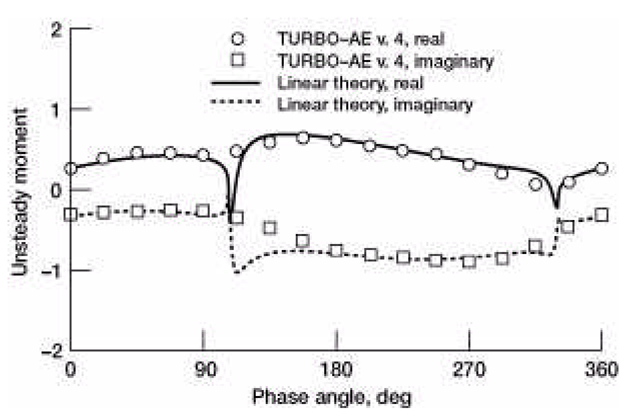
Flutter Version of Propulsion Aeroelasticity Code Completed

NASA's Advanced Subsonic Technology (AST) Program seeks to develop new technologies to increase the fuel efficiency of commercial aircraft engines, improve the safety of engine operation, and reduce emissions and engine noise. For new designs of ducted fans, compressors, and turbines to achieve these goals, a basic aeroelastic requirement is that there should be no flutter or high resonant blade stresses in the operating regime. For verifying the aeroelastic soundness of the design, an accurate prediction/analysis code is required. Such a three-dimensional viscous propulsion aeroelastic code, named TURBO-AE, is being developed at the NASA Lewis Research Center. The development and verification of the flutter version of the TURBO-AE code (version 4) has been completed. Validation of the code is partially complete.

The TURBO-AE aeroelastic code is based on a three-dimensional unsteady aerodynamic Euler/Navier-Stokes turbomachinery code TURBO, developed previously under a grant from Lewis. This code can model viscous flow effects, which play an important role in certain aeroelastic problems such as flutter with flow separation, flutter at high loading conditions near the stall line (stall flutter), and flutter in the presence of shock and boundary-layer interaction. In the TURBO-AE code, the structural dynamics representation of the blade is based on a normal mode representation. Any finite-element analysis code can be used to calculate in-vacuum vibration modes and the associated natural frequency. As an alternative, experimental measurements of these vibration characteristics can be used.

A work-per-cycle approach is used to determine aeroelastic stability (flutter). With this approach, the motion of the blade is prescribed to be a harmonic vibration in a specified in-vacuum normal mode. The work done by aerodynamic forces on the vibrating blade during a cycle of vibration is calculated. If this work is positive, the blade is dynamically unstable, because it will extract energy from the flow, leading to an increase in the amplitude of the blade's oscillation.



Unsteady moment for the torsional blade vibrations of a helical fan.

As part of the verification of the TURBO-AE code, calculations were performed for a helical fan test configuration. This configuration was used to compare the code to two-dimensional linear potential (classical linear/flat plate) theory. Results from the midspan of the blade undergoing torsional vibrations were compared with linear theory results for the pitching motion of a flat plate cascade. Excellent agreement was observed for this test case, providing a fundamental verification of the TURBO-AE code.

TURBO-AE code will provide a useful aeroelastic prediction/analysis capability for engine manufacturers. It will reduce design cycle times by allowing new blade designs to be verified for aeroelastic soundness before blades are built and tested. Using this prediction capability, it will be possible to build thinner, lighter, and faster rotating blades without encountering aeroelastic problems like stall flutter and high-cycle fatigue due to forced vibrations.

Bibliography

Bakhle, M.A., et al.: Aeroelastic Calculations Based on Three-Dimensional Euler Analysis. AIAA Paper 98-3295, July 1998.

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