NACA

RESEARCH MEMORANDUM

FREE-FLIGHT-TUNNEL INVESTIGATION OF THE DYNAMIC LATERAL STABILITY AND CONTROL CHARACTERISTICS OF A TIP-TO-TIP BOMBER-FIGHTER COUPLED AIRPLANE CONFIGURATION

By Charles V. Bennett and Robert B. Cadman Jr.

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
April 4, 1951

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

FREE-FLIGHT-TUNNEL INVESTIGATION OF THE DYNAMIC LATERAL STABILITY AND CONTROL CHARACTERISTICS OF A TIP-TO-TIP BOMBER-FIGHTER COUPLED AIRPLANE CONFIGURATION

By Charles V. Bennett and Robert B. Cadman

SUMMARY

An experimental investigation has been made in the Langley free-flight tunnel to determine the dynamic lateral stability and control characteristics of a coupled airplane configuration consisting of simplified fighter models attached to the wing tips of a simplified bomber model. This coupled arrangement represents a configuration in which fighter airplanes are carried on the wing tips of a bomber airplane to provide fighter protection for the bomber or for in-flight refueling. The ailerons of the fighters operate automatically in response to the relative bank angle between the bomber and fighters to keep the fighters alined.

The results of the investigation showed that when the fighters were attached to the bomber with one degree of freedom (roll), two degrees of freedom (roll and pitch), or three degrees of freedom (roll, pitch, and yaw), the rolling motion of the fighters with respect to the bomber decreased with increasing gearing ratio (ratio of fighter aileron angle to angle of bank of the fighter with respect to the bomber). When sufficient aileron gearing was supplied, the general flight behavior was considered satisfactory with the fighters attached with one, two, or three degrees of freedom. Progressively more gearing was required for satisfactory flight behavior as the number of degrees of freedom was increased.

INTRODUCTION

Wing-tip to wing-tip coupling of airplanes has been proposed as one means for carrying fighter protection on bombing missions or for in-flight refueling. In this arrangement the fighters are supported by their own lifting surfaces and, because of the increase in effective aspect ratio, the fighters probably can be carried more efficiently in this manner than by any other means. The bending loads produced by the fighter on the bomber wing can be minimized by coupling the fighters to the bomber with angular freedom. In this arrangement the ailerons of the fighters are automatically operated in response to the relative bank angle between the fighters and bomber to keep the fighters alined. In order to determine the dynamic lateral stability and controllability of such an arrangement, an experimental investigation has been conducted in the Langley free-flight tunnel with the use of simplified research models to represent the bomber and fighters. The investigation consisted of flight tests of fighter models attached either rigidly or with freedom in roll, freedom in roll and pitch, or freedom in roll, pitch, and yaw with respect to the bomber.

APPARATUS AND TESTS

The investigation was conducted in the Langley free-flight tunnel which is described in reference 1. A sketch of the simplified research models coupled together is shown in figure 1. The dimensional and mass characteristics of the models are given in table I. All tests were made at a dynamic pressure of 2.75 pounds per square foot.

The fighter models were attached to the bomber by means of a hinge (fig. 2), located at 0.20 mean aerodynamic chord of the fighter and 0.25 mean aerodynamic chord of the bomber, which could be locked to give a rigid coupling or which could allow freedom in roll, pitch, and yaw either singularly or in any combination. It can be seen from figure 2 that the roll, pitch, and yaw axes are not coincident and that the hinge does not therefore exactly represent a ball joint. With three degrees of freedom of the fighter with respect to the bomber and with the displacement of axes as shown in figure 2, the yaw axis remains fixed to the bomber, the roll and pitch axes yaw with the fighter, and the pitch axis also rolls with the fighter. This order of displaced axes was arbitrarily selected and it is possible that slightly different results might have been obtained if another sequence had been used. The gaps between the bomber and fighter tips caused by the hinge installation were unsealed for all tests.

A mechanical linkage was installed on the fighters to deflect the outboard ailerons of the fighters in response to the relative bank angle between the bomber and fighters. With this linkage on the model, gearing ratios (ratio of fighter aileron angle to bank angle of fighter with respect to the bomber) from 1 to 9 could be obtained. Cushioning springs were installed in the linkage system to permit the fighters to roll with respect to the bomber after the maximum aileron deflection of the fighters was reached. The purpose of the linked ailerons was to minimize the rolling motion of the fighters relative to the bomber by producing aerodynamic forces on the fighters which tended to keep them alined with the bomber. For instance, as the fighter model rotated up, the outboard aileron of the fighter went up and the lift on the fighter was reduced, and, therefore, the fighter tended to return to its trimmed position. A linkage system of this type was used in the investigation of reference 2 and was very effective in reducing the flapping motion of the tips on a free-floating wing-tip configuration.

The restoring moments about the rolling hinge produced by the linked ailerons are shown in figure 3. The maximum outboard aileron deflection of $\pm 30^{\circ}$ produced a restoring moment of 0.0485 foot-pounds. The addition of a $\frac{1}{2}$-inch extension to the aileron chord (42-percent additional area) increased the aerodynamic restoring moment by approximately 17 percent. The vertical portion of the restoring-moment curves (fig. 3) represents the preload in the cushioning springs that must be overcome before the fighters can bank to an angle greater than that which corresponds to $\pm 30^{\circ}$ aileron deflection. After the preload is overcome the fighters can reach higher angles of bank by compressing the cushioning springs. The restoring moments provided by compression of the springs are shown by the constant slope above the vertical portion of the curve. The maximum angle of bank that could be reached by the fighters (springs fully compressed) was approximately 46° for a gearing ratio of 1 and approximately 20° for a gearing ratio of 9.

Flight tests were made of the bomber alone, of the bomber with the fighters attached rigidly, and of the bomber with the fighters attached with the various degrees of angular freedom. In the flight tests made with the fighters attached with one or more degrees of angular freedom, the pilot paid particular attention to the flapping of the fighters (rolling motion of the fighters with respect to the bomber) and to the effects of this flapping on the general fighter behavior of the coupled configuration. In addition the flapping motions of the fighters were determined quantitatively from motion-picture records taken with a camera located at the rear of the tunnel test section. No film records of the yawing and pitching motions were obtained because it was felt that a satisfactory over-all indication of the relative merit of the various test conditions was provided by records of the flapping or rolling motions of the fighters.

RESULTS AND DISCUSSION

The flight behavior of the bomber with the fighters attached rigidly was used as a basis for comparison with that of the bomber with the fighters attached with one or more degrees of angular freedom. The flight behavior of the bomber alone was representative of that of a conventional airplane having good stability and control characteristics. The controllability and general flight behavior of the bomber with the fighters attached rigidly were less satisfactory than those of the bomber alone because of the slower response to aileron control and because of the decreased lateral stability. These results are similar to those reported in reference 2. The rolling in response to a given aileron control was slower than that of the bomber alone because of the increased rolling inertia and the increased damping in roll. The decreased lateral stability apparently resulted from the increased rolling and yawing inertia - an effect that is more fully discussed in reference 3.

The rolling motions of the bomber in controlled flight and the corresponding angles of bank of the fighter models (measured with respect to the horizontal) are shown in figure 4 for the fighters attached with freedom in roll only, in figure 5 for the fighters attached with freedom in roll and pitch, and in figure 6 for the fighters attached with freedom in roll, pitch, and yaw. Since the film records were read within an accuracy of $\pm 0.5^{\circ}$ and no attempt was made to fair smooth curves through the scatter of points, any abrupt motion falling within these limits may not represent the actual motions of the fighter models. In some cases the fighter rolling motions are displaced from those of the bomber because no attempt was made to trim the fighter to exactly zero bank with respect to the bomber. It was also difficult to keep the fighters trimmed so that the ailerons were at 0° deflection when the fighters were at 0° bank. The data of figure 3, therefore, cannot be used to obtain accurate estimates of the restoring moments for a given condition. These data can be used, however, to obtain a general indication of the variation of restoring moment with fighter bank angle for the various gearing ratios used in the tests.

Fighters Attached with Freedom in Roll

The motions of the bomber and the corresponding motions of the fighters when attached with freedom in roll are shown in figure 4 for the various gearing ratios. The flight records of figure 4(a) show that there was considerable flapping of the fighters with respect to the bomber for a gearing ratio of 1. These flapping motions, which were most noticeable after a gust or control disturbance, were very lightly damped and the random disturbances caused by this erratic flapping of the fighters made it almost impossible for the pilot to maintain smooth wing-level flight.

The data of figures 4(b) to 4(e) show the effect on the flapping motion of the fighter of increasing the gearing ratio. Although these records show that the flapping of the fighter models was decreased as the gearing ratio was increased, the flapping was still objectionable to the pilot until a gearing ratio of 8 (fig. 4(d)) was reached. A further increase in effective gearing obtained by adding the $\frac{1}{2}$-inch extension to the fighter aileron decreased the flapping still further. In the record for this condition (fig. 4(e)) the pilot was intentionally disturbing the model to show how closely the fighters followed the banking motions of the bomber. The flight characteristics for these conditions (figs. 4(d) and 4(e)) were considered satisfactory and it was the opinion of the pilot that the flight behavior for these configurations compared quite favorably with the condition in which the fighters were attached rigidly to the bomber.

Fighters Attached with Freedom in Roll and Pitch

The records of figure 5 show the relative rolling motions of the bomber and fighters when the fighters were attached with freedom in roll and pitch. In general, these records show that for comparable gearing ratios there was more flapping of the fighters relative to the bomber when the fighters were attached with freedom in roll and pitch than when attached with freedom in roll only. The pitching motions permitted by the freedom in pitch apparently caused changes in lift on the fighter and these changes in lift resulted in additional rolling moments about the hinge and consequently in an increase in the amount of flapping. Because of this flapping, the pilot felt that the general flight behavior was also less satisfactory. Although the flapping of the fighter models was reduced when the gearing ratio was increased from 2 to 4 (figs. 5(a) and 5(b)), the general flight behavior did not appear to be appreciably improved. A further increase in gearing ratio reduced the flapping and resulted in an improvement in the flight characteristics such that flights made with a gearing ratio of 8 and with the extensions on the ailerons were considered satisfactory.

Fighters Attached with Freedom in Roll, Pitch, and Yaw

The film records of flights made with the fighters free to roll, pitch, and yaw with respect to the bomber are shown in figure 6. These records show generally that for comparable gearing ratios there was considerably more flapping of the fighters relative to the bomber when the fighters were attached with freedom in roll, pitch, and yaw than when attached with freedom in roll and pitch or roll alone. The yawing motions of the fighter models were rather large with the lower gearing ratios, and apparently these yawing motions caused rolling moments about the hinge which resulted in increased flapping. Because of this flapping the pilot felt that the general flight behavior was also worse. The data of figure 6 indicate that, as in the previously discussed cases, the flapping of the fighters decreased as the gearing ratio was increased. The flight behavior of the models also improved as the gearing ratio was increased because of the lesser flapping tendency.

CONCLUDING REMARKS

The results of the investigation made in the Langley free-flight tunnel to determine the dynamic lateral stability and control characteristics of a coupled airplane configuration consisting of a simplified bomber model with a simplified fighter model attached to each wing tip may be summarized as follows:

1. When the fighters were attached to the bomber with either one degree of freedom (roll), two degrees of freedom (roll and pitch), or three degrees of freedom (roll, pitch, and yaw), the rolling motion of the fighters with respect to the bomber decreased with increasing gearing ratio (ratio of fighter aileron angle to angle of bank of the fighter with respect to the bomber).

2. When sufficient gearing was supplied, the flight behavior of the coupled configuration could be made satisfactory with the fighters attached with either one, two, or three degrees of freedom.

3. Progressively more gearing was required for satisfactory flight behavior as the number of degrees of freedom was increased.

The model flight test results indicate that the coupled combination could be flown satisfactorily by the bomber pilot even with the gearing ratios that permitted a moderate amount of flapping of the fighters. These conditions might not be considered satisfactory for a full-scale configuration, however, because it is likely that the fighter pilot would object to the lightly damped flapping motion, especially in flights of long duration or in rough air. It would be possible for the fighter pilot to keep the fighter alined with the bomber by the use of manual control, but he probably would object to controlling the airplane continually in order to keep it alined with the bomber. It appears therefore that higher gearing ratios might be required from the standpoint of fighter-pilot comfort than would be required from the standpoint of ease of flying the coupled combination with the bomber controls.

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

REFERENCES

1. Shortal, Joseph A., and Osterhout, Clayton J.: Preliminary Stability and Control Tests in the NACA Free-Flight Wind Tunnel and Correlation with Full-Scale Flight Tests. NACA TN 810, 1941.

2. Shanks, Robert E., and Grana, David C.: Flight Tests of a Model Having Self-Supporting Fuel-Carrying Panels Hinged to the Wing Tips. NACA RM L9I07a, 1949.

3. Campbell, John P., and Seacord, Charles L., Jr.: The Effect of Mass Distribution on the Lateral Stability and Control Characteristics of an Airplane as Determined by Tests of a Model in the Free-Flight Tunnel. NACA Rep. 769, 1943.

4. National Advisory Committee for Aeronautics: Aerodynamic Characteristics of Airfoils. NACA Rep. 315, 1929.

TABLE I

DIMENSIONAL AND MASS CHARACTERISTICS

	Bomber model	One fighter model	Coupled configuration
Weight, lb	8.55	0.62	[a]10.88
Wing loading, lb/ft^2	3.54	1.82	3.52
Radius of gyration about longitudinal body axis, spans	[b]0.15	[c]0.35	[d]0.20
Radius of gyration about vertical body axis, spans	[b]0.29	[c]0.32	[d]0.25
Wing:			
Airfoil section	[e]Rhode St. Genese-35	[e]Rhode St. Genese-35	------
Span, ft	3.54	0.92	5.54
Area, sq ft	2.41	0.34	3.09
Aspect ratio	5.06	2.44	------
Taper ratio	0.55	1.00	------
Aileron:			
Area, percent wing area (one aileron)	3.87	8.90	------
Chord, percent wing chord	20.00	26.50	------
Span, percent wing span (one aileron)	20.00	33.00	------
Vertical tail:			
Airfoil section	NACA 0012	NACA 0012	------
Span, ft	0.875	0.25	------
Area, percent wing area	15.00	11.75	------
Aspect ratio	2.10	1.56	------
Taper ratio	0.50	0.50	------
Tail length ($\frac{1}{4}$-chord of wing mean aerodynamic chord to rudder hinge line), ft	1.98	0.75	------
Horizontal tail:			
Airfoil section	NACA 0012	NACA 0012	------
Span, ft	1.46	0.50	------
Area, percent wing area	22.80	23.50	------
Aspect ratio	4.06	3.12	------
Taper ratio	0.50	0.50	------

NACA

[a]Includes weight of two hinges.
[b]Based on bomber span.
[c]Based on fighter span.
[d]Based on span of coupled configuration.
[e]Ordinates are given in reference 4.

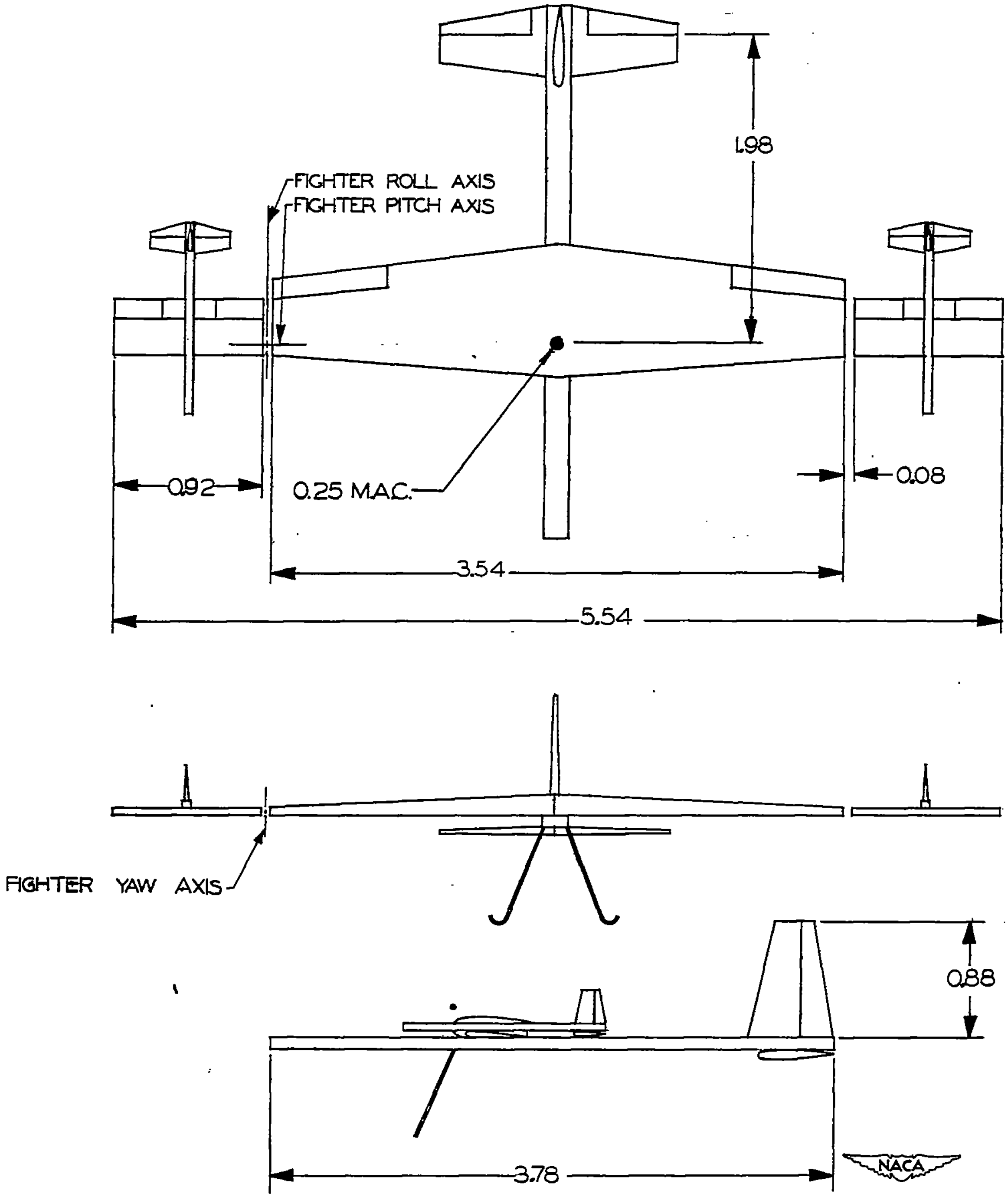
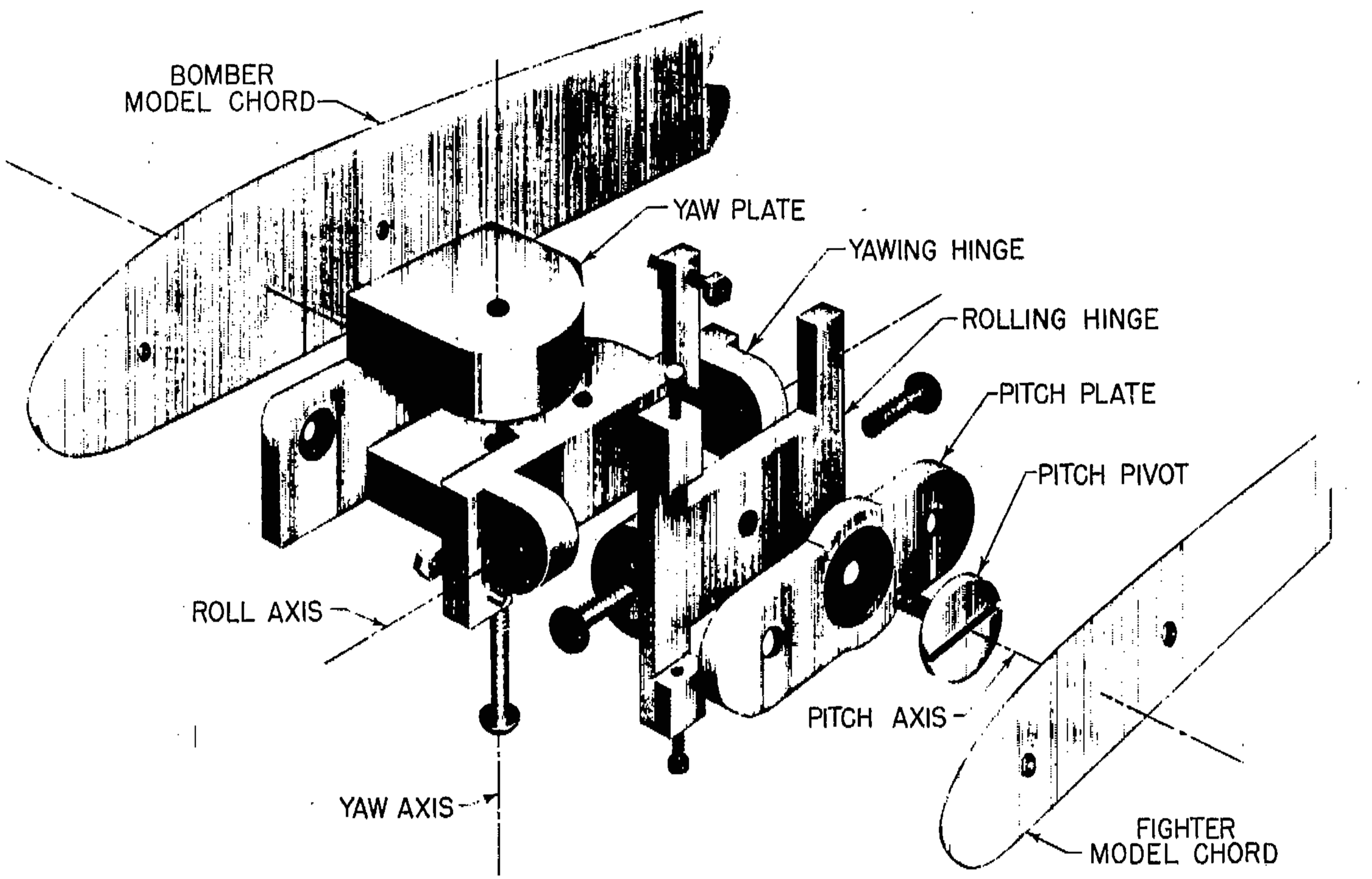


Figure 1.- Three-view sketch of wing-tip to wing-tip fighter-bomber configuration tested in the Langley free-flight tunnel. All dimensions are in feet.



NACA
L-67777

Figure 2.- Attachment hinge used to couple fighter models to bomber.

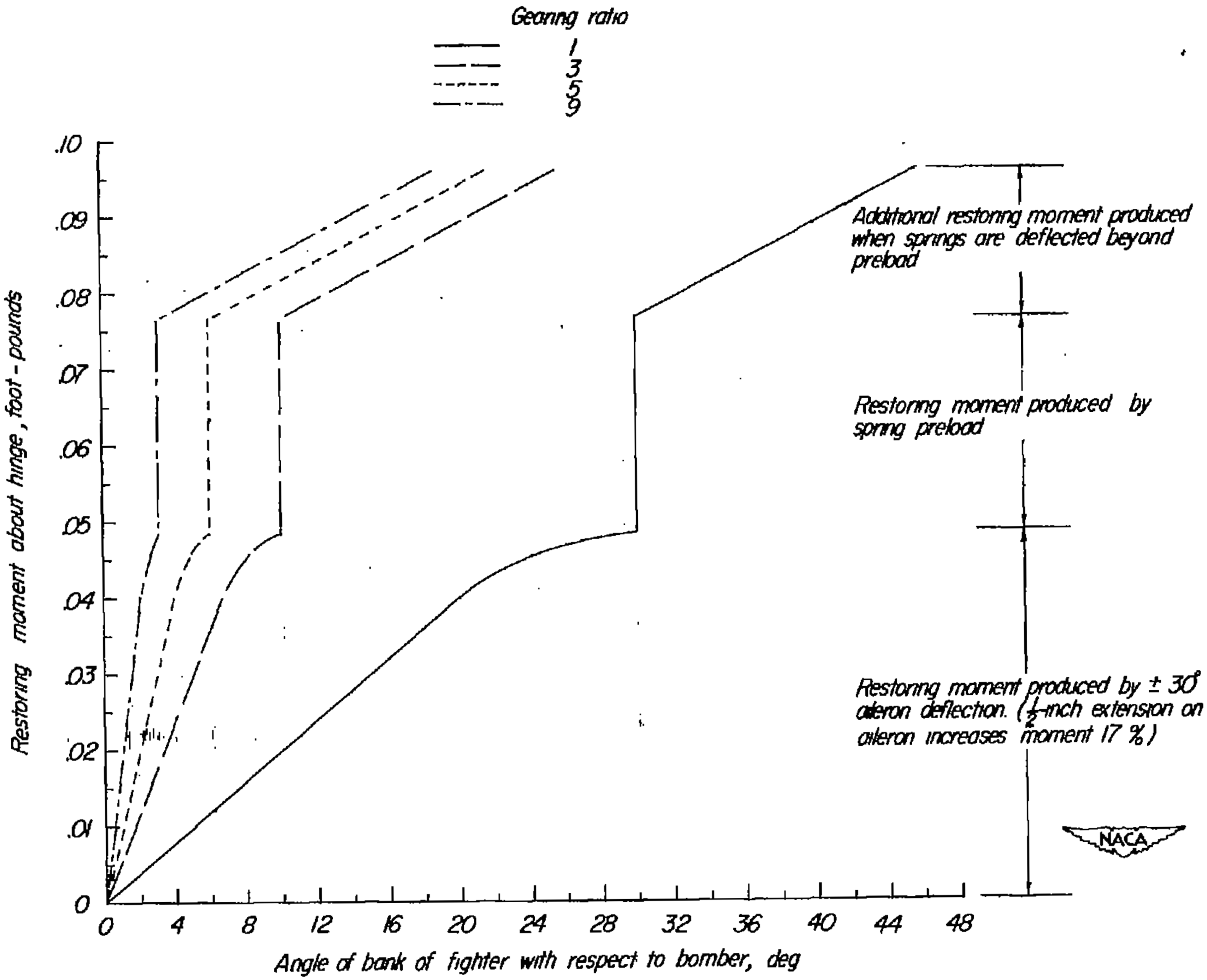


Figure 3.- Variation of applied restoring moment with angle of bank of fighter with respect to bomber.

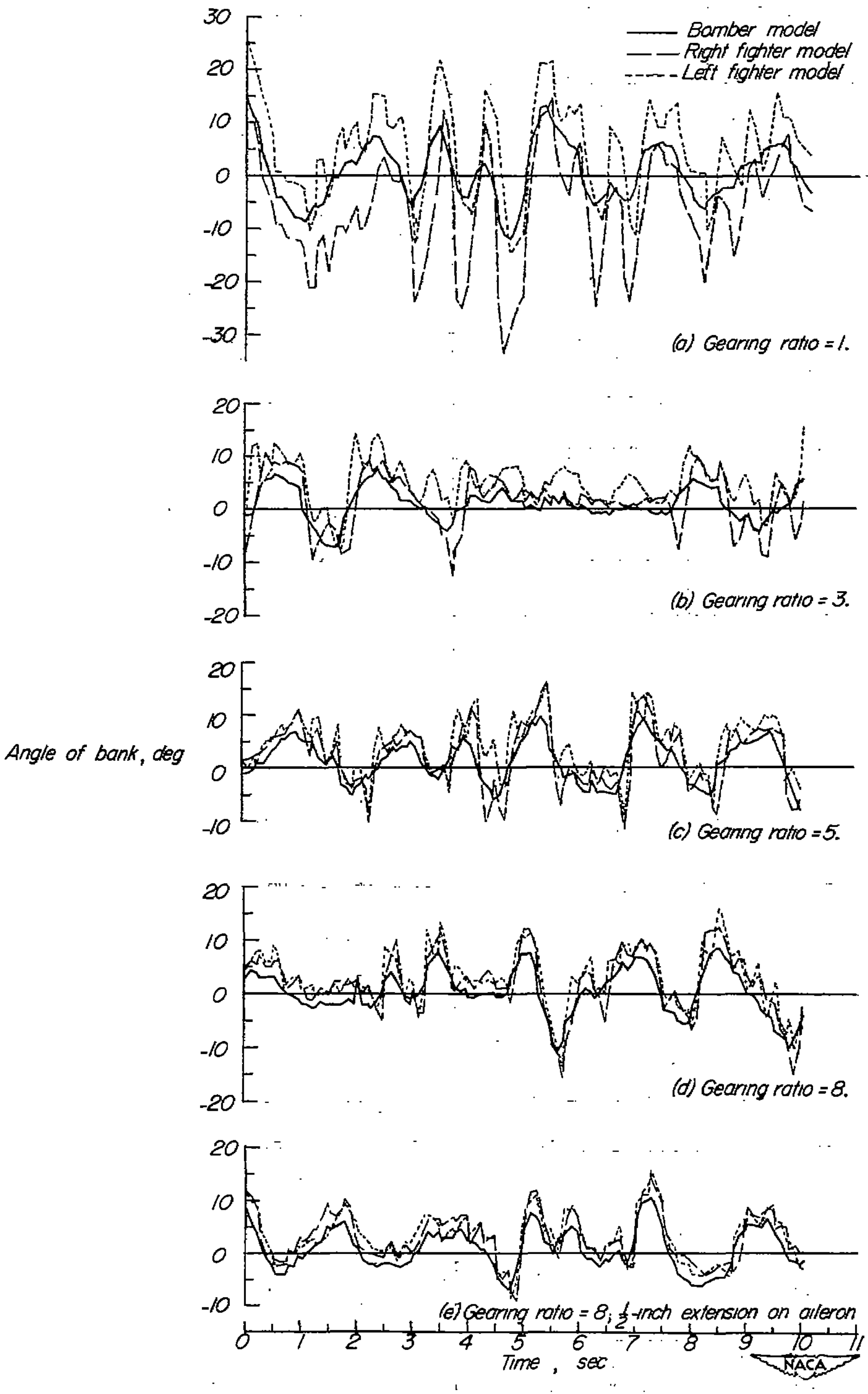


Figure 4.- Rolling motions of coupled bomber-fighter configuration with fighters attached with freedom in roll.

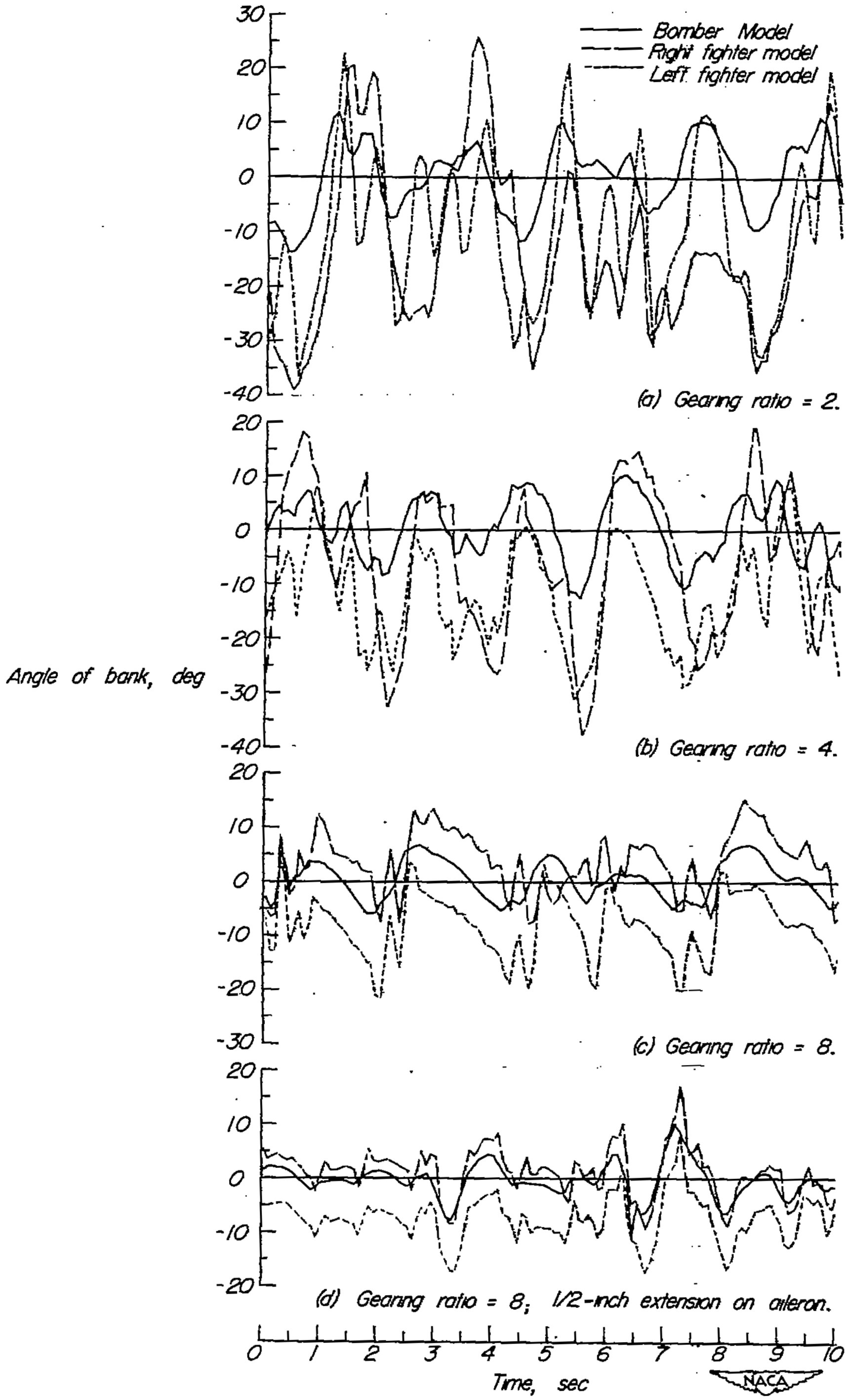


Figure 5.- Rolling motion of coupled bomber-fighter configuration with fighters attached with freedom in roll and pitch.

[redacted]

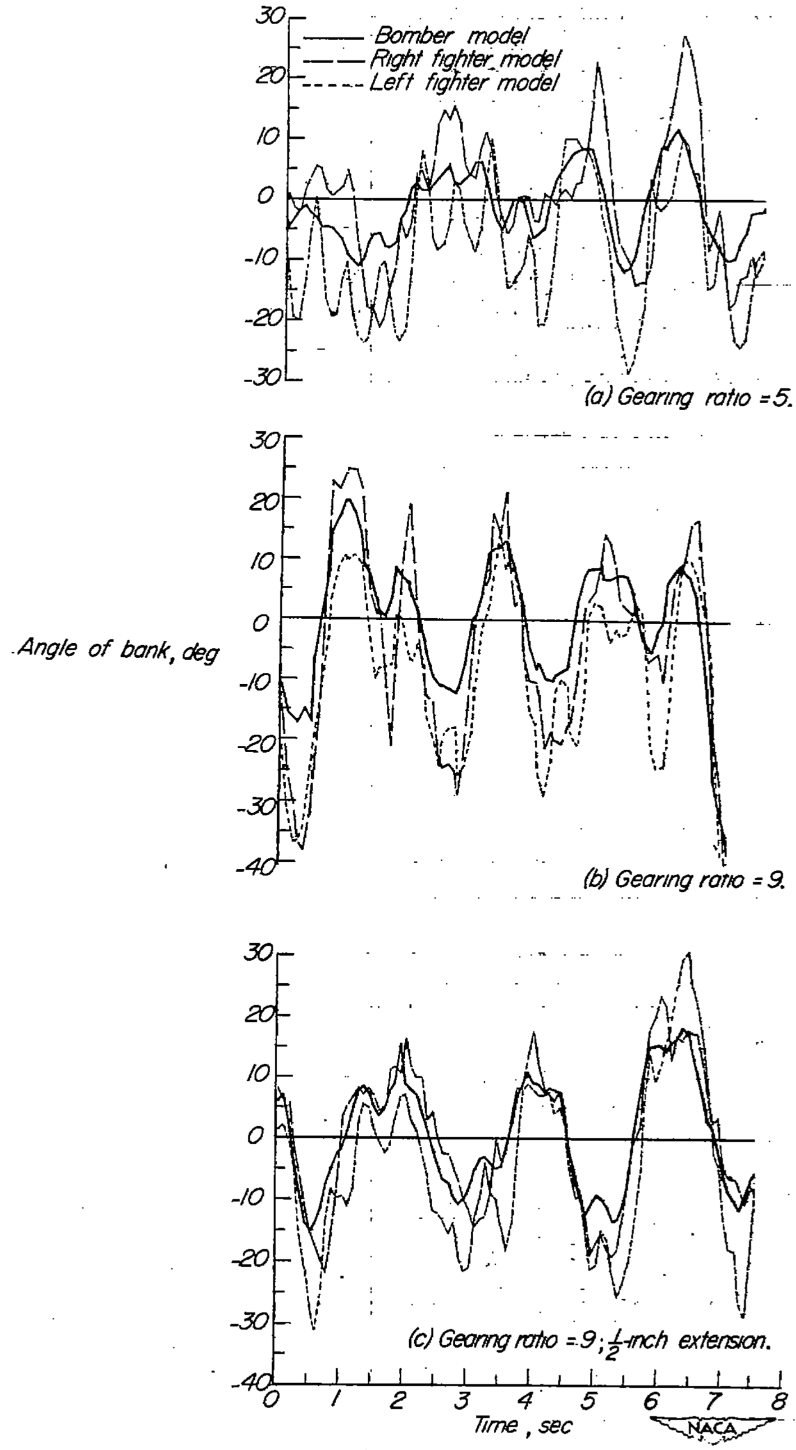


Figure 6.- Rolling motions of coupled bomber-fighter configuration with fighters attached with freedom in roll, pitch, and yaw.

[redacted]

NACA-Langley - 4-4-51 - 250