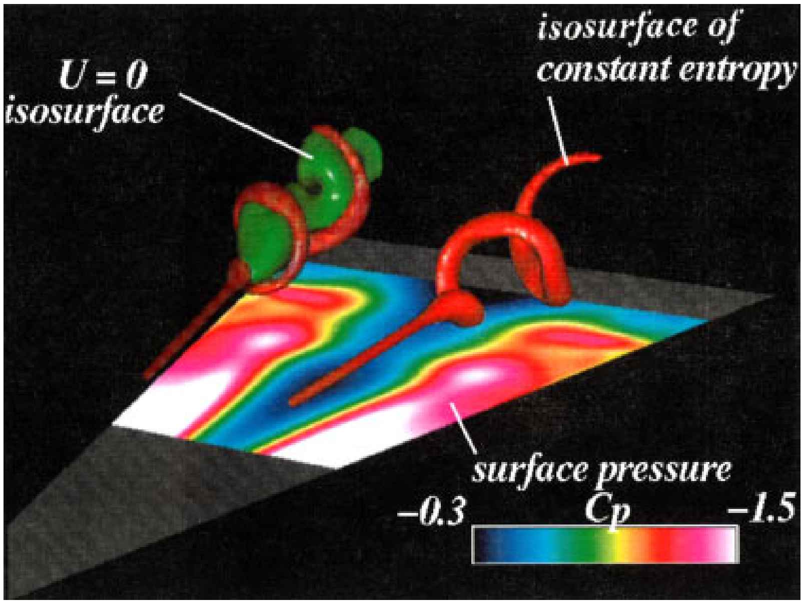

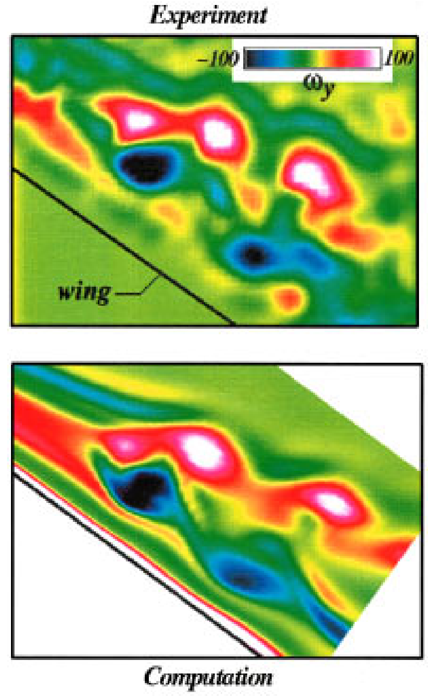

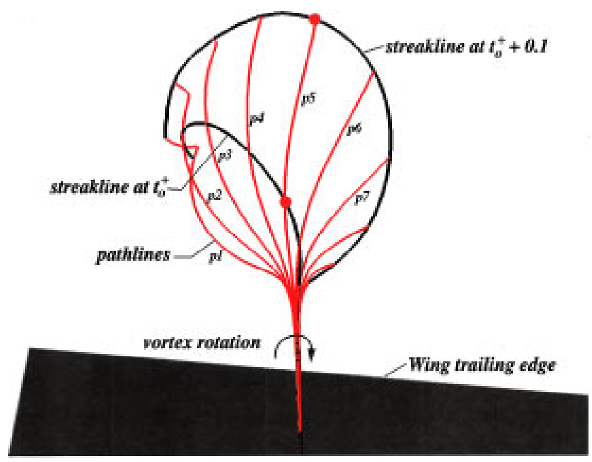

COMPUTED UNSTEADY STRUCTURE OF SPIRAL VORTEX BREAKDOWN ON A DELTA WING

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The unsteady structure of spiral vortex breakdown above a 75° sweep delta wing was investigated numerically through direct solution of the full unsteady compressible Navier–Stokes equations.[12] The visualizations presented above correspond to an angle of attack of 34° and a chord Reynolds number of 9200. The 3-D instantaneous representation of Fig. 1 (taken from the video animation) clearly shows the sudden transformation of the rectilinear vortex core (depicted in red) into a whirling spiral of winding sense opposite to the swirling flow. A region of axial flow reversal (depicted in green) is contained within the spiral winding, and its outer envelope and internal structure are found to fluctuate dramatically in time. A strong interaction between the spiral breakdown and the wing surface also occurs as evidenced by the surface pressure contours. The instantaneous spanwise vorticity distribution on a plane normal to the wing and passing through the vortex center (Fig. 2) is characterized by staggered concentrations of vorticity at the locations where the spiral pierces the plane. These concentrations appear to propagate downstream as the spiral rotates. The computed unsteady structure was found to be in qualitative agreement with available PIV measurements.[13]

For the purpose of comparison with experimental observations, the numerical equivalent of streakline visualizations (Fig. 3) were generated by releasing material particles near the vortex axis upstream of breakdown. Computed pathlines and streaklines in the nose of the breakdown region are shown in Fig. 4. The streakline forms a spiral with winding opposite to the vortex and it rotates in time with the same sense of the upstream swirl. The material particles, however, do not follow spiral paths but instead are deflected radially away from the axis and proceed initially over the flow reversal region with little rotation consistent with conservation of angular momentum. Although the particles decelerate sharply as they approach breakdown, a true 3-D stagnation point in the instantaneous velocity field does not exist for spiral breakdown in front of the region of axial flow reversal.

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