TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 346

SPAN LOAD DISTRIBUTION ON TWO MONOPLANE WING MODELS AS AFFECTED BY TWIST AND SWEEPBACK

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Summary

The results presented in this note show the effect of twist and sweepback on the span load distribution over two monoplane wing models. The tests were made in the Atmospheric Wind Tunnel of the Langley Memorial Aeronautical Laboratory. The data are taken from the results of an investigation dealing primarily with lateral stability. As presented, they are suitable as an aid in the structural design of certain monoplane wings.

Introduction

In designing an airplane wing for maximum structural safety and efficiency, a knowledge of the actual distribution of the air loads along the span is essential. If the wing is provided with either twist or sweepback, the distribution is no longer the same as for a straight wing. However, comparatively little information as to the changes thus produced has been published heretofore.

This report has been prepared for the purpose of making available for design a limited amount of data on the aerodynamic characteristics of two monoplane wing models as affected by changes in twist and sweepback. The results are taken from a series of pressure distribution tests made primarily for the study of lateral stability. The tests were conducted in the Atmospheric Wind Tunnel of the Langley Memorial Aeronautical Laboratory (Reference 1).

Models and Tests

The shapes of the two semi-span models and the locations of the points at which the pressures were measured are shown in Figure 1. One of the models, which was designated the N.A.C.A. 84 wing, had the N.A.C.A. 84 airfoil profile from the root to the tip. The other, the N.A.C.A. 86 wing, had the N.A.C.A. 84 profile at the root and the symmetrical N.A.C.A.-M2 profile at the tip. These profiles are shown in Figure 1, and their ordinates in per cent of chord are given in Tables I and II. As may be seen from the figure, both wings had essentially rectangular plan forms except at the extreme tips which were so designed that any tip cross section normal to the mean camber line was a semicircle whose diameter was the wing thickness at that section.

To permit giving the wings the desired amount of twist, a special type of construction was necessary. Each wing was made up of 3/16 inch mahogany laminations mounted parallel to the plane of symmetry and clamped together by two long internal bolts running spanwise. By loosening the bolts and rotating the laminations relative to each other through a small angle, any desired geometric twist up to 15° was obtainable. The "steps" on the surface of the wing formed by the laminations slipping past each other were faired over with plasticine.

The sweepback adjustment was made by rotating the wing in its mounting bracket about an axis normal to the midspan chord at its 50 per cent point and lying in the plane of symmetry.

The semi-span wing models were used in conjunction with a separation plane as shown in Figure 2, which is a view of the tunnel set-up looking upstream. This method has been used almost exclusively in making pressure distribution tests in this wind tunnel and is based on the assumption that the imaginary plane of symmetry of the wing can be replaced with an actual plane surface without affecting the flow. It then becomes necessary to study only one-half of the wing model. The results obtained by this method of testing have checked satisfactorily with the results of other methods, showing that the assumption is reasonably valid.

The apparatus and test procedure in general are described in Reference 2, with the exception of the manometer. This instrument was unusual in that it was designed to integrate automatically the pressures over each test section so as to give the total section load in a single reading. A detailed description of the principle of operation and of the design of the instrument will be published in a later report.

The test program on each wing included the following variables:

1. Geometric twist - washin = 5°,

washout = 0°, 5°, 10°, 15°,

2. Sweep - sweepforward = 20°, 10°,

sweepback = 0°, 10°, 20°,

tested at angles of attack of the root section = -9°, -6°, -3°, 0°, 3°, 6°, 9°, 12°, 15°, 18°, 21°, 24°, 27°, 30°.

During all tests the dynamic pressure was held constant at 1.25 pounds per square foot, corresponding to an air speed of about 22 m.p.h., and a Reynolds Number of 160,000.

Results

The results are presented in absolute coefficient form in the following two groups of curves which show the effects of twist and sweepback on the two monoplane wing models:

1. Semi-span load distribution (Figs. 3 to 6).
2. Normal force versus angle of attack (Figs. 7 to 10).

In the first group three standard loading conditions used in structural analysis are represented, viz., nose dive, low angle of attack, and high angle of attack. These conditions are taken as occurring at $C_{NF} = 0$, 1/4 max. C_{NF} and max. C_{NF}, respectively. The data from which these curves were plotted are given in Tables III and IV.

To determine the magnitude of the section normal load per unit span, N', for any given set of conditions shown in Figures

3 to 6, the following equation may be used:

$$N' = q\ c\ C_{NF}'$$

where C_{NF}' = absolute coefficient of section normal force,

c = chord,

q = dynamic pressure.

The total normal force N, on a wing may be obtained from the data in the second group of curves as follows:

$$N = q\ S\ C_{NF}$$

where C_{NF} = absolute coefficient of total normal force,

S = total area of wing.

In general, the data may be considered accurate to within ±5 per cent.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 23, 1930.

References

1. Reid, Elliott G. : Standardization Tests of N.A.C.A. No. 1 Wind Tunnel. N.A.C.A. Technical Report No. 195 (1924).

2. Reid, Elliott G. : Pressure Distribution Over Thick Tapered Airfoils, N.A.C.A. 81, U.S.A. 27-C Modified, and U.S.A. 35. N.A.C.A. Technical Report No. 229 (1926).

TABLE III

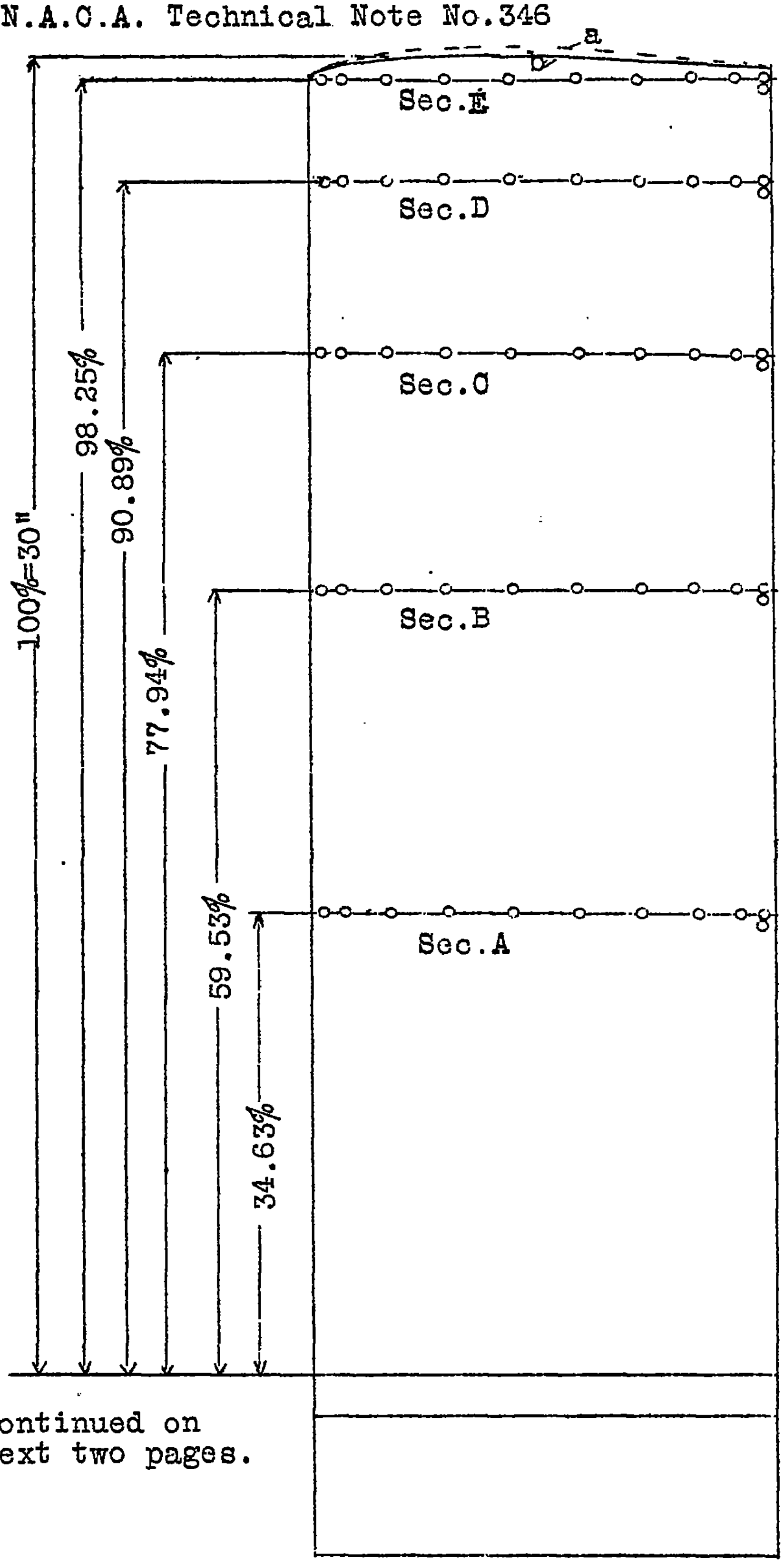
N.A.C.A. 84 Section Normal Force Coefficients

Wing condition	Semi-span C_{NF}	C_{NF}' sec. A	sec. B	sec. C	sec. D	sec. E
Straight	0	.000	+.010	.000	-.015	+.012
	1/4 max.	.440	.384	.300	.230	.160
	max.	1.550	1.573	1.473	1.230	1.396
5° washin	0	-.030	+.027	+.050	-.005	+.005
	1/4 max.	.400	.425	.395	.244	.244
	max.	1.510	1.364	1.430	1.256	1.600
5° washout	0	+.040	-.025	-.040	-.112	-.052
	1/4 max.	.465	.380	.275	.125	.110
	max.	1.570	1.600	1.468	1.155	1.308
10° washout	0	+.080	-.060	-.096	-.187	-.145
	1/4 max.	.515	.310	.152	.045	.052
	max.	1.555	1.548	1.287	1.015	1.139
15° washout	0	+.108	-.070	-.155	-.250	-.168
	1/4 max.	.530	.265	.070	-.035	.000
	max.	1.570	1.533	1.270	.964	1.208
20° sweep-forward	0	+.028	-.011	-.010	-.015	-.140
	1/4 max	.395	.354	.284	.250	.250
	max.	1.340	1.613	1.570	1.461	2.552
10° sweep forward	0	+.027	+.006	-.020	+.025	-.089
	1/4 max.	.430	.380	.315	.246	.206
	max.	1.475	1.579	1.510	1.344	2.073
10° sweepback	0	+.020	-.002	-.026	-.002	+.018
	1/4 max.	.406	.380	.295	.212	.065
	max.	1.527	1.345	1.290	1.060	.630
20° sweepback	0	+.010	+.001	-.002	-.002	.000
	1/4 max.	.390	.350	.308	.207	.016
	max.	1.612	1.340	1.164	.897	.078

TABLE IV

N.A.C.A. 86 Section Normal Force Coefficient

Wing condition	Semi-span C_{NF}	C_{NF}' sec. A	sec. B	sec. C	sec. D	sec. E
Straight	0	.078	-.080	-.130	-.094	-.089
	1/4 max.	.400	.225	.165	.100	.037
	max.	1.282	1.160	.995	.795	.913
5° washin	0	.020	-.020	-.030	-.030	-.020
	1/4 max.	.335	.268	.230	.150	.090
	max.	1.175	1.058	.940	.845	1.025
5° washout	0	.115	-.060	-.180	-.160	-.140
	1/4 max.	.430	.240	.090	.030	-.012
	max.	1.292	1.172	.935	.720	.730
10° washout	0	.150	-.080	-.220	-.200	-.180
	1/4 max.	.458	.200	.024	-.030	-.045
	max.	1.342	1.170	.919	.661	.644
15° washout	0	.190	-.140	-.338	-.300	-.322
	1/4 max.	.510	.176	-.054	-.123	-.118
	max.	1.355	1.200	.900	.625	.555
20° sweep forward	0	.080	-.038	-.108	-.087	-.194
	1/4 max.	.410	.242	.185	.122	.185
	max.	1.190	1.086	1.046	.912	1.770
10° sweep forward	0	.050	-.105	-.130	-.105	-.190
	1/4 max.	.385	.200	.130	.090	.070
	max.	1.257	1.110	.971	.880	1.290
10° sweepback	0	.047	-.075	-.105	-.082	-.020
	1/4 max.	.354	.235	.156	.090	.020
	max.	1.215	1.070	.872	.670	.305
20° sweepback	0	.060	-.060	-.112	-.094	-.020
	1/4 max.	.350	.211	.140	.100	.030
	max.	1.255	.996	.721	.590	.260



a= N.A.C.A. 84 Tip
b= N.A.C.A. 86 Tip

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Fig.1 Orifice locations and profile ordinates for N.A.C.A. 84 and N.A.C.A. 86 semispan wing models.

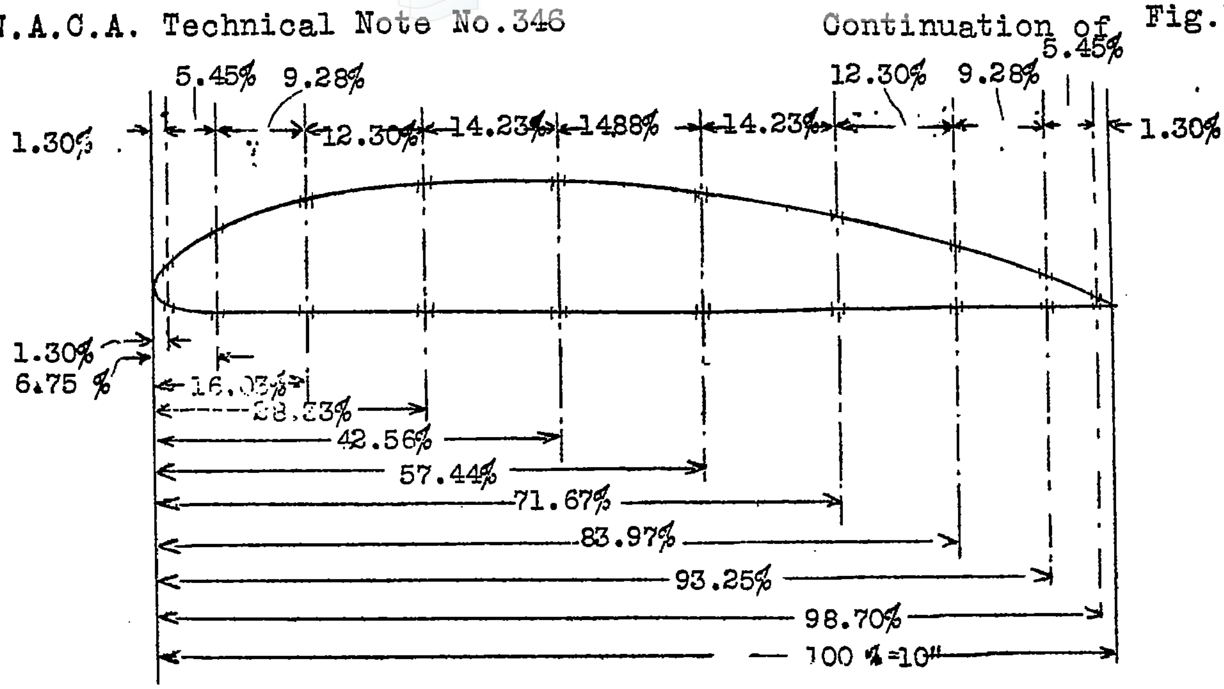


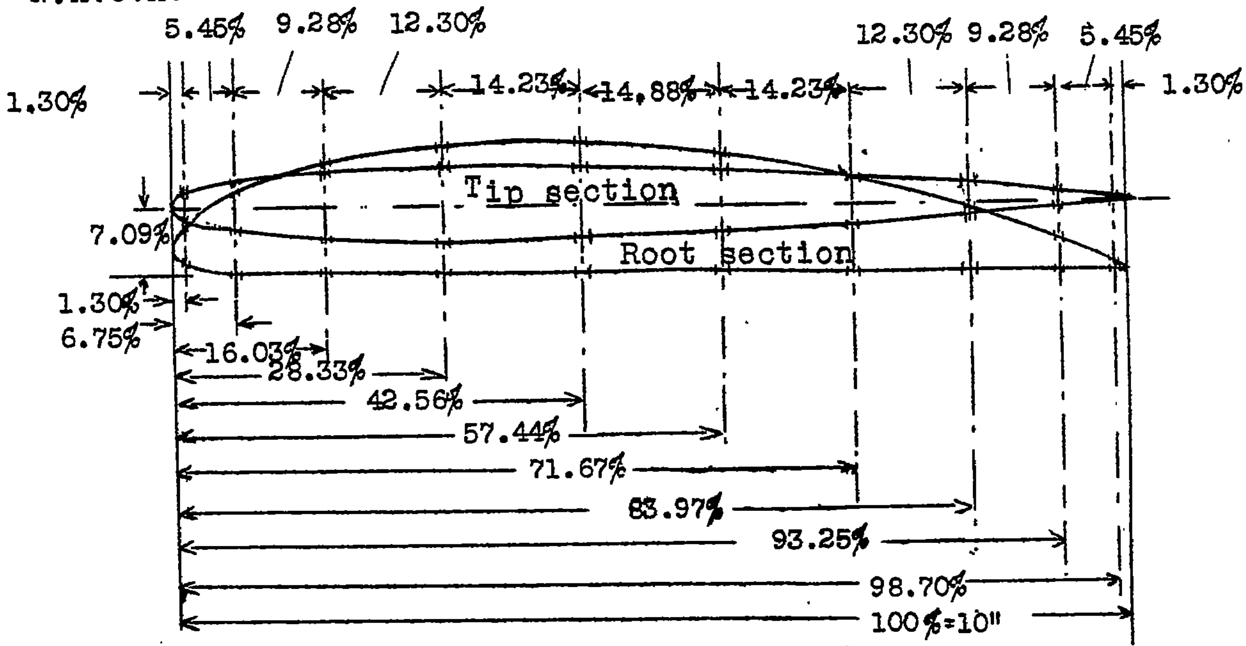
Fig.1

N.A.C.A. 84 Profile

Table I.

Profile ordinates		
Stations in % chord	N.A.C.A. 84	
	Upper	Lower
0	2.50	2.30
1.25	4.85	.95
2.50	6.05	.41
5.00	7.78	.10
7.50	9.03	.02
8.50	----	0
10.00	10.00	0
15.00	11.50	0
20.00	12.71	0
25.00	13.51	0
30.00	14.00	0
35.00	14.18	0
40.00	14.11	0
50.00	13.50	0
60.00	12.31	0
70.00	10.32	0
80.00	7.71	0
90.00	4.39	0
95.00	2.41	0
100.00	.30	0

Continuation of Fig.1



N.A.C.A. 86 Profile
Root section N.A.C.A. 84
Tip section N.A.C.A. M2

Table II

Profile ordinates				
Stations in % chord	N.A.C.A. 84		N.A.C.A. M2	
	Upper	Lower	Upper	Lower
0	2.50	2.50	0	0
1.25	4.85	.95	1.30	-1.30
2.50	6.05	.41	1.74	-1.74
5.00	7.78	.10	2.33	-2.33
7.50	9.03	.02	2.74	-2.74
8.50	---	0	---	---
10.00	10.00	0	3.05	-3.05
15.00	11.50	0	3.49	-3.49
20.00	12.71	0	3.78	-3.78
25.00	13.51	0	---	---
30.00	14.00	0	4.03	-4.03
35.00	14.18	0	---	---
40.00	14.11	0	4.00	-4.00
50.00	13.50	0	3.74	-3.74
60.00	12.31	0	3.30	-3.30
70.00	10.32	0	2.71	-2.71
80.00	7.71	0	1.99	-1.99
90.00	4.39	0	1.15	-1.15
95.00	2.41	0	.69	-.69
100.00	.30	0	.20	-.20

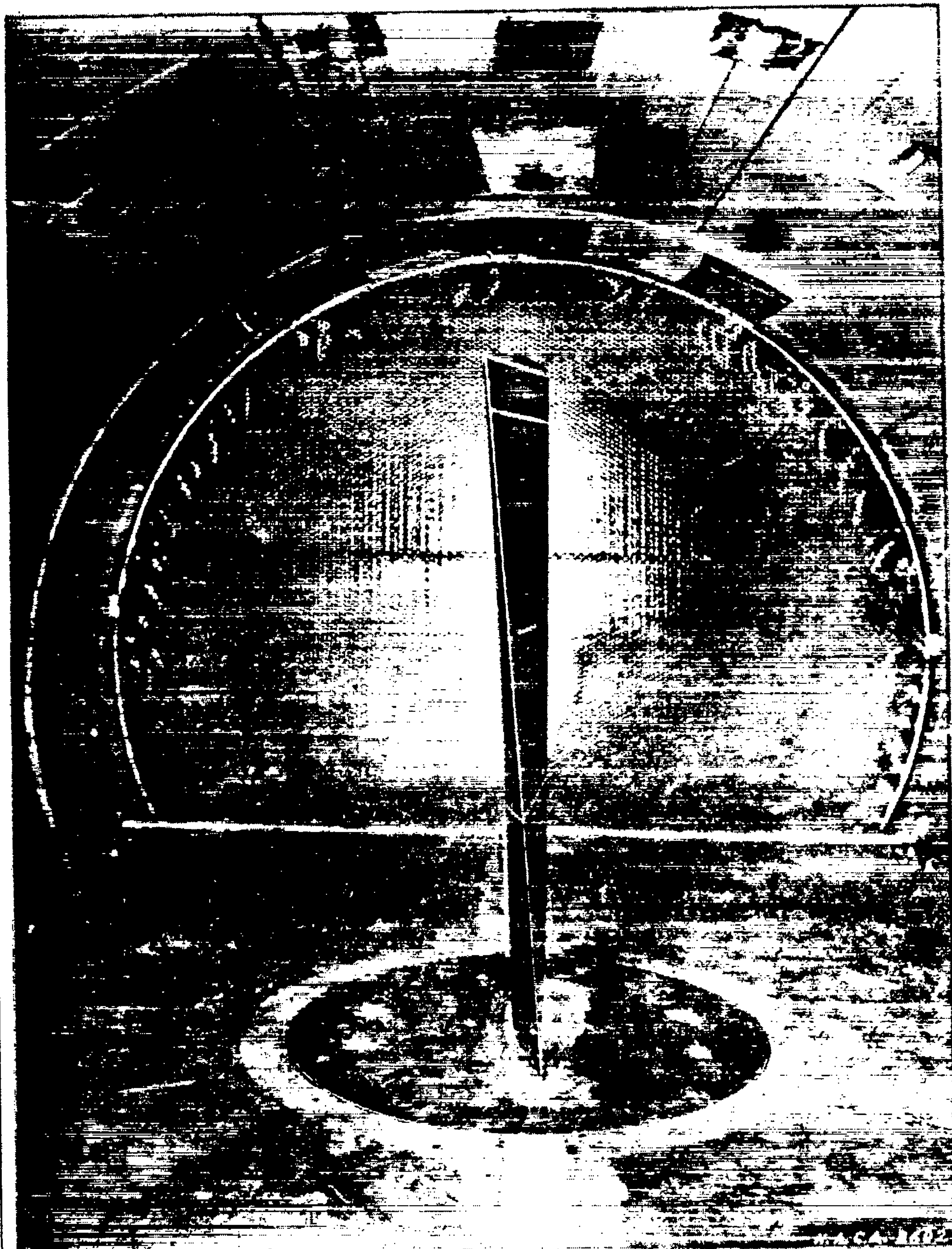


Fig.2 Wind tunnel set-up of twisted wing.

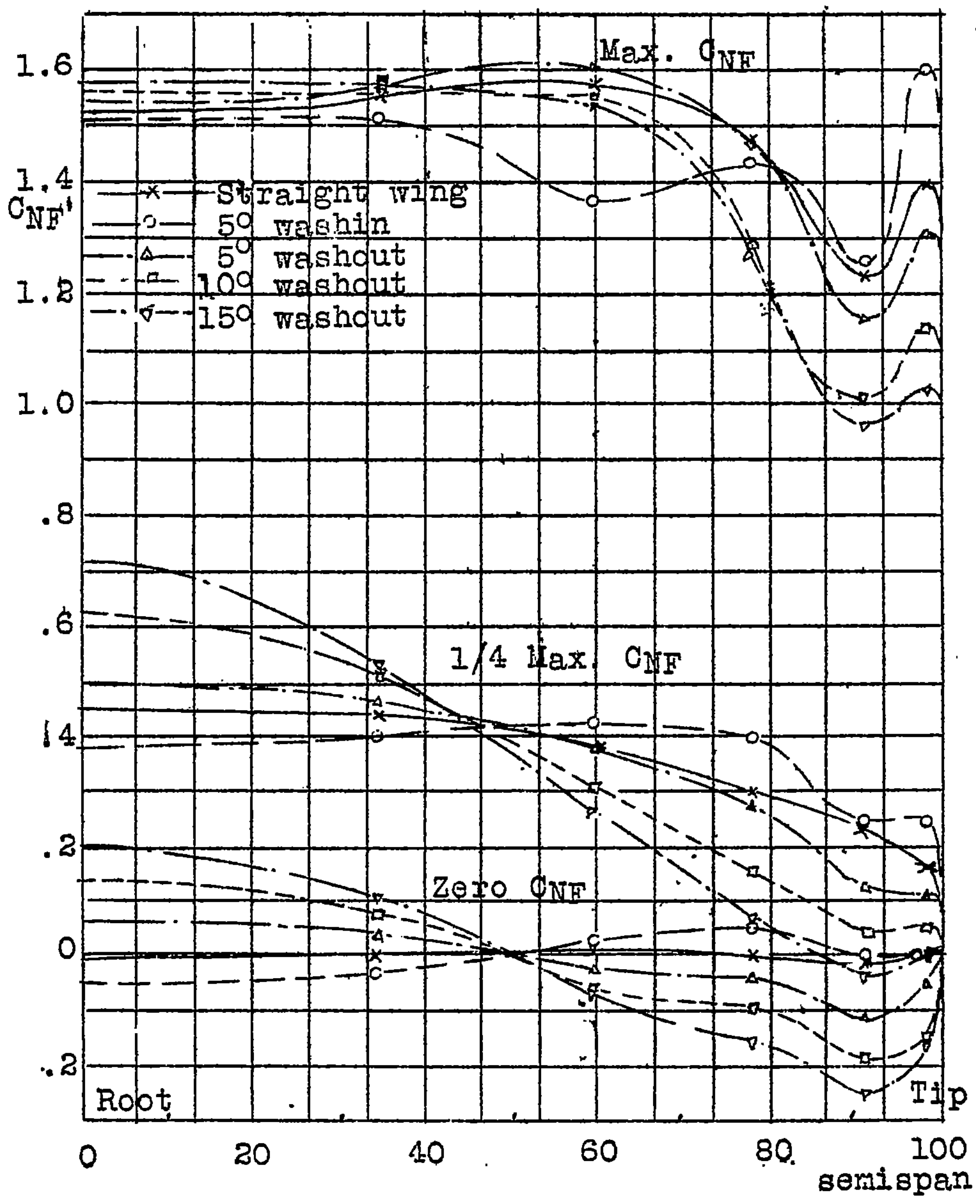


Fig.3 Effect of twist on N.A.C.A.84 semispan load distribution.

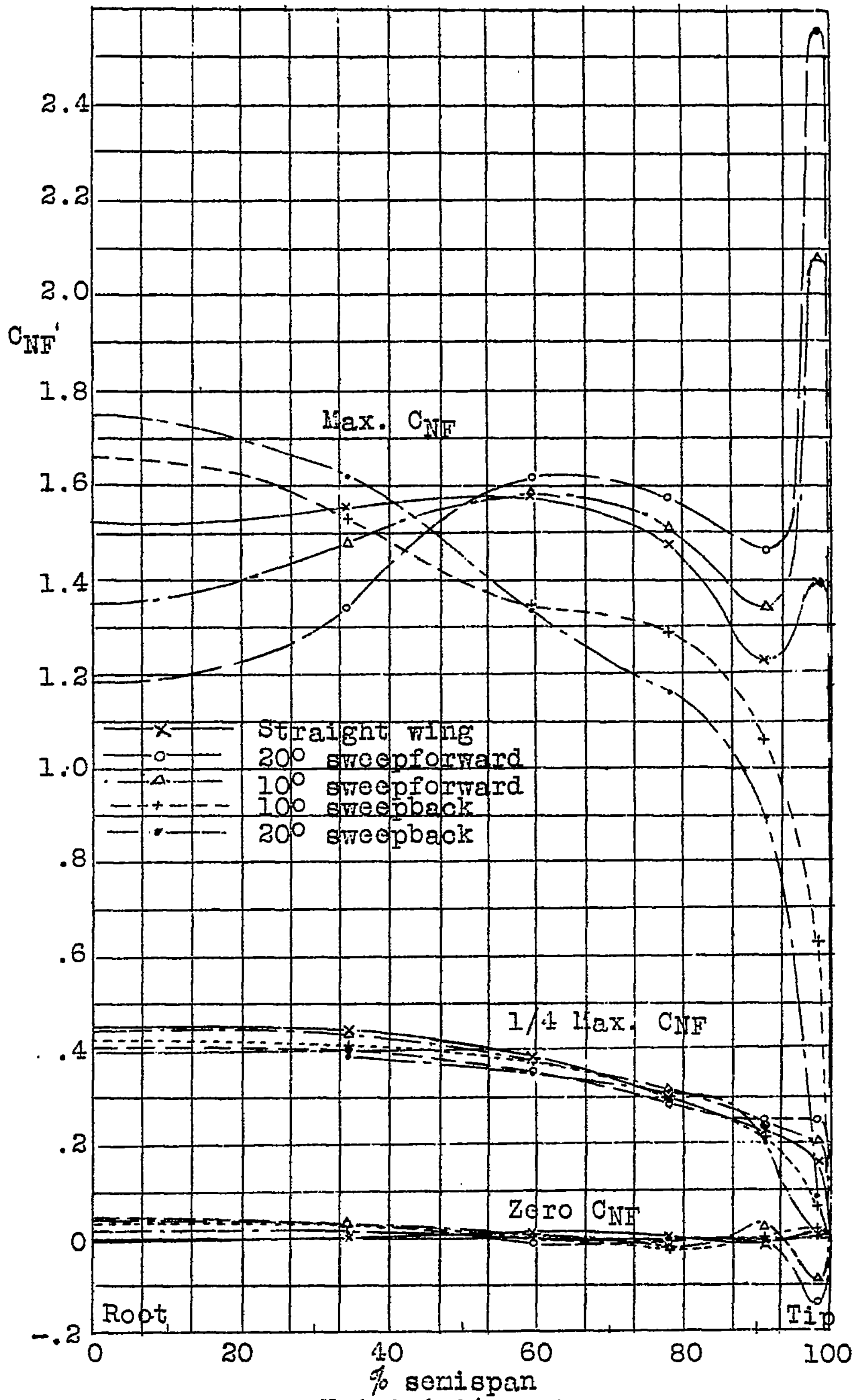


Fig.4 Effect of sweep on N.A.C.A.84 semispan load distribution.

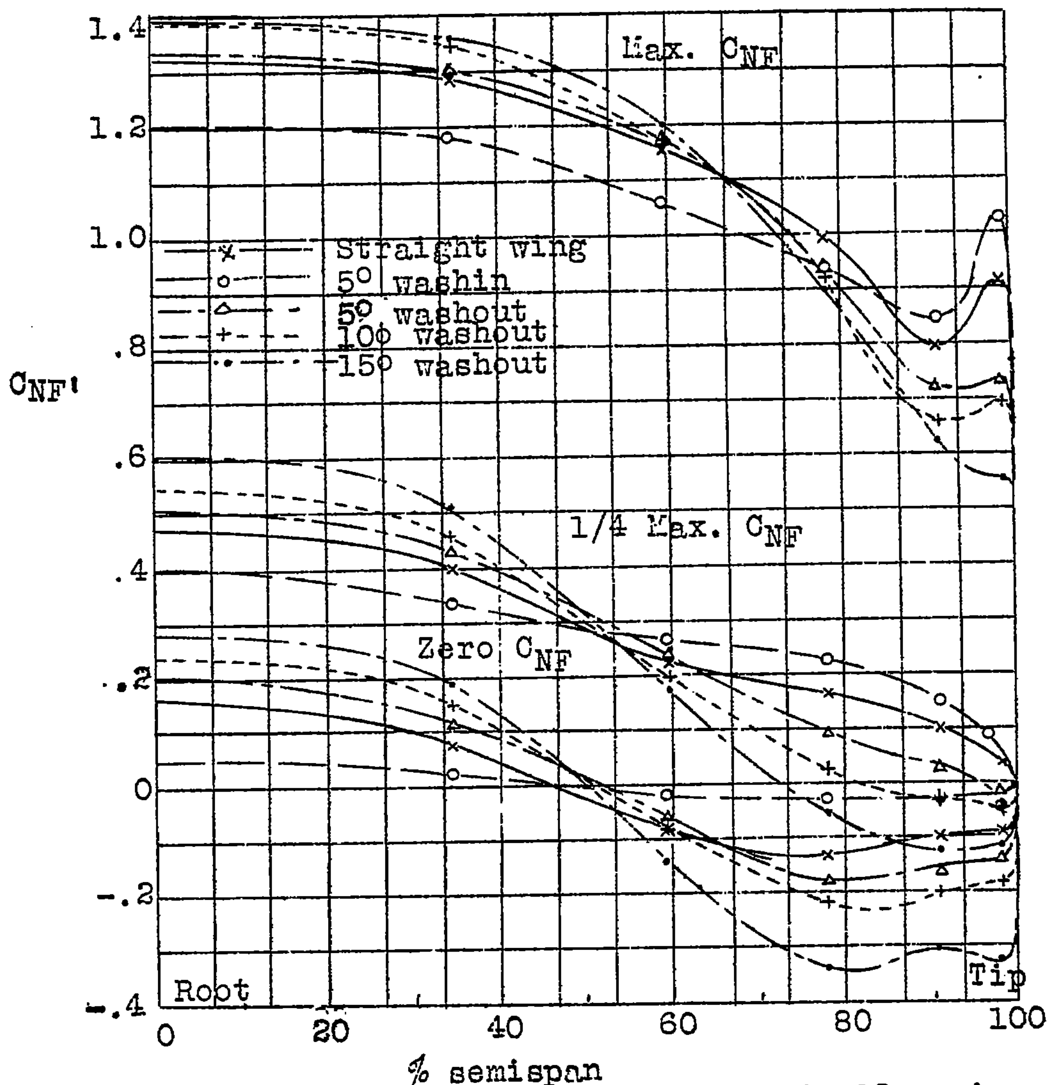


Fig.5 Effect of twist on N.A.C.A. 86 semispan load distribution.

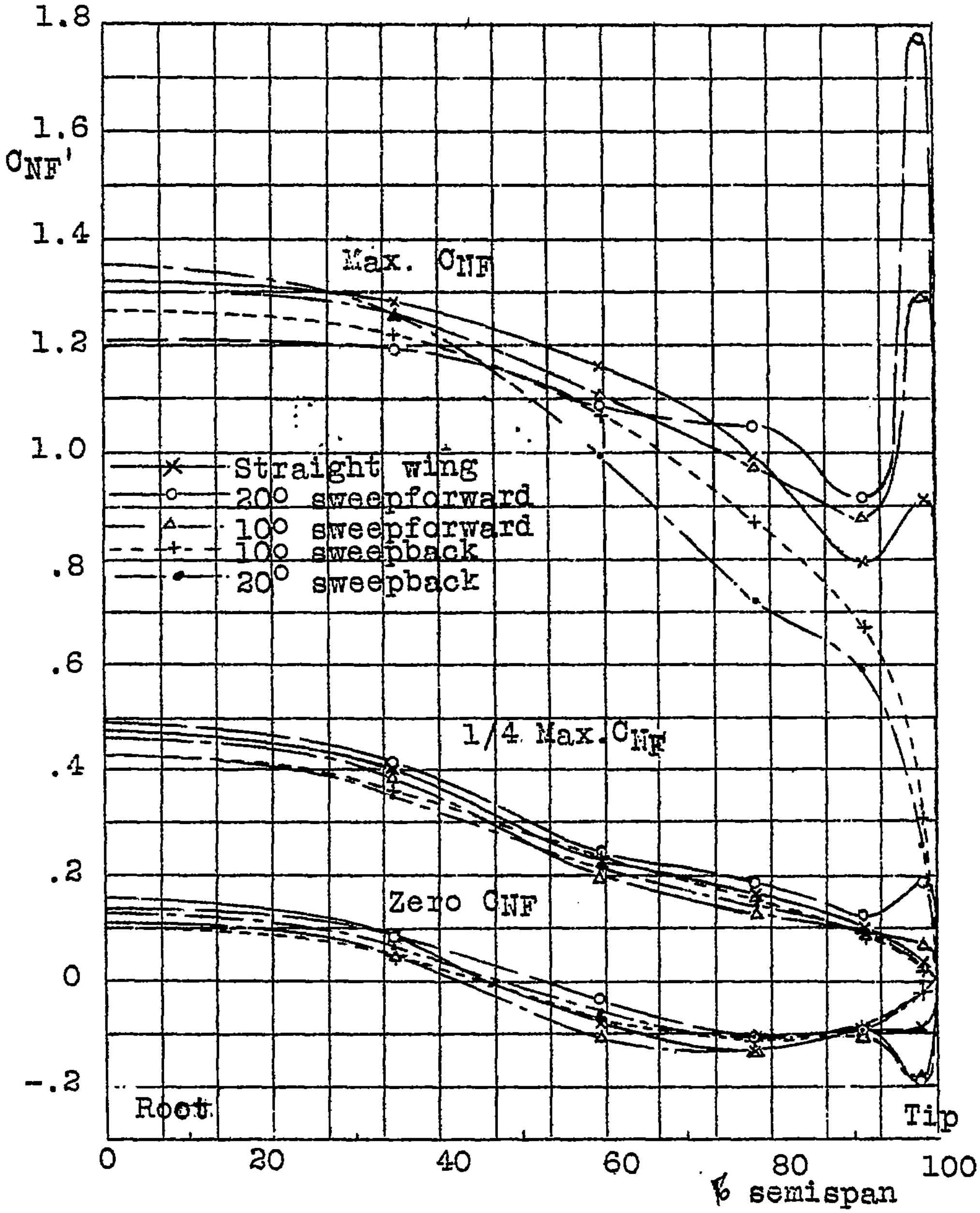


Fig.6 Effect of sweep on N.A.C.A.86 semispan load distribution.

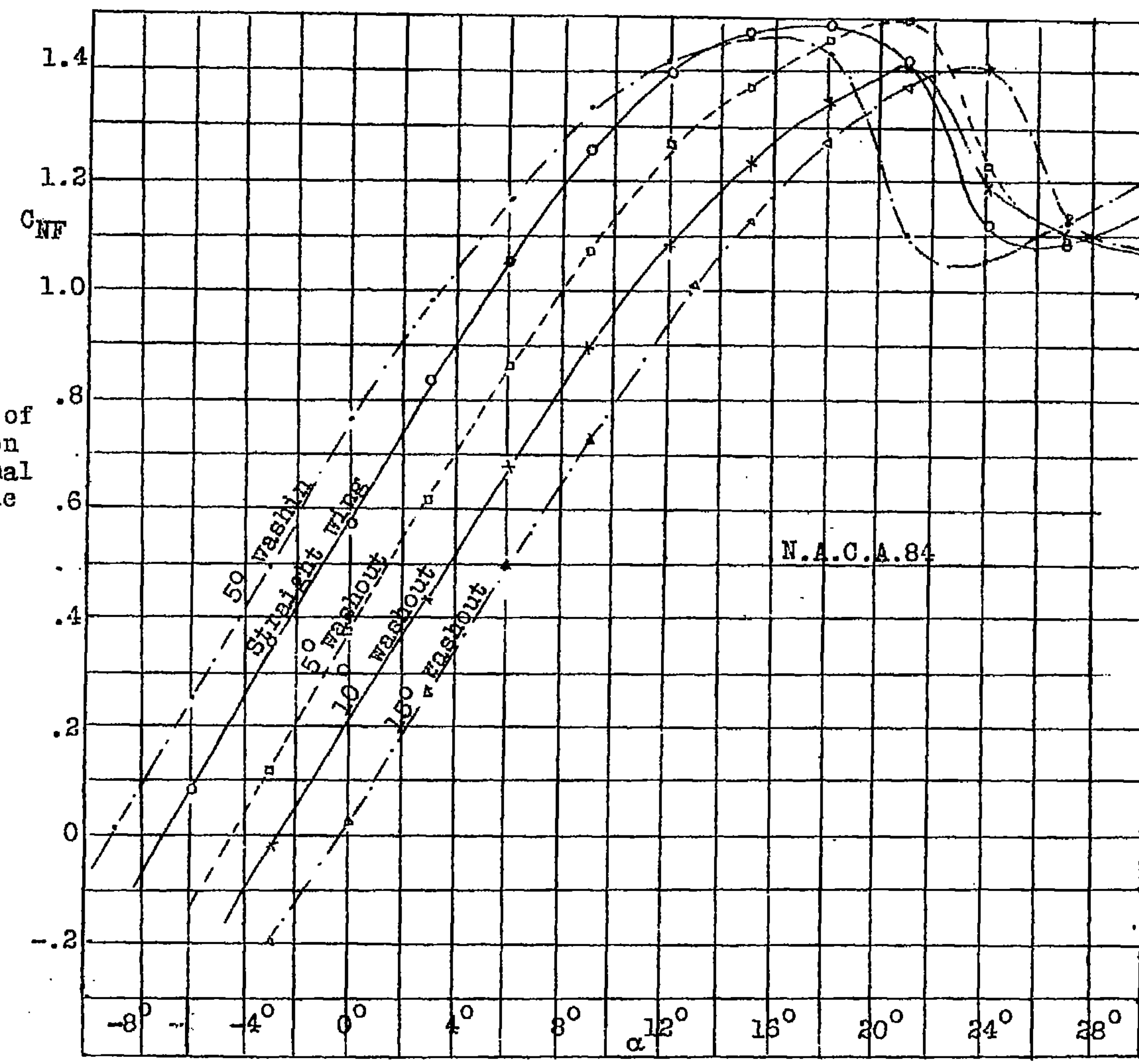


Fig.7 Effect of twist on the total normal force vs. angle of attack.

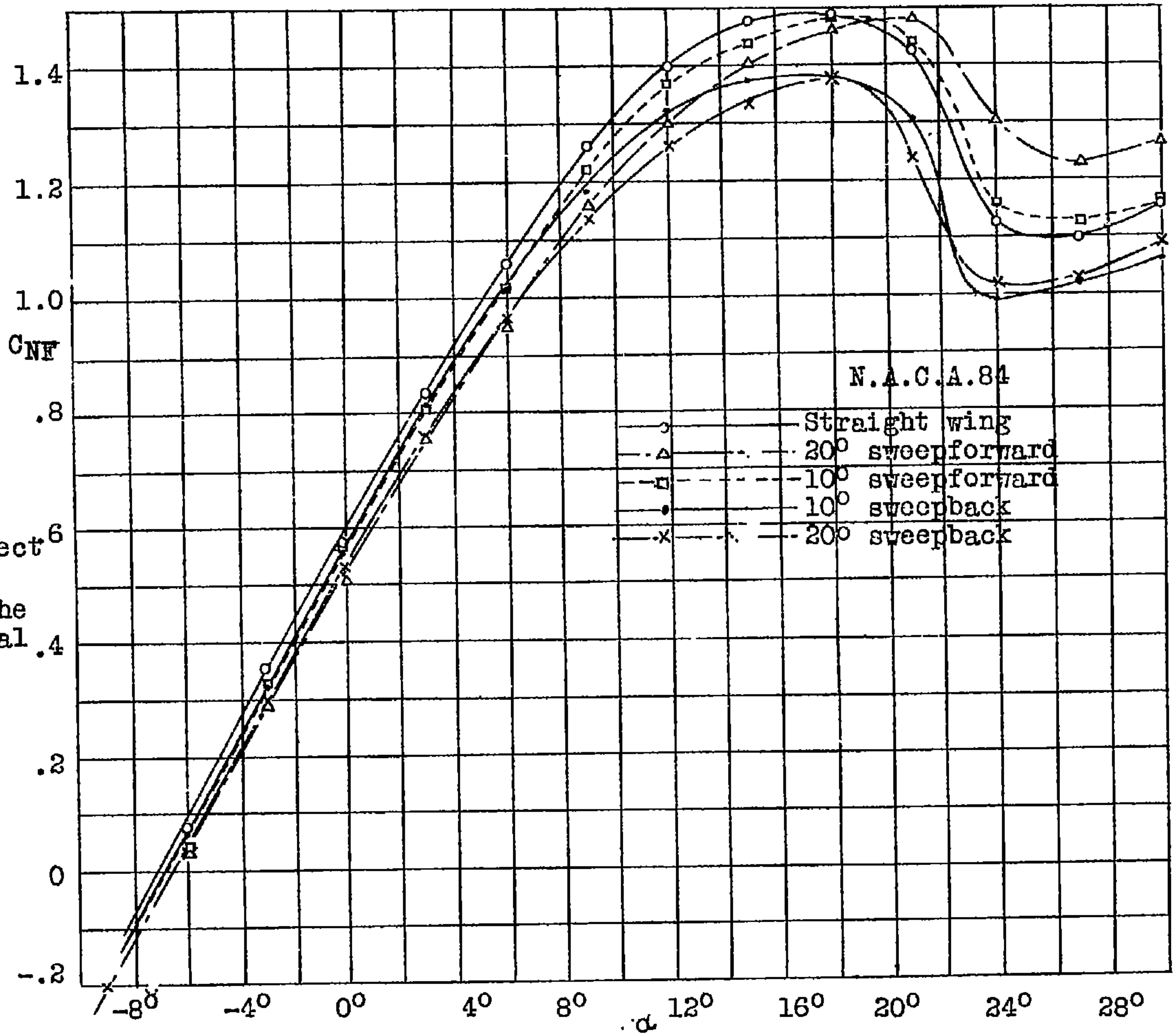


Fig.8 Effect of sweep on the total normal force vs. angle of attack.

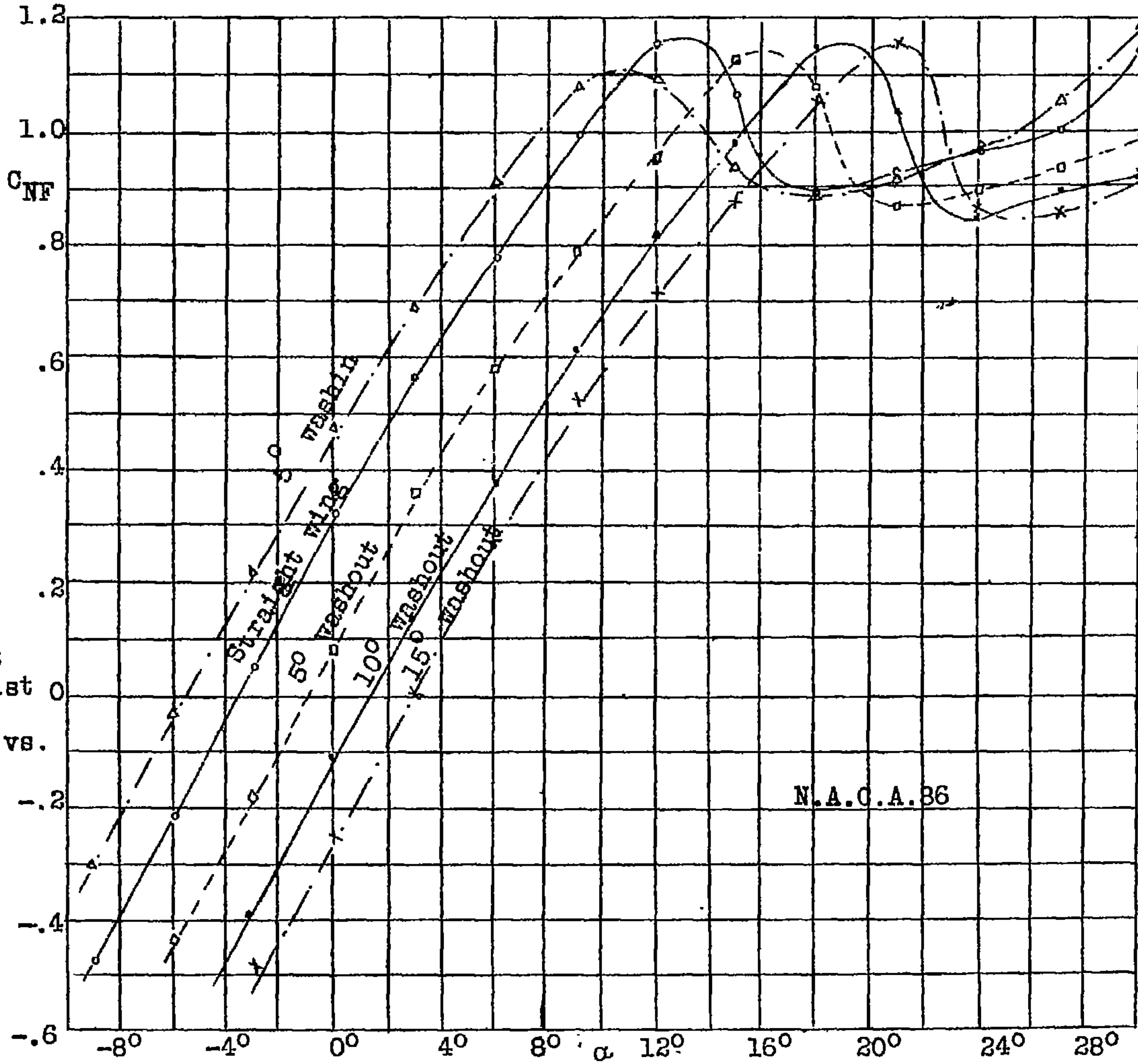


Fig.9 Effect of twist on the total normal force vs. angle of attack.

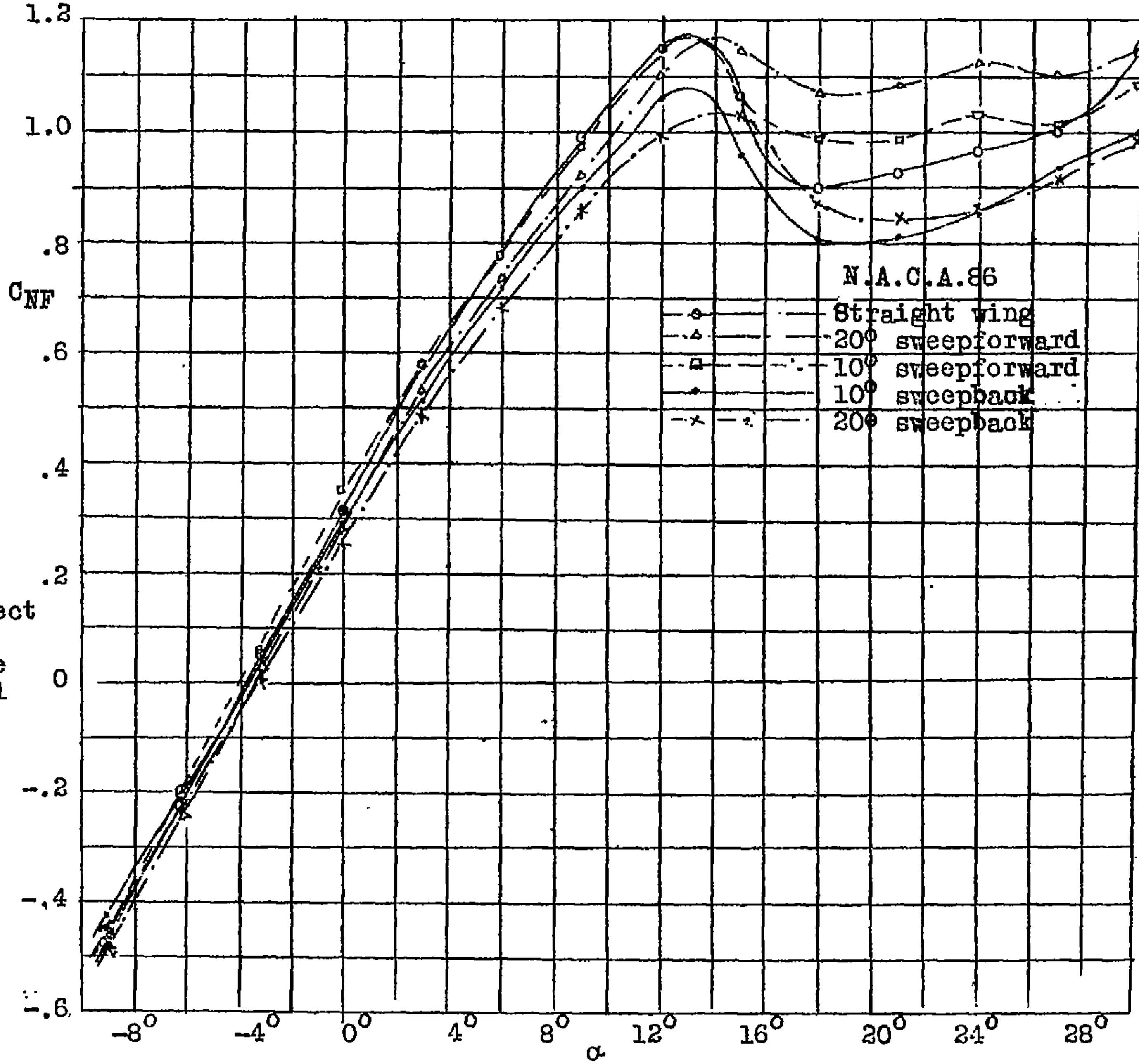


Fig.10 Effect of sweep on the total normal force vs. angle of attack.