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Parametric Flutter Studies of an Arrow-Wing Configuration - Some Early Results

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SUMMARY

Some early experimental results from a combined experimental and analytical study being conducted at the NASA-Langley Research Center of the transonic flutter characteristics of a generic arrow-wing configuration are presented. The planned study includes the parametric variation of a variety of structural and geometric characteristics. Presented here are flutter results for the basic arrow wing, for the basic wing with the addition of an upper-surface-mounted fin, for the basic wing with the addition of two simulated lower-surface-mounted engine nacelles, and for the basic wing with the addition of both the fin and the engine nacelles.

INTRODUCTION

For a number of years researchers have been studying the flutter characteristics of supersonic transport-type configurations. Two illustrative examples of this research are references 1 and 2. The material presented in this report are some early results from a study currently underway at the NASA Langley Research Center aimed at furthering the understanding of the transonic flutter characteristics of supersonic cruise aircraft. For the most part this paper presents the figures used by the most junior author in a presentation given at the fall 1987 meeting of the Aerospace Flutter and Dynamics Council. The data are presented here with a minimum of connecting narrative. This report may be thought of as the early release of recent research results in the interest of rapid technology transfer from Government researchers to the outside technical community pending the preparation and release of a more comprehensive report.

The flutter research study that is underway consists of determining the effects of several parameters (See fig. 1.) on the transonic flutter characteristics of a generic arrow-wing design representative of a supersonic cruise airplane. Presented in this paper are some results obtained from varying the four parameters shown in figure 2. It should be pointed out that the planned study when completed will include a more extensive investigation of the effects of the four parameters discussed herein.

MODELS

A photograph of the basic arrow-wing configuration is shown in figure 3. The semi-span wing had a root chord of 91.3 inches and a semispan of 35.1 inches. The planform geometry was very similar to that of the models described in reference 2. The model structure consisted of an aluminum alloy plate (See fig. 4.) which was covered with end-grain balsa wood to provide the desired parabolic arc airfoil section. Cutouts in the plate were used to simulate an arrangement of spars and ribs. Four different configurations were tested, namely, the basic arrow wing, the basic wing with the addition of an upper-surface-mounted fin, the basic wing with the addition of two simulated lower-surface-mounted engine nacelles, and the basic wing with the addition of both the fin and the engine nacelles. The models were instrumented with resistance-wire strain gage bridges and accelerometers for measuring dynamic response. Measured natural frequencies for all four model configurations are presented in figure 5. Node lines are presented in figure 6 for the basic wing and the wing-with-fin-and-nacelles configurations. Note that in the frequency range shown, the two "with nacelles" configurations have an additional mode, labeled mode 2A in the figures.

WIND-TUNNEL TESTS

The wind-tunnel tests were conducted in the Langley Transonic Dynamics Tunnel (TDT). This wind-tunnel is used almost exclusively for aeroelastic testing. It is of the single return type and speed and stagnation pressure are continuously controllable over a range of Mach numbers from near zero to 1.2 and of pressures from near vacuum to about one atmosphere. Either air or Freon-12[1] can be used as the test medium. Freon was used for the present test.

A photograph of the basic wing model mounted in the wind-tunnel is presented in figure 7. The model was clamped to a fixture using the two tabs (See figs. 3 and 4.) which extended from the root of the aluminum plate. The fixture was inturn attached to a remotely controlled turntable on the wall so that the angle of attack could be changed during testing. The fixture was covered with a streamlined fairing. The widths of the fixture and fairing were such that the root chord of the model was outside the wind-tunnel wall boundary layer.

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[1]Freon is registered trademark of E. I duPont de Nemours and Co., Inc.

PRESENTATION OF RESULTS

The basic flutter results are presented in figures 8 thru 11 as the variation of flutter dynamic pressure with Mach number. The basic wing data are in figure 8; the wing-with-fin data are in figure 9; the wing-with-nacelles data are in figure 10; the wing with-fin-and-nacelles data are in figure 11. These flutter broundaries are all presented in figure 12 to facilitate comparisons. The curves in figure 12 are repeats of the curves that were faired through the data points in figures 8 thru 11. The shapes of these flutter boundaries are similar to those that have been observed by many investigators previously for a variety of different configurations, namely, a decrease in flutter dynamic pressure with increasing Mach number to a minimum value near M=1.0 followed by an increase in dynamic pressure with increasing Mach number. These data show that the addition of the fin to the basic wing increased the flutter dynamic pressure. Near M=1.0 the flutter dynamic pressure for both "with-nacelles" configurations is lower than that of the basic wing. At lower Mach numbers, say M=0.80, the with-nacelles configurations have a higher flutter dynamic pressure than does the basic wing. It should be pointed out that some data obtained subsequent to that presented here on a similar basic wing configuration show a higher level of flutter dynamic pressure, about the same level as the present wing-with-fin case. These data would lead one to conclude that the addition of the fin has little effect on the flutter dynamic pressure and that the addition of the simulated engine nacelles results in a lower flutter dynamic pressure throughout the Mach number range shown here. The reasons for the different levels of dynamic pressure for similar (designed to be identical, but, of course, actually slightly different) model wings is under study.

The variation of flutter frequency with Mach number is presented in figure 13 for all four configurations. The flutter frequencies for the two with-nacelles configurations are similar and lower than the frequencies for the other two configurations. The frequencies of the wing-with-fin configuration are lower than the frequencies for the basic wing.

Some effect of angle of attack, lift, on the flutter of the basic wing and the wing-with-fin-and-nacelles configuration are presented in figures 14 and 15, respectively, as the variation of flutter dynamic pressure with Mach number. In both instances, increasing the angle of attack reduced the flutter dynamic pressure.

CONCLUDING REMARKS

Some experimental flutter results for a generic arrow-wing flutter model with and without a vertical fin and with and without two simulated engine nacelles have been presented. These data are some early results from a larger program aimed at providing a better understanding of the aeroelastic characteristics of supersonic cruise airplane configurations.

REFERENCES

1. Wykes, J. H.; Sweet, H. R.; Joseph, J. A.; and Hodson, C. H.: Commercial Supersonic Transport Flutter Studies. ASD-TRD-63-818, 1964.

2. Doggett, Robert V., Jr.; and Ricketts, Rodney H.: Effects of Angle of Attack and Vertical Fin on Transonic Flutter Characteristics of an Arrow-Wing Configuration. NASA TM-81914, 1980.

STRUCTURAL ARRANGEMENT - WING TIP REGION

MASS DISTRIBUTION - WING TIP REGION

GEOMETRY - WING TIP REGION

FUEL LOADING

UPPER SURFACE MOUNTED WING FIN
- ON/OFF
- STIFFNESS
- MASS EQUIVALENT

ENGINE NACELLES - ON/OFF

ANGLE OF ATTACK (LIFT)

Figure 1.- Overall study parameters.

ONE STRUCTURAL ARRANGEMENT - WING TIP REGION

UPPER SURFACE MOUNTED WING FIN ON/OFF

ENGINE NACELLES - ON/OFF

ANGLE OF ATTACK (LIFT)

Figure 2.- Parameters discussed in this paper.

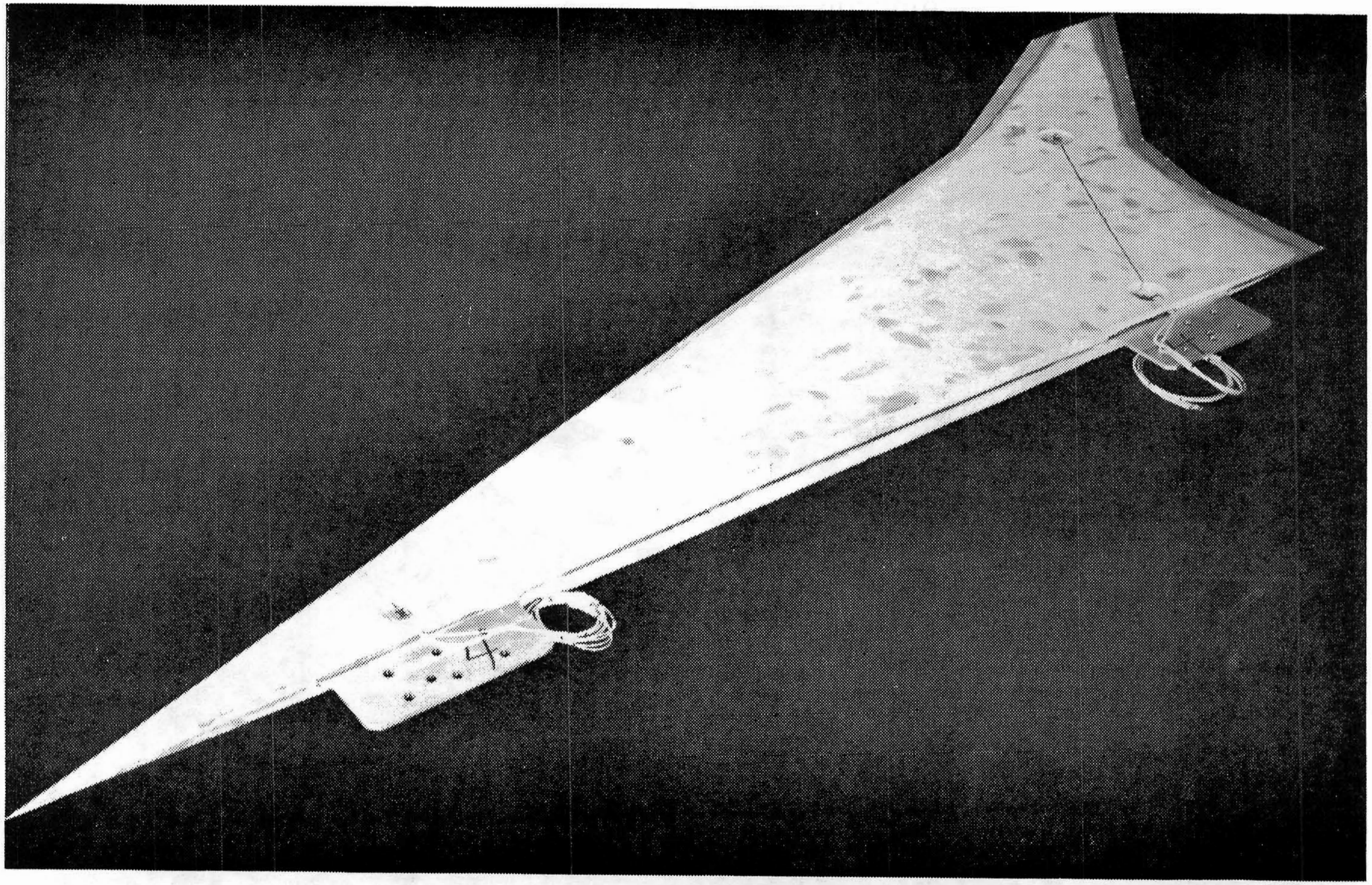

Figure 3. - Photograph of arrow-wing model wing.

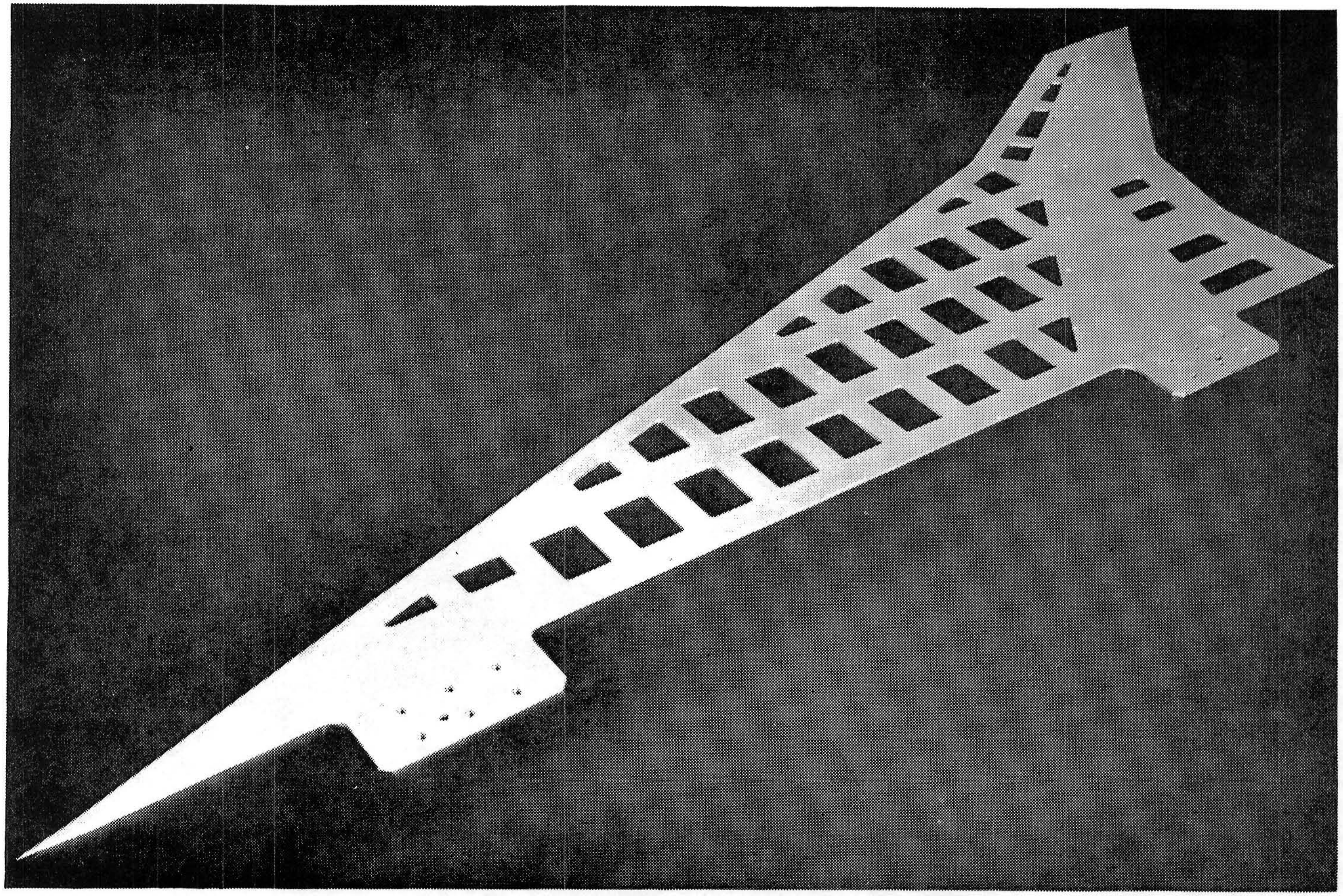

Figure 4. - Photograph of plate structure.

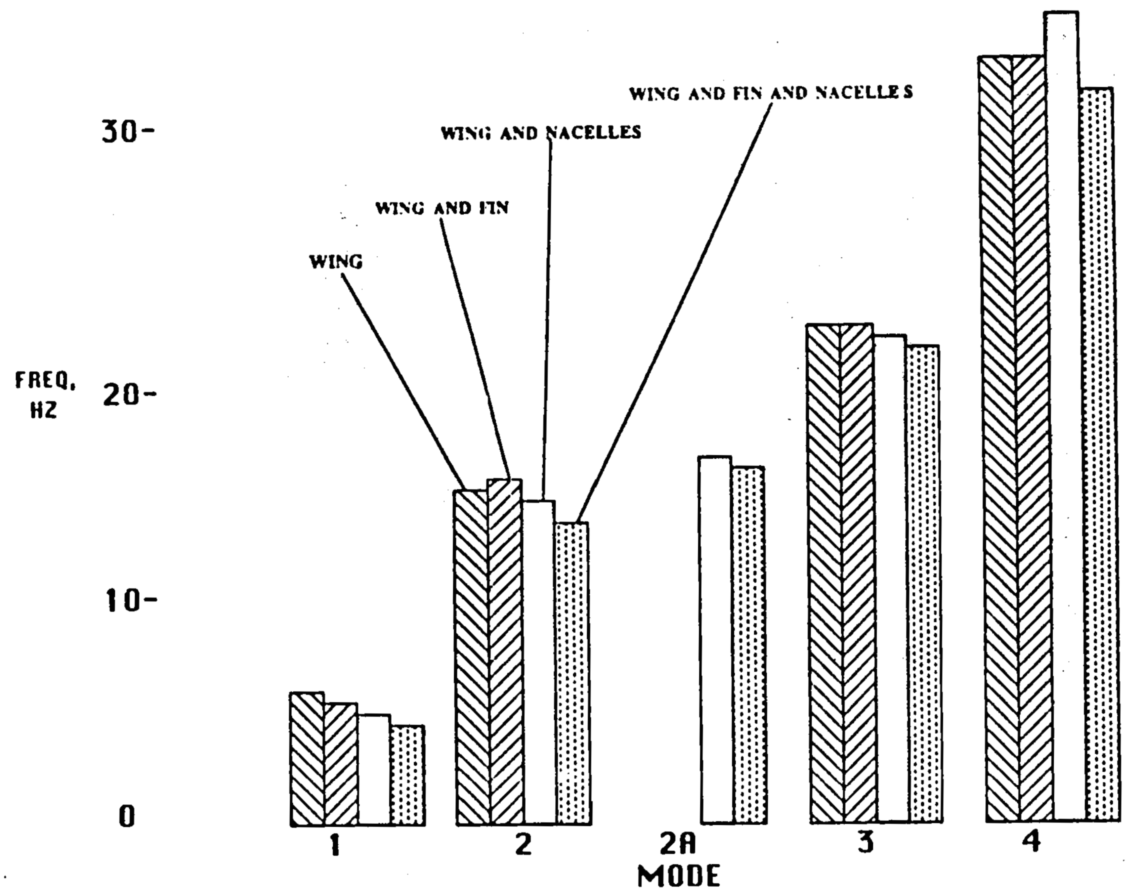

Figure 5. - Measured natural frequencies.

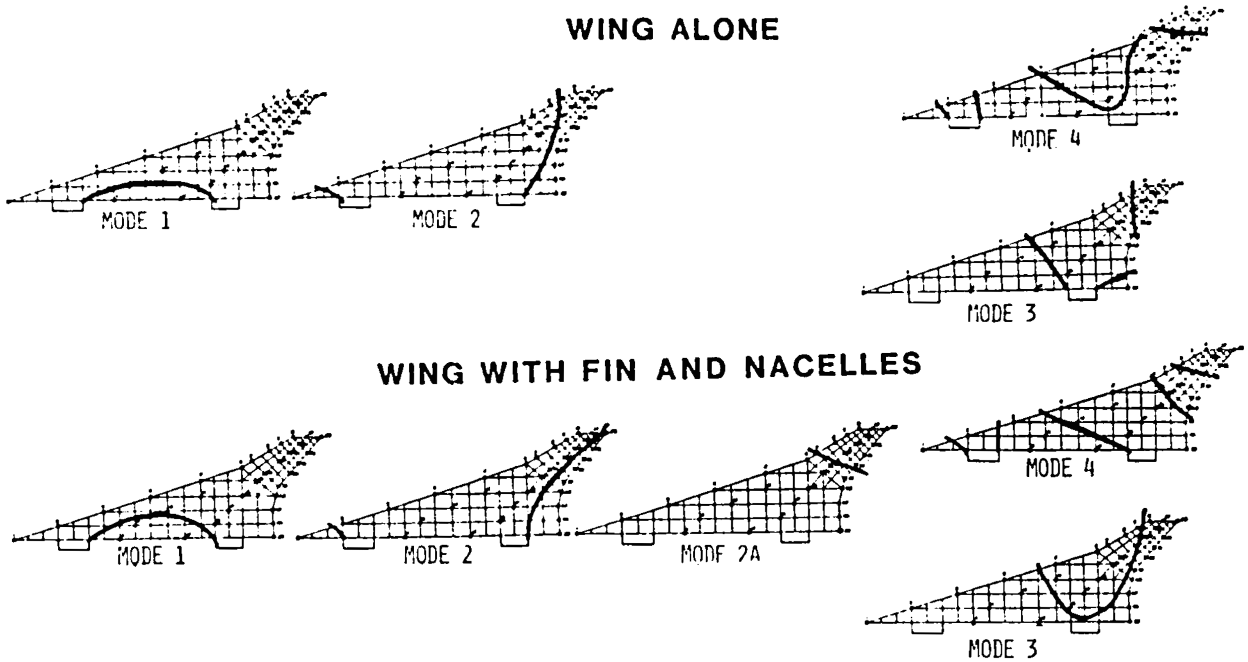

Figure 6. - Measured node lines.

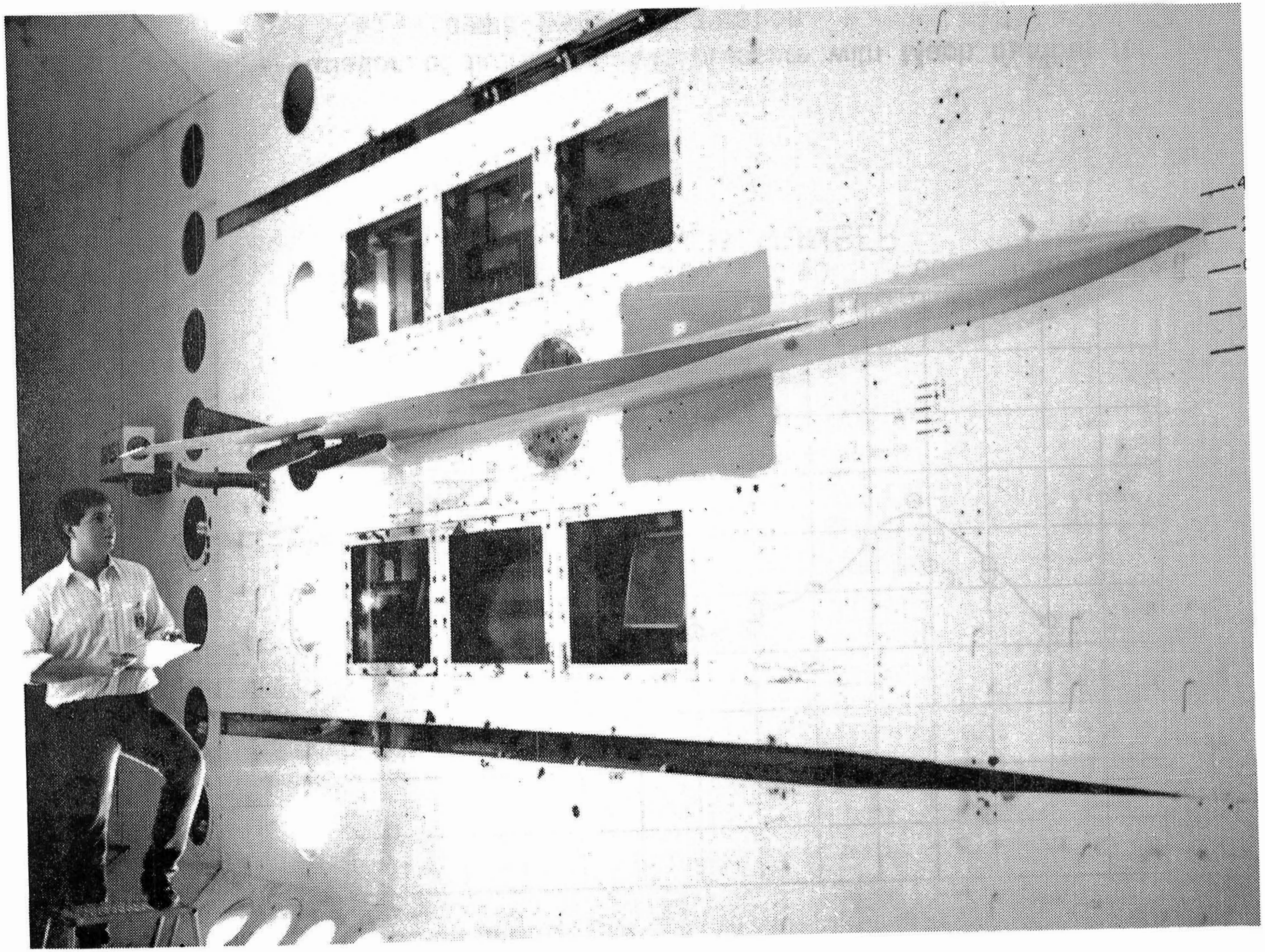

Figure 7. - Photograph of arrow wing model mounted in wind tunnel.

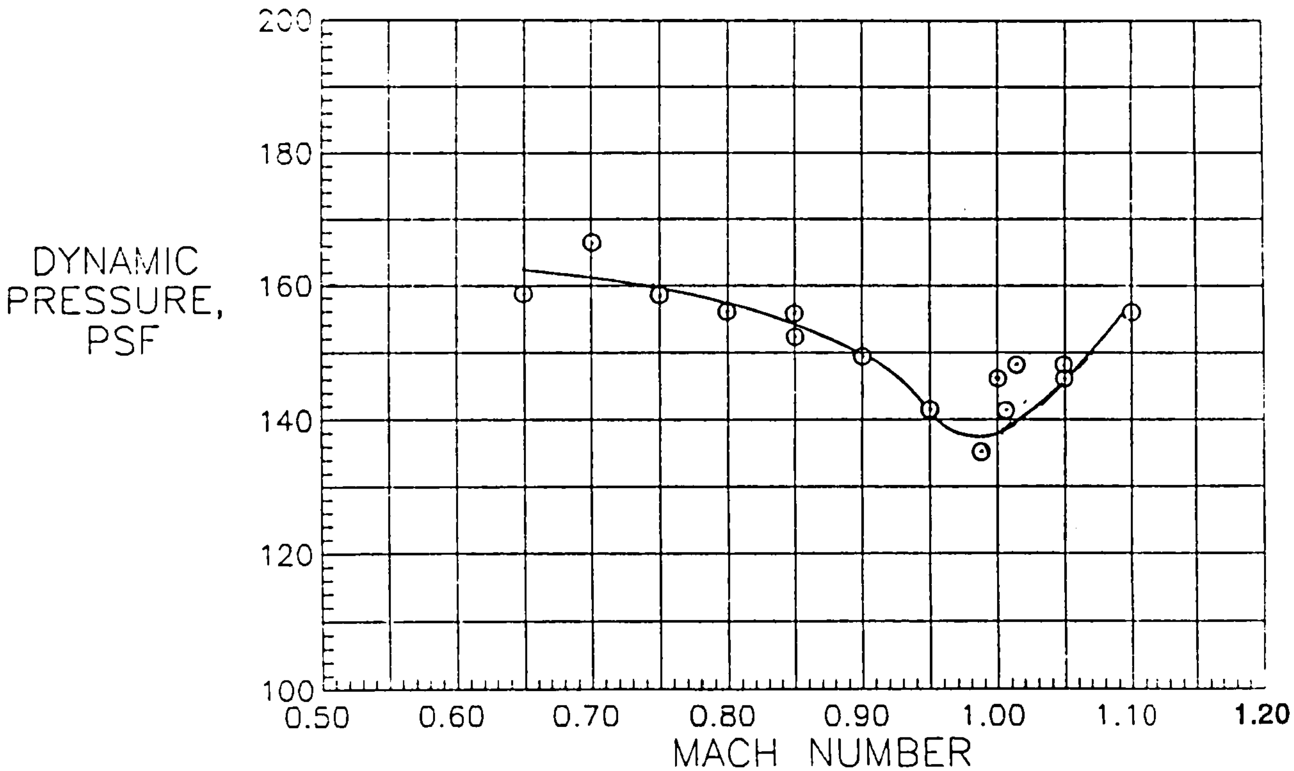

Figure 8. - Variation of flutter dynamic pressure with Mach number for basic wing configuration.

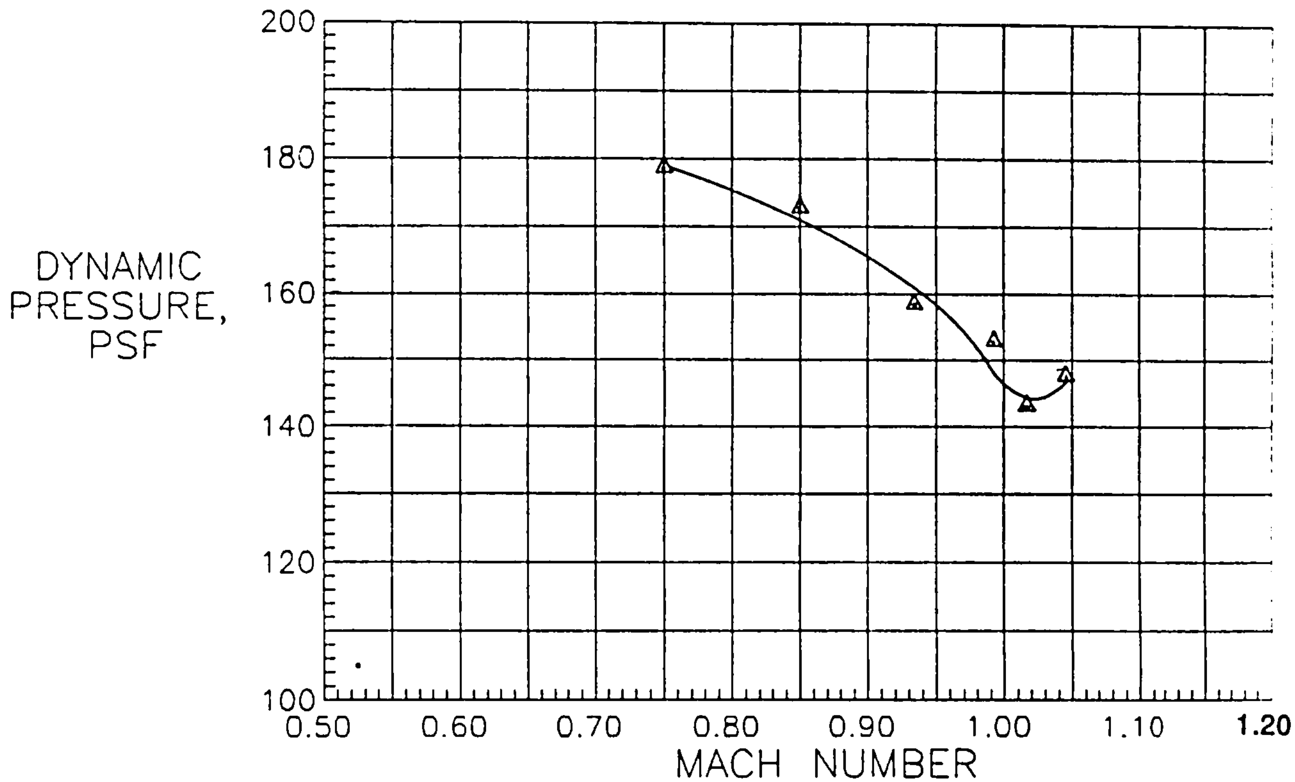

Figure 9. - Variation of flutter dynamic pressure with Mach number for wing-with-fin configuration.

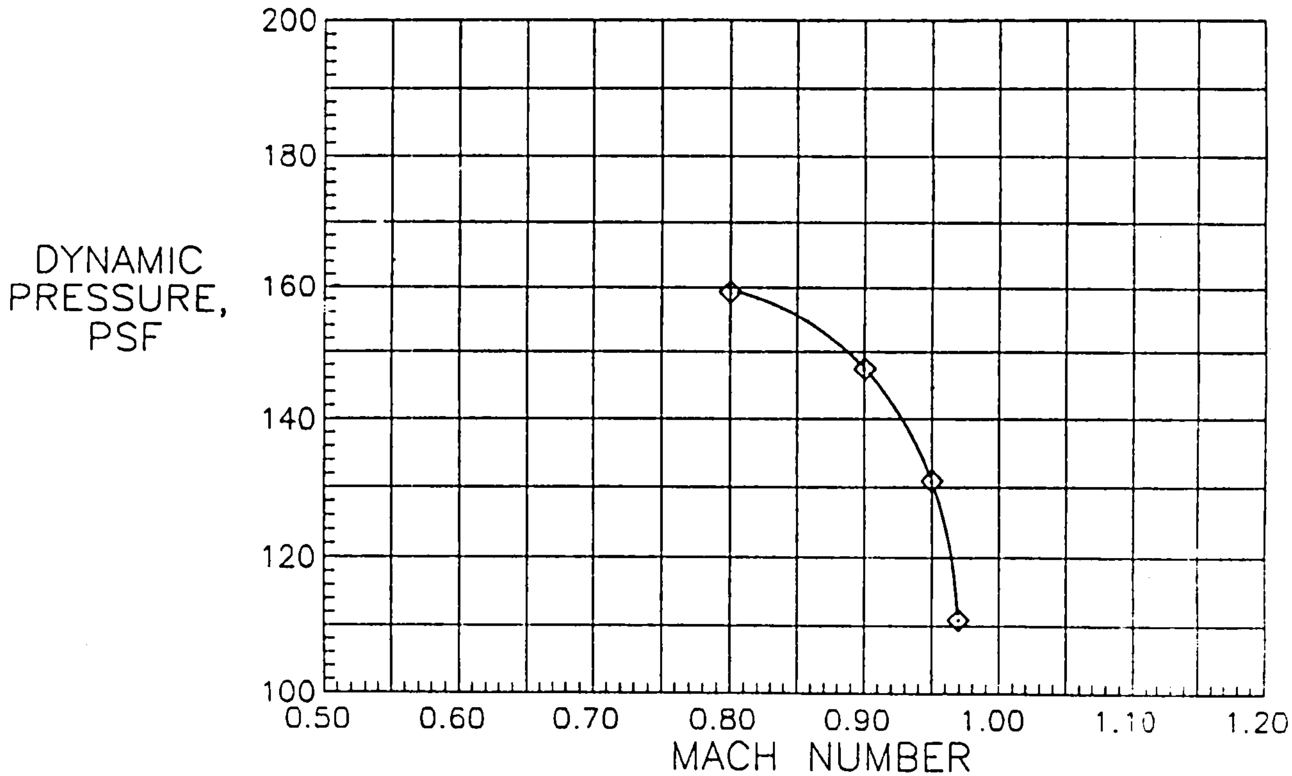

Figure 10. - Variation of flutter dynamic pressure with Mach number for wing-with-nacelles configuration.

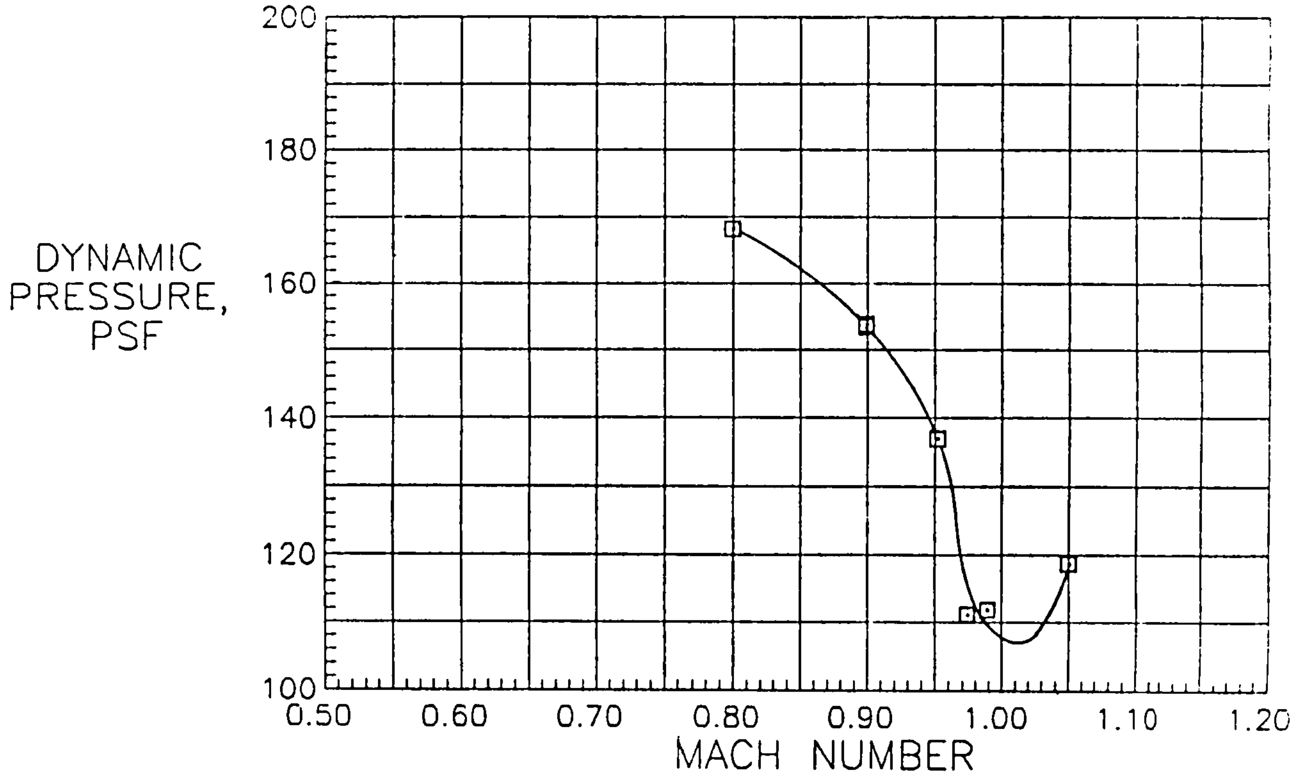

Figure 11. - Variation of flutter dynamic pressure with Mach number for wing-with-fin-and-nacelles configuration.

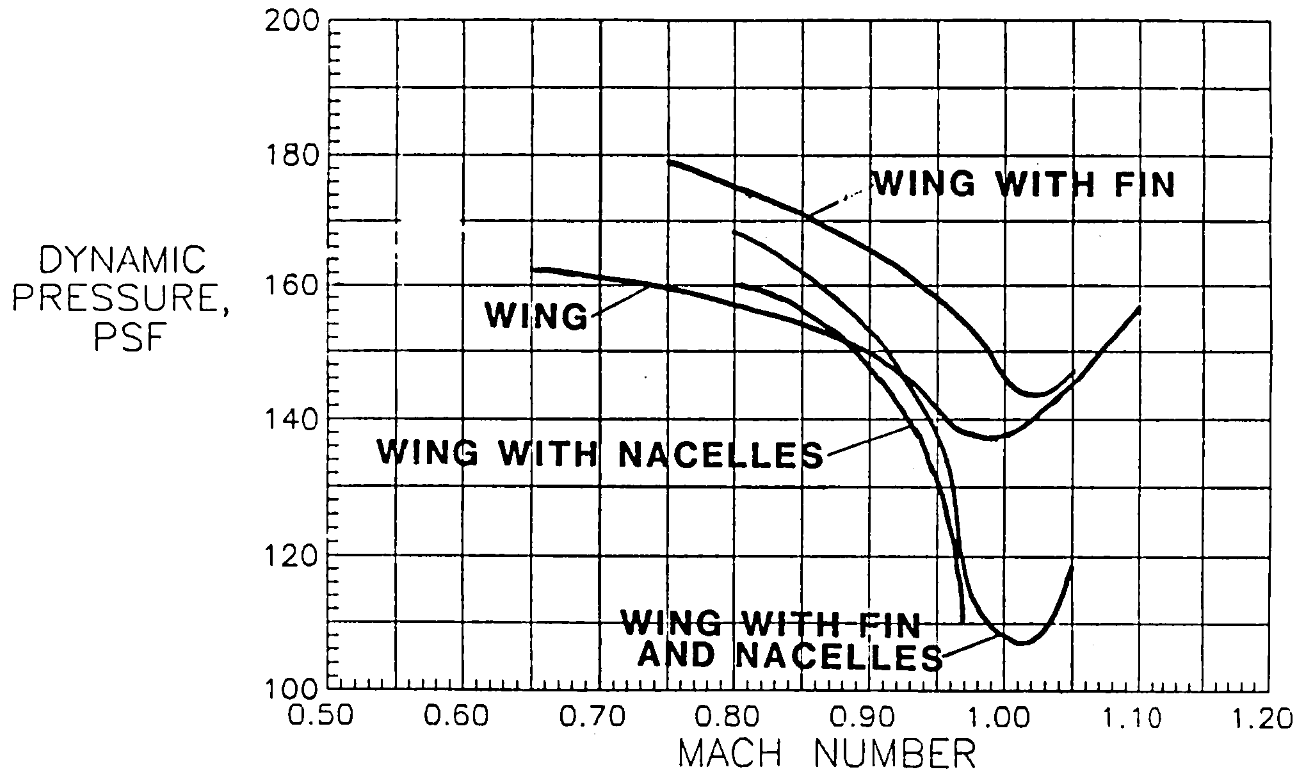

Figure 12. - Comparison of variation of flutter dynamic pressure with Mach number for all four configurations.

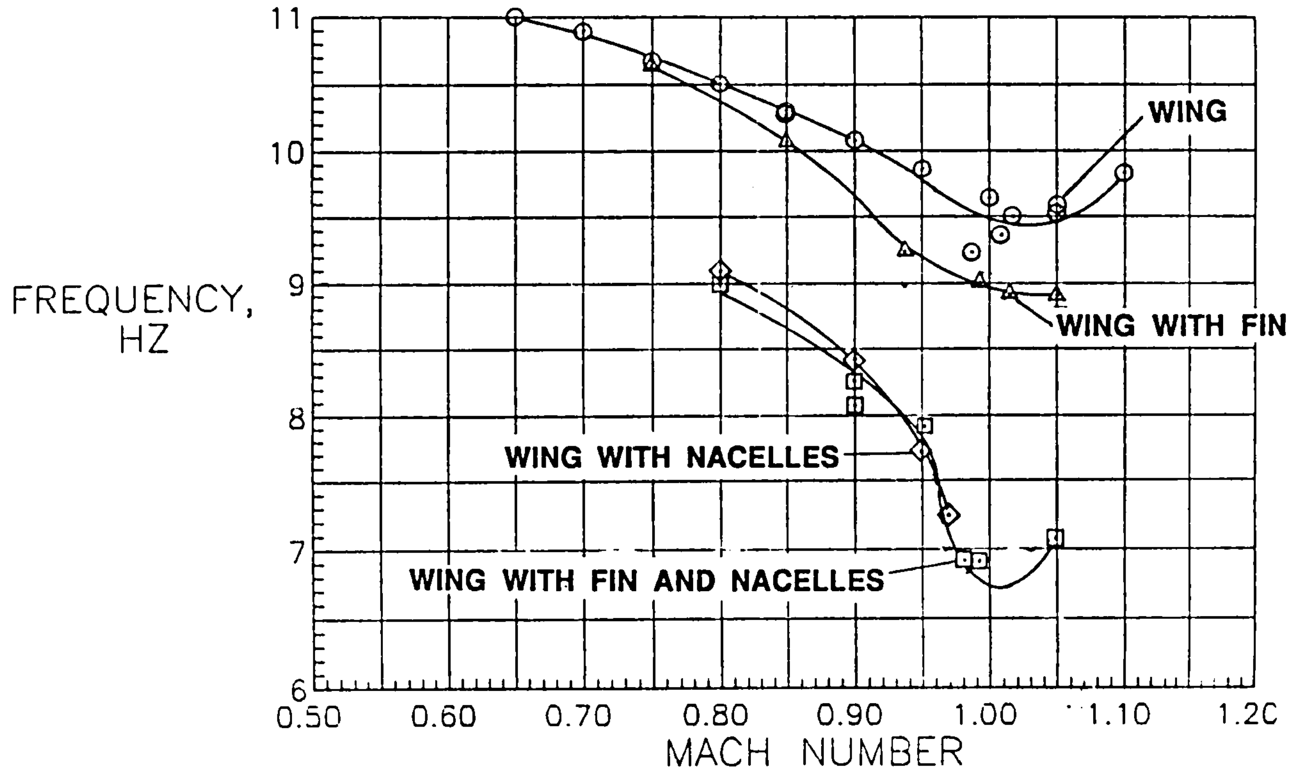

Figure 13. - Comparison of variation of flutter frequency with Mach number for all four configurations.

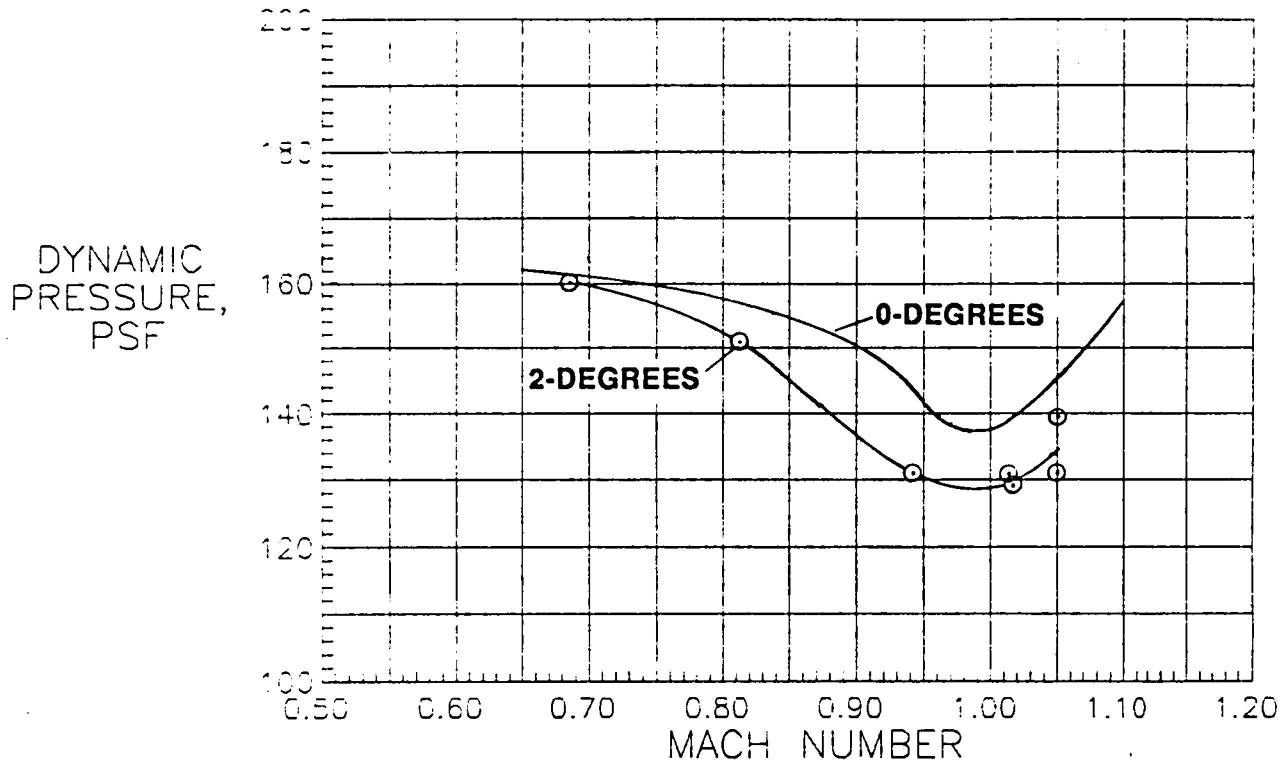

Figure 14. - Effects of angle of attack on flutter dynamic pressure for basic wing configuration.

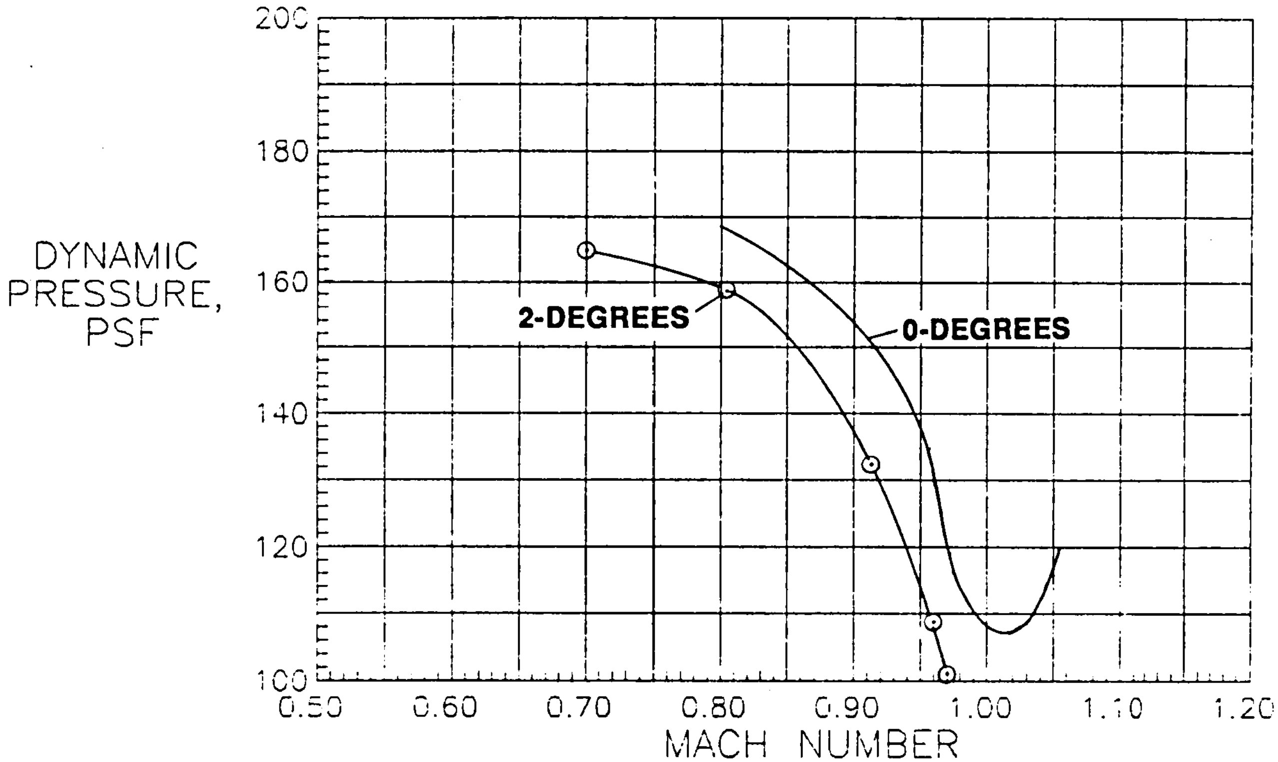

Figure 15. - Effects of angle of attack on flutter dynamic pressure for wing-with-fin-and-nacelles configuration.

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15. Supplementary Notes

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16. Abstract

Some early experimental results from a combined experimental and analytical study being conducted at NASA-Langely Research Center of the transonic flutter characteristics of a generic arrow wing configuration are presented. The planned study includes the parametric variation of a variety of structural and geometric characteristics. Presented here are flutter results for the basic arrow wing, for the basic wing with the addition of an upper-surface-mounted fin, for the basic wing with the addition of two simulated lower-surface-mounted engine nacelles, and for the basic wing with the addition of both the fin and the engine nacelles.

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