Mechanical Systems and Signal Processing 25 (2011) 373–382

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/jnlabr/ymssp

Smart machines with flexible rotors

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ARTICLE INFO

Article history:
Received 22 April 2010
Received in revised form
1 September 2010
Accepted 4 September 2010
Available online 22 September 2010

Keywords:
Rotor
Vibration
Control

ABSTRACT

The concept of smart machinery is of current interest. Several technologies are relevant in this quest including magnetic bearings, shape memory alloys (SMA) and piezo-electric activation. Recently, a smart bearing pedestal was proposed based on SMAs and elastomeric O-rings. However, such a device is clearly relevant only for the control of rigid rotors, for flexible rotors there is a need for some modification on the rotor itself. In this paper, rotor actuation by piezo-electric patches on the rotor is studied. A methodology is presented for the calculation of rotor behaviour and appropriate control strategies are discussed.

1. Introduction

The concept of smart machinery is in its infancy and has received significantly less attention than has been devoted to the related study of smart structures. A smart machine is one in which there is some facility for automatic diagnosis of faults coupled with a capacity to apply corrective loads to optimise machine duty until such time as corrective maintenance can be undertaken. The precise form which these facilities take will depend significantly on the duty of the machine in question. The development of smart machines is inherently more complex than the associated structural problem owing to the rotor motion and problems associated with the bearings. However, in essence, the idealized machine has three main features:

(a) The facility to infer its own internal state.
(b) A capability to diagnose faults.
(c) The introduction of corrective forces in the event of faults.

The simplest case to consider is a machine with a rigid rotor, such as occurs in a range of small machines. This is a particularly simple case to consider since the natural frequencies (or more particularly, critical speeds) are controlled entirely by the stiffness of the bearing pedestals. Lees et al. [1] have shown how a controllable bearing pedestal may be designed using shape memory alloys and elastomers, although it is appreciated that there are a number of possible routes to achieve this goal. Other approaches to the introduction of controllable support stiffness have been considered by Zak et al. [2] and Cartmell et al. [3]. Recently, Maslen [4] has given a brief review of progress on smart machinery, but this too focuses of bearings, with particular emphasis on magnetic bearings: this is not surprising as this technology offers great promise.

However, looking further ahead one is naturally led to consider the possibility of controlling machines with flexible rotors. This is important for two reasons: in machinery generally there is a trend towards the use of flexible rotors and

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doi:10.1016/j.ymssp.2010.09.006