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RESEARCH MEMORANDUM

LANGLEY FULL-SCALE-TUNNEL INVESTIGATION OF THE

FACTORS AFFECTING THE STATIC LATERAL-

STABILITY CHARACTERISTICS OF A

TYPICAL FIGHTER-TYPE AIRPLANE

By

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NATIONAL ADVISORY COMMITTEE

WASHINGTON

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

LANGLEY FULL-SCALE-TUNNEL INVESTIGATION OF THE

FACTORS AFFECTING THE STATIC LATERAL-

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TYPICAL FIGHTER-TYPE AIRPLANE

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SUMMARY

The factors that affoct the rate of ohange of rolling moment with yaw of a typical fightor-type airplane were investigated in the Langley full-scale tunnel on a typical fighter-type airplane. Eight ropresentative flight conditions were investigated in detail. The separate effects of propeller operation, of the wing-fuselage combination, and of the vertical tail to the offective dihedral of the airplane in each condition were determined.

The results of the tests showed that for the airplane with the propeller removed, the wing-fuselage combination had positive dihedral effect which increased considerably with increasing angle of attack for all conditions. Flap deflection decreased the dihedral effect of the wing-fuselage combination slightly as compared with that with the flaps retracted. The contribution of the vertical tail to C_{ij} of the airplane with the propeller removed decreased from about 0.0002 at $\alpha = 1.0^{\circ}$ to zero for angles of attack

greater than 8.9°. Flap deflection resulted in negative dihedral effect due to the vertical tail. Propeller operation decreased the lateral stability paremeter of the airplane for all the conditions investigated with larger decreases being measured for the flaps deflected conditions.

INTRODUCTION

Systematic wind-turnel tests were made in the Langloy fullscale tunnel to determine the factors affecting the static directional and lateral stability characteristics of a typical fightertype airplane. The results of the directional stability tests

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are given in reference 1. The present report gives the results of the tests made to determine the lateral stability characteristics.

The lateral stability tests consisted of the determination of the rolling moments of the airplane in yaw for a wide range of flight conditions. For each of the flight conditions investigated, teste were made of the complete airplane, of the airplane less the propeller, of the airplane less the vertical tail, and of the airplane less both the propeller and the vertical tail. The effect of landing-flap deflection on the lateral stability characteristics was also investigated. The data thus obtained permitted determinations of the separate contributions of the propeller, of the wing-fuselage combination, and of the vertical tail to the effective dihedral of the complete airplane.

SYMEOLS

cL	lift coefficient (Lift/q _o S)
c,	rolling-moment coefficient $(L/q_{o}Sb)$
Tc	effective thrust coefficient $(T_{e}/2q_{o}D^{2})$
Q _C	torque coefficient (Q/2q _o D ³)
L	moment about X-axis; positive when it tends to depress right wing
Te	effective propeller throat $(X_R - X^{\dagger})$
x _R	recultant force along X-axis with propeller operating
χı	force along X-axis, propeller removed
Q.	propellor torque
D	propeller diameter (13.08 ft)
S	wing area (334 sq ft)
ď	wing span (42.83 ft)
ψ	angle of yaw, degrees; positive with left wing forward
α	angle of attack of fuselage reference line relative to

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 δ_{r} angle of flap deflection, degrees

β propeller blade angle at 0.75 radius, degrees

q free-stream dynamic pressure

V₁ indicated airspeed

AIRPLANE

The tests were made of the Grumman XF6F-4, which is a low midwing eingle-place fighter airplane weighing about 11,400 pounds and equipped with a Pratt & Whitney R-2800-27 engine rated at 1600 horsepower at 2400 rpm at an altitude of 5700 feet. A three-view drawing of the airplane showing the principal dimensions and eurface areas is given in figure 1. Details of the vertical tail surface are given in figure 3 of reference 1. Photographe of the airplane mounted on the balance-support struts in the Langley full-scale tunnel are given as figure 2. The vertical tail was removed from the airplane for some of the tests and was replaced by a fairing shown in the photograph of figure 3.

METHODS AND TESTS

<u>Teets</u>.- All the teste were made with the airplane landing gear retracted and the cowling flape closed at a tunnel airepeed of approximately 60 miles per hour, which corresponds to a Reynolds number of approximately 4,380,000 based on a mean wing chord of 7.80 feet. The rudder was locked in the neutral for all the teste with the vertical tail in place. No attempt was made in the teste to duplicate the "blow-up" characteristics of the landing flaps.

The separate effects of the airplane component parts on the rolling moments of the complete airplane were determined for the eight representative flight conditions summarized in table I. Forces and momente wers measured on the airplane for each

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flight condition at approximately 5° increments of angle of yaw between $\pm 15^{\circ}$. For each flight condition, tests were made of the airplane with the propeller both removed and operating and with the vertical tail surface both removed and in place.

For the tests with the propeller operating, it was desired to simulate the variations shown in figure 4 of thrust and torque coefficient with lift coefficient for constant-power operation at sea level. It was found that these relationships could very nearly be reproduced with a constant propeller-blade-angle setting of 24.8° measured at the 0.75 radius; hence, this blade-angle setting was used for all the tests with the propeller operating. A comparison of the variation of thrust coefficient with torque coefficient for constant-power operation and for the propeller with a blade-angle setting of 24.8° messeured at the 0.75 radius is shown in figure 5. For the idling-power conditions, the engine was run at the lowest speed considered possible (700 rpm) without fouling the engine spark plugs. The thrust and torque coefficients thus obtained for the idling-power conditions were 0.01 and 0.005, respectively.

<u>Precision of measuremente</u>. The accuracy of the resulte is shown by the scatter of the test points of figures 6 and 7. Although considerable scatter is shown in some cases, it is believed that the fairing of the curves represents a mean evaluation of the data. Deviations of the test results from zero for apparently symmetrical conditions are probably due to differences in the airplane on the two sides of the plane of symmetry and to asymmetries in the tunnel flow.

RESULTS AND DISCUSSION

The data are given in etandard nondimensional coefficient form with respect to the stability area end center-of-gravity location shown in figure 1. The stability area are a system of axea having their origin at the center of gravity and in which the Z-axis is in the plane of symmetry and perpendicular to the relative wind, the X-axis is in the plane of symmetry and perpendicular to the Z-axie, and the Y-axis is perpendicular to the plane of symmetry.

The results of the force tests are given in figures 6 and 7 which show the variations of C_1 with Ψ for each of the eight test conditions listed in table I. For each test condition, curves are presented for the complete airplane, for the airplane with the propeller removed, for the airplane with the vertical tail removed, and for the airplane with both the propeller

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and the vertical tail removed. No test points are shown in figures 6 and 7 for the propellar removed data as these data were obtained from faired curves. Values of $C_{l,j}$ for the complete

airplane in each flight attitude investigated are given in table I. From these values of $C_{l_{1}}$ the effective dihedral can be determined, assuming that a $C_{l_{1}}$ of 0,0002 is equivalent to 1⁰ of effective dihedral.

Tests with Propeller Removed

Wing-fuselage combination .- Values of Cly for the wing-

fuselage combination are shown plotted in figure 8 as a function of angle of attack for flaps retracted and flaps deflected 50°. These values of $C_{l,\psi}$ were obtained from the results shown in figure 7 at small angles of yaw (between $\psi = \pm 5^{\circ}$) for the airplane with the propeller and the vartical tail removed. As shown in figure 8 the wing-fuselage combination has positive dihedral effect which increases with angle of attack both with the flaps retracted and with flaps deflected 50°. With flaps retracted the value of $C_{l,\psi}$ increases from 0.0012 at $\alpha = 1.0^{\circ}$ to about 0.0022 at $\alpha = 12.3^{\circ}$. Flap deflection decreased the value of $C_{l,\psi}$ slightly throughout the angle-of-attack range investigated.

Theoretical computations were made in an affort to account for the large increases in $C_{L_{ij}}$ with angle of attack. The results of these computations given in figure 16 of reference 2 indicate a value of $C_{l_{ij}}$ for the wing alone of 0.00146. No account is taken in the theory for the effect of wing-tip shape. Reference 3 shows large increases in the value of $C_{l_{ij}}$ with angle of attack for a wing having blunt tips. It is expected from the data of reference 4 that the low midwing position on this airplane would produce wing-fuelage interference tending to decrease the value of $C_{l_{ij}}$ with angle of attack. It is indicated, therefore, from the data of figure 8 that the effects of blunt wing tips predominate.

<u>Vertical tail</u>.- The increments of $C_{i\psi}$ at small angles of yaw ($\psi = \pm 5^{\circ}$) due to the addition of the vertical tail to the airplane are given in figure 9. With the flaps retracted, the contribution of the vertical tail to $C_{i\psi}$ decreases from about 0.0002 at $\alpha = 1.0^{\circ}$ to about 0 for angles of attack greater

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than 8.9° . (See fig. 9.) At low angles of attack the center of pressure of the vertical tail is above the center of gravity of the airplane which results in an increment of positive dihedral effect. The flow conditions of the tail are such as to produce a small decrease of $C_{l_{10}}$, with engle of attack. (See reference 1.)

It is believed, however, that as the angle of attack is increased the center of pressure of the vertical tail is lowered with respect to the center of gravity of the airplane and thus has the predominate effect on the decrease of ΔC_{klr} .

Flap deflection resulted in negative dihedral effect due to the vertical tail throughout the range of angle of attack investigated. (See fig. 9.) While the reason for this change in the increment of $C_{\lambda\psi}$ due to the vertical tail with flap deflection is not apparent, it is believed that change in flow conditions

at the tail due to flap deflection may be the cause for this change,

Effects of Propeller Operation

The values of C_{1,1} of the complete airplane with the pro-

peller operating were obtained from figure 6 and are listed in table I and are compared with the values of C_{LM} for the airplane

with the propeller removed. For the airplane with the flaps retracted and deflected 50° , propeller operation decreased the values of C_{l,l_l} at angles of yaw between $\pm 5^{\circ}$ for all the conditions

investigated. With the flaps retracted a slight increase in effective dihedral with angle of attack was noted. These results are not what would normally be expected inasmuch as previously published data for this airplane and data for other airplanes of similar type indicate a decrease in effective dihedral with increasing angle of attack. With the flape deflected 50° , the decrease of effective dihedral due to propeller operation was about 0.0001 for the landing condition (idling power, $T_c = 0.01$), about 0.0007 for the approach condition (0.65 rated power, $T_c = 0.33$), and about 0.0009 for the wave-off condition (rated power, $T_c = 0.51$), as shown in table I.

The decrease in effective dihedral caused by propeller operation is due mainly to the fact that, when the airplane is yawed, the slipstream is deflected over the trailing-wing panel which increases the dynamic pressure, and consequently, the lift of the trailing wing. This increased trailing-wing lift produces rolling moments which tend to decrease the effective dihedral. The rotational component of the propeller slipstream tends to increase

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the effective dihedral as indicated by the sidewash angle values given in reference 1; however, this effect is overbalanced by the slipstream action on the yawed wing as shown in table I. These effects are larger with the flaps deflected because the lift increment due to the propeller slipstream over the wing with flaps deflected is greater than with the flaps retracted.

The effect of propeller operation on the effective dihedral of the wing-fuselage combination is shown in figure 7 which presents tail-removed curves of C_2 versus Ψ for the airplane with both the propeller operating and with the propeller removed. Values of $C_{L\psi}$ of the wing fuselage combination at small angles of yaw with the propeller operating are summarized in table I for all the conditions investigated. Values of $C_{L\psi}$ for corresponding angles

of attack but with the propeller removed are also given in table I for comparison. The curves of figure 7 with the propellers operating include both the direct effect of the propeller forces and the effect of slipstream passage over the wing-fuselage combination.

As shown by table I, propeller operation decreased the dihedral effect of the wing-fuselage combination appreciably for all conditions except those with idling power. For the two idling-power conditions (gliding and landing) the effect of propeller operation was negligible. As expected, the decrease in dihedral effect due to propeller operation was greater for the flaps-deflected conditions than for the flaps-retracted conditions. For the wave-off condition (rated power $T_c = 0.51$), the value of $C_{1,b'}$ of the

wing-fuselage combination was decreased 0.0011 as a result of propeller operation. At the same thrust coefficient but with flaps retracted (climb condition), the value of $C_{l,M}$ of the wing-fuselage

combination decreased only 0.0002 due to propeller operation.

The effects of the propeller slipstream on the contribution of the vertical tail to the effective dihedral is shown in table II which gives increments of C_{hh} due to the vertical tail with the

propeller removed and with the propeller operating. The results of table II show no consistent variations of $\Delta G_{l_{1}}$ with propeller

operation; however, the effects of the propeller slipstream on the contribution of the vertical tail to the airplane effective dihedral are generally small.

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SUMMARY OF RESULTS

Data ere precented of measuremente made in the Langley fullecale tunnel on a typical fighter-type airplane to investigate the factore affecting the rate of change of rolling moment with yew of a fighter-type airplane. Although these data are quentitative for this particular airplane, the trends are believed to be generally applicable to reasonably similar airplanes. The results are summerized as follows:

1. With the flape both retracted and deflected 50° , the wingfuse lage combination with the propoller removed had positive dihedral effect at angles of yaw between $\pm 5^{\circ}$ which increased considerably with increasing angle of attack.

2. Flap deflection docreased the lateral-stability parameter C_{ly} of the wing-fueelage combination with propeller removed slightly at small angles of yaw as compared with that obtained with flape retracted.

3. For the airplane with the propeller removed and with flape retracted, the contribution of the vertical toil to $c_{h_{l_f}}$

decreased from about 0.0002 at $\alpha = 1.0^{\circ}$ to about zero for angles of attack greater than 8.9° . Flap deflection resulted in negative dihedral effect due to the vertical tail throughout the range of angle of attack investigated.

4. Propeller operation decreased the lateral stability parameter of the airplane at small angles of yaw for all the conditions investigated. With the flaps retracted the effect of propeller operation was small; however, with the flaps deflected 50° the decrease of effective dihedral due to propeller operation was about 0.0001 for the landing condition, NACA RM No. 16118

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about 0.0007 for the landing-approach condition, and about 0.0009 for the wave-off condition.

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

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TABLE I .- REFECT OF PROPELLER OPERATION ON THE VALUES OF CL OF THE

COMPLETE AIRPLANE AND OF THE WING-FUSELAGE COMBINATION

	COMPLETE AIRPLANE	AND O	F THE	WIING	FUSELAGE	COMBINATIO	N		NACA
	a		•			,	С _{2.} (Ъ)		No.
Condition	. Power	δ _f (deg)	a (deg)	CL (a)	Complete	airplane	Wing-fuselage	combination	E
			, ,,		Propeller operating	Propeller removed	Propeller operating	Propeller . removed	
Climb Climb Climb Climb Glide Landing approach Wave-off Landing	Rated $(T_0 = 0.05)$ Rated $(T_c = 0.11)$ Rated $(T_c = 0.30)$ Rated $(T_c = 0.51)$ Idling $(T_c = 0.01)$ 0.65 rated $(T_c = 0.33)$ Rated $(T_c = 0.51)$ Idling $(T_c = 0.01)$	0 0 0 50 50 50	1.0 3.4 8.9 12.3 9.2 5.8 4.9 11.8	0.24 .43 .96 1.39 .83 1.37 1.39 1.58	0 .0014 .0014 .0018 .0020 .0019 .0006 .0003 .0015	0.0014 .0017 .0020 .0022 .0020 .0013 .0012 .0016	0.0009 .0011 .0016 .0020 .0019 .0008 .0004 .0021	0.0012 .0014 .0020 .0022 .0020 .0016 .0015 .0020	

^BValues given for $C_{I_{\rm L}}$ are values with the propeller operating.

^bValues given for slopes are average values between $\psi = 5^{\circ}$ and $\psi = -5^{\circ}$.

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Condition	a	δ _f	ړيک (e	^{يار} ت .)
Condition	(deg)	(deg)	Propeller operating	Fropeller removed
Climb	1.0	0	0.0005	0.0002
Climb	3.4	Ο.	.0003	.0003
Climb	8.9	0	.0002	0
Climb	22.3	0	0	0
Glide	9.2	0	0	0
Landing approach	5.8	50	0002	0003
Wave off	4.9	50	0001	0003
Landing	11.8	50	0006	0004

TABLE II .- CONTRIBUTION OF VERTICAL TAIL TO $C_{2\psi}$

^aValues given for slopes are average values between $\psi = 5^{\circ}$ and $\psi = -5^{\circ}$.

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Wing area (including ailerons, flaps, and
48.5 sq ft of body area)
Control surface areas:
Full flap area (NACA slotted)
Total horizontal tall surface area77.84 sq ft
Fin area (incl. 1.9 sq ft of cantained
rudder balance)
Rudder area aft af hinge
(incl. 0.62 sq ft of tab)

Engine..... Pratt and Whitney R-2800-27 BHP normal rating, 1600 at 2400 rpm at 5700 ft Hamilton Standard Hydromatic Propeller, Blade Design 6501A-0 Propeller gear ratio, 2:1 Gross weight, 11,400 lb





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(a) Front view

Figure 2.- Airplane mounted for tests in the Langley full-scale tunnel.



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(b) Side view.

Figure 2.- Concluded.

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Figure 3.- Three-quarter side view of airplane with vertical tail removed and tail fairing installed.

Fig. 3

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Fig. 4

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Rated power	/600	2400
0.65 rated power	1040	/960
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NACA RM No. L6L18

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 Investigation of the Factors Affecting the Static Lateral-Stability Charecteristics of a Typical Fighter-Type Airplane

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ABSTRACT:

Results of tests on Grumman F6F-4 fighter indicated that the wing-fuselage combination with propeller removed had a positive dihedral effect which increased with angle of attack. Flap deflection decreased dihedral effect as compared to that with the flaps retracted. Addition of the vertical tail tended to decrease the rate of change of the rolling moment with yaw as the angle of attack increased. Propeller operation materially decreased the lateral stability parameter of this fighter.

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