Improved Higher-Order Panel Method for Linearized Supersonic Flow

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Abstract

An improved higher-order panel method for linearized supersonic flow is described. Each panel, defined by four points on the surface, is divided into eight subpanels in such a way that all subpanel and panel edges are contiguous. By prescribing a quadratic distribution of the doublet on each subpanel, the doublet strength is made strictly continuous on the paneled surface. A linear source distribution is also used. Numerical results are smoother and in better agreement with experiment than the previous method with less strict continuity. A brief discussion of superinclined panels used to eliminate interior interference in nacelles is included.

Contents

To analyze the linearized supersonic flow over configurations of general shape, Ehlers et al.[1] developed a higher-order panel method using linear source and quadratic doublet strengths over each panel. Small discontinuities in geometry and in doublet strength occurred at panel edges and the resulting infinite singularities in velocity which propagate unattenuated along Mach cones from the panel corners, introduced some sensitivity to the choice of paneling and location of control points.

An improved higher order panel method to overcome these difficulties utilizing combined source and doublet panels is described here. With the source distribution equal to the negative of the normal component of the freestream velocity to the surface, the normal component of the perturbation mass flux on the exterior surface is made to vanish by choosing the doublet strength to make the perturbation potential $\phi = 0$ on the inside surface of the configuration. Equivalent boundary conditions are used by Morino et al.[2]

For nacelles, where the inlet flow is to be taken into account, the interior flow can be eliminated by closing the inlet with superinclined panels having the boundary conditions $\phi = 0$ and the normal component of the perturbation mass flux equal to zero on the downstream side of the superinclined surface. Prescribed over the projection of each panel onto the average plane is a linear source distribution whose coefficients are determined by a least-square fit with the values of the source strength at the centers of itself and of neighboring panels. In the panel method of Ref. 1, the doublet strength is a quadratic applied over the projection of the entire panel onto the average plane in the same manner as for the source with the six coefficients determined by a least-square fit with the doublet strength at the centers of 8 to 12 neighboring panels. With this method, discontinuities in doublet strength and panel geometry were found to produce oscillations on the flow over a parabolic arc profile swept wing, which were eliminated by the improved panel method with continuous doublet strength and contiguous panels.

The basic panel defined by four points on the surface is divided into planar contiguous subpanels by lines joining the midpoints of the four edges (see Fig. 1). Division of the resulting central parallelogram into four triangles leads to eight subpanels for each panel. Utilizing the values of the doublet strength at the nine corner points of the subpanels in Fig. 1, found by a least-square fit of a quadratic with the

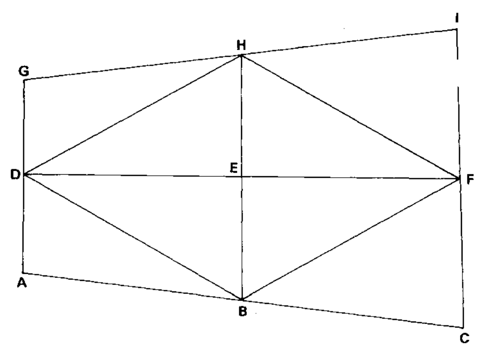

Fig. 1 Schematic description of the planar contiguous subpanels in which the basic panel is divided.

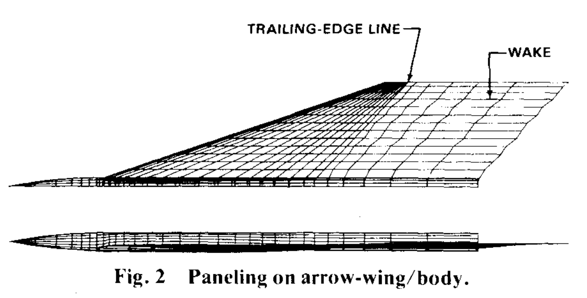

Fig. 2 Paneling on arrow-wing/body.

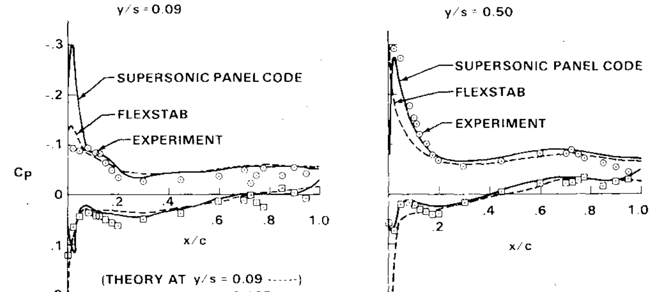

Fig. 3 Comparison of experimental and calculated pressures on arrow-wing of Fig. 2.

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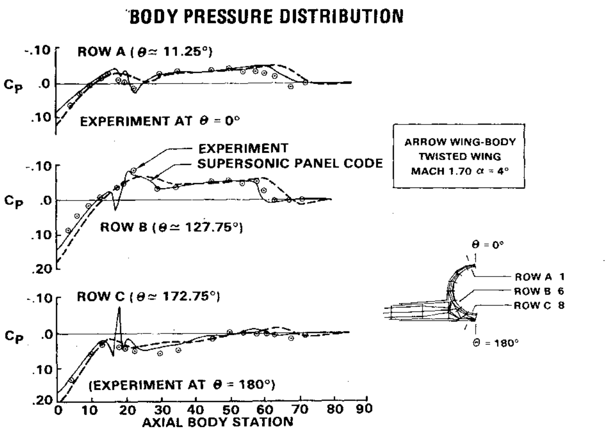

Fig. 4 Comparison of experimental and calculated pressures on body of Fig. 2.

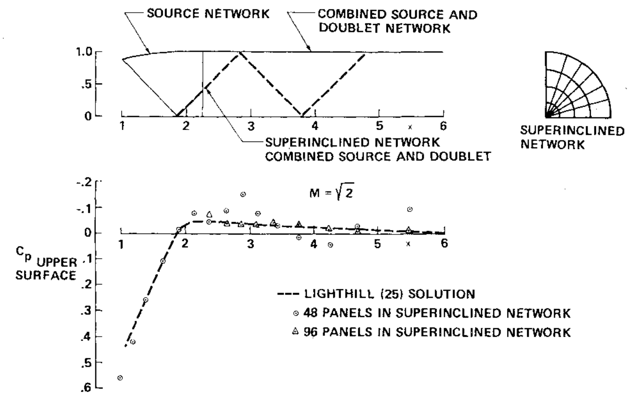

Fig. 5 Example flow showing the effectiveness of a superinclined network for eliminating interior perturbations of a nacelle.

doublet strength at centers of itself and of neighboring panels, we establish a piecewise continuous quadratic distribution of doublet strength over the entire network by separate quadratic distributions of doublet strength in each triangular subpanel.

The new spline and subpanel system was tested on an arrow wing/body combination featuring a twisted wing, using 983 control points (see Fig. 2). A comparison of wing surface pressure distribution with experiments is shown in Fig. 3 for a Mach number of 1.70 and 4-deg angle of attack. Good agreement is shown except at the most inboard station. Poor paneling near the wing-body intersection where one of the subpanels was found to be superinclined caused a pressure peak at the leading edge and at nearby points on the body as seen in Fig. 4.

To test the effectiveness of the superinclined panels, a plane superinclined network was placed inside the nacelle in Fig. 5 at axial station 2.25. On the upstream portions of the nacelle, zero normal mass flux boundary conditions were prescribed on the upper surface of the source network. Figure 5 shows the exterior pressure distribution on the nacelle as a function of axial position for two different panelings of the superinclined network. The 48-panel network is seen to be too coarse to absorb adequately the interior reflections from the source network. The pressure is oscillatory with a wavelength about equal to the reflected Mach wave pattern. Doubling the panels smooths out the pressure distribution. Except for the region near the superinclined network, the pressure is in excellent agreement with Lighthill's theory.[3]

Acknowledgment

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References

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