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MAXIMUM LIFT COEFFICIENTS OF AIRPLANES BASED ON SUM OF WING AND TAIL AREAS

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MAXIMUM LIFT COEFFICIENTS OF AIRPLANES BASED ON SUM OF WING AND TAIL AREAS

By Herman O. Ankenbruck

SUMMARY

Some designers of tailless airplanes believe that a fair comparison of the maximum lift coefficients of conventional and tailless airplanes can be made only if the lift coefficients are based on the sum of wing and tail areas. In the present paper, values of maximum lift coefficient based on three different areas have been computed from airplane stalling speeds in order to show representative values of maximum lift coefficient that are being reached by present-day conventional airplanes. The areas used were wing area alone, wing area plus horizontal-tail area, and wing area plus horizontal- and vertical-tail areas. The maximum lift coefficients were determined from the stalling speeds obtained for the gliding condition (power off, flaps up) and landing condition (power off, flaps down) of 10 airplanes in flight tests conducted by the NACA. The highest maximum lift coefficients based on wing area alone were 1.6 for the gliding condition and 2.4 for the landing condition, whereas the highest maximum lift coefficients based on wing area plus horizontal-tail area were 1.3 for the gliding condition and 1.9 for the landing condition.

INTRODUCTION

One of the principal arguments advanced against the tailless airplane is that its maximum lift coefficient is necessarily low compared with that of a conventional airplane. Some designers of tailless all-wing airplanes contend, however, that a fair comparison of the maximum lift coefficients of conventional and tailless airplanes cannot be made if the lift coefficients are computed on the basis of wing area alone. These designers point out that, inasmuch as the function of the tail surfaces is performed by a portion of the wing on a tailless airplane, the horizontal-tail area, and perhaps the vertical-tail area, should be added to the wing area in calculating lift coefficients. This procedure, of course, causes a reduction in the computed maximum lift coefficient of the conventional airplane and thereby decreases its superiority over the tailless airplane in this respect.

In order to illustrate the effect of using wing area plus tail area in computing the values of maximum lift coefficient that are being reached by present-day airplanes, the maximum lift coefficients, as determined from the stalling speeds of 10 airplanes that have been tested in flight by the NACA, have been expressed in terms of three areas: (1) wing area alone, (2) wing area plus horizontal-tail area, and (3) wing area plus horizontal- and vertical-tail areas. The results are given in the present report.

SYMBOLS

$C_{L_{max}}$ maximum lift coefficient

W gross weight of airplane, pounds

ρ density of air at standard sea-level conditions (0.002378 slug-ft^2)

V_s correct indicated stalling speed, miles per hour

S_w wing area, square feet

S' wing area used in computing maximum lift coefficients, square feet

S_h horizontal-tail area, square feet

S_v vertical-tail area, square feet

b_f total flap span, feet

b_w total wing span, feet

c_f flap chord, feet

c_w wing chord, feet

$\delta_{f_{max}}$ maximum flap deflection, degrees

SOURCE OF DATA

The maximum lift coefficients were computed from the correct indicated stalling speeds obtained in the gliding condition (power off, flaps up) and landing condition (power off, flaps down) in flight tests conducted by the NACA at Langley Memorial Aeronautical Laboratory and Ames Aeronautical Laboratory. Military aircraft that ranged in size from single-engine fighters to four-engine bombers were tested. The dimensional characteristics of the airplanes are given in table I.

CALCULATIONS

The following formula was used for calculating the maximum lift coefficients:

$$C_{L_{max}} = \frac{W}{1.077\ \rho S' V_s^2}$$

Values of S' used for each airplane were

$$S' = S_w$$

$$S' = S_w + S_h$$

$$S' = S_w + S_h + S_v$$

RESULTS

The maximum lift coefficients calculated by the three methods for each flight condition are given in table II. The maximum lift coefficients based on wing area alone ranged from 1.4 to 1.6 for the gliding condition and from 1.8 to 2.4 for the landing condition, whereas the values based on wing area plus horizontal-tail area varied from 1.2 to 1.3 for the gliding condition and from 1.5 to 1.9 for the landing condition. The highest maximum lift coefficient for the landing condition (2.4) was obtained by an airplane with a full-span slotted flap (airplane 8). The highest value for the landing condition reached by airplanes with partial-span flaps was 2.1 based on wing area alone, or 1.8 based on wing area plus horizontal-tail area.

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TABLE I

DIMENSIONAL CHARACTERISTICS OF THE AIRPLANES TESTED

Airplane	Type	W (lb) (a)	S_w (sq ft) (b)	S_h (sq ft) (b)	S_v (sq ft)	Flap type	$\frac{b_f}{b_w}$	$\frac{c_f}{c_w}$	$\delta_{f_{max}}$ (deg)
1	Four-engine bomber	49,000	2780	505	143	Split	0.51	0.15	60
2	Four-engine bomber	48,400	1420	336	181	Split	.48	.17	45
3	Twin-engine bomber	15,000	545	125	65.5	Fowler	.49	.33	39
4	Single-engine torpedo bomber	13,400	490	112	38.8	Split	.58	.20	45
5	Single-engine scout bomber	12,400	422	107	46	Split	.48	.23	60
6	Single-engine fighter	7,500	236	41	20	Plain	.51	.22	50
7	Single-engine fighter	7,010	258	37	22	Split	.48	.18	80
8	Single-engine fighter	5,760	209	49	20	Slotted	.81	.25	40
9	Single-engine scout bomber	5,770	258	61	26	Split	.50	.15	67
10	Single-engine trainer	4,900	254	50	18.5	Split	.58	.18	45

[a] Gross weight as tested.
[b] Over-all area including area through fuselage.

TABLE II

MAXIMUM LIFT COEFFICIENTS

Airplane	Gliding condition (a)			Landing condition (b)		
	Calculation based on S_w	Calculation based on $S_w + S_h$	Calculation based on $S_w + S_h + S_v$	Calculation based on S_w	Calculation based on $S_w + S_h$	Calculation based on $S_w + S_h + S_v$
1	1.4	1.2	1.1	2.0	1.7	1.6
2	1.5	1.2	1.1	1.9	1.5	1.4
3	1.6	1.3	1.2	2.1	1.7	1.6
4	1.6	1.3	1.2	2.1	1.7	1.6
5	---	---	---	2.0	1.6	1.5
6	1.5	1.3	1.2	1.9	1.6	1.5
7	1.4	1.2	1.1	2.1	1.8	1.7
8	1.6	1.3	1.2	2.4	1.9	1.8
9	---	---	---	1.8	1.5	1.3
10	1.6	1.3	1.3	2.0	1.7	1.6

[a]Flaps up, landing gear up, power off.
[b]Flaps down, landing gear down, power off.

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ABSTRACT:

Some designers believe that a fair comparison of the maximum lift coefficients of conventional and tailless airplanes can be made only if lift coefficients are based on the sum of wing and tail areas. In the case discussed, areas used were wing area alone, wing area plus horizontal tail area, and wing area plus horizontal and vertical tail areas. Maximum lift coefficients were determined from the stalling speeds of ten airplanes, and results tabulated.

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