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# Study of coupling between bending and torsional vibration of cracked rotor system supported by radial active magnetic bearings

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**Abstract**

The coupling of bending and torsional vibration due to the presence of transverse fatigue crack in a rotor system supported by radial active magnetic bearings (AMB) is investigated. For this purpose the modified stiffness matrix with six degrees of freedom per node is used and takes into account all the coupling phenomena that exists in a cracked rotor. The partial opening and closing of crack is considered by means of status of stress intensity factor along the crack edge. The equation of motion of rotor system is nonlinear due to response dependent non-linear breathing crack model and nonlinear force coupling introduced by AMB. A response of the rotor system is obtained by direct integration of nonlinear equation of motion. When the torsional harmonic excitation is applied to the rotor system with the crack then the sum and difference of torsional frequency around a bending natural frequency is observed in the lateral vibration spectrum. Influence of different values of crack parameters for two different speeds of rotor is investigated with help of frequency spectra.


*Keywords:* rotor system, active magnetic bearing, breathing crack

## 1. Introduction

Most of breakdowns in modern machinery are due to fatigue of the material. Transverse cracks in the rotor system can result in catastrophic damage and large economic loss as stated in the review of the literature [4] devoted to dynamics of rotor systems with cracks.

The transverse fatigue crack in a structural member introduces local flexibility, which for a beam element can be described by a local flexibility matrix. A full 6x6 local flexibility matrix for a transverse crack on a shaft was first introduced by Dimarogonas [2]. Computing of elements of this matrix is based on available expressions of the stress intensity factor and the associated expressions of the strain energy density function. In general, of the full 6x6 stiffness matrix available to model a crack, only the diagonal terms have been previously utilized for dynamic analysis of cracked rotors. In this work the full local flexibility matrix has been used to investigate coupling of various modes in a rotor system supported by radial AMB.

It is known, that during each revolution of the shaft the transverse crack can be opened, closed or it can periodically open and close [2]. The last case is referred to as so-called the breathing crack or the closing crack. When the rotor is operating at a steady-state speed far away from critical speed and without any transient excitation, the breathing of the crack can be approximated by an appropriate function of stiffness variation. A more realistic breathing crack model includes gradual opening and closing of the crack by means of the stress intensity factor along the crack edge. This model would be adaptable for all speed ranges and all

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