Close-Coupled Canard-Wing Vortex Interaction

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Abstract

THE present experiment investigates the interaction of canard and wing vortices and their effect on the lifting wing's flowfield turbulence and Reynolds stresses. Spanwise wing blowing was used to enhance the leading edge vortex and alter the vortex trajectory in an effort to keep it locked to the wing's leading edge for lift enhancement. The turbulence intensity and Reynolds stress values, obtained by using hot film anemometers, illustrate the vortex structure.

Contents

The flow at the leading edge of sweptback wings at moderate to high angles of attack separates and produces vortex sheets that roll up into vortices on the wing's upper surface. When canards are closely coupled with the wings, an interference between the leading edge vortices occurs. The interference changes the turbulence characteristics and the trajectories of the vortices.[1-7] Turbulence intensity and Reynolds stress measurements were performed by means of hot wire anemometers for various canard-wing body configurations. The data obtained refer to the canard-wing vortex interaction and can be used to improve the eddy viscosity models used in the solution of the Navier-Stokes equations applied to the present aerodynamic configuration.[8]

The tests were performed in the 5-ft (1.524-m) subsonic wind tunnel of the Air Force Institute of Technology. The sting-mounted canard-wing model used is shown Fig. 1. The canard area was 28% of the wing area. The hot film cross-shaped anemometer used was aligned with the freestream direction, and the data were taken in the $\tilde{z}$ direction, perpendicular to the wind tunnel axis. Model and instrumentation details are found in Ref. 9. A screen with tufts was placed behind the model to locate the vortices position. The tests were performed at Mach number $M_\infty = 0.134$, a unit Reynolds number of 2.8×10^6/m, and at angles of attack of $\alpha = 10$, 16, and 20 deg. Three configurations were tested: 1) close-coupled canards coplanar with the wings, 2) close-coupled canards placed 4.29 cm higher than the wings, and 3) canards removed. Spanwise mass injection was used in some tests to alter the trajectory of the wing leading edge vortex.

The distribution of the axial mean velocity u/V_∞ shows that the leading edge vortex emanating from the canard has a wave-like behavior because of a velocity decrease at its center and an increase at its edge. Spanwise contours of the velocity and stresses at the canard trailing edge give a good visualization of the canard leading edge vortex's position and are shown in Ref. 9. In Figs. 2 and 3, the lateral velocity and Reynolds stresses in the axial plane (perpendicular to the wing) are shown for $\alpha = 16$ deg at a location just outboard of the midspan point behind the wing's leading edge. The point of zero lateral velocity, which corresponds to the maximum turbulence intensity, indicates the location of the vortex center. The canard produces a downwash velocity that affects the leading edge vortex with an attendant decrease in lateral velocity and downward shift of its center closer to the wing surface. The effect of the canard downwash on the Reynolds

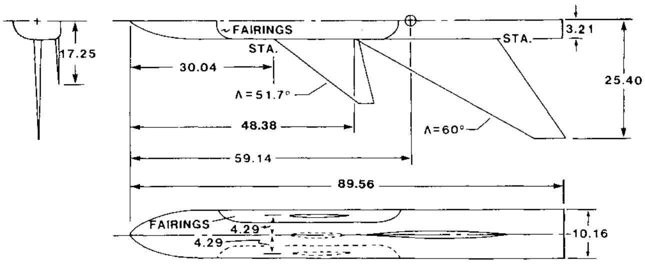

Fig. 1 Canard configuration; sketch of model. (All dimensions in centimeters.)

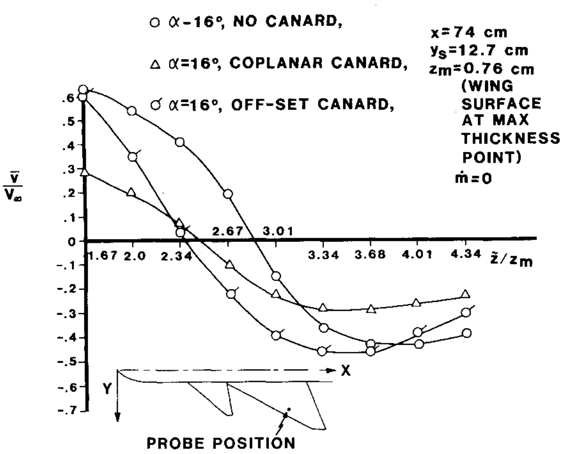

Fig. 2 Lateral mean velocity, $\alpha = 16$ deg.

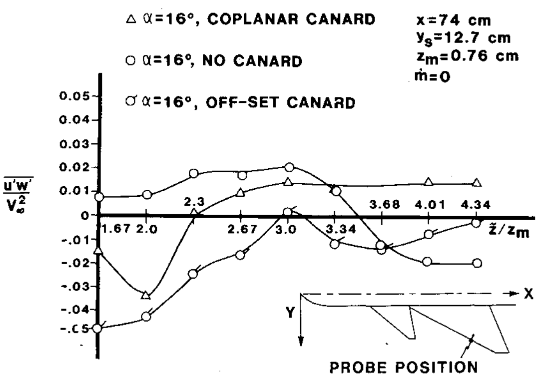

Fig. 3 Reynolds stresses in the axial plane, $\alpha = 16$ deg.

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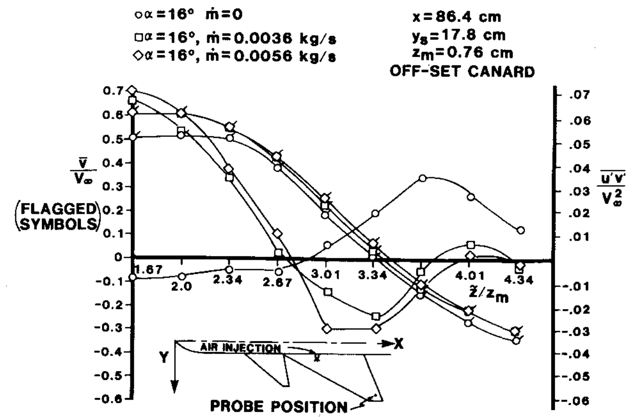

Fig. 4 Air injection effects on lateral mean velocity and Reynolds stresses in the lateral plane, $\alpha = 16$ deg.

stresses in the axial plane behind the leading edge is shown in Fig. 3 and consists of a change in direction of the stresses. At the trailing edge instead, the magnitude of the stresses obtained with off-set canard is more than twice that of the stresses without canard.[9]

Figure 4 shows the effect of lateral (spanwise) air injection on the lateral mean velocity ($\bar{u}/V_\infty$) and stresses in the lateral plane (wing plane) at the midchord location, close to the wing tip. The injection increases the lateral mean velocity, which produces a stronger circulation over the wing and improves the wing's lift characteristics. The level of the Reynolds stresses also increases together with a change in direction.

As shown in Ref. 9, the Reynolds stresses in the axial plane and in the lateral plane are an order of magnitude bigger than the stresses in the plane normal to the fuselage. This is due to the strong contribution of the velocity component in the axial direction. The off-set canard generates stresses in the axial plane at the wing's trailing edge with magnitude more than twice that of the stresses obtained without canard. The level of turbulence in the leading edge vortices increases with increasing angle of attack. Spectral analyses revealed no coherent structure of turbulence over the wing and no periodic disturbances. The turbulence levels were high inside the vortex core.

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