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DISTRIBUTED UPPER-SURFACE BLOWING CONCEPT

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SUMMARY

A low-speed investigation was conducted in the Langley V/STOL tunnel to determine the powered-lift aerodynamic performance of a distributed upper-surface-blown propulsive-lift transport model. The model used blowing slots across the span of the wing to produce a thin jet efflux near the leading edge and at the knee of the trailing-edge flap (internally blown jet flap). These concepts have both good propulsive-related lift and low drag-due-to-lift characteristics because of uniform spanwise propulsive thrust. The leading-edge blowing concept provides low-speed lift characteristics which are competitive with the flap-hinge-line blowing concept and does not require additional leading-edge treatment for prevention of abrupt stall.

INTRODUCTION

Several propulsive-lift concepts have been investigated recently in efforts to develop a quiet short-take-off-and-landing (STOL) aircraft. The upper-surface-blown (USB) jet-flap concept appears to offer an attractive solution for a quiet STOL aircraft. Most of the investigations to date have used configurations that direct the efflux from discrete engine nozzles over the wing upper surface and high-lift system to provide increases in lift by means of Coanda turning of the jet (ref. 1). These results indicated that the propulsive lift capabilities were greatly dependent upon the nozzle geometry and their [illegible]tion to the high-lift system, with thin well-spread jets giving the best Co[illegible] turning.

Another version of the USB concept utilizes full-span slot nozzles near the leading edge and flap hinge. These slot nozzles are beneficial in several ways. First, they improve the aerodynamic performance by distributing the propulsive efflux in the spanwise direction, which improves the induced lift and reduces the induced drag relative to that obtained with discrete USB nacelles. Second, this arrangement reduces the propulsive noise by the use of very high aspect-ratio nozzles which produce high-frequency noise that damps out quickly and by shielding the ground with the wing.

Figure 1(a) shows a photograph and a sketch of this distributed blowing concept applied to a subsonic transport configuration with an aspect-ratio-6.8 swept wing tested in the Langley V/STOL tunnel. The wing had internal plenums which supplied air to full-span slot nozzles located along the wing leading edge and along the flap hinge line. It is anticipated that this arrangement would approach the upper limit for propulsive induced lift. However, such an arrangement would introduce weight and volume penalties and would require systems studies to determine if it is a practical concept for subsonic transport applications.

SYMBOLS

A	aspect ratio
C_D	drag coefficient, Drag/qS
C_L	lift coefficient, Lift/qS
$C_{L,jr}$	jet-reaction lift coefficient
C_{L_Γ}	circulation lift coefficient due to power
C_μ	thrust coefficient, Thrust/qS
c	wing chord
q	free-stream dynamic pressure
S	wing area
α	angle of attack, deg
δ_f	flap deflection measured streamwise, deg (Dual notation indicates deflection of forward element with respect to the basic airfoil chord line, followed by the deflection of the rear element with respect to the chord line of the forward element. See fig. 1(b).)

DISCUSSION

The basic data for distributed blowing over the flap and at the leading edge for several flap deflections are presented in figure 2 for a nominal value of C_μ of 2.0. These data show that with blowing over the deflected trailing-edge flaps and with no leading-edge high-lift device, there was an abrupt stall near $\alpha = 12^\circ$. However, for the leading-edge blowing configuration, there was no stall through the angle-of-attack range tested.

The theoretical minimum drag-due-to-lift curve (ref. 2) is plotted along with the basic data for both blowing concepts in figure 2 and shows that the basic data approach this curve quite well.

The variations of lift coefficient with angle of attack for the two blowing concepts are presented in figure 3. All configurations had two element flaps (fig. 1(b)) with the forward and aft elements deflected 45° and 15°, respectively. A comparison of the leading-edge and flap blowing indicates that at low angles of attack, the flap-hinge-line blowing results in somewhat higher values of C_L than the leading-edge blowing. Also, if the leading edge is dropped to 30° on the flap-hinge-line blowing configuration, it performs as well as, or better than, the leading-edge blowing configuration at the higher angles of attack.

Figure 4 presents the propulsive-related lift as a function of thrust coefficient for the distributed leading-edge blowing concept and a conventional USB concept. The propulsive-related lift is the combination of the jet-reaction lift $C_{L,jr}$ and the additional circulation lift due to power $C_{L\Gamma}$. The conventional USB concept (ref. 2) used rectangular exhaust nozzles having an aspect ratio of 6. The distributed leading-edge blowing concept produced much more propulsive-related lift than the USB concept.

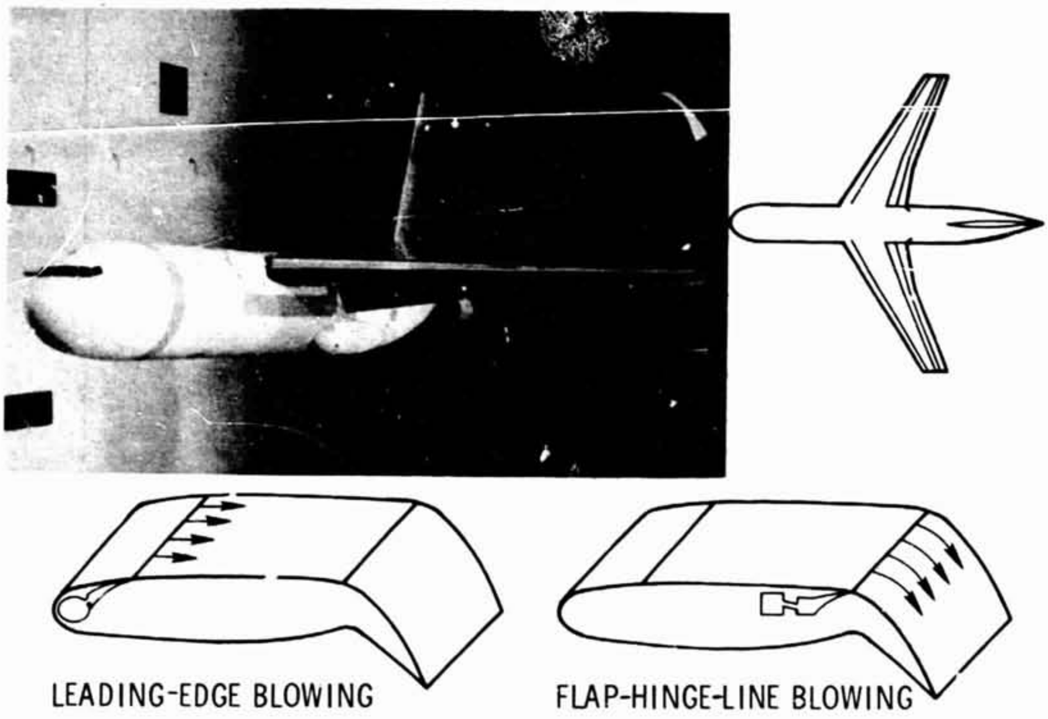
CONCLUDING REMARKS

The distributed blowing concepts, with blowing at either the leading edge or flap hinge line, have both good propulsive-related lift and low drag due to lift because of the uniform spanwise propulsive thrust. The leading-edge blowing concept provides low-speed lift characteristics which are competitive with the flap-hinge-line blowing concept and does not require additional leading-edge treatment for prevention of abrupt stall.

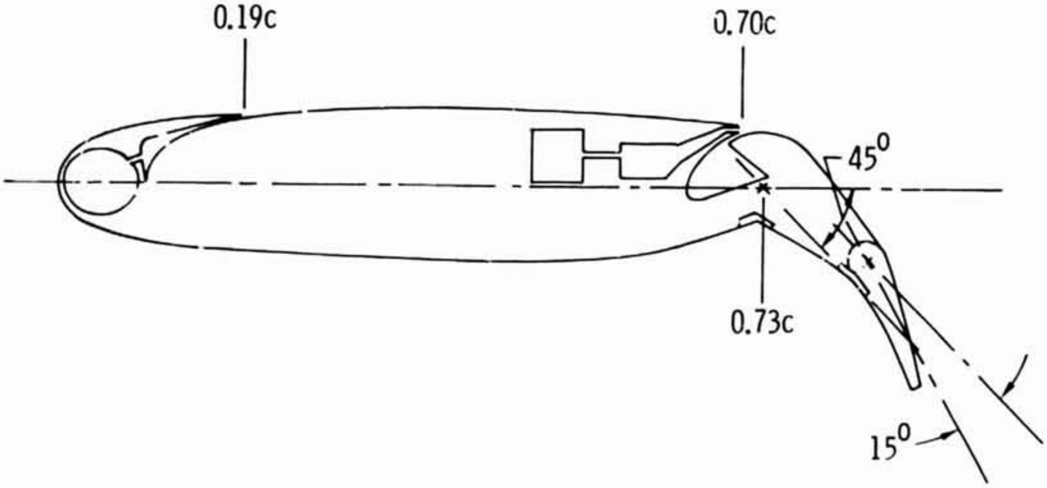
REFERENCES

1. Sleeman, William C., Jr.; and Hohlweg, William C.: Low-Speed Wind-Tunnel Investigation of a Four-Engine Upper Surface Blown Model Having a Swept Wing and Rectangular and D-Shaped Exhaust Nozzles. NASA TN D-8061, 1975.

2. McCormick, Barnes W., Jr.: Aerodynamics of V/STOL Flight. Academic Press, Inc., 1967.

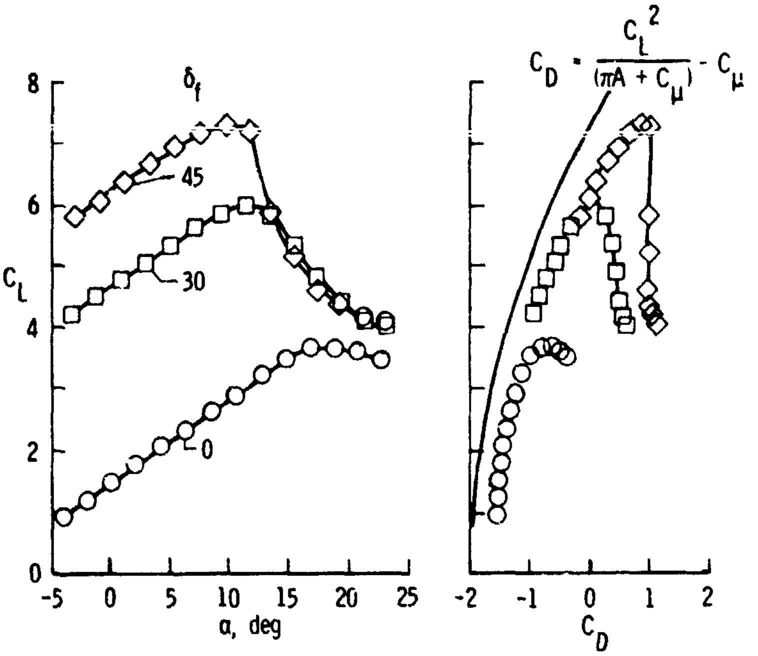


(a) Sketch and photograph of model.

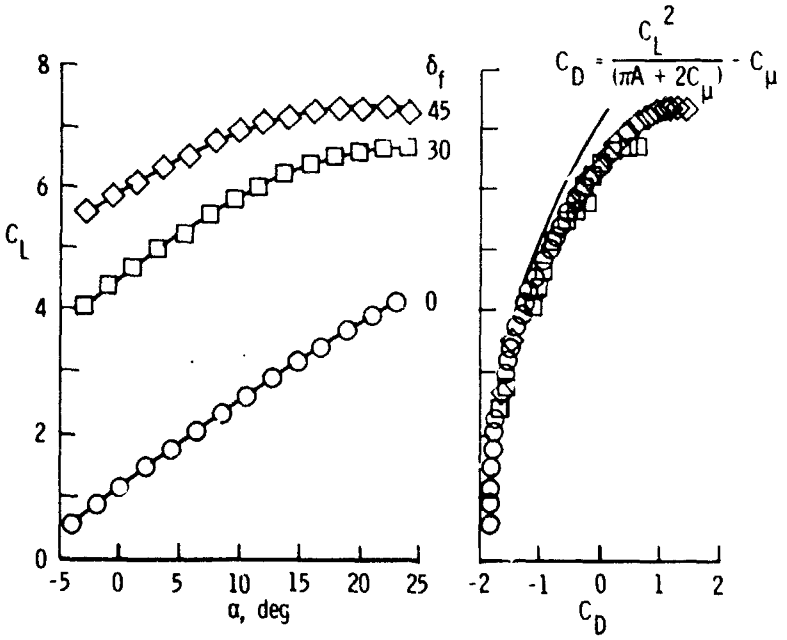


(b) Flap details.

Figure 1.- Distributed blowing concepts applied to subsonic transport.



(a) Flap-hinge-line blowing. $C_\mu = 1.9$.



(b) Leading-edge blowing. $C_\mu = 2.0$.

Figure 2.- Effect of flap deflection on lift and drag coefficients for model with distributed blowing concepts. Tail off; $\delta_f = 45^\circ\text{-}0^\circ$; $C_\mu \approx 2$.

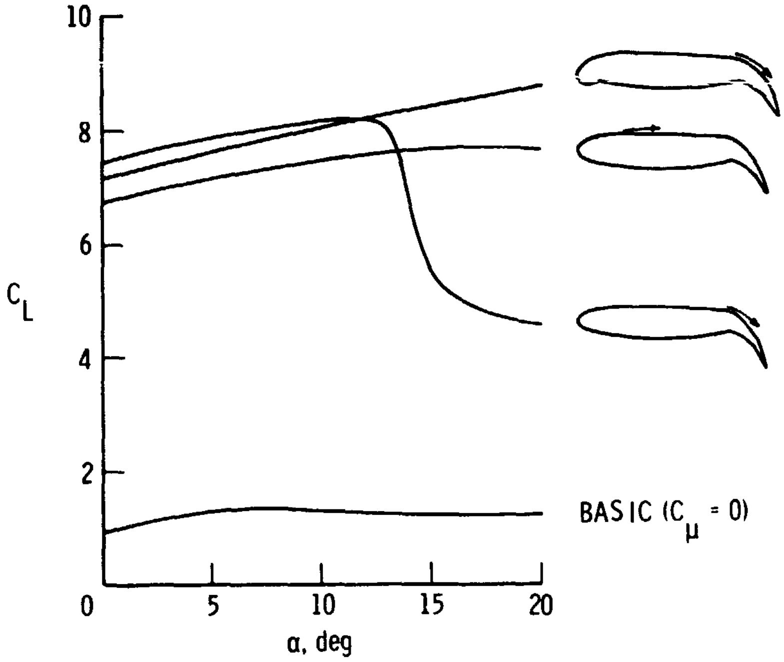


Figure 3.- Variation of C_L with α for the distributed blowing concepts. $\delta_f = 45^\circ-15^\circ$; $C_\mu = 2.0$.

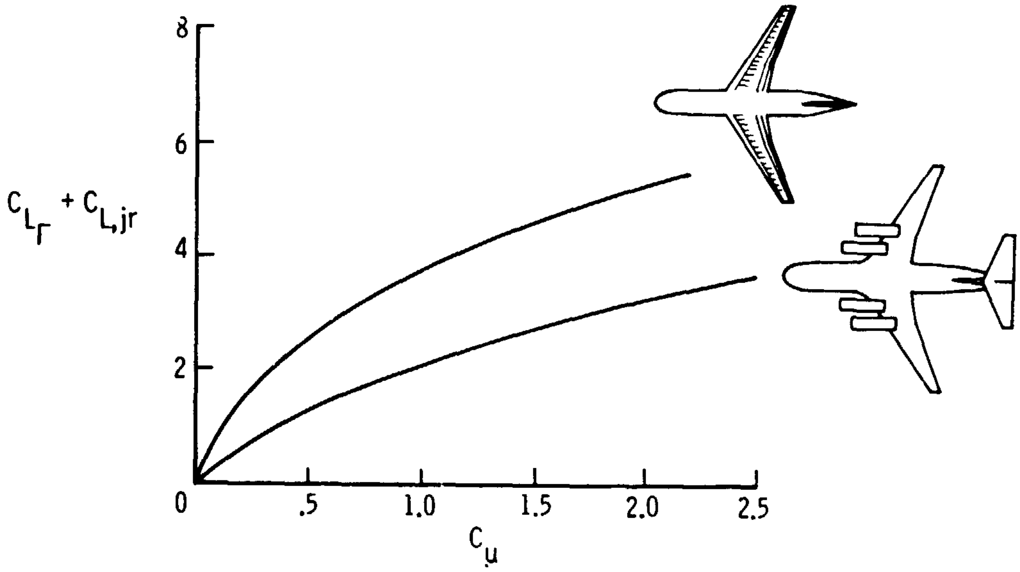


Figure 4.- Variation of propulsive-related lift with thrust coefficient for the distributed leading-edge blowing concept and a conventional USB concept.