Optimization-Driven Dynamic Structural Design of Bladed Disks with Friction Contacts

Abstract

The dynamic design represents a crucial step in the overall development of bladed disks. In this context, a key criterion is the mitigation of vibrations induced by non-stationary pressure fields acting on the blades. To this end, friction damping technologies have proven to be an effective solution. However, the introduction of contact nonlinearities makes the prediction of the vibratory response of bladed disks particularly challenging within the turbomachinery community, mainly due to several uncertainties associated with friction phenomena. One major source of uncertainty lies in the non-uniqueness of contact friction forces, which can lead to the existence of multiple response levels.

Although the first evidence of this phenomenon dates back two decades, it is only in recent years that the community has shown growing interest in it. An emerging approach involves the use of optimization algorithms to identify both the maximum and minimum vibration response levels. In this thesis, optimization algorithms are employed in the design of bladed disks with friction interfaces under two distinct strategies.

The first strategy is design by verification, where a friction damping solution is first implemented and then its effectiveness in reducing vibratory levels is assessed. In this context, optimization algorithms are extended to consider different equilibrium hypotheses in the solution of the system equations.

The second strategy is design by intent, which involves a nested optimization process to achieve a configuration where the difference between the maximum and minimum response levels is minimized. Here, the concept of robustness is introduced, understood as the ability of a vibrating system to limit the uncertainty arising from the existence of multiple response levels.

Both design strategies are applied to lumped parameter systems, which are particularly suitable due to the high computational cost associated with the optimization algorithms. Nevertheless, interesting phenomena related to the existence of multiple solutions are investigated, and the insights obtained can be considered of general relevance.

Finally, methods to accelerate the use of optimization algorithms for vibrating systems with friction damping are explored, with the aim of enabling the application of the proposed methods to more realistic structures.