Flutter is an aeroelastic instability phenomenon that can result either in serious damage or complete destruction of a gas turbine blade structure due to high cycle fatigue. Although 90% of potential high cycle fatigue occurrences are uncovered during engine development, the remaining 10% stand for one third of the total engine development costs. Field experience has shown that during the last decades as much as 46% of fighter aircrafts were not mission-capable in certain periods due to high cycle fatigue related mishaps. As recently as September 1997, wing flutter partly the result of faulty structural maintenance caused an F-117A Nighthawk, the first operational “stealth” plane, to lose most of one wing and crash at an air show. Like the aircraft structure, it is also a great threat to the integrity of gas turbine blade structure.

To assure a reliable and safe operation, potential for blade flutter must be eliminated from the turbomachinery stages. However, even the most computationally intensive higher order models of today are not able to predict flutter accurately. Moreover, there are uncertainties in the operational environment, and gas turbine parts degrade over time due to fouling, erosion and corrosion resulting in parametric uncertainties. Therefore, it is essential to design engines that are robust with respect to the possible uncertainties. In this thesis, the robustness of an axial compressor blade design is studied with respect to parametric uncertainties through the Mu analysis. The analytical description of the nominal flutter model used is based on matching a two dimensional incompressible flow field across the flexible rotor and the rigid stator. The aerodynamic load on the blade is derived via the control volume analysis. For use in the Mu analysis, first the model originally described by a set of partial differential equations is reduced to ordinary differential equations by the Fourier series based collocation method. After that, the nominal model is obtained by linearizing the achieved non-linear ordinary differential equations. The uncertainties coming from the modeling assumptions and imperfectly known parameters and coefficients are all modeled as parametric uncertainties through the Monte Carlo simulation. As compared with other robustness analysis tools, such as Hinf, the Mu analysis is less conservative and can handle both structured and unstructured perturbations.

Finally, Genetic Algorithm is used as an optimization tool to find ideal parameters that will ensure best performance in terms of damping out flutter. Simulation results show that the procedure described in this thesis can be effective in studying the flutter stability margin and can be used to guide the gas turbine blade design.