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Canard-Wing Vortex Effects in Subsonic Flow

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Abstract

A FULLY three-dimensional subsonic panel method that can handle arbitrary shed vortex wakes is used to compute the nonlinear forces and moments on simple canard-wing configurations. The lifting surfaces and wakes are represented by doublet panels. The Mangler-Smith theory[1] is used to provide an initial estimate for the vortex sheet shed from the leading edge. The technique yields reasonable overall results for a modest investment of computer time.

Contents

To compute the flowfield, this sheet is discretized so that the separated wake is essentially modeled by a collection of concentrated line vortices, which are described using vortex quadrilaterals. To align the vortex trajectories with the streamlines, the corner points along the leading edge of each wake panel are obtained by integrating the velocity field.

This vortex description is then combined with two panel codes. The first method uses constant-strength doublet panels and is referred to as the potential flow analysis program or POTFAN.[2] The second method uses quadratically varying doublet panels and is referred to as the advanced panel code[3] or APC. The APC is still in the process of development, consequently its range of applicability was limited. Therefore, the primary emphasis in this paper is centered on results obtained from POTFAN.

The results are displayed in two parts. Figures 1-4 show the results for flat delta wings with sharp leading edges. Figure 1 compares the lift coefficient predicted by POTFAN and APC with the Polhamous analogy and experiment[4] up to 40 deg angle of attack. The agreement among the panel codes and experimental results is very good. Figure 2 compares the longitudinal load distribution for $\alpha = 10$, 20, and 30 deg with experiment. Again, the predicted values agree well with experiment. Since the trailing-edge Kutta condition has not been strictly enforced, the center of pressure is not as far forward as the experimental position as shown in Fig. 3. In conical flow the center of pressure is at the centroid of the wing and Fig. 3 also shows the three-dimensional panel singularity field to differ substantially from conical flow.

Finally, Fig. 4 compares the spanwise variation of the axial velocity components predicted by POTFAN with measurements[5] at flowfield points above a wing of $\mathcal{R} = 1.07$ at $\alpha = 29$ deg. At the time of this study, the pilot version of the APC did not allow for velocities to be computed at off-body points so no comparable results are available from the APC. The predicted core location in the crossflow plane is $y/s = 0.710$ and $z/s = 0.413$. The axial velocity exhibits steep gradients as the core is appraoched from either side and a leveling off near the center line $y = 0$. Near the surface ($z/s = 0.102$), the velocity exhibits some small fluctuations probably due to boundary-layer effects.

The study then considered the effects of the canard wake for a simple canard-wing configuration of trapezoidal planform with the canard and wing in the same plane. It is assumed that inboard of the canard tip the trailing canard wake produces a downwash over the wing which counteracts the angle of attack, thus decreasing the leading-edge suction and eliminating leading-edge separation from this portion of the wing. Outboard of the canard tip there is an upwash field which increases the wing local angle of attack, thus flow separation is assumed outboard of the canard tip. The model used is given in Ref. 6.

Figure 5 shows the canard and total lift coefficients up to $\alpha = 40$ deg. Below $\alpha = 24$ deg, the rollup from the leading

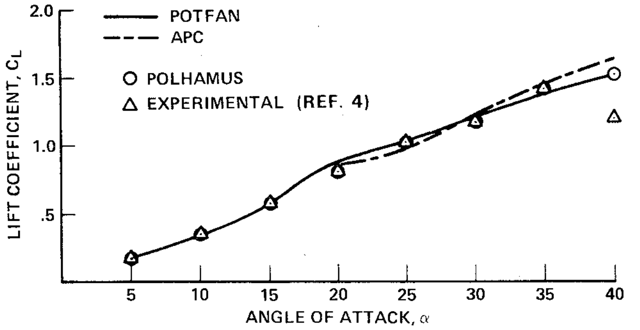

Fig. 1 Variation of lift wing angle of attack for delta wing; $\mathcal{R} = 1.15$; $\Lambda = 74$ deg.

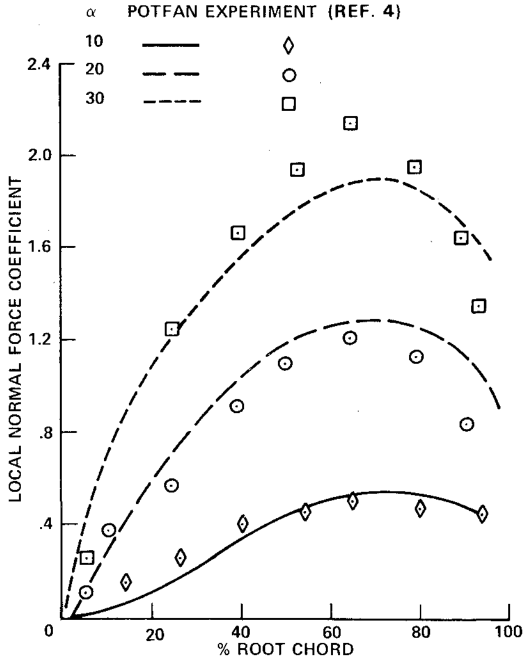

Fig. 2 Longitudinal distribution of normal forces; $\mathcal{R} = 1.15$; $\Lambda = 74$ deg.

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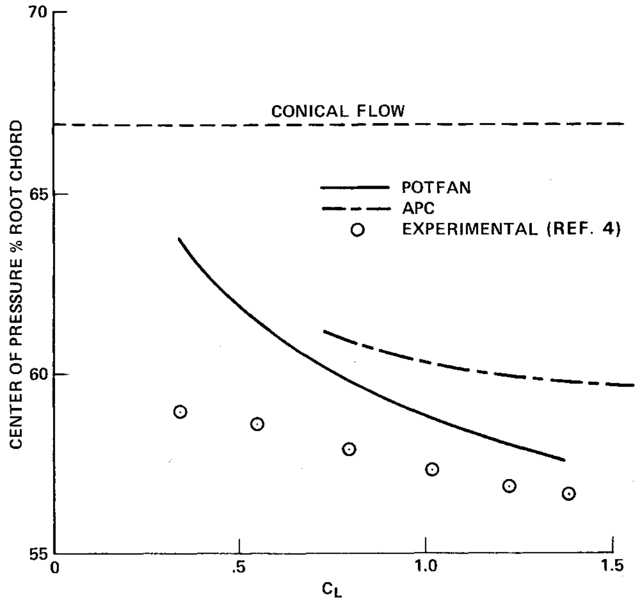

Fig. 3 Center of pressure; $\mathcal{R} = 1.15$; $\Lambda = 74$ deg.

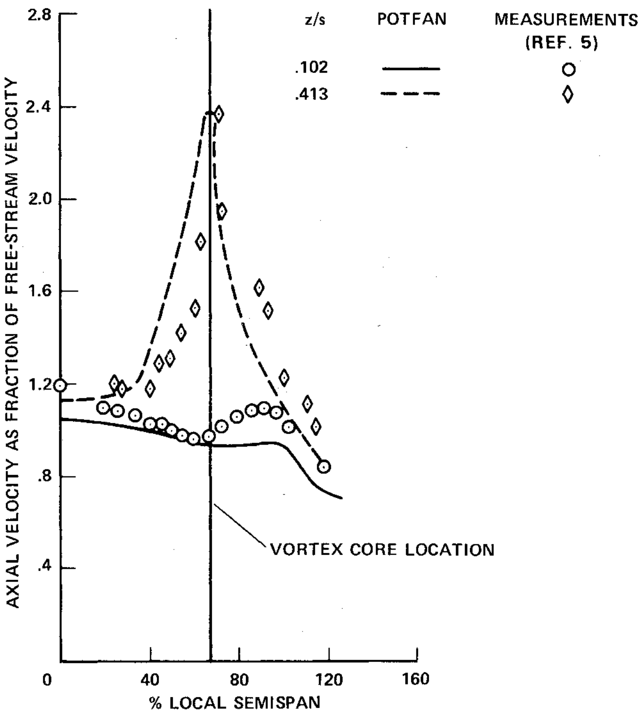

Fig. 4 Spanwise variation of axial velocity component above a wing at $x/c_r = 0.8$, $\mathcal{R} = 1.07$; $\Lambda = 75$ deg, $\alpha = 29$ deg.

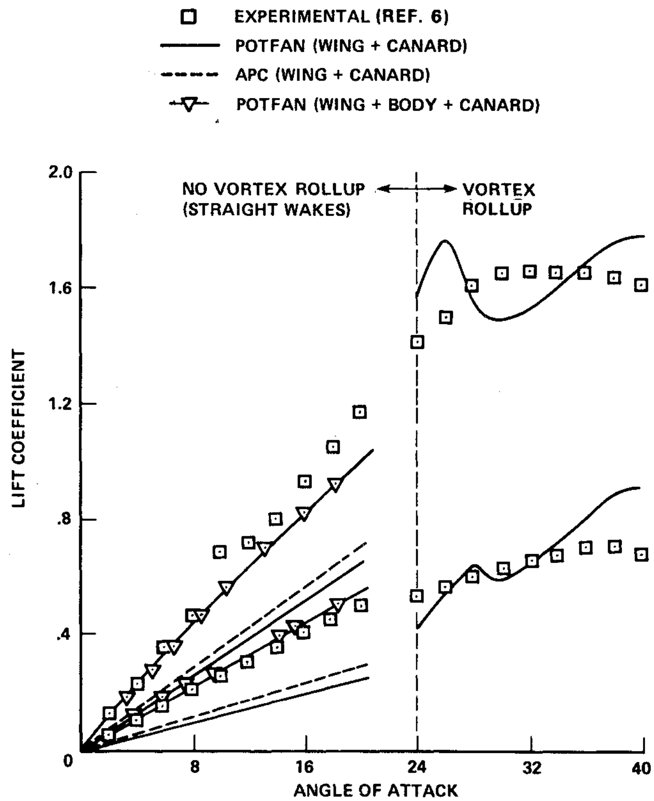

Fig. 5 Variation of lift for canard-wing configurations with angle of attack; $\mathcal{R}_c = 4.12$, $\Lambda_c = 51.7$ deg, $\mathcal{R}_w = 2.5$, $\Lambda_w = 60$ deg, $M = 0.3$.

edges is omitted. The lower curves refer to the canard lift while the upper curves correspond to the total lift.

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