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A LINEAR REGRESSION MODEL FOR THE IDENTIFICATION OF UNBALANCE CHANGES IN ROTATING MACHINES

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This paper presents a numerical method for the full identification of multi-plane unbalance changes in a multi-bearing rotating machine. This new method is a further development of the methods for one and two-plane identification of unbalance changes. In modern rotating machinery, it is common practice to place permanent probes into the main supporting bearings as a means of "health monitoring" or "condition monitoring". These probes pick up the real-time vibration signals from a machine during its operation. By reprocessing these monitored signals and comparing them against developed criteria, the location and magnitude of any unbalance change during the machine's operation is identified. This is achieved by using the algorithm that combines the processed signals with the use of a non-linear mathematical model for the rotating machine. Assumption is made that the steady state responses before and after the unbalance change takes are available for comparison, and that the mathematical model as well as the dynamic and static properties of the system under consideration are truly representative. Verification of the proposed algorithm has been conducted using computer simulations of a real machine.

1. INTRODUCTION

The dynamic response of a multi-bearing rotor system depends not only on the dynamic properties of its subsystems but also on its configuration and its residual unbalance. The subsystems include rotors, oil bearings and supporting structures. Studies of the dynamics of rotating machines and their subsystems have been reported using both linear and non-linear models by numerous researchers such as Krodkiewski and co-workers [1–3], Craggs [4, 5], Bishop and Gladwell [6], Goodman [8], Lund and Tonnesen [9] and Parszewski and Roszkoowski [10] among others.

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There have been a number of established procedures for balancing large rotating machines. Most of these procedures have been developed for balancing rotating machines prior to their installations. Many of them assume a linear model and require many test runs for the full identification of residual unbalance in the specified correction planes.

In the procedure for the balancing of large turbogenerator units described by Cragg [4] the equivalent residual unbalance is found by multiplying the measured response vector by the influence coefficient matrix, which is determined from the finite element model of the turbogenerator considered. In the theory of modal balancing, the unbalance distribution is developed into a series of modal functions. The modal functions are either computed by means of the finite element method or determined experimentally. The unknown modal coefficients, which represent the participation of individual models, are determined mode after mode by using the data which are usually measured for speeds close to the critical ones. The influence coefficient balancing methods allow for the computation of the correction weights from measurements of the system response taken with test masses attached to the rotor at various locations along its length. This method results in both the identification of the linearized system considered and the identification of the residual unbalance.

During the operation of the system, the available data are usually limited to the supported cross-sections of the rotor only. Furthermore, in the case of large-amplitude vibration of a rotor supported upon oil bearings, the linearization of the system leads to poor assessment or the identified parameters.

In the case of a turbogenerator set, changes in the balancing conditions may occur during its operation — this may be due to the result of the machine losing one or more of its blades. Development of procedures for on-side identification of unbalance changes has, therefore, drawn much attention. On-site identification involves using real-time vibration signals measured from a machine during its operation. Since the monitored dynamic information is often limited, proposals have been made to combine the efforts in measurements with the modelling and numerical analysis of the system to aid the balancing of a rotating machine such as a large turbine generator set.

In many situations, large-amplitude vibrations may result from a dramatic change in balancing conditions such as the loss of blades during the operation of a turbogenerator. The presence of large-amplitude vibrations often implies a machine operating beyond the linearized equilibrium, particularly in the case of a rotating machine using oil bearings. The linearization of the system in these cases may lead to poor assessment of the identified parameters.

To handle large-amplitude vibration problems, studies have been reported to focus on the non-linear dynamic characteristics of rotating machines. Krodkiewski *et al.* [1] presented a method that uses a non-linear mathematical model for the on-site identification of unbalance change that may take place during the operation of a multi-bearing rotor system. The mathematical model includes the dynamic properties of the rotor and foundations as well as the non-linearity of the oil bearings.

In brief the method proposes that the signals measured before and after the unbalance change takes place are used to compute the time history of the