Spline-Based Smoothing of Airfoil Curvatures

Spurious curvature oscillations and bumps are suppressed.

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Constrained fitting for airfoil curvature smoothing (CFACS) is a spline-based method of interpolating airfoil surface coordinates (and, concomitantly, airfoil thicknesses) between specified discrete design points so as to obtain smoothing of surface-curvature profiles in addition to basic smoothing of surfaces. CFACS was developed in recognition of the fact that the performance of a transonic airfoil is directly related to both the curvature profile and the smoothness of the airfoil surface.

Older methods of interpolation of airfoil surfaces involve various compromises between smoothing of surfaces and exact fitting of surfaces to specified discrete design points. While some of the older methods take curvature profiles into account, they nevertheless sometimes yield unfavorable results, including curvature oscillations near end points and substantial deviations from desired leading-edge shapes.

In CFACS as in most of the older methods, one seeks a compromise between smoothing and exact fitting. Unlike in the older methods, the airfoil surface is modified as little as possible from its original specified form and, instead, is smoothed in such a way that the curvature profile becomes a smooth fit of the curvature profile of the original airfoil specification.

CFACS involves a combination of rigorous mathematical modeling and knowledge-based heuristics. Rigorous mathematical formulation provides assurance of removal of undesirable curvature oscillations with minimum modification of the airfoil geometry. Knowledge-based heuristics bridge the gap between theory and designers’ best practices.

In CFACS, one of the measures of the deviation of an airfoil surface from smoothness is the sum of squares of the jumps in the third derivatives of a cubic-spline interpolation of the airfoil data. This measure is incorporated into a formulation for minimizing an overall deviation-from-smoothness measure of the airfoil data within a specified fitting error tolerance.

CFACS has been extensively tested on a number of supercritical airfoil data.
sets generated by inverse design and optimization computer programs. All of the smoothing results show that CFACS is able to generate unbiased smooth fits of curvature profiles, trading small modifications of geometry for increasing curvature smoothness by eliminating curvature oscillations and bumps (see figure).

This work was done by W. Li and S. Krist of Langley Research Center. Further information is contained in a TSP (see page 1). LAR-17227-1

### Reducing Spaceborne-Doppler-Radar Rainfall-Velocity Error

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A combined frequency-time (CFT) spectral moment estimation technique has been devised for calculating rainfall velocity from measurement data acquired by a nadir-looking spaceborne Doppler weather radar system. Prior spectral moment estimation techniques used for this purpose are based partly on the assumption that the radar resolution volume is uniformly filled with rainfall. The assumption is unrealistic in general but introduces negligible error in application to airborne radar systems. However, for spaceborne systems, the combination of this assumption and inhomogeneities in rainfall [denoted non-uniform beam filling (NUBF)] can result in velocity measurement errors of several meters per second.

The present CFT spectral moment estimation technique includes coherent processing of a series of Doppler spectra generated in a standard manner from data over measurement volumes that are partially overlapping in the along-track direction. Performance simulation of this technique using high-resolution data from an airborne rainmapping radar shows that a spaceborne Ku-band Doppler radar operating at signal-to-noise ratios >10 dB can achieve root-mean-square accuracy between 0.5 and 0.6 m/s in vertical-velocity estimates.

This work was done by Simone Tanelli, Eastwood Im, and Stephen L. Durden of Caltech for NASA’s Jet Propulsion Laboratory. For more information, contact infooffice@jpl.nasa.gov. NPO-40590