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INDUCED INTERFERENCE EFFECTS ON JET AND BURIED-FAN VTOL CONFIGURATIONS IN TRANSITION

By Kenneth P. Spreemann

Langley Research Center

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SUMMARY

Recent investigations of some jet and buried-fan configurations have indicated that in the transition speed range configurations with considerable area surrounding the jet or buried fan can encounter large losses in lift and nose-up pitching moments due to the pressures induced on the lower surfaces by the interaction of the jet and free-stream flow. The obvious way of minimizing these effects is to reduce the surface area surrounding the jets or buried fans, that is, to consider these effects in the preliminary stages of the airplane design.

INTRODUCTION

Previously reported investigations have indicated how the performance of buried-fan VTOL configurations can be affected by the characteristics of the fan inlet flow. The exit flow of buried-fan and turbojet VTOL aircraft can also have important effects on the aerodynamics of these aircraft. This paper will deal primarily with the interaction of the existing jet and the free-stream flow which can induce pressures on the bottom of the wing or fuselage and cause losses in lift and nose-up pitching moments.

SYMBOLS

α	angle of attack, deg
A	area, sq ft
D	diameter, ft
L	lift, lb
M	pitching moment, ft-lb

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T thrust, lb

V velocity

W weight, lb

Subscripts:

∞ free stream

j jet

w wing

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RESULTS AND DISCUSSION

Results of some recent investigations have indicated that serious interference effects can be encountered with some jet and buried-fan configurations in transition such as shown in figure 1. These effects can be shown to be principally the results of the interaction of the exiting jet and the free-stream flow, which induces pressures on the bottom of the wing or fuselage. These interference pressures can be illustrated with some pressure-distribution data that have recently been obtained on a flat plate with a jet issuing vertically beneath it.

Figure 2 shows the pressures schematically imposed on the plate lower surface. Positive pressures are generated in front of the jet and negative pressures behind the jet. Negative pressures as high as 3 to 4 times the free-stream dynamic pressure were measured. The pressures diminish with distance from the jet but extend 10 to 15 jet diameters downstream and 5 to 10 diameters to each side of the jet. The negative pressures outweigh the positive pressures and thus cause a loss in lift. The combination of positive pressures ahead of the jet and negative pressures behind gives a nose-up pitching moment.

There are two factors which affect the magnitude of the lift and nose-up moments: (1) the jet velocity which determines the amplitude of the pressures induced on the lower surface and (2) the extent of the surface area around the jet. For example, with a small plate high pressures on a relatively small area give a loss in lift and nose-up moments; however, with a large plate not only is there this loss in lift, but in addition pressures extend over a much larger area and therefore cause greater losses in lift and larger nose-up moments.

Some force and moment data are available on a number of models to show these effects. Sketches of some of the configurations on which data are available are shown in figure 3. At the top are two buried-fan configurations and at the bottom two jet configurations. A fairly wide range of ratios of jet area to wing area is covered. Data for the semispan buried-fan configuration are given in reference 1 and for the configuration with the smallest ratio of jet area to wing area in reference 2. Data for the remaining two configurations are from unpublished investigations. It should be noted that the lowest ratio of jet area to wing area is probably impractical $\left(A_j/A_W = 0.009\right)$. A more realistic area ratio for a jet aircraft would be somewhere between the largest jet and smallest fan-in-fuselage configurations.

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Figure 4 shows some data that have been obtained for these models through the transition speed range at zero angle of attack. As can be seen from the figure, in general the lift losses increase with reductions in the ratio of jet area to wing area. Also the nose-up moments are increased with decreases in jet area to wing area.

The two buried-fan configurations include inlet flow over the top of the model which contributes to the nose-up moments. However, for the jet configuration there is no inlet flow and the moments are primarily due to the induced pressures on the lower surface.

These data are for zero angle of attack with the jet efflux perpendicular to the bottom of the wing or fuselage. For some configurations the loss in lift can be compensated for with wing lift by going to higher angles of attack.

Figure 5 shows some typical examples of transition at angles of attack of 0°, 10°, and 20° for the delta-wing jet model. At zero angle of attack the same adverse effects existed as were shown in figure 4. At 20° angle of attack the wing lift more than compensated for the loss in lift due to the jet interference throughout the transition; however, the pitching-moment problem remained.

Some efforts have been made to alleviate these losses in lift and nose-up moments with fixes such as flow diverters and various types of spoilers and ramps. These fixes have not been particularly helpful, possibly because the fixes were placed too close to the jet. However, in one full-scale flight investigation deflecting a trailing-edge flap reduced the losses in lift and nose-up pitching moments. The beneficial effects of the flaps on this configuration can be attributed to positive pressures being built up in front of the flap on the lower surface.

In addition to the trim problem there can be a problem of stability in transition on conventional aft-tailed configurations. This point is illustrated in figure 6, which shows the attitude stability parameter, pitching moment in foot-pounds per degree of angle of attack, plotted against velocity in knots, for a 4-jet 9,000-pound airplane with a conventional aft tail. The data points on the curve correspond to the jet deflection angles required to maintain steady level flight. In the transition speed range the airplane is unstable up to about 170 knots.

A similar instability was pointed out in reference 3 for the propeller-driven VTOL configurations; however, the instability extended up to only 30 or 40 knots and consequently was not particularly troublesome to the pilots because of the low dynamic pressures involved. However, the higher dynamic pressures involved in the present case would be expected to cause some difficulty as has been verified by free-flight tests of a dynamically scaled model of this configuration which indicated some piloting problems in this speed range.

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CONCLUDING REMARKS

All the data in this paper are based on model results at low Reynolds numbers. While full-scale results may differ somewhat in the magnitude of specific values, the general trends indicated would not be changed. Thus it appears that configurations with considerable lifting area surrounding the jet or buried fan can encounter large losses in lift and large nose-up moments at low forward speeds as a result of the pressures induced on the lower surfaces by the jets. The obvious way of minimizing these effects is to reduce the surface area surrounding the jets or buried fans, that is, to consider these effects in the preliminary stages of the airplane design.

In one full-scale flight investigation a trailing-edge flap reduced the losses in lift and nose-up moments in the transition speed range. Another problem is the reduction of the stabilizing contribution of an aft-mounted horizontal tail which may make flight in the transition speed range difficult.

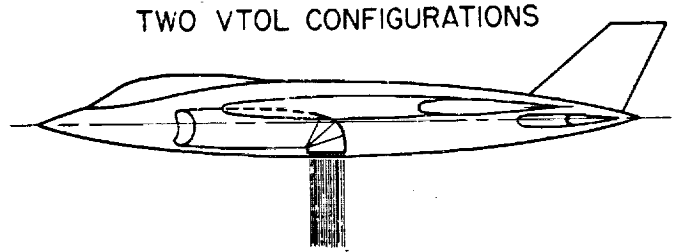
REFERENCES

1. Hickey, David H., and Ellis, David R.: Wind-Tunnel Tests of a Semi-span Wing With a Fan Rotating in the Plane of the Wing. NASA TN D-88, 1959.

2. Williams, John: Some British Research on the Basic Aerodynamics of Powered Lift Systems. Jour. R.A.S., vol. 64, no. 595, July 1960, pp. 413-437.

3. Kirby, Robert H.: Aerodynamic Characteristics of Propeller-Driven VTOL Aircraft. (Prospective NASA Paper.)

TWO VTOL CONFIGURATIONS



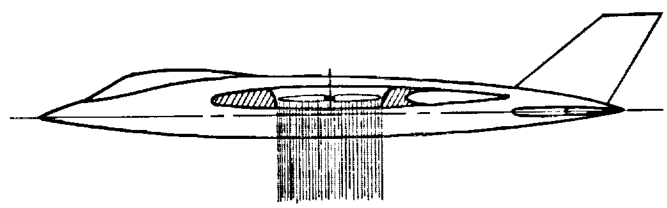


Figure 1

SCHEMATIC DIAGRAM OF PRESSURES ON PLATE

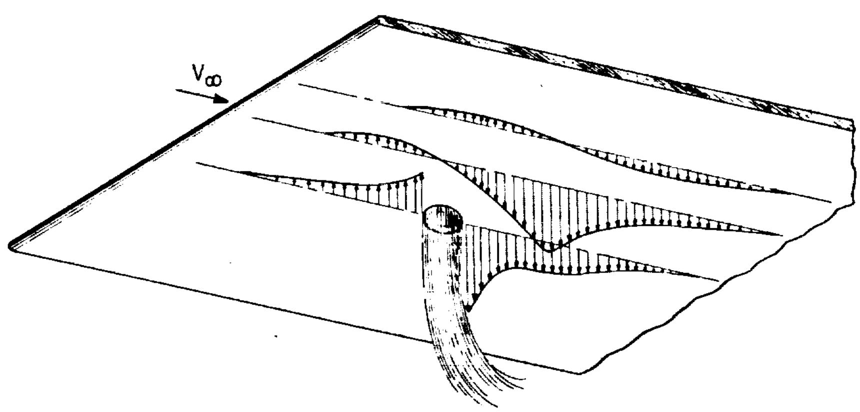


Figure 2

PLANFORMS STUDIED

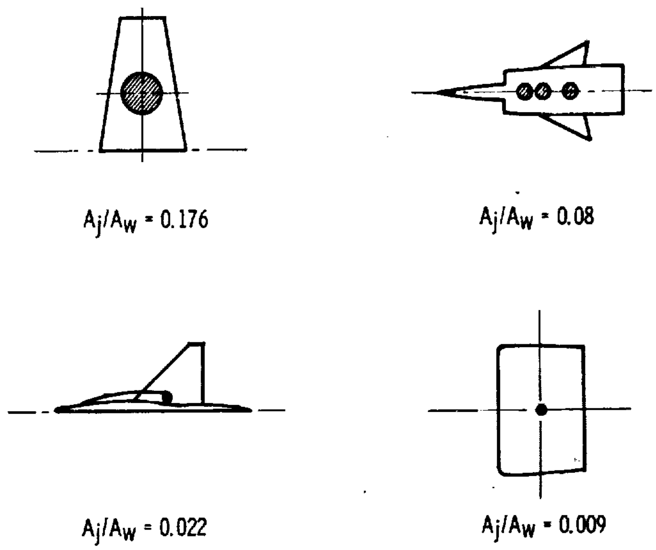


Figure 3

EFFECT OF SPEED ON LIFT AND PITCHING MOMENT

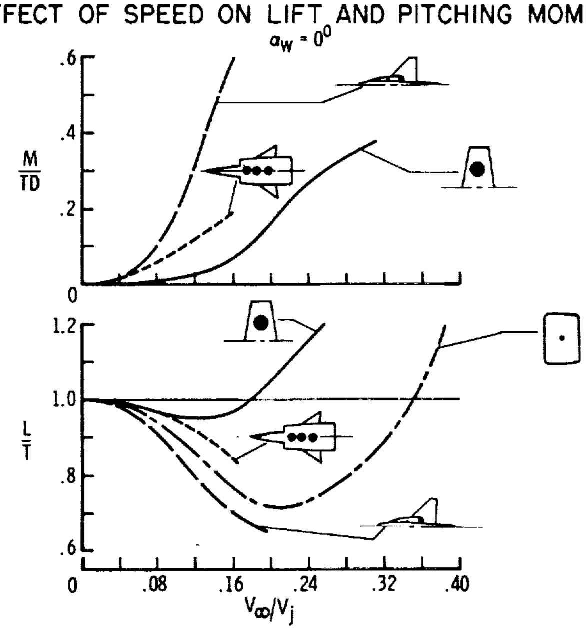


Figure 4

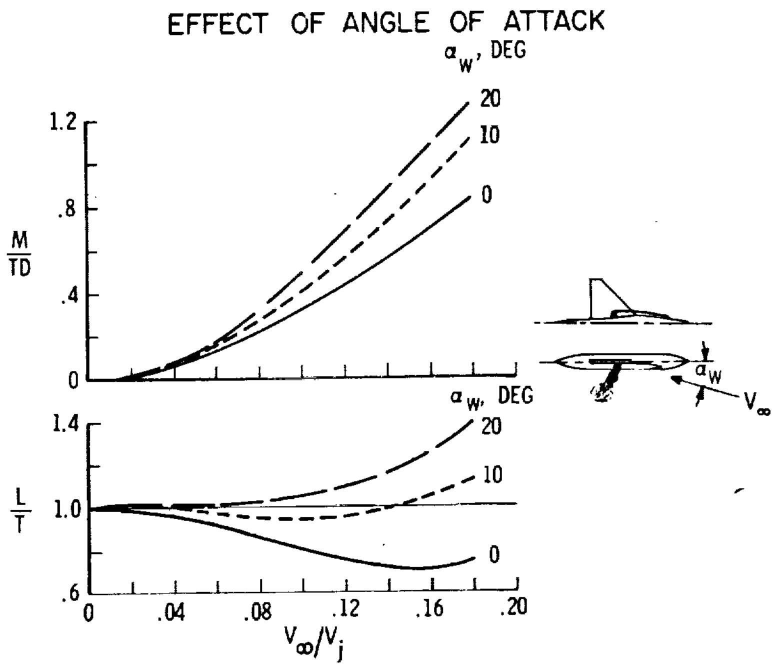


Figure 5

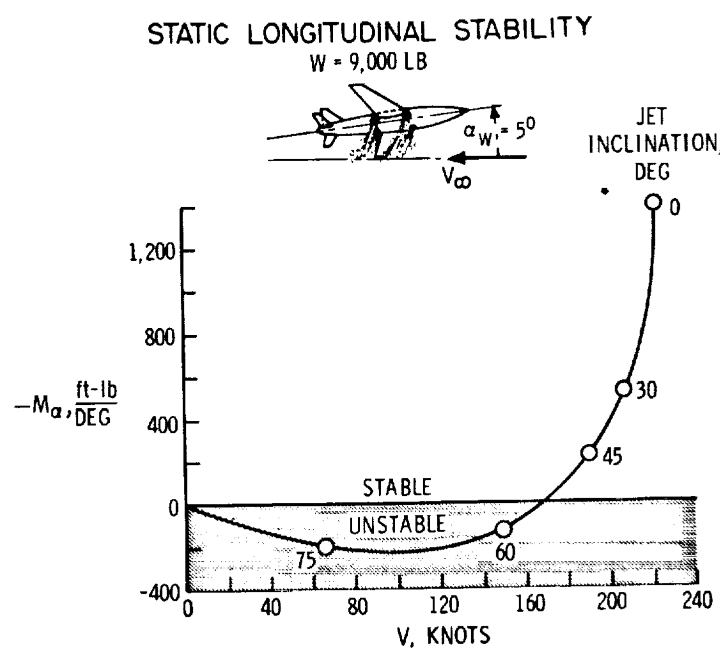


Figure 6