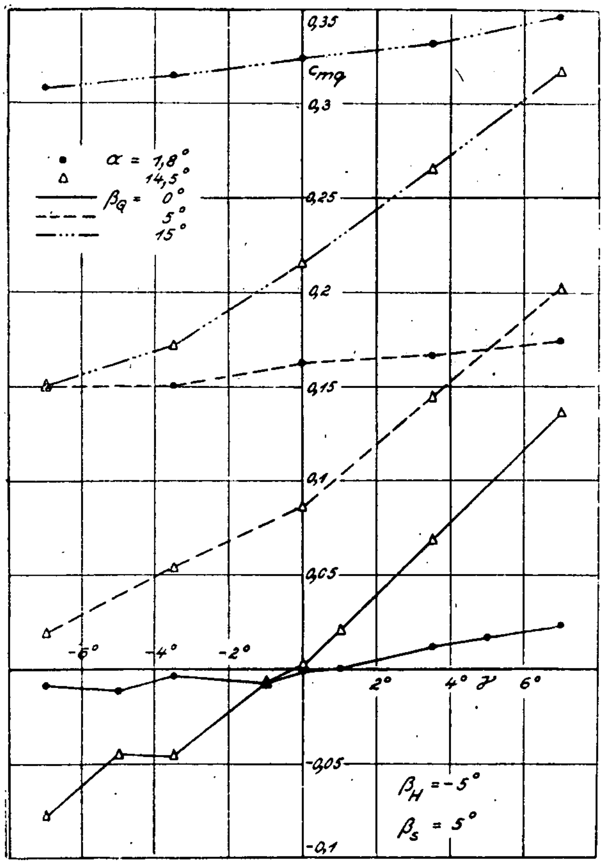

Fig.14

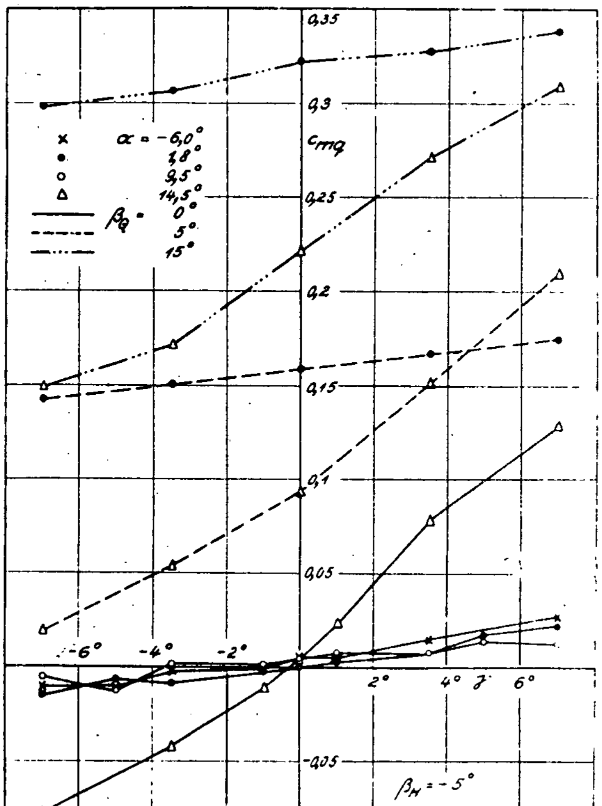

Fig.15