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Flexible rotor balancing without trial runs using experimentally tuned FE based rotor model

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Abstract

A method based on experimentally calibrated rotor model is proposed in this work for unbalance identification of flexible rotors without trial runs. Influence coefficient balancing method especially when applied to flexible rotors is disadvantaged by its low efficiency and lengthy procedure, whilst the proposed method has the advantage of being efficient, applicable to multi-operating spin speeds and do not need trial runs. An accurate model for the rotor and its supports based on rotordynamics and finite elements analysis combined with experimental modal analysis, is produced to identify the unbalance distribution on the rotor. To create digital model of the rotor, frequency response functions (FRFs) are determined from excitation and response data, and then modal parameters (natural frequencies and mode shapes) are extracted and compared with experimental analogies. Unbalance response is measured traditionally on rotor supports, in this work the response measured from rotating disks instead. The obtained results show that the proposed approach provides an effective alternative in rotor balancing. Increasing the number of balancing disks on balancing quality is investigated as well.

Keywords: Flexible rotor, Balancing, Unbalance identification, Finite elements, Experimental modal analysis, Rotordynamics.

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1. Introduction

Rotor unbalance is the main cause of rotor vibration and its serious consequences. When such problems met, it is resorted to balancing process, which includes attaching correction masses in predefined balancing planes to compensate eccentric mass distribution that generates large centrifugal forces and the high levels of vibration. Determining the magnitude, phase (angular position) and axial distribution of the correction masses along the shaft, is the objective of the balancing process.

Mostly, if the rotational speed of the rotor approximates or exceeds its critical speed, the resulting vibrations due to unbalance become serious. This is a result of considerable deflections in the rotor when operating in the vicinity of its critical speed.

When the rotor operates below 70 % of its critical speed, it is known as rigid rotor. This type when balanced at one speed will be balanced at any speed below 70 % of its critical speed. In contrary, flexible rotor (that operates above 70 % of its critical speed) will distort due to unbalance (centrifugal) forces, and when balanced at one speed, may not be balanced at another speed.

Two main strategies still in use widely until now, are influence coefficients method and modal balancing method. The influence coefficients method assumes direct and linear proportion between the unbalance (cause) and the measured response (effect) of the rotor, and can be employed to balance rigid and flexible rotors. Modal Balancing method aims to balance flexible rotor using its modal properties. In this technique, every vibration mode was corrected by attaching a set of masses to the rotor so that no effect was caused on previously balanced modes.

Both two techniques have its own advantages and disadvantages, but the common feature of the two is the large number of trial runs required to identify the correction masses (in the literature, several texts and papers give exhaustive description [1, 2]). Modal balancing method cannot be adopted in this work for the following reasons:

1. Restricted optionality in selecting the axial locations of balancing planes, since the rotor under study is relatively short and considerable spaces on its length are occupied by coupling, supports and shaft collars on the discs. Hence available spaces for the discs will be limited.
2. In a system with influential damping as in the rotor under study, the mode shapes do not appear clearly.

On the other hand, efficiency of influence coefficients method depends highly on number of trial runs, which are cost and time consuming and even may expose the rotor parts to damage. Thus, it is required to minimize or eliminate the trial runs. In this work, the rotor taken as a balancing case study will be described (physically in detail in the following sections), and examined at 70 %, 83 %, 92 % and 140 % of the first critical rotational speed, and thus it is considered as flexible rotor. This wide and “critical speed crossing” range of operational speeds, makes the influence coefficients method not applicable in its traditional strategy [2].

The alternative is the balancing procedure proposed in this work, which is Model Based Balancing (MBB) method. The model in MBB is digital twin to the real rotor [3]. One of the most important features of the MBB is the reduction of