Mechanical Engineering Master's Defense

Approximate a-priori Estimation of the Response Amplification due to Geometric and Young's Modulus Mistuning

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abstract

Mistuning refers to small variations of the properties (material and/or geometric) of blades in rotors of turbomachines and jet engines. These variations, induced by the finite tolerances of the manufacturing process and/or in-service wear or damage, are typically small but their effects on the steady state response of the rotor are much larger. Blade-to-blade variations of their natural frequencies by a few percent have been reported to generate changes, increases in particular, of the forced response of some blades by 50%, 100%, and even larger. This issue has been the subject of a large number of investigations in the last 50 years which have demonstrated the need to consider the prediction of the effects from a probabilistic point of view, introducing random blade properties and predicting in a Monte Carlo format the statistics and distribution of the amplitude of forced response of the blades.

Such Monte Carlo simulations can be computationally time consuming even when using the various reduced order modeling techniques available in the literature.

In this light, the overall focus of the present effort is a revisit of harmonic mistuning of rotors focusing first the confirmation of the previously obtained findings with a more detailed model of the blisk in both conditions of an isolated blade-dominated resonance and of a veering between blade and disk dominated modes. The latter condition cannot be simulated by a single degree of freedom per sector model. Further, the analysis will consider the distinct cases of mistuning due to variations of material properties (Young's modulus) and geometric properties (geometric mistuning). In the single degree of freedom model, both mistuning types are equivalent but they are not, as demonstrated here, in more realistic models. The difference arises because changes in geometry induce not only changes in natural frequencies of the blades alone but of their modes and the importance of these two sources of variability is discussed with both Monte Carlo simulation and harmonic mistuning results.

The present investigation focuses also on the possible extension of the harmonic mistuning concept and of its quantitative information that can be derived from such analyses. From it, a novel measure of blade-disk coupling is introduced and assessed in comparison with the coupling index introduced in the past.

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