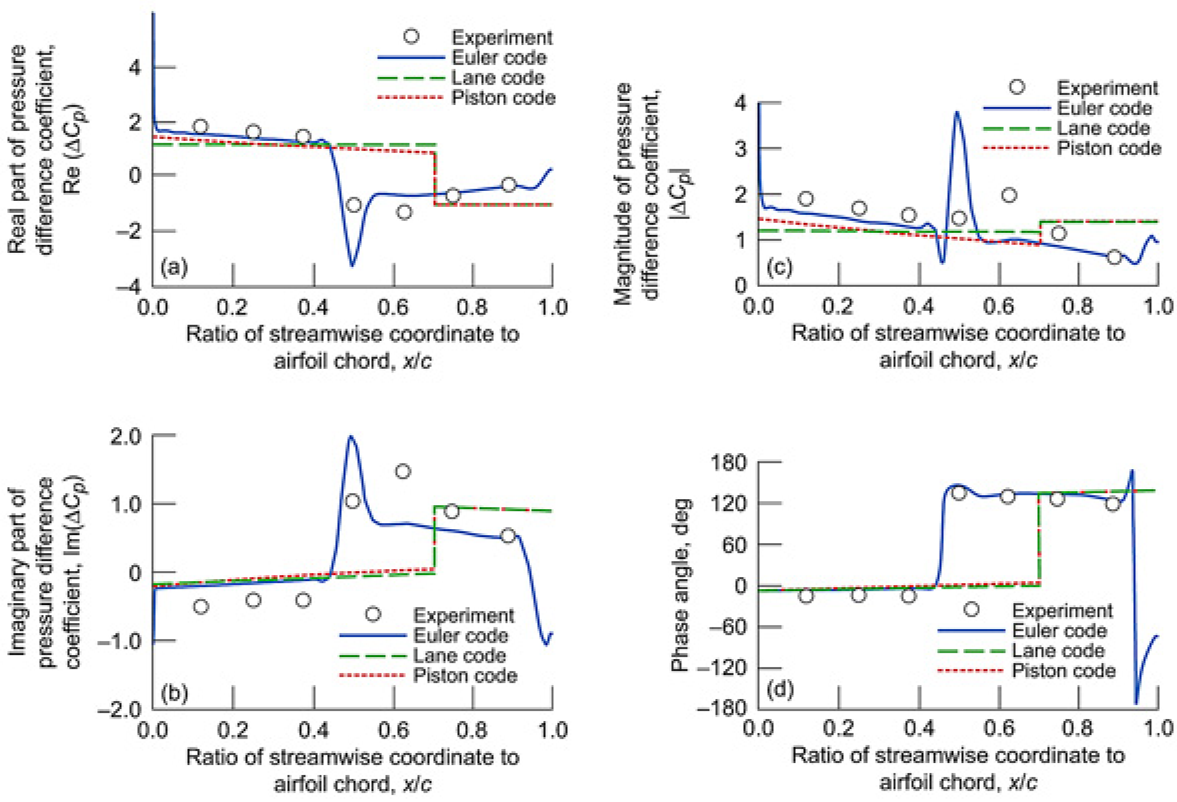
Theoretical and Experimental Unsteady Aerodynamics Compared for a Linear Oscillating Cascade With a Supersonic Leading-Edge Locus

Experimental data were obtained to help validate analytical and computational fluid dynamics (CFD) codes used to compute unsteady cascade aerodynamics in a supersonic-axial-flow regime. Results from two analytical codes and one CFD code were compared with experimental data. One analytical code did not account for airfoil thickness or camber; another, using piston theory (piston code), accounted for thickness and camber upstream of the first shockwave/airfoil impingement locations. The Euler CFD code accounted fully for airfoil shape.



Unsteady pressure difference with interblade phase angle β = 0° (reduced frequency, k, 0.14577; stagger angle, θ, 0°; free-stream Mach number, M_∞, 1.9617; ratio of blade spacing to airfoil chord, s/c, 0.417). (a) Real part. (b) Imaginary part. (c) Magnitude of pressure difference coefficient. (d) Phase angle.

Long description of figure. Acoustic transducer immersed in an electroplating tank. Note the unusually long laminar flow driven entirely by intense ultrasound.

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An experimental influence coefficient technique was used to obtain unsteady pressures for a cascade of symmetric airfoils oscillating in pitch about midchord. Stagger angles of 0° and 10° were investigated for a cascade with a gap-to-chord ratio of 0.417 operating at an axial Mach number of 1.9, resulting in a supersonic leading-edge locus. Reduced frequencies ranged from 0.056 to 0.2. The influence coefficients obtained can be used to determine the unsteady pressures for any interblade phase angle. The unsteady pressures were compared with those predicted by two analytical and one CFD code for interblade phase angles of 0° and 180°.

This experimental program has laid the foundation for future unsteady aerodynamic cascade testing in the supersonic leading-edge-locus flow regime. The findings indicate that

1. Piston theory does reflect the general effects of the airfoil thickness distribution on unsteady pressures.
2. When the differences in shock wave/airfoil impingement locations predicted by the analytical and Euler CFD codes are accounted for, all of the codes predict similar phase angles between the airfoil motion and the unsteady pressure. Thus, the airfoil thickness distribution does not have a large effect on the unsteady-pressure phase angle.
3. The analytical codes do not accurately locate the shock wave/airfoil impingement locations, partly because of flat-plate airfoil assumptions. Even though the piston code accounts for airfoil geometry in the isolated airfoil regions, the shock wave/airfoil impingement locations were still based on flat-plate geometry.
4. The unsteady pressures predicted by the analytical codes could be greatly improved by repositioning the shock wave/airfoil impingement locations by using a steady-flow theory (e.g., the method of characteristics or a steady CFD flow solver) that accounts for airfoil geometry.
5. The accuracy of the experimental data can easily be improved by reducing oscillating system wear. This can be accomplished if the airfoil moment of inertia is decreased through an alternate design, the use of different materials, and the resizing of some oscillating system components.

Bibliography

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