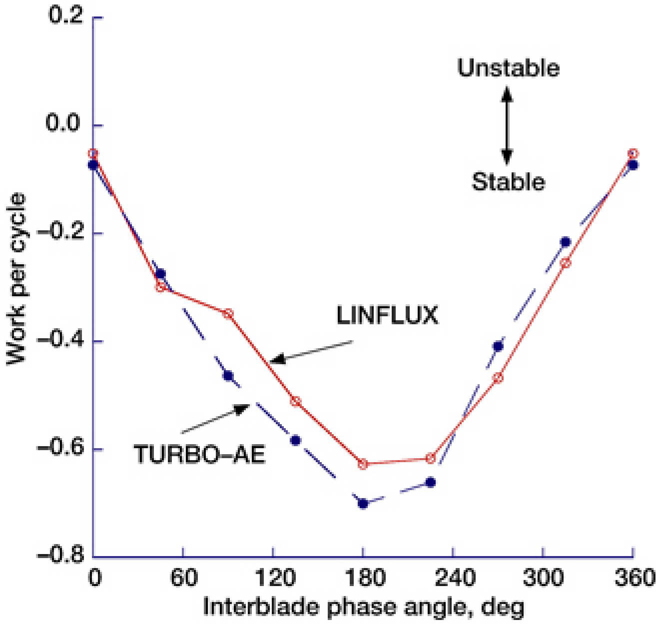
Linearized Aeroelastic Solver Applied to the Flutter Prediction of Real Configurations

A fast-running unsteady aerodynamics code, LINFLUX, was previously developed for predicting turbomachinery flutter. This linearized code, based on a frequency domain method, models the effects of steady blade loading through a nonlinear steady flow field. The LINFLUX code, which is 6 to 7 times faster than the corresponding nonlinear time-domain code, is suitable for use in the initial design phase. Earlier, this code was verified through application to a research fan, and it was shown that the predictions of work per cycle and flutter compared well with those from a nonlinear time-marching aeroelastic code, TURBO-AE. Now, the LINFLUX code has been applied to real configurations: fans developed under the Energy Efficient Engine (E-cubed) Program and the Quiet Aircraft Technology (QAT) project.

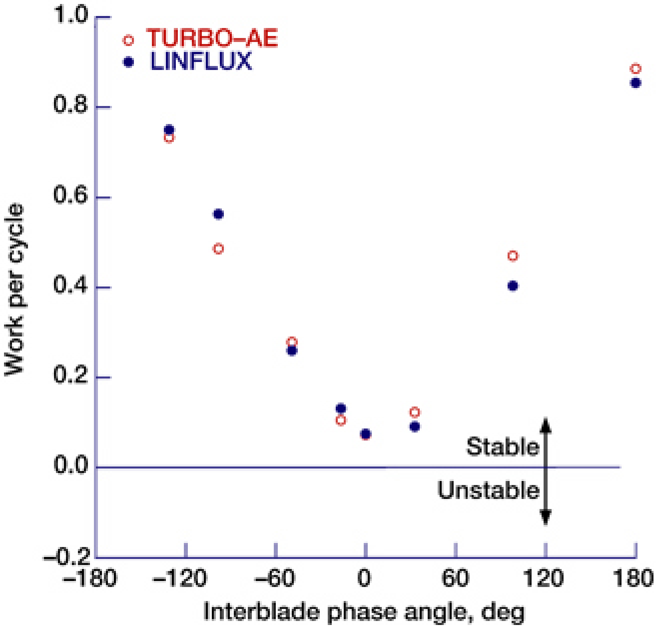
The LINFLUX code starts with a steady nonlinear aerodynamic flow field and solves the unsteady linearized Euler equations to calculate the unsteady aerodynamic forces on the turbomachinery blades. First, a steady aerodynamic solution is computed for given operating conditions using the nonlinear unsteady aerodynamic code TURBO-AE. A blade vibration analysis is done to determine the frequencies and mode shapes of the vibrating blades, and an interface code is used to convert the steady aerodynamic solution to a form required by LINFLUX. A preprocessor is used to interpolate the mode shapes from the structural dynamics mesh onto the computational fluid dynamics mesh. Then, LINFLUX is used to calculate the unsteady aerodynamic pressure distribution for a given vibration mode, frequency, and interblade phase angle. Finally, a post-processor uses the unsteady pressures to calculate the generalized aerodynamic forces, eigenvalues, an esponse amplitudes. The eigenvalues determine the flutter frequency and damping.

Results of flutter calculations from the LINFLUX code are presented for (1) the E-cubed fan developed under the E-cubed program and (2) the Quiet High Speed Fan (QHSF) developed under the Quiet Aircraft Technology project. The results are compared with those obtained from the TURBO-AE code.



Work per cycle versus interblade phase angle for the first vibration mode of the E-cubed fan.

The preceding graph the work done per vibration cycle for the first vibration mode of the E-cubed fan. It can be seen that the LINFLUX results show a very good comparison with TURBO-AE results over the entire range of interblade phase angle. The following graph shows the work done per vibration cycle for the first vibration mode of the QHSF fan. Once again, the LINFLUX results compare very well with the results from the TURBO-AE code.



Work per cycle for the first vibration mode of the Quiet High Speed Fan.

With the validation of the LINFLUX code through application to real configurations, it is now possible to apply this code for the aeroelastic calculations in the initial design of new turbomachinery blade rows. The aeroelastic development and calculations described here were performed under a NASA grant by University of Toledo researchers in collaboration with Glenn researchers.

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