ROTOR SUPPORT STIFFNESS ESTIMATION BY SENSITIVITY ANALYSIS

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Abstract **– In the present work, a method for rotor support stiffness estimation via a model updating process using the sensitivity analysis is presented. This method consists in using the eigenvalues sensitivity analysis, relating to the rotor support stiffnesses variation to perform the adjustment of the model based on the minimization of the difference between eigenvalues of reference and eigenvalues obtained via mathematical model from previously adopted support bearing stiffness values. The mathematical model is developed by the finite element method and the method of adjustment should converge employing an iterative process. The performance and robustness of the method have been analyzed through a numerical example.**

Keywords **– parameter estimation, rotor support, sensitivity analysis**

I. INTRODUCTION

Mathematical models have been used to simulate and to accomplish predictions of the vibratory behavior of the dynamic systems. In fault detection and model updating there is a particular interest in obtaining relationships between the parameter variations of the system and its modal behavior or its response due to different excitation forces. In this case, the sensitivity analysis has been successfully used (Zimock, 1987).

In general, the model adjustment is carried out in terms of the mass and stiffness parameters of the system. In the publication of Zhang *et al.* (2000), a successfully model updating method to reduce the difference between the measured and calculated natural frequencies was presented. Sun *et al.* (2000) also present a sensitivity-based model updating method to automatically minimize the difference between the analytical and experimental model by using the least square algorithm. Several works (Sheinman, 1996; Kosmatka and Ricles, 1999; Dems and Mróz, 2001) have been devoted to model updating in the process of fault detection employing modal parameter sensibility.

An application that has demanded a lot of interest in the model adjustment is the identification of stiffness of supports of rotating systems (Su and Huang, 1997; Rajan *et al.*, 1986). In the rotating machines, the support stiffness values normally are very difficult to be determined and they are not directly found in the literature. They are function of the bearing type, rotating speed of the machine, characteristics of the oil lubricant or rolling bearing employed, pedestal and foundation. However, the other dynamic parameters of the machine can be calculated with satisfactory accuracy from its design and from user or manufacturer information. The support stiffness identification is very important in the development of mathematical models with guaranteed accuracy in representing the dynamic of the system, and it is known that it is only possible when the parameter uncertainties are significantly reduced (Smart *et al.*, 2000; Sinha *et al.*, 2002).

Although numerous papers on support stiffness identification have been published, most of them just work with flexible supports. However it is known when the supports have high stiffness, their sensibility with respect to the modal response becomes very small, and it can induce instability in the algorithm, hindering the convergence, so a robust algorithm is necessary.

II. SENSITIVITY ANALYSIS

Consider a multi-degree-of-freedom undamped mechanical system described by equation,

$$[M]\{\ddot{y}\}+[K]\{y\}=0\,, \tag{1}$$

where $[M]$ and $[K\,]$ are matrices of mass and stiffness respectively, and $\{y\}$ is the displacement response vector. Now, it is admitted that in the eigenproblem solution the vibration modes are conveniently normalized to produce,

$$[\Phi]^T[M][\Phi]=[I]\,, \tag{2a}$$

$$[\Phi]^T[K][\Phi]=[\Lambda]\,, \tag{2b}$$

where $[\Phi]$ and $[\Lambda]$ are the eigenvector and eigenvalue matrices respectively, and $[I\,]$ is the identity matrix. Mathematical sensitivity analysis relations are now sought that show how the matrices $[\Lambda]$ and $[\Phi]$ change when the matrices $[M]$ and $[K]$ change. For this purpose the matrix Taylor expansion can be used. For sufficiently small changes in the parameters of the system (1), only the first term in the expansions need to be retained, i.e.,