EFFECT OF SPEED BRAKES ON THE SUPERSONIC AERODYNAMIC CHARACTERISTICS OF A VARIABLE-SWEEP TACTICAL FIGHTER MODEL AT MACH NUMBERS FROM 1.60 TO 2.50

by Celia S. Richardson

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SUMMARY

An investigation has been made in the Langley Unitary Plan wind tunnel to determine the effect of various speed-brake configurations on the aerodynamic characteristics of a current multimission tactical fighter model. The speed-brake configurations, which included ungapped and gapped brakes with variations in area, location, planform, and deflection angle, were tested at Mach numbers from 1.60 to 2.50 for a wing-leading-edge sweep angle of 72.5°. Tests were made through an angle-of-attack range from about -4° to 28° and at angles of sideslip from about -6° to 11°. The test Reynolds number was 3.0 \times 10^6 \text{ per foot} \ (9.84 \times 10^6 \text{ per meter}).

The results indicated the drag values of a gapped and an ungapped brake configuration were about the same; even though the gapped speed brakes were somewhat smaller than the ungapped brakes.

The ungapped speed brakes generally increased the directional stability of the model. The gapped speed brakes generally reduced the directional stability of the model particularly at the higher test Mach numbers.

INTRODUCTION

The National Aeronautics and Space Administration is currently conducting wind-tunnel studies directed toward the development of a multimission, variable-sweep wing, tactical fighter aircraft for use by the military services. References 1 to 15 present some of the results of these studies.

The purpose of the current investigation is to determine the effectiveness of various speed-brake configurations and the effects of these brakes on the static stability and performance of the aircraft.
This report presents data for the wing-leading-edge sweep angle of 72.5° and shows the effects of variations in area, deflection angle, and location of the speed-brake configurations. The tests were performed at angles of attack from about -4° to 28° and at angles of sideslip from about -6° to 11°. The test Mach numbers ranged from 1.60 to 2.50, and the test Reynolds number was $3.0 \times 10^6$ per foot ($9.84 \times 10^6$ per meter).

SYMBOLS

The results of this investigation are presented as force and moment coefficients, with the longitudinal characteristics referred to the stability-axis system and the lateral parameters referred to the body-axis system. The present data obtained for a wing-leading-edge sweepback of 72.5° are based on the wing geometry in a 16° sweepback position (see table 1) in order to have them compatible with data from references 1 to 15.

- $b$ wing span, inches (meters)
- $\bar{c}$ wing mean aerodynamic chord, inches (meters)
- $C_D$ drag coefficient, $\frac{\text{Drag}}{qS}$
- $C_{D,b}$ duct-exit-plug base-drag coefficient, $\frac{\text{Duct-exit-plug base drag}}{qS}$
- $C_{D,c}$ fuselage-chamber-drag coefficient, $\frac{\text{Chamber drag}}{qS}$
- $C_{D,i}$ internal-drag coefficient for primary and secondary ducts, $\frac{\text{Internal drag}}{qS}$
- $C_L$ lift coefficient, $\frac{\text{Lift}}{qS}$
- $C_{l,\beta}$ effective-dihedral parameter, $\frac{\partial C_l}{\partial \beta}$, per degree
- $C_m$ pitching-moment coefficient, $\frac{\text{Pitching moment}}{qSc}$
- $C_{m,o}$ pitching-moment coefficient at $C_L = 0$
- $C_{n,\beta}$ directional-stability parameter, $\frac{\partial C_n}{\partial \beta}$, per degree
- $C_{Y,\beta}$ side-force parameter, $\frac{\partial C_Y}{\partial \beta}$, per degree
L/D  lift-drag ratio
M  free-stream Mach number
$p_t$  stagnation pressure, pounds/inch$^2$ (newtons/meter$^2$)
$q$  free-stream dynamic pressure, pounds/foot$^2$ (newtons/meter$^2$)
r  radius of curvature, inches (meters)
S  wing area, feet$^2$ (meters$^2$)
$T_t$  stagnation temperature, degrees Fahrenheit (degrees Kelvin)
$\alpha$  angle of attack of wing (wing reference chord at 1$^\circ$ incidence to water line), degrees
$\beta$  angle of sideslip of model center line, degrees
$\delta_{S.B.}$  speed-brake deflection angle referenced to model, degrees
$\Lambda$  wing-leading-edge sweep angle, degrees

Abbreviations:

B.L.  buttock line
$HL$  hinge line
S.B.  speed brake
Sta  fuselage station
W.L.  water line
APPARATUS AND TESTS

Tunnel

Tests were conducted in the low Mach number test section of the Langley Unitary Plan wind tunnel. This tunnel is a variable-pressure, continuous-flow tunnel having a test section approximately 4 feet square and 7 feet long (1.22 meters square and 2.13 meters long). The nozzle leading to the test section is of the asymmetric sliding-block type which permits a continuous variation in test-section Mach number from about 1.5 to 2.9.

Model

Details of the 1/24-scale model are shown in figure 1. Dimensional details are listed in table I. The model was a high-wing configuration with the wing at 1° incidence with respect to water lines and had a wing-glove fairing into the fuselage.

TABLE I.- GEOMETRIC CHARACTERISTICS OF MODEL

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing area, S</td>
<td>0.911 ft² (0.085 m²)</td>
</tr>
<tr>
<td>Wing span, b</td>
<td>31.500 in. (80.010 cm)</td>
</tr>
<tr>
<td>Wing mean aerodynamic chord, ( \bar{c} )</td>
<td>4.521 in. (11.483 cm)</td>
</tr>
<tr>
<td>Fuselage chamber area</td>
<td>0.012531 ft² (11.64 cm²)</td>
</tr>
<tr>
<td>Duct-inlet area (one side)</td>
<td>0.012945 ft² (12.03 cm²)</td>
</tr>
<tr>
<td>Duct-exit area (one side)</td>
<td>0.014142 ft² (13.15 cm²)</td>
</tr>
<tr>
<td>Duct-exit-plug base area</td>
<td>0.016433 ft² (15.27 cm²)</td>
</tr>
<tr>
<td>Duct-exit angle with respect to wing reference line</td>
<td>-4°32'</td>
</tr>
</tbody>
</table>

The speed brakes investigated were of two types, gapped and ungapped, and were positioned on the under side of the fuselage. The details of the speed brakes are shown in figure 2. The \( D_{8e} \) and \( D_{8f} \) speed brakes (fig. 2(a)) represent 25 percent and 40 percent increases in planform area to the \( D_8 \) speed brake while maintaining the basic shape of the \( D_8 \). The \( D_{11} \) speed brake (fig. 2(b)) has a 1-inch (2.54-cm) gap at the hinge line, and the \( D_{11}^{\delta} \) is the \( D_{11} \) configuration mounted 4.437 inches (11.27 cm) aft of the \( D_{11} \) location. The \( D_{13} \) is a T-shaped gapped configuration having about the same area as \( D_{11} \) and is located 4.696 inches (11.93 cm) aft of the \( D_{11} \) location.

In order to relate this report with references 1 to 15, the following table of model component designations is provided:
Component | Designation
---|---
Body | B_{42}
Wing glove | G_{17}
Wing | W_{29}
Horizontal tail | H_{13}
Vertical tail | V_{38}
Inlet spike | I_{43}
Nozzle | N_{32}
Ventral fin (twin) | V_{29}
Dorsal fairing | X_{25}
Ungapped speed brakes | D_{8}, D_{8e}, D_{8f}
Gapped speed brakes | D_{11}, D_{11}^{a}, D_{13}

Note: For the present report, the basic configuration is B_{42}G_{17}H_{13}I_{43}N_{32}V_{29}V_{38}W_{29}X_{25}.

Test Conditions

The following table presents the conditions at which the tests were performed:

<table>
<thead>
<tr>
<th>M</th>
<th>T_t</th>
<th>P_t</th>
<th>Reynolds number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°F</td>
<td>°K</td>
<td>lb/in^2 abs</td>
</tr>
<tr>
<td>1.60</td>
<td>150</td>
<td>338</td>
<td>11.89</td>
</tr>
<tr>
<td>2.16</td>
<td>150</td>
<td>338</td>
<td>14.87</td>
</tr>
<tr>
<td>2.50</td>
<td>150</td>
<td>338</td>
<td>17.61</td>
</tr>
</tbody>
</table>

The dewpoint, measured at stagnation pressure, was maintained below -30°F (239°K) for all tests in order to assure negligible condensation effects.

All configurations incorporated 1/16-inch-wide (0.159-cm-wide) transition strips composed of No. 80 carborundum grit (nominal diameter of 0.008 in. (0.20 mm)) embedded in acrylic plastic. These strips were located 1/2 inch (1.27 cm) rearward (streamwise) on the wing, wing glove, horizontal and vertical tails, and ventral fins. In addition, a 1/16-inch-wide (0.159-cm-wide) transition band was placed 1 inch (2.54 cm) rearward around the model nose.

Measurements

Aerodynamic forces and moments were measured by means of a six-component electrical strain-gage balance housed within the model. The balance in turn was rigidly
fastened to a sting-support system. Fuselage chamber pressures and duct-exit-plug base pressures were measured by means of single static orifices located in the balance cavity and at the duct-exit-plug base, respectively.

**Corrections**

Angles of attack and sideslip have been corrected for both tunnel-flow angularities and deflection of sting and balance caused by aerodynamic loads. The drag data have been adjusted to a condition of free-stream static pressure acting over the fuselage and duct-exit-plug bases. In addition, the drag data have been adjusted to zero momentum and pressure losses at the duct exits. Typical values of these corrections are presented in figure 3.

**PRESENTATION OF RESULTS**

The results of this investigation are presented in the following figures:

<table>
<thead>
<tr>
<th>Figure</th>
<th>Effect on longitudinal characteristics of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Speed brakes $D_8$, $D_{8e}$, and $D_{8f}$ in pitch</td>
</tr>
<tr>
<td>5</td>
<td>Speed brakes $D_{11}$, $D_{11}^a$, and $D_{13}$ in pitch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure</th>
<th>Effect on lateral characteristics of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Speed brakes $D_8$, $D_{8e}$, and $D_{8f}$</td>
</tr>
<tr>
<td>7</td>
<td>Speed brakes $D_{11}$, $D_{11}^a$, and $D_{13}$</td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSION**

**Longitudinal Characteristics**

The aerodynamic characteristics in pitch for the various speed-brake configurations are presented in figures 4 and 5.

In comparison with the basic model (speed brakes retracted) all of the $D_8$-type speed-brake configurations caused large increases in minimum drag and corresponding decreases in $(L/D)_{max}$ (fig. 4). The addition of the basic speed brake $D_8$, at a deflection angle of $50^\circ$, more than doubled the minimum drag of the basic model at all Mach numbers. Increases in the area or deflection angle of the speed brake produced an expected increase in minimum drag over the minimum drag values obtained with the $D_8$ brake configuration at $\delta_{S,B} = 50^\circ$. For example, the configuration with the $D_{8f}$ speed brake, which is the $D_8$ with 40 percent additional area, caused a 25 percent increase in
minimum drag over that obtained for a similar deflection of the Dg brake. At a deflection angle of 77°, the D8f configuration produced minimum drag approximately \(3\frac{1}{2}\) times greater than that for the basic model.

Deflection of the ungapped speed brakes generally caused an increase in \(C_{m,o}\) for the aircraft throughout the test Mach number range.

Deflecting the speed brakes caused a slight decrease in the lift-curve slope over that for the basic model. Increasing the area of the speed brakes, or increasing the deflection angle, caused a further decrease in the lift-curve slope. The linearity of the lift and pitching-moment curves was not materially affected by the addition of speed brakes to the model.

The results in figure 5 indicate that the D11, D11, and D13 speed brakes, at each of the deflection angles, produce effects on the aerodynamic characteristics in pitch of the model that are generally similar to those obtained with the D8-type speed brakes.

The D11 speed brake, deflected 77°, provided the largest increase in minimum drag and gave about the same minimum drag values as that obtained with the D8f brake deflected 77°. Moving the D11 aft 4.437 inches (11.27 cm), which is the D11 configuration, yields drag results comparable to those for the D11 speed brake.

The T-shaped D13 brake, which has an area comparable to the D11 and is located 0.259 inch (0.66 cm) further aft than the D11, had slightly less drag than the D11 at all three Mach numbers.

At the two higher Mach numbers, the D11 and the D13 brakes reduced the \(C_{m,o}\) of the basic model. At all Mach numbers, the D11 produced slight increases in the basic model \(C_{m,o}\) values.

The D8f and the D11 speed brakes are located at approximately the same position on the fuselage and are the most effective brakes for increasing the minimum drag of the basic model throughout the test Mach number range. The drag values of the D8f configuration and the D11 configuration are about the same; however, the D11 speed brake is somewhat smaller than the D8f and thus indicates increased braking effectiveness for the gapped brakes.

Lateral Characteristics

The lateral aerodynamic characteristics of the model with the various speed-brake configurations are presented in figures 6 and 7.

All the D8 series of speed-brake configurations were directionally stable and, with the exception of the D8 brake deflected 50°, produced an increase in the directional stability at the higher angles of attack over that for the basic model. The D8 configuration
at the 50° deflection angle had less directional stability than the basic model at all test Mach numbers and was only marginally stable at $M = 2.50$.

Each of the D8-type speed-brake configurations resulted in a positive effective dihedral for the model. At $M = 1.60$, above angles of attack of $6^\circ$, all the ungapped speed brakes slightly reduced the positive effective dihedral of the basic model. At the higher Mach numbers, throughout the angle-of-attack range, the positive effective dihedral was increased over that for the basic model.

The data in figure 7 show that with the exception of the D11 configuration at $M = 1.60$ and a deflection angle of $77^\circ$, these speed-brake configurations generally have an adverse effect on the directional stability of the model.

All the gapped speed-brake configurations, except the D11 at the higher angles of attack at $M = 1.60$, resulted in an increase in positive effective dihedral.

In comparison, the D8-type speed brakes generally increase the directional stability of the model; whereas, the D11- or D13-type speed brakes generally reduced the directional stability of the model, particularly at the higher test Mach numbers.

CONCLUSIONS

An investigation has been conducted to determine the effects of various speed-brake configurations on the aerodynamic characteristics of a current multimission tactical fighter model. Tests at Mach numbers from 1.60 to 2.50 indicate the following conclusions:

1. The drag values for a gapped and an ungapped brake configuration were about the same; even though the gapped speed brakes were somewhat smaller than the ungapped brakes.

2. The ungapped speed brakes generally increased the directional stability of the model; whereas, the gapped-type speed brakes generally reduced the directional stability of the model particularly at the higher test Mach numbers.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., February 6, 1968,
126-13-02-20-23.
REFERENCES


Figure 1.- Model details. (All dimensions are in inches unless otherwise noted; 1 in. = 2.54 cm.)
1.072 - D8e and D8f

Sta. 19.698

Fuselage Contour

W. L. 5.880

Hinge line

0.417

1.020

1.072

-2.635

D8

Sta. 19.708

Fuselage Contour

W. L. 5.880

Hinge line

r = 0.436

0.417

1.000

1.020

1.934

2.287

D8f

D8e

D8e and D8f

(a) Ungapped speed brakes.

Figure 2.- Speed brake details. (All dimensions are in inches unless otherwise noted; 1 in. = 2.54 cm.)
(b) Gapped speed brakes.

Figure 2.- Concluded.
(a) Base- and chamber-drag coefficients.

Figure 3.- Typical values of base-, chamber-, and internal-drag coefficients.
Figure 3.- Concluded.
Figure 4.- Effect of $D_8$, $D_{8e}$, and $D_{8f}$ speed brakes on the aerodynamic characteristics of the model in pitch.

(a) $M = 1.60.$
(a) Concluded.

Figure 4.- Continued.
Figure 4.- Continued.

(b) $M = 2.16$. 

The diagram shows the variation of $C_{D}$ and $C_{L}$ with $L/D$. The legend includes symbols for different conditions, such as $S$, $B$, $\delta_{S}$, and $\delta_{B}$, with values and degrees indicated.
Figure 4.- Continued.
(c) $M = 2.50$.

Figure 4.- Continued.
Figure 4. Concluded.
Figure 5.- Effect of $D_{11}$, $D_{11}^{3}$, and $D_{13}$ speed brakes on the aerodynamic characteristics of the model in pitch.
Figure 5.— Continued.

(a) Concluded.
(b) $M = 2.16$.

Figure 5.- Continued.
Figure 5.- Continued.
Figure 5.- Continued.

(c) $M = 2.50$. 

Figure 5.- Continued.
(c) Concluded.

Figure 5.- Concluded.
Figure 6.- Effect of $D_8$, $D_{8e}$, and $D_{8f}$ speed brakes on lateral parameters of the model.

(a) $M = 1.00$. 

S. B. $\delta_{S.B. \text{,deg}}$

- off
- $D_8$ 50
- $\nabla_8$ 77
- $D_{8e}$ 77
- $\nabla_{8f}$ 50
- $D_{8f}$ 77
Figure 6. Continued.

(b) \( M = 2.16 \).

S. B. \( \delta_{S.B.}, \text{deg} \)

- off
- \( D_8 \) 50
- \( D_8 \) 77
- \( D_{8e} \) 77
- \( D_{8f} \) 50
- \( D_{8f} \) 77

\( \alpha, \text{deg} \)
Figure 6.- Concluded.
Figure 7.- Effect of $D_{11}$, $\theta_{11}$, and $D_{13}$ speed brakes on lateral parameters of the model.

(a) $M = 1.60$. 

Figure 7.- Effect of $D_{11}$, $\theta_{11}$, and $D_{13}$ speed brakes on lateral parameters of the model.
(b) $M = 2.16$.

Figure 7.- Continued.
Figure 7.: Concluded.

(c) $M = 2.50$.

Figure 7.: Concluded.
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—National Aeronautics and Space Act of 1958

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