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VIBRATION ANALYSIS OF STRUCTURES WITH CONTACT INTERFACES USING NONLINEAR MODES

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The assessment of the vibration behavior is a crucial task in mechanical design processes of mechanical structures with contact interfaces. This task is generally complex due to (a) the model dimension required for accurate predictions, (b) strong nonlinearity arising from the contact interactions, and (c) uncertainties that necessitate the conduction of exhaustive parametric studies.

The present work focuses on the nonlinear vibration behavior of a structure with contact interfaces in the resonance regime of an isolated mode. A model reduction technique is presented that is based on the concept of Nonlinear Normal Modes. The generalized Fourier-Galerkin method [3, 1] is employed for the direct computation of the modal properties within a certain energy regime. It is emphasized that the reduced order model (ROM) retains parameters such as possible external forcing frequency and amplitude as well as linear damping.

Moreover, a scale invariance [2] is addressed for the commonly applied contact law involving the elastic Coulomb dry friction law in the tangential plane combined with the elastic unilateral contact law in the normal direction. Starting from a known vibration response for a specific normal preload, it is shown that the scale invariance can be exploited to determine the response for scaled normal preload and forcing without the need for re-computation. This is particularly interesting because the normal preload is typically an important design variable. Moreover, this relation explains the often reported linear relationship between normal preload and limit cycle oscillation amplitudes induced by negative damping [4].

The methodology is applied to a turbomachinery bladed disk with underplatform friction dampers. The investigations focus on the steady-state forced response subject to traveling-wave-type excitation. The performance of the proposed approach in terms of accuracy and superior efficiency compared to conventional methods is indicated. By carrying out parameter variations of excitation level, linear damping, normal preload and friction coefficient, it is demonstrated how the method could be used in the course of structural mechanical design processes.

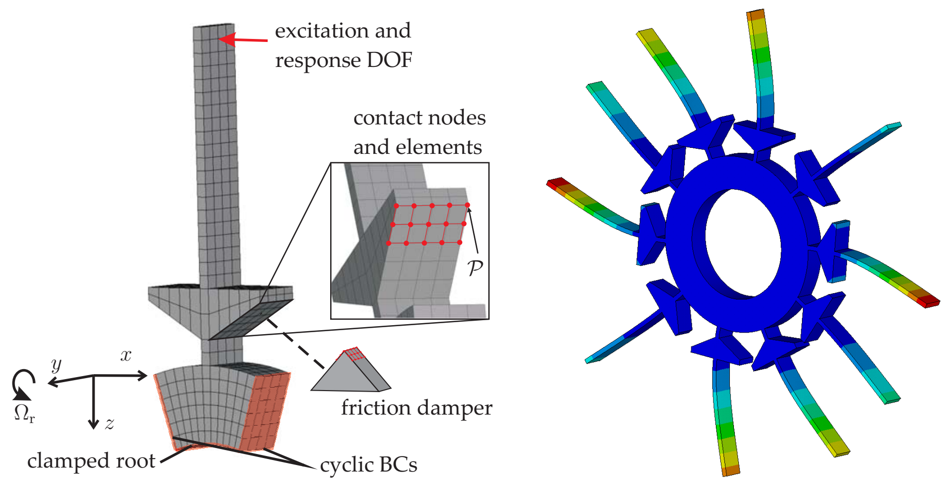

Figure 1: Finite element model of a bladed disk with underplatform dampers (left: cyclic segment with boundary conditions, right: investigated mode shape without friction dampers)

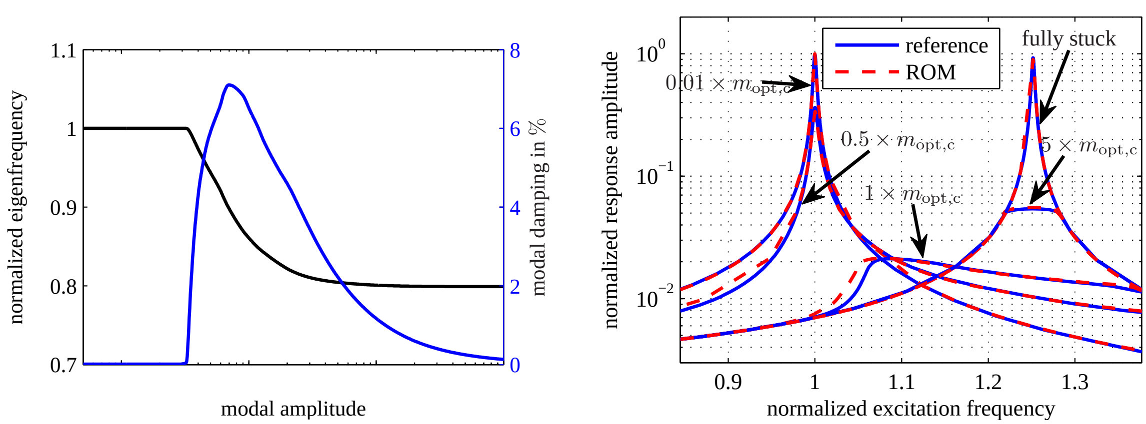

Figure 2: left: eigenfrequency and modal damping, right: frequency response functions for different damper mass values

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