Analytical-Numerical Approach for Non-Linear Dynamic Modeling of the Bearing-Rotor-Shaft Systems to Design and Fault Diagnostics

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ABSTRACT

During operation of the rotating machines there are observed severe transient mechanical overloads which together with misalignments and cracks in the rotor-shafts are often a source of dangerous coupled vibrations. In order to achieve a sufficiently high accuracy, reliability and numerical efficiency of simulations of these dynamic effects necessary for design and fault diagnostics, in the paper an analytical-numerical approach based on the discrete-continuous mechanical model of the bearing-rotor-shaft systems is proposed. In this model the stepped rotor-shaft is substituted by the axially rigid and flexurally and torsionally deformable cylindrical visco-elastic macro-elements with continuously distributed parameters. Each bearing is represented by means of the dynamic oscillator, in which beyond the oil-film interaction also visco-elastic properties of the bearing housing and foundation are taken into consideration. The bladed disks are substituted by discrete-substructures in the form of sets of the rigid rings mutually attached to the rotor-shaft by means of the visco-elastic mass-less membranes enabling rotations of these rings as well as their translational displacements in the shaft axial direction. The crack and misalignments are described by proper dynamic boundary conditions formulated for extreme cross-sections of respective adjacent macro-elements. By the use of this model non-linear and parametric lateral-torsional-axial vibrations simultaneously coupled by residual unbalances, shaft misalignments, cracks and bladed disk interactions can be investigated. Solution for this model has been obtained using the analytical-numerical approach based on the Fourier solution of the partial differential equations, which leads to the set of modal equations mutually coupled by the parametric, non-linear and gyroscopic terms regarded as external excitations expanded in series in the base of orthogonal analytical eigenfunctions. The numerical results have been obtained for the double-span rotor-shaft system with two identical bladed disks supported on three journal bearings and with a crack assumed on the given shaft segment. For various rotational speeds and several circumferential crack locations there were analyzed coupling effects by means of studying time histories, amplitude characteristics and amplitude spectra of the dynamic responses. The obtained results can be then used to design and fault diagnostics as well as to fatigue life estimation of the elements most heavily affected.