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Predicted Airframe Noise Levels for Certification Flights

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Introduction

A RECENT publication by the author[1] evaluated the ICAO reference method for airframe noise prediction. The ICAO method, which was developed by Fink,[2] was used to predict approach noise levels in terms of EPNL of several aircraft. These predicted airframe noise levels were compared with certification data of selected commercial aircraft and with current FAA stage 3 (1977) noise regulations. Comparisons with certification data and with FAA certification requirements created an inconsistency in the last figure of Ref. 1 in that the predicted noise levels were for approach velocities lower than required for certification. This inconsistency will be corrected in this Note.

Corrected Computations of Airframe Noise Levels

The values for aircraft approach speeds and flap settings used in the last figure (Fig. 13) of Ref. 1 are given in Table 1. These values are typical for normal operations of these aircraft but are not the same values required for certification flights. The certification values are also given in Table 1. The certification velocities are higher than the typical approach velocities and this results in higher predicted airframe noise levels. The predicted airframe noise levels have been recalculated using the certification values and are listed along with the previous calculations in Table 2. The predicted airframe noise levels under certification conditions average 2.3 dB higher than those calculated using the typical approach values.

The new levels are replotted in Fig. 1 of this Note and represent a consistent comparison with certification requirements. Predicted levels for Space Shuttle Orbiter, Spanloader, LFC, and AST-100 aircraft are not recalculated for Fig. 1 of this Note since certification velocities have not been established for these aircraft.

For further discussion of the more controversial aspects of this prediction procedure together with numerical predictions resulting from a modified method, the reader is referred to Ref. 3.

Table 1 Input values for airframe noise prediction

Aircraft	Typical approach values (used in Ref. 1) Velocity, m/s	Flaps, deg	Certification values Velocity, m/s	Flaps, deg
DC-9-30	64.43	45	73.6	40
727-200	64.84	45	71.55	40
A300-B2	67.94	45	83.50	25
L-1011	73.34	45	77.16	42
DC-10-10	70.64	45	77.16	50
747-200B	72.44	45	85.14	30

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Table 2 Airframe noise prediction for approach EPNL

Aircraft	Predicted levels from Ref. 1, EPNdB	Predicted levels using certification values, EPNdB	Difference from original calculation EPNdB
DC-9-30	84.3	87.2	+2.9
727-200	91.9	93.6	+1.7
A300-B2	88.5	91.8	+3.3
L-1011	90.2	91.2	+1.0
DC-10-10	90.3	92.8	+2.5
747-200B	97.5	99.6	+2.1

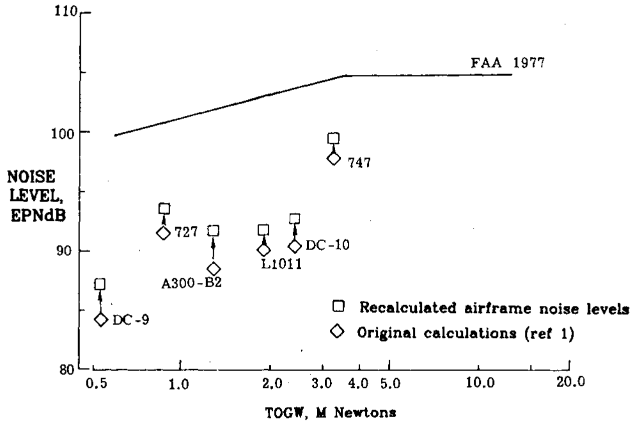

Fig. 1 Predicted landing airframe noise levels for certification flights.

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Effect of Leading-Edge Vortex Flaps on Aerodynamic Performance of Delta Wings

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Nomenclature

A	= aspect ratio
b	= wing span
$\bar{c}$	= aerodynamic mean chord
c_r	= root chord
C_D	= drag coefficient
C_L	= lift coefficient

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C_m = pitching moment coefficient
D = drag
FVS = free vortex sheet
L = lift
x,y,z = body axis coordinates
α = angle of attack
δ_n = flap angle normal to hinge

Introduction

MANY modern aircraft and missiles designed for supersonic speeds employ highly swept-back and low aspect-ratio wings with sharp edges. However, such wings are inefficient in subsonic and high lift-flight regimes such as climb to cruise, maneuver, and approach to landing, and have serious performance, stability, and control deficiencies. Flow separation occurs near the leading edges of such wings at moderate to high angles of attack. The separation produces vortex sheets that roll up into strong vortices which generate additional lift at the cost of increasing the drag due to the loss of leading-edge suction. The forward movement of the center of vortex lift with increasing angle of attack causes longitudinal instability. Generally, the formation of concentrated vortices on the wing surface induces undesirable stability and control problems.[1]

Leading-edge flaps can be used to maintain attached flow even at higher angles of attack in case of the wings with moderate sweep angles. However, such an approach is less practical in the case of highly swept-back wings typically employed in supersonic aircraft because of the difficulties involved in complete suppression of the separation.

The leading-edge vortex flap physically resembles a conventional leading-edge flap, but its aerodynamic function is quite different. Unlike the latter whose function is to maintain a smooth on-flow, the former's function is to force the separation to take place on the flap and thereby produce a significant thrust component in the flight direction. Depending upon the flap deflection in the upward or downward direction, the thrust component generated owing to the vortex formation on the flap can be exploited to increase or decrease the drag. This type of vortex management can be profitably used in different flight regimes of an aircraft. A good account of the leading-edge vortex flap concept can be found in the recent works by Rao.[2,3]

In the present work, the effect of leading-edge vortex flap on the aerodynamic characteristics of highly swept-back wings is analytically investigated. The method employed for this purpose is the free vortex sheet (FVS) method[4] developed by Boeing Aircraft Company under a contract with NASA Langley Research Center (LaRC). The method is based on a three-dimensional inviscid flow model. This is an advanced panel method using quadratic doublet distributions to represent the wing surface, the rolled up vortex sheet and wake. It is capable of computing forces, moments and the surface pressures. It has been tested[5-7] and found to predict the aerodynamic results satisfactorily up to moderate angles of attack for various configurations, especially delta wings.

Results and Discussion

In order to determine the accuracy of the method, the results predicted by the FVS method are compared in Figs. 1 and 2 with the experimental data for two 74-deg delta wings with different types of leading-edge vortex flaps—one varying-chord flap and another constant-chord flap. The varying chord is deflected down by $\delta_n = 24$ deg and the constant chord is deflected up by $\delta_n = 30$ deg. The agreement between lift and drag and the corresponding data is very good up to the moderate angles of attack. At high angles of attack, the predicted lift is higher maybe because the actual vortex might have burst. This is not taken into account by the method. The agreement between theory and data for the pitching moment is not favorable. From this it appears that the center of pressure locations in theory and experiment are

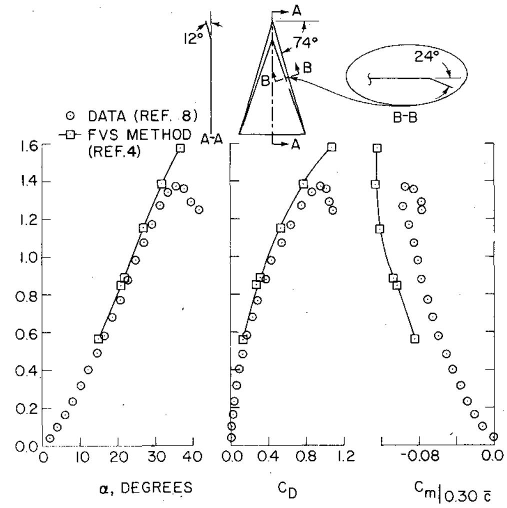

Fig. 1 Longitudinal aerodynamic characteristics of delta wing with $\delta_n = 24$ deg, 0.15c leading-edge flap down at $M \simeq 0$.

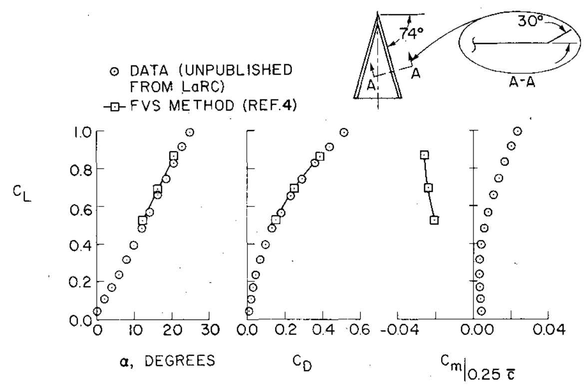

Fig. 2 Longitudinal aerodynamic characteristics of delta wing with $\delta_n = 30$ deg, leading-edge flap up at $M = 0.2$.

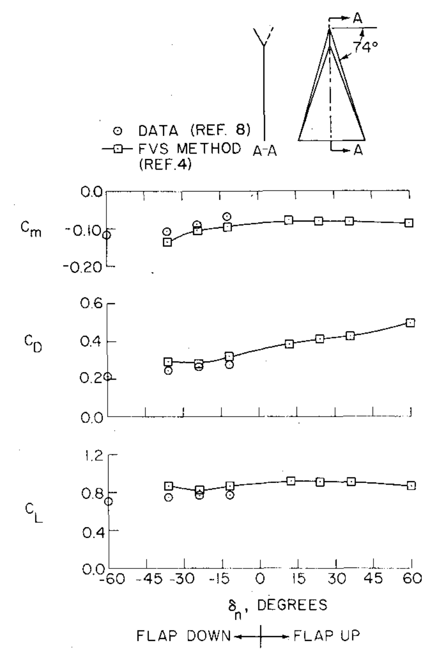

Fig. 3 Effect of flap angle on longitudinal aerodynamic characteristics of delta wing with leading-edge flap at $\alpha = 20.63$ deg and $M \simeq 0$.

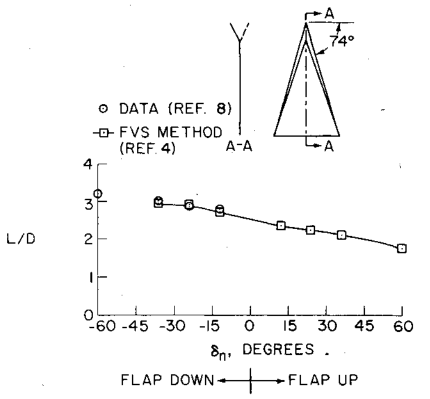

Fig. 4 Effect of flap angle on lift-to-drag ratio for delta wing with leading-edge flap at $\alpha = 20.63$ deg and $M = 0$.

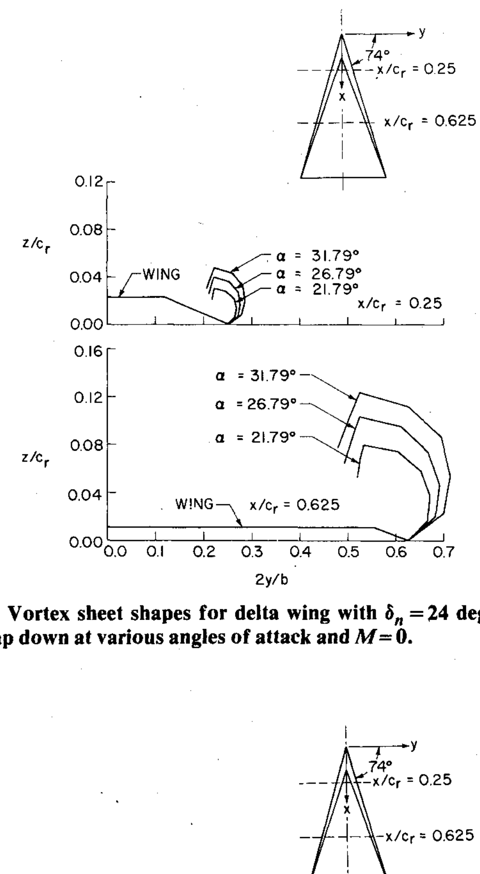

Fig. 5 Vortex sheet shapes for delta wing with $\delta_n = 24$ deg leading-edge flap down at various angles of attack and $M = 0$.

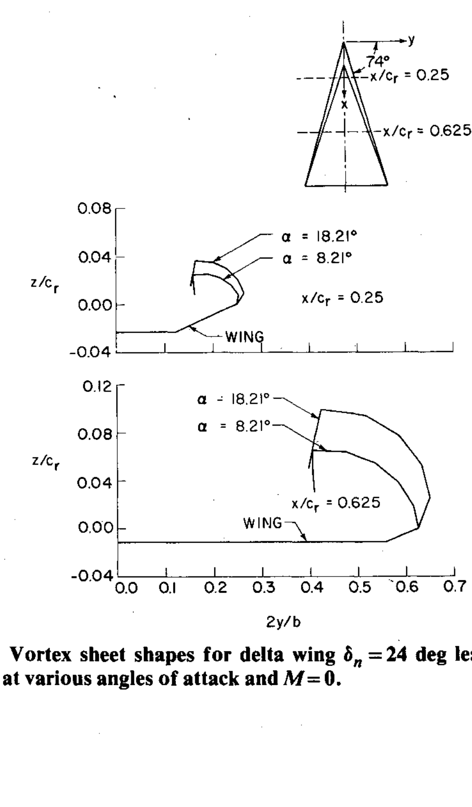

Fig. 6 Vortex sheet shapes for delta wing $\delta_n = 24$ deg leading-edge flap up at various angles of attack and $M = 0$.

different. A slight shift in the location with respect to the reference point about which the moment is calculated may cause the pitching moment to change its signs. For example, in Fig. 1 at $\alpha = 30$ deg, a shift of about 1.59% of the reference chord would produce the observed disagreement.

Figures 3 and 4 show the effect of the flap deflection on the performance of a delta wing for -60 deg $\leq \delta_n \leq 60$ deg. The experimental data[8] are available only for a few flap-down situations. The agreement between the predicted results and the data is fairly good. The effect of the flap deflection is more pronounced on the drag and the L/D characteristic compared to the lift and pitch. The drag increases with the flap angle. This is expected because in the flap-down situations the thrust component due to the leading-edge suction is in the direction of the flight thereby reducing the overall drag. This situation can be taken advantage of in take-off and cruise regimes. In the flap-up case, the opposite happens and can be effectively used in landing. This effect is clearly illustrated in Figs. 5 and 6 where vortex sheet shapes are shown for flap-up and -down situations at two chordwise stations for different angles of attack. The end of the vortex sheet represents the vortex core location. The vortex is entirely on the flap in the forward position of the wing, whereas in the aft portion, the vortex extends beyond the flap and it is not conducive for the effective management of the vortex. The vortex becomes bigger as the trailing edge is approached, so the flap chord has to be increased if a major portion of the vortex is to be accommodated. This necessitates the flap to be of conical shape. However, it may be noted here, at higher angles of attack, the vortex becomes so enormous that it would be virtually impractical to limit it entirely to the flap alone and take its full advantage. Therefore the optimum size of the flap chord has to be determined taking aerodynamic as well as structural considerations into account.

Conclusions

The leading-edge vortex flaps appear to be very effective flow manipulating devices that can profoundly influence the performance and the controlability of highly swept-back delta wings operating in the environment of leading-edge separation and vortex flow. By proper deflection of the flap, the drag can be increased or decreased. This can be utilized advantageously during various stages of the flight. Therefore it seems worthwhile to do further research in the application of the vortex flap concept to more realistic wing configurations such as cropped arrow and double delta wings, of course, taking into account practical design constraints.

Acknowledgments

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