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Experimental Validation of a Numerical Analysis for Transient Resonance Response of an Integral Bladed Disk

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The design process of modern aeronautical engines requires the dynamic characterization and stress certification tests of critical components, such as the bladed disks forming the stages of compressor and turbine modules.
During these tests, the bladed disk is assembled into a spinning test rig where a predefined acceleration ramp is recreated simulating different operating conditions. In particular, the operating loads due to fluid-structure interaction, are replicated by a separate excitation system.
From the experimental Campbell diagram, obtained as an output, it is sometimes possible to observe a series of unconventional dynamic responses (Non-Synchronous Vibrations) that are not predicted by the dynamic analyses as a part of the standard industrial workflow. A possible explanation is found in literature as transient effects introduced in the dynamic response of the system by an excessive ramp applied to the disk.
The objective of this work is to reproduce NSV in an academic environment and confirm the capability of commercially available structural FEA software to accurately predict the transient resonance response in bladed disks to finally introduce these transient analyses in the design process of aero-engines.
In order to achieve this goal, a series of 3D finite element transient dynamic analyses are validated with the results of a test campaign conducted on a dummy integral bladed disk subjected to various sweep rates and excited by means of permanent magnets. A set of critical crossings from the Campbell diagram, corresponding to well separated vibration modes, are selected for the validation.
The numerical time-history of a rotating blade's axial displacement is compared with the experimental one, measured through strain gauges (SGs), and the relative error is calculated.
The results show an optimal correlation between the numerical and experimental transient resonance response for a vibrating mode of a tuned bladed disk (i.e. a disk ideally having all sectors equally to each other), while the correlation decreases in presence of mistuning. Differences between the predicted and the measured results are mainly attributable to a difference in the natural frequencies of the selected modes between the real disk and the finite element model and to the real geometry of the disk which is actually mistuned.
In conclusion, for the test case that have been considered, commercially available FEA software proved to be able to accurately predict the transient response in bladed disks as well as the actual related stress field to consider for fatigue damage prediction.

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