IX. Comparisons of L_v Variations

Since the variation of the XV-4B derivatives indicated L_v to have the strongest effect on its dutch roll roots, a root comparison was made in Fig. 8 with two other aircraft. From this comparison it can be seen that sufficient reduction of dihedral effect, no matter how it is done or on what aircraft, will result in a dynamically stable vehicle in the lateral mode down to very low speeds.

X. Conclusions

I have, in this paper, briefly described the results of a digital computer parameter variation study in which the effects on vehicle dynamics were evaluated while modifying the "best available dimensional derivatives" for the XV-4B aircraft.

From the results of this program it has been shown that L_v is the most important lateral-directional derivative influencing the dutch roll characteristics of V/STOL aircraft at low speeds. To dynamically stabilize a V/STOL in the lateral mode it is necessary to reduce the dihedral effect. On a jet lift aircraft low-speed dynamics can be improved by proper location of jet inlets and also by placing as much distance as possible between the lift jet exit and the wing.

Other derivatives such as Y_v, L_p, and N_v can be modified by physically changing the vehicle but their effects on the dynamics are not as strong as L_v. The proper changing of the derivatives in combination can, however, produce more favorable stability characteristics.

The use of parameter variation can provide understanding of V/STOL stability and control characteristics and establish the factors that are important in the vehicle's dynamic behavior.

Thus, for V/STOL aircraft design, the stability and control considerations of the design should be put on equal status with considerations of performance requirements, because configuration variables can have gross effects on flying qualities.

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Prediction of Interference Loading on Aircraft Stores at Supersonic Speeds

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A method for theoretically predicting forces and moments on aircraft stores in supersonic flow is investigated. Linear theory is used to predict the flowfield due to a jet fighter-bomber type aircraft, representing aircraft wing, nose, pylons, and inlets. The interference loading is integrated over the store length by considering crossflow effects and buoyancy effects. The method is computerized. Theoretical pitching and yawing moment calculations for a store under an F-4C aircraft at Mach 1.2 are compared with wind-tunnel data. The results show reasonably good agreement, with the exception that finite shock effects shift the experimental data axially forward of the linear theory prediction.

Introduction

A USEFUL method for obtaining aircraft store separation characteristics is that of wind-tunnel "traverse testing," coupled with digital computer trajectory simulation. The purpose of the traverse test is to obtain interference forces and moments on the store as a function of position under the aircraft. The computer simulation uses this loading information in table form, together with the store physical characteristics and free air characteristics, to predict the store behavior at separation.

If the store interference loading is a function of store angle of attack as well as position under the aircraft, the matrix table of loading information can become prohibitively large. Fortunately the store angle of attack effect on the interference loading can usually be neglected with small error if pitch angles are small. If so, traverse testing is performed at zero store angle of attack to obtain interference coefficients, which are added linearly to free air data to obtain store loading at angle of attack. This linear superposition assumption is generally used.[1]

The purpose of the present work is to develop a theoretical method for predicting store interference loadings at zero store angle of attack as would be obtained by wind-tunnel traverse testing. The intent is to supplement wind-tunnel methods and thereby reduce the cost of separation analysis. To

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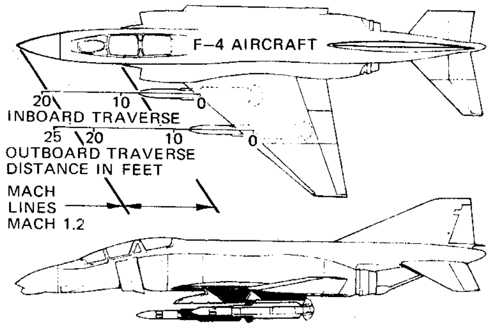


Fig. 1 Aircraft and store geometry used for comparing predictions with experiment.

accomplish this, the nonuniform flowfield about the aircraft is predicted by linear theory; the loading on the store in this nonuniform flowfield is predicted by using the free air load distribution properties of the store locally, with additional considerations as discussed later. This approach was developed in Ref. 2 as applied to subsonic flow, with good results. The present work is an extension of the method of Ref. 2 into supersonic flow.

The field of aircraft/store interference theoretical prediction has seen much recent activity.[2–7] References 3 and 4 use linear theory for representing the aircraft in subsonic flow, similar to Ref. 2. They differ from Ref. 2 in that they use linear theory to predict store loads. Reference 4 offers supersonic prediction capability as well but differs from the present work in representing the aircraft (wing-body interference is emphasized in Ref. 4, while pylons and jet inlets are not considered). References 5–7 use slender body theory assumptions to predict the aircraft flowfield. This approach is not adequate for predicting loading on these aircraft, and it is even less adequate for predicting the flowfield off the surface, because of the interference between crossflow planes.

Method

The method consists of predicting the flowfield about the aircraft by using source distributions to represent the aircraft according to linear theory. The effect of the variable interference flowfield is integrated over the length of the store by using the load distribution characteristics of the store in uniform flow. A computer program performs the calculations and is designed to accept the geometry of a jet fighter-bomber aircraft as input.

The aircraft wing, pylon thickness envelope, and jet inlet ramps are represented by source distributions. These aircraft surfaces are divided into small segments of constant source strength. The source strengths to represent wing thickness, pylon thickness, and inlet ramps are simply equal to the local surface slopes. Mutual interference between aircraft components is not included. The source strengths to represent wing lift, including camber and twist effects, are determined by the "Mach Box" numerical step procedure of Ref. 8. The aircraft fuselage nose thickness envelope is represented by a source distribution along the axis of symmetry according to the method of superposition of conical solutions.[9]

The source distributions representing the aircraft yield the interference flowfield over the length of the store for each store position of interest. The effect of this flowfield on the store is in two parts: one is the variable angle of attack field due to the crossflow perturbation velocity components; the other is the variable static pressure field, or buoyancy effect. These two effects are added linearly. The crossflow contribution to the loading is given by the store load per unit length and angle of attack, as measured in the freestream, times the local interference angle of attack and integrated over the store length. The buoyancy contribution is given by numerical integration of the interference static pressure over the store cylindrical surface. The effects of crossflow axial rate of change, and of downwash interference of the wing-tail type, are neglected in computing store loads. These effects are to be investigated in future studies.

The mathematical details of representing the aircraft by source distributions, of calculating the flowfield at the store due to these source distributions, and of integrating the loading over the store length, are all contained in Ref. 10.

Results

The ability of the computerized method to predict store interference moment coefficients was examined by comparing calculations with wind-tunnel data for a finned store configuration in the influence of an F-4C aircraft. Figure 1 shows the aircraft and store geometry. Figures 2a and 2b present pitching and yawing moments, respectively, for the store under the outboard pylon. Figures 2c and 2d present corresponding data under the inboard pylon. Pitching and yawing moment coefficients about the store center of gravity are used here for evaluating the method because these are the coefficients which most affect store behavior at separation. These moment coefficients are presented vs axial traverse distance of the store forward of the mate position, for separation at Mach 1.2, at zero angle of attack for aircraft and store. The solid lines are the wind-tunnel data. The dashed lines are the results of the computerized theoretical calculations, showing the separate interference contributions of each aircraft component as well as the total.

In the theoretical calculations, the wing is represented by 14 rows of Mach boxes per semispan. The inlet ramps are represented by two thickness surfaces, with it assumed that no ramp disturbance exists inside the Mach cone of the inlet lip (lower outside corner). The inboard pylon is represented by four thickness surfaces, and the outboard by two thickness surfaces (leading and trailing edges). The flow about the fuselage nose is calculated using 12 cone source distributions distributed along the axis of the nose. The store is divided into 12 axial sections for numerically integrating the interference effect over the length of the store.

Discussion

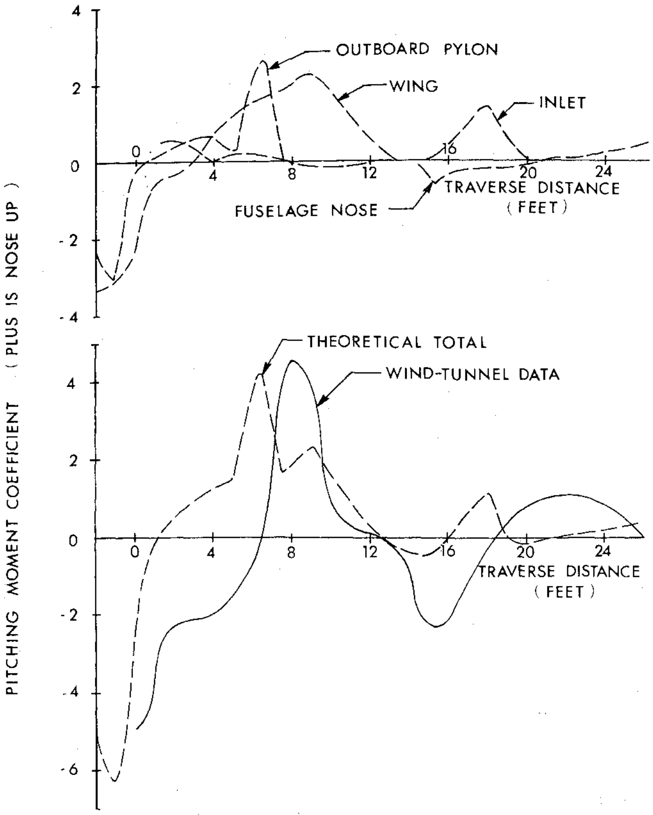
The aircraft components considered in the theoretical calculations are wing thickness, camber, and twist; inlet ramps; pylon thickness; fuselage nose. The major effect of each component is somewhat localized on the axial traverse so that it is possible to say something about the accuracy of each component prediction by comparison with the experimental total. The accuracy of each component prediction will now be discussed in turn.

Wing Effect

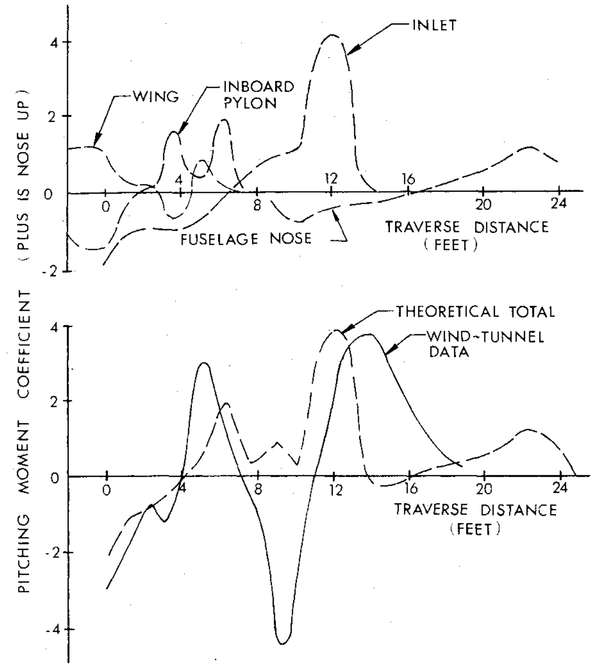
The wing interference effect is not large at zero aircraft angle of attack because the F-4 wing camber near the leading edge tends to cancel the effects of leading edge thickness. No angle of attack comparisons were made because of the lack of test data, although the computerized prediction method does include angle of attack capability. More test case comparisons are needed to determine the adequacy of the wing representation for interference calculations.

Inlet Ramp Effect

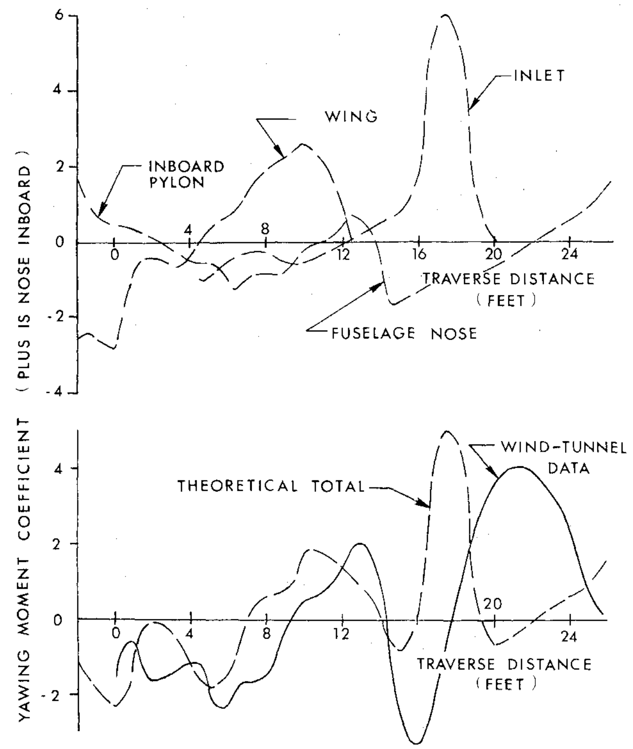
Figures 2a and 2b for traverse from the outboard mate position show the peak influence of the inlet ramps predicted at about 18 ft, whereas tunnel data shows the peak at 22 ft. This shift in peak influence reflects the fact that linear theory is being used here, with all disturbances traveling along Mach lines. The inlet ramp slopes are about 13° and 18°, and they produce a curved shock at Mach 1.2 which is dis-



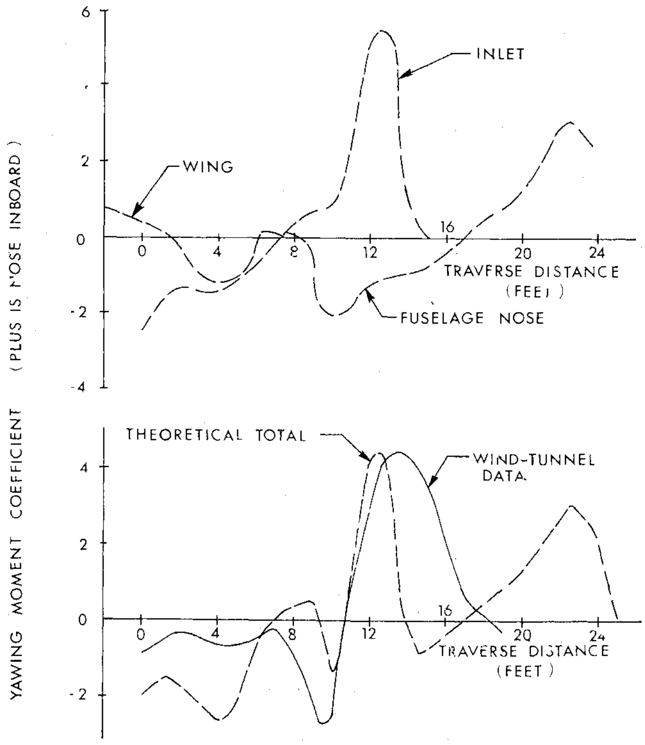
2a) Pitching moment at outboard pylon



2c) Pitching moment at inboard pylon



2b) Yawing moment at outboard pylon



2d) Yawing moment at inboard pylon

Fig. 2 Interference coefficient prediction for the separate aircraft components and comparison with experiment; Mach 1.2 F-4 aircraft angle of attack = 0, store axial traverse from mate, location at angle of incidence = 0.

placed forward of the Mach wave. The same type of shift is shown in Figs. 2a and 2b for traverse from the inboard mate position, although the shift is smaller because the store is closer to the inlet ramps. The magnitude of the predicted inlet disturbance shows fair agreement, however.

Pylon Thickness Effect

The pylon thickness produces a store pitching moment, Figs. 2a and 2c, with some effect of the inboard pylon on yawing moment of the store at the outboard pylon, Fig. 2b.

Figure 2a shows a peak in pitching moment, due to the store tails passing under the pylon leading edge, predicted at 6.5 ft but occurring at 8 ft. This peak shift is due partly to the shock curvature and displacement from the Mach wave at the pylon leading edge. It is also because of the fact that the velocity field is calculated at the store cylindrical surface, which may leave the influence of the pylon while the tails remain. A similar peak shift in negative pitching moment near $X = 0$ on Fig. 5a is probably another result of using a store with high span tails; the tails protrude into the expansion fan region of the pylon trailing edge while the velocity field calculated at the store cylindrical surface is outside this influence.

Fuselage Nose Effect

Figures 2a and 2b show a negative spike in pitching and yawing moment at about 16 ft from the outboard mate position as the store nose passes through the bow shock of the fuselage nose. Figures 2c and 2d show a similar spike at about 10 ft from the inboard mate position. The axial location of these spikes is predicted well by the theory. However, the magnitude of the spike is underpredicted, especially for pitching moment.

Conclusion

Linear theory has been used in an attempt to develop a computerized method for predicting the interference loading on aircraft stores in supersonic flow. Test case predictions show that good progress has been made toward obtaining a workable prediction method. The results of this study point to the necessary areas of improvement in the method. They are 1) consideration of the propagation angles of finite shock waves, differing from that of Mach waves, which shift the interference effect axially from the location predicted by linear theory; 2) consideration of flowfield variations over the span of the fins of the store from root to tip, especially for large span panels close to a pylon. With this as well as other theoretical prediction methods being introduced and improved upon, the theoretical approach will become a valuable and much used tool for aircraft/store interference evaluation in the near future.

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