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The effect of underplatform dampers on the forced response of bladed disks by a coupled static/dynamic harmonic balance method

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ABSTRACT

Friction contacts are often used in turbomachinery design as passive damping systems. In particular, underplatform dampers are mechanical devices used to decrease the vibration amplitudes of bladed disks.

Numerical codes are used to optimize during designing the underplatform damper effectiveness in order to limit the resonant stress level of the blades. In such codes, the contact model plays the most relevant role in calculation of the dissipated energy at friction interfaces. One of the most important contact parameters to consider in order to calculate the forced response of blades assembly is the static normal load acting at the contact, since its value strongly affects the area of the hysteresis loop of the tangential force, and therefore the amount of dissipation.

A common procedure to estimate the static normal loads acting on underplatform dampers consists in decoupling the static and the dynamic balance of the damper. A preliminary static analysis of the contact is performed in order to get the static contact/gap status to use in the calculation, assuming that it does not change when vibration occurs.

In this paper, a novel approach is proposed. The static and the dynamic displacements of the system (bladed disk+underplatform dampers) are coupled together during the forced response calculation. Static loads acting at the contacts follow from static displacements and no preliminary static analysis of the system is necessary.

The proposed method is applied to a numerical test case representing a simplified bladed disk with underplatform dampers. Results are compared with those obtained with the classical approach.

1. Introduction

Large resonant stresses may cause high-cycle fatigue failure of turbine blades. Dry friction damping is recognized as an efficient way for passive control of vibration in turbines. Energy is dissipated due to the relative displacement of contact surfaces, provided that they are held in contact by a normal pre-load.

A largely used configuration of friction dampers are the so-called underplatform dampers (UPDs): metal devices placed under the blade platforms and held in contact with the blades by the centrifugal load acting on the damper, due to the shaft rotation. In this case, friction forces arise at the contact between the damper and the blade.

The need of reliable models for the design of UPDs for turbine blades has led to a large technical literature on UPDs modelling in the past ten years. In [1] and [2], the damper is modelled as a wedge placed under the blade platforms. The 2D damper kinematics was deduced by the blade platform displacements under the hypothesis of continuous contact between the damper and the blades. Damper balance equations are used to compute the periodic contact forces as a function of contact kinematics and contact parameters (i.e. contact stiffness, centrifugal load and coefficient of friction) in case of harmonic vibration of the system.

In [3], a 3D damper kinematics was proposed, neglecting also in this case the partial detachment of the damper from the blades. Damper rotation, significant in case of blade vibration, characterised by a low inter-blade phase angle (IBPA), was taken into account for the first time by means of an empirical correction factor.

In [4], important improvements are introduced: the damper is modelled as a rigid body connected to the blades by means of contact elements characterised not only by the tangential stiffness of the contact, such as in [1] and [3], but also the normal stiffness ([5–7]) taking into account damper rotation by means of a novel kinematic model.

The models developed in [4] for wedge shaped and cylindrical dampers, have been extended in [8] for the first time to semi-cylindrical UPDs, with one flat side and one curved side, while in [9] damper models are extended to split dampers.

A further step in the damper modelling was taken by [10] and [11], where the damper is modelled by means of finite elements, taking into account the bulk compliance of the damper also, whose contribution to the dynamics of the system may be significant in case of thin dampers.

All the above listed models have been implemented in numerical codes for the forced response calculation of bladed disks under

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