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Review

Efficient computational techniques for mistuning analysis of bladed discs: A review

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ABSTRACT

This paper describes a review of the relevant literature about mistuning problems in bladed disc systems, and their implications for the uncertainty propagation associated to the dynamics of aeroengine systems. An emphasis of the review is placed on the developments of the multi-scale computational techniques to increase the computational efficiency for the linear mistuning analysis, especially with the respect to the reduced order modeling techniques and uncertainty quantification methods. The non-linearity phenomena are not considered in this paper. The first two parts describe the fundamentals of the mechanics of tuned and mistuned bladed discs, followed by a review of critical research efforts performed on the development of reduced order rotor models. The focus of the fourth part is on the review of efficient simulation methods for the stochastic analysis of mistuned bladed disc systems. After that, we will finally provide a view of the current state of the art associated to efficient inversion methods for the stochastic analysis, followed by a summary.

1. Fundamentals of bladed discs

The objective of this section is to give the readers a brief introduction to bladed discs systems in aeroengines. The basic definitions and terminology related to bladed discs and their modal properties are firstly described. Then, we will briefly introduce an account of the loading occurring on bladed discs in aeroengines, as well as the resulting vibrational problems and implications. A review of the current strategies to suppress vibrations in bladed disc systems problems is also presented.

1.1. Basic definitions and terminology

A bladed disc is usually composed by a disc with a relatively large number of blades assembled in its circumference. A bladed disc is a typical example of a cyclically periodic structure, in which a cyclic-symmetric sector repeats itself around the axis of rotation (Fig. 1). In gas turbine engines, dovetail root fixings are frequently used to attach the blades to the disc. Under aerodynamic loading the surfaces of the blade and the disc can therefore come into contact with each other either at a point, or along a line or a surface, or a combination of those. The contact region transmits the forces from one body to the other by means of normal compressive stresses,

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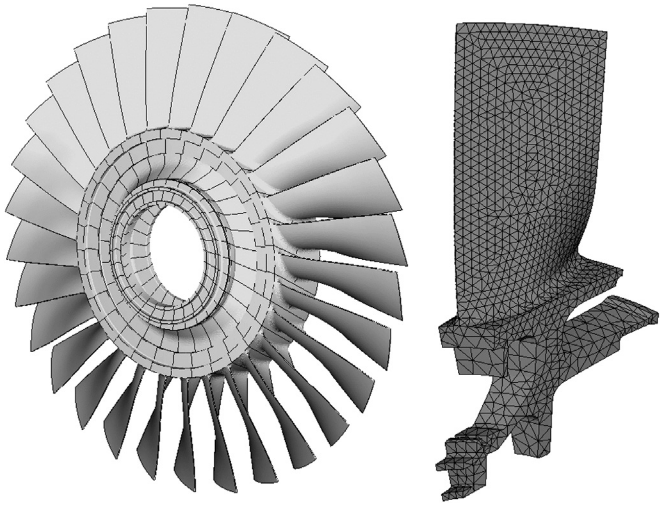

Fig. 1. A high pressure compressor and one of its blades components [2].

Fig. 2. A bladed disc with shrouds [4].

and tangential or shear stresses when friction is present. In an axial flow compressor, bladed discs are commonly mounted on a rotating shaft, together with a stator fixed to the casing. All the blades assembled in either the rotors or the stators are aerodynamically profiled to generate a pressure difference across the stages. In order to create sufficient thrust, the bladed discs are commonly subjected to very severe mechanical stresses and vibrations, due to the unsteady aerodynamic forces originated from the relative motions of the non-rotating and rotating parts at speeds between 10,000 and 17,000 rpm. These large and periodic loadings may result in high-cycle fatigue (HCF) failure, or create large plastic deformations in the blades or the whole assembly [1].

Depending on the type of application, blades are assembled around the disc in various ways. Their configurations can be with shrouds, which can increase the blade stiffness and also provide the so-called inter-blade coupling. Fig. 2 shows an example of a bladed disc with shrouds. From an aeroelastic point of view, shrouds can also be used to enhance the stability of the system because they can be tailored to avoid flutter caused by the interaction between aerodynamic loadings, inertias and the elasticity of the structure itself. In bladed discs without shrouds neighbouring blades are coupled through the disc itself, and the degree of the inter-coupling depends on the flexibility of the disc. Inter-blade coupling is in general an important parameter for the dynamic performance of mistuned bladed discs [3].

Compared to classical bladed disc systems, a blisk has blades that are an integral part of the system. The blades and the disc are manufactured together as a whole structure. The use of blisks in aero-engines can potentially reduce significantly the weight, the aerodynamic losses and the number of the parts leading to a significant increase in efficiency and decrease of the complexity of the system [5]. The use of blisks can also significantly eliminate the presence of contact stresses otherwise existing in classical blades systems, and therefore alleviate HCF and low-cycle fatigue (LCF) problems, increase the fundamental frequencies and lower the vibrational and centrifugal loads during service. Moreover, blisks can minimize the chances of blades leaving the disc due to high centrifugal stresses and the rubbing of their tip against the casing. Blisks however present some disadvantages for gas turbine engines applications. One of their main drawbacks being that once one of the blades fails the entire blisk assembly has to be replaced,