# Probabilistic Aeroelastic Analysis Developed for Turbomachinery Components

Aeroelastic analyses for advanced turbomachines are being developed for use at the NASA Glenn Research Center and industry. However, these analyses at present are used for turbomachinery design with uncertainties accounted for by using safety factors. This approach may lead to overly conservative designs, thereby reducing the potential of designing higher efficiency engines. An integration of the deterministic aeroelastic analysis methods with probabilistic analysis methods offers the potential to design efficient engines with fewer aeroelastic problems and to make a quantum leap toward designing safe reliable engines.

In this research, probabilistic analysis is integrated with aeroelastic analysis: (1) to determine the parameters that most affect the aeroelastic characteristics (forced response and stability) of a turbomachine component such as a fan, compressor, or turbine and (2) to give the acceptable standard deviation on the design parameters for an aeroelastically stable system. The approach taken is to combine the aeroelastic analysis of the MISER (MIStuned Engine Response) code with the FPI (fast probability integration) code. The role of MISER is to provide the functional relationships that tie the structural and aerodynamic parameters (the primitive variables) to the forced response amplitudes and stability eigenvalues (the response properties). The role of FPI is to perform probabilistic analyses by utilizing the response properties generated by MISER. The results are a probability density function for the response properties. The probabilistic sensitivities of the response variables to uncertainty in primitive variables are obtained as a byproduct of the FPI technique.

The combined analysis of aeroelastic and probabilistic analysis is applied to a 12-bladed cascade vibrating in bending and torsion. Out of the total 11 design parameters, 6 are considered as having probabilistic variation. The six parameters are space-to-chord ratio (SBYC), stagger angle (GAMA), elastic axis (ELAXS), Mach number (MACH), mass ratio (MASSR), and frequency ratio (WHWB). The cascade is considered to be in subsonic flow with Mach 0.7. The results of the probabilistic aeroelastic analysis are the probability density function of predicted aerodynamic damping and frequency for flutter and the response amplitudes for forced response.
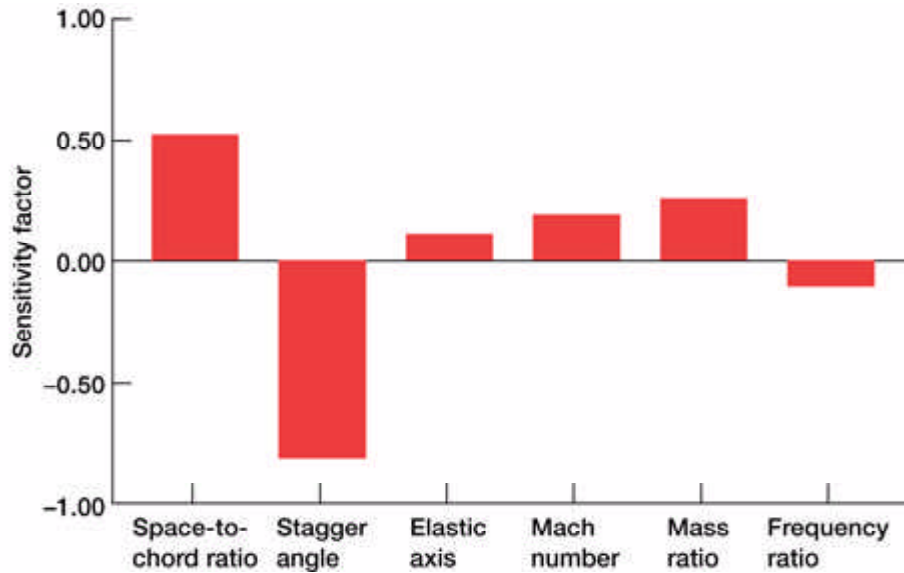
Sensitivity factors of damping (probability level, 0.978).

The bar chart shows the design variables that affect the aerodynamic damping. It can be seen from the figure that the space-to-chord ratio and the stagger angle affect the aerodynamic damping most. The following graph shows the probability density function of aerodynamic damping for the torsion mode. It shows that the aerodynamic damping has a mean value of about 0.08 and a range of 0.05 to 0.11. The results of the bar chart reveal that reducing the scatter of the space-to-chord ratio and the stagger angle give the highest payoff in reducing the scatter range (standard deviation) of aerodynamic damping. The probabilistic aeroelastic calculations described here were performed under a NASA grant by University of Toledo researchers in collaboration with Glenn researchers.
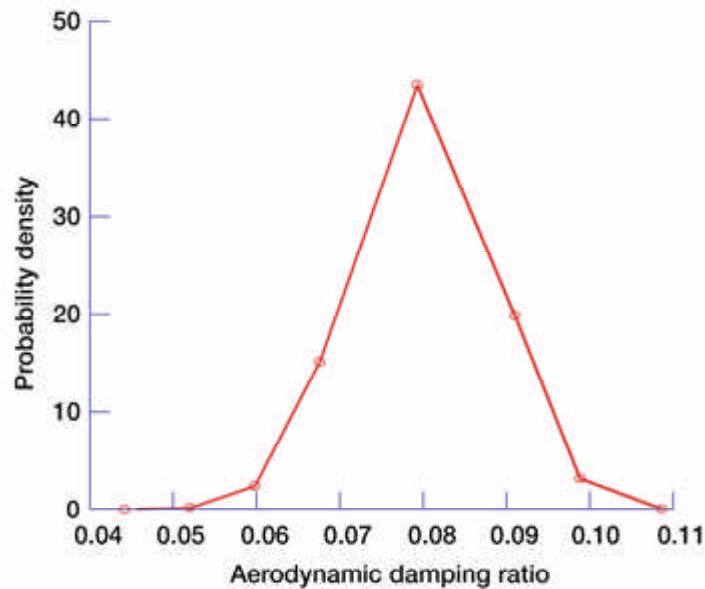
Probability density function of damping, torsion mode; mean, 0.0787; standard deviation, 0.0078.

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