RESEARCH MEMORANDUM
for the
Air Materiel Command, U. S. Air Force

PRELIMINARY RESULTS OF A FREE-FLIGHT INVESTIGATION
OF THE STATIC STABILITY AND AILERON CONTROL
CHARACTERISTICS OF 1/6-SCALE MODELS
OF THE BELL MX-776

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Preliminary Results of a Free-Flight Investigation of the Static Stability and Aileron Control Characteristics of \( \frac{1}{6} \)-Scale Models of the Bell MX-776

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Summary

An investigation of the static longitudinal stability, static directional stability, and aileron control characteristics at transonic and supersonic speeds is being made of \( \frac{1}{6} \)-scale rocket-propelled models of the Bell MX-776. A stability investigation has been made of two symmetrical models with controls undeflected and centers of gravity one-half and one-body diameter, respectively, ahead of the equivalent design center-of-gravity location of the full-scale version. Both models developed large normal-force coefficients in both the subsonic and supersonic ranges which indicated longitudinal instability at low angles of attack. The side-force coefficients were small for both models and indicated that the models were directionally stable. A possible tendency toward dynamic directional instability in the transonic region was indicated by short-period oscillations of the side forces.

The results showed a partial-span inboard aileron to be ineffective or to cause negative control in the transonic region when deflected approximately 5° but not when deflected 10°. An investigation of drag showed it to increase with a rearward movement of the center of gravity. This indicates an increase in the trim angle of attack as could be caused by a decrease in static stability.

Introduction

At the request of the Air Materiel Command, Army Air Forces, the Langley Pilotless Aircraft Research Division is conducting tests...
of \( \frac{1}{6} \)-scale models of the Bell MX-776 at the NACA Pilotless Aircraft Research Station, Wallops Island, Va. The purpose of these tests is to investigate the static longitudinal stability, static directional stability, and aileron control characteristics of the MX-776. This paper covers the flights of six models which were launched during a 3-month period that ended in September 1948. Models 1 and 2 were instrumented to measure normal and transverse acceleration and were flown with 0° deflection of the control surfaces. Models 3, 4, 5, and 6 were instrumented to measure rolling velocity and were flown with ailerons deflected 0°, 4.7°, 10.0°, and 4.6°, respectively.

Some drag data were obtained from all but one flight. The tests were conducted by means of free-flight techniques described in references 1 and 2.

SYMBOLS

\[
\begin{align*}
M & \quad \text{Mach number} \\
R & \quad \text{Reynolds number based on a body diameter (0.473 ft)} \\
\frac{p}{2V} & \quad \text{tip helix angle, radians} \\
p & \quad \text{rolling velocity, radians per second} \\
b & \quad \text{diameter of circle swept by wing tips (2.072 ft)} \\
v & \quad \text{flight-path velocity, feet per second} \\
q & \quad \text{dynamic pressure, pounds/square foot} \left( \frac{pV^2}{2} \right) \\
\rho & \quad \text{density, slugs/cubic foot} \\
S_F & \quad \text{body frontal area (0.1758 sq ft)} \\
C_N & \quad \text{normal-force coefficient} \left( \frac{\text{Normal-force}}{qS_F} \right) \\
C_Y & \quad \text{side-force coefficient} \left( \frac{\text{Side force}}{qS_F} \right) \\
C_D & \quad \text{drag coefficient} \left( \frac{\text{Drag}}{qS_F} \right) \\
\alpha & \quad \text{average aileron deflection measured in the free-stream direction, degrees} \\
W & \quad \text{weight of model, pounds}
\end{align*}
\]
normal acceleration, feet per second per second
transverse acceleration, feet per second per second
acceleration due to gravity, feet per second per second

MODELS AND TESTS

Models

The \( \frac{1}{6} \)-scale models used for this investigation were supplied by the MX-776 contractor. The fuselages were constructed of balsa wood with aluminum castings to serve as mounts for the metal wings and tails. The nose sections were made of plexiglas and contained a small radio transmitter.

Figure 1 shows a three-view drawing of the model. The pertinent general specifications are given in table I, and the model characteristics are given in table II. The areas given in figure 1 include wing areas obtained by extending all leading and trailing edges to body center line. The center of gravity shown in figure 1 is the corresponding full-scale-design location. For the models covered by the present paper the centers of gravity were located forward of this point as indicated in table II. Photographs of one of the models are shown in figures 2 to 4.

The models were propelled by a two-stage rocket-propulsion system to a Mach number of about 1.7. The booster delivered 3100 pounds of thrust for 1.5 seconds, and the sustainer motor developed 2000 pounds of thrust for 0.9 second.

Tests

The models were launched from a rail-type launcher (fig. 3) set at an elevation angle of approximately 60°. The flight-path velocity was generally obtained with a continuous-wave Doppler velocimeter radar unit. For the lower speed ranges of some of the models, the velocity was calculated using drag data measured for the other models. Atmospheric data were obtained by the use of radiosondes. Models 1 and 2 were equipped with two-channel nose-type telemeters that transmitted continuous signals of normal and transverse acceleration to two ground stations. These stations recorded the signals in the form of time histories. The accelerations were measured relative to the center line of the models. Time histories of the rolling velocity were obtained with spinsonde radio equipment for the four aileron-effectiveness models. A plot of Reynolds number against Mach number, shown in figure 5, indicates the scale of the tests.
REDUCTION OF DATA

Mach number was determined by use of radiosonde data and Doppler flight-path velocity. The values of normal and transverse accelerations obtained from the telemeter time histories for the deceleration phase of the flights were converted to coefficients by the relationships

$$C_N = \frac{W_a}{qSfg}$$

and

$$C_Y = \frac{W_y}{qSfg}$$

The rates of roll from the spinsonde time histories were used to obtain tip helix angles as functions of Mach number. The values of drag were obtained by the graphic differentiation of the curve of Doppler flight-path velocity against time.

ACCURACY

The accuracy of the tests is estimated to be within the following limits:

- $$C_N$$: $$\pm 0.065$$
- $$C_Y$$: $$\pm 0.032$$
- $$\rho_D$$: $$\pm 0.001$$
- $$\Sigma V$$: $$\pm 0.02$$
- $$\Sigma P$$: $$\pm 0.01$$

The calculated flight-path velocities and corresponding Mach numbers are estimated to be accurate to 15 percent.

RESULTS AND DISCUSSION

Stability

The data obtained from the flight of model 1 are shown in figure 6 as variation of normal-force and side-force coefficients with Mach number. Although the center of gravity of this model was one-half body diameter
ahead of the design location and all controls were neutral, the model
developed large normal forces which at some speeds exceeded the limit
of the measuring instrument. The actual normal-force coefficients could
be determined only for the Mach number ranges from 0.76 to 0.95
and 1.65 to 1.69. Inasmuch as the normal acceleration exceeded the
limits of the instrumentation in the Mach number range from 0.95 to 1.65,
no values for $C_N$ were obtained in this range, but the maximum value of
normal acceleration for the instrumentation was used to indicate the
minimum possible $C_N$ as shown by the dash part of the curve in figure 6.
Model 2 was similar to model 1 with the exception of the center-of-gravity
location which was approximately one body diameter ahead of the design
center of gravity. The data for model 2 are presented in figure 7.
The values of $C_N$ were smaller for model 2 than for model 1 for corresponding
Mach numbers which indicated that model 2 was trimming at smaller angles
of attack. For model 2 the change in sign of $C_N$ at a Mach number
of approximately 0.925 indicates that the model was disturbed and changed
from a trim point at a positive angle of attack to one at a negative angle
of attack. No force data were obtained in the Mach number range
from 0.95 to 0.97 and is so indicated in figure 7 by dash lines. Unpublished,
supersonic wind-tunnel data showed a model with the center of gravity at
the design location to be unstable at angles of attack near $0^\circ$, with trim
points at approximately $6^\circ$ at a Mach number of 1.26 and $14^\circ$ at a Mach
number of 1.72. The values of $C_N$ (figs. 6 and 7) were sufficiently small
throughout the speed range of the tests to indicate static directional
stability. The fact that short-period oscillation of the side forces
occurred as the models decelerate through the transonic region indicates
possible tendency towards dynamic directional instability in this region.

Aileron Effectiveness

The results of the data obtained from the flights of models 3, 4, 5,
and 6 are shown in figure 8 as plots of $\rho b/2V$ against Mach number.
Doppler flight-path velocity was obtained for a Mach number range
from 1.26 to 1.48 for model 3, from 0.95 to 1.73 for model 4, and
from 1.18 to 1.78 for model 5. Doppler flight-path velocity was not
obtained for model 6. Tip helex angles were derived for each model by
using these velocities and the rolling velocities obtained from the
spinosonde records. These curves of $\rho b/2V$ were extended by using
calculated flight-path velocities in conjunction with the measured rolling
velocities. The results from the test of a partial-span inboard aileron
deflected $4.7^\circ$ (model 4) showed that the rolling effectiveness decreased
abruptly in the Mach number range from 0.85 to 0.95. The direction of
roll was reversed in the Mach number range between 0.93 and 1.07 and
showed a gradual increase in aileron rolling effectiveness up to a Mach
number of 1.40. The results of the test of the same aileron configuration
deflected $4.6^\circ$ (model 5) showed the same general characteristics except in
the Mach number range from 0.93 to 1.07. In this Mach number range model 6
showed an almost complete loss of aileron control but no actual control
reversal. The results of the same aileron configuration deflected 10.00
(model 5) showed no reversal, but showed an abrupt decrease in rolling
effectiveness in the Mach number range from 0.85 to 0.90 and a gradual
decrease in rolling effectiveness up to the maximum Mach number tested
of 1.78.

Drag

The exact drag of the configuration cannot be evaluated because of
the erratic flight caused by the instability of the models. The approximate
drag data presented in figure 9 as variation of drag coefficients with
Mach number show the more stable models (models 2 and 3) to have had
less drag than the others and therefore must have been trimming at smaller
angles of attack.

CONCLUDING REMARKS

The present MX-776 has a region of static longitudinal instability
near 0° angle of attack. This region appears to be largest in the
transonic range and to decrease with an increase in Mach number in the
supersonic range. The configuration appeared to be statically stable
directionally with the possibility of a tendency toward dynamic
directional instability in the transonic range. Additional tests are
planned for models modified to improve the stability.

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REFERENCES


TABLE I.
GENERAL SPECIFICATIONS

[Fuselage: Over-all length, 68.637 in.; maximum diameter, 5.678 in.]

<table>
<thead>
<tr>
<th></th>
<th>Aft horizontal wings</th>
<th>Forward horizontal wings</th>
<th>Aft vertical fins</th>
<th>Forward vertical fins</th>
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<td>0</td>
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<tr>
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<td>10.6</td>
<td>10.5</td>
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<td>Symmetrical wedge of 0.05 thickness ratio</td>
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<td>Models</td>
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<td>Weight (lb)</td>
<td>C.G. location station</td>
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Figure 1.—General arrangement of \( \frac{1}{6} \)-scale MX-776 rocket-powered flight-test model.
Figure 2.— MX-776 rocket-powered flight-test model.

Figure 3.— Model and booster on launcher.
Figure 4.- Aft horizontal wing with partial-span inboard aileron.
Figure 5.—Variation of Reynolds number with Mach number for the range of climatic conditions encountered during the tests.
Figure 6. Variation of normal-force coefficient and side force coefficient with Mach number.

Normal force coefficient, \( C_n \)
Side force coefficient, \( C_y \)

Mach number, \( M \)

\( C_n \) is above this line

\( C_y \)
Figure 7.—Variation of normal-force coefficient and side-force coefficient with Mach number; c.g. at station 32.9; $\delta_a = 0^\circ$; model 2.
Figure 8—Variation of tip helix angle with Mach number.
Figure 9.—Variation of trim drag coefficients with Mach number.