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ANALYSIS OF RESONANCE NONLINEAR VIBRATIONS FOR HIGH-FIDELITY MODELS OF STRUCTURES WITH CONTACT INTERFACES

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ABSTRACT

A methodology for direct analysis of resonance peak amplitudes and frequencies of steady-state forced response for strongly nonlinear vibrations of structures with joints is presented. Large-scale finite element models of linear components, detailed modeling of the nonlinear contact interfaces and high-accuracy model reduction are applied in the analysis. The efficiency of the methodology is demonstrated on test cases and examples of analysis of realistic gas-turbine structures.

The majority of the machinery structures are assembled, jointed structures. They usually comprise several components, which interact among themselves and with other structures through contact interfaces. Forces occurring at these interfaces are essentially nonlinear due to the friction, the presence of clearances and interferences, the variation of actual contact area during vibrations, the application of devices with nonlinear properties, etc.

The gas-turbine and some other industries rely increasingly in the design practice of the critical structures with joints on the numerical analysis. This requires development of high-fidelity models and methods for effective and comprehensive analysis of nonlinear dynamics of structures with friction, gaps and other nonlinear contact interfaces.

Periodic loading, which is typical for gas-turbine and many other structures, excites mostly steady-state periodic nonlinear vibrations. Forced response levels of these vibrations at resonance peaks and values of the resonance frequencies are of particular interest since the resonance peak vibrations are usually defining integrity and longevity of a structure and, therefore, the choice of its design parameters.

In this paper effective methods are discussed which have been developed by the author for analysis of the resonance amplitude and frequencies including a direct calculation of their dependency on the variations of design parameters and excitation conditions (see details in Refs.[1]-[4]). Large-scale finite elements models, which can contain millions degrees of freedom, are used for modelling of the linear components of structures and the interactions at contact interfaces can be described in detail by a multitude of contact interface elements.

Steady-state resonance peak regimes are calculated in frequency domain using multiharmonic balance formulation for the equations of motions. All expressions for the contact interface elements including those required for calculation of resonance peaks, tracing of the solutions with parameter variation and determination of resonance peak sensitivities are derived analytically which ensures exceptionally fast and accurate calculations for all types of the advanced analysis.

High efficiency of the analysis for resonance peak forced response allows development of efficient algorithms aimed at the search contact interface parameters, which provide required resonance peak characteristics. The problem of search for the optimum parameter values is formulated and solved as the global optimization problem.

The efficiency of the methodology developed is demonstrated on a representative set of examples, which include test cases using high-fidelity finite elements models of realistic gas-turbine structures.

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