Finite element computational dynamics of rotating systems

A bibliography (1994–1998)

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This bibliography lists references to papers, conference proceedings and theses/dissertations dealing with finite element analysis of rotor dynamics problems that were published in 1994–1998. It contains 319 citations. Also included, as separate subsections, are finite element analyses of rotor elements – discs, shafts, spindles, and blades. Topics dealing with fracture mechanics, contact and stability problems of rotating machinery are also considered in specific sections. The last part of the bibliography presents papers dealing with specific industrial applications.

1. Introduction

The information is the most valuable, but least valued, tool the professional has. The output of scientific papers is growing and it is becoming more difficult to be fully up-to-date with all the relevant information. It is also known that a number of channels that researchers/practical engineers have at their disposal for information retrieval increases fast but it is questionable if researchers/practical engineers are willing to spend the time necessary to look for information. It has been pointed out that in engineering, informal knowledge channels are the most frequently used means of obtaining information. Many professionals prefer to rely on personal judgment or on the wisdom of their colleagues whenever they have problems to solve. Hopefully, it is the author's expectation that this bibliography will save time for readers looking for information dealing with subjects described below.

Modern rotating systems, often operating under extreme conditions and performing demanding tasks, are a prime machinery for transporting momentum, mass, and heat in many engineering systems. To understand the dynamics of these systems is very important in the design process as well as in the requirements to enhance the reliability and operational efficiency of these machines. In the design stage it is necessary to predict the dynamic behavior of rotor systems in bending and torsion, today frequently computed by using finite element techniques. This is the main subject of this bibliography. Topics dealing with fracture mechanics, contact and stability problems of rotating machinery are also considered in separate sections.

This bibliography provides a list of references on finite element dynamic analysis of rotating systems and their elements. General solution techniques as well as problem-specific applications are included. The entries have been retrieved from the author's database, MAKEBASE [1,2]. The references have been published in scientific journals, conference proceedings, and theses/dissertations between 1994–1998. They are sorted in each category alphabetically according to the first author's name. If a specific paper is relevant for several subject categories, the same reference can be listed under respective section headings, but the interested reader is expected to consider also areas adjacent to his/her central area of research. Listed references are grouped into the following sections and subsections:

- rotors and their elements (rotors, discs, shafts, spindles, blades)
- fracture mechanics and fatigue
- contact and contact-impact problems
- stability analysis
- specific industrial applications

Not included in the bibliography: drilling shafts, bearings, seals, passive/active vibration control of rotor systems, optimization problems.

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2. Rotors and their elements

The basic elements of a rotor are the disc, the shaft, the bearings and the seals. In this section of the bibliography listed papers are dealing with dynamic finite element analyses of rotors and their elements, with emphasis on their characteristics and behavior. Free and forced vibrations are studied. A rotating shaft is typically modelled as a series of line or beam elements; papers on rotating beams are also included. The determination of natural frequencies and mode shapes of rotating structures, such as turbine blades is very important in the design of turbomachines. Therefore as special subsections also blades and spindels are addressed.

2.1. Rotors

Topics included: finite element modelling techniques in rotating machinery; linear and nonlinear vibration analysis; modal analysis; rotor model updating; multi-body dynamic modelling; flexural behavior of rotors; torsional vibration analysis; analysis of whirl speeds; aeroelastic/aerodynamic rotorcraft analysis; vibratory rotor hub loading; effect of misalignment on rotor vibrations; rotary machines subjected to earthquake; finite elements for rotor modelling.

Types of rotor systems under consideration: flexible rotor systems; flexible rotors on flexible suspensions; flexible rotors in magnetic bearings; rotor-bearing systems; multi-bearing rotors; geared rotor-bearing systems; rotor-shaft-bearing systems; rotor-bearing with misaligned shafts; rotors supported by a spherical spiral groove bearings; rotors supported by a piecewise linear journal bearings; blade-disc-shaft systems; composite rotors.

2.2. Discs

The following topics are included in this subsection: dynamic modelling of discs; linear and nonlinear vibration analysis; vibration localization; prediction of forced response in time and frequency domains; modal interactions is spinning discs; flexural, torsional and axial dynamic analysis; thermally stressed spinning plates.

Types of discs analyzed: rotating isotropic/orthotropic/anisotropic discs; rotating pretwisted plates; circular discs with noncentral holes; bladed discs; mistuned bladed discs; bladed discs with friction dampers; flexible bladed disc-shaft assemblies; disc-shaft assemblies; composite discs; reinforced ceramic rotating discs.

2.3. Shafts

In this subcategory the following subjects are handled: dynamic modelling of rotating beams/shafts; modal analysis; linear and nonlinear vibration analysis; high-speed rotation analysis; model updating techniques; twisted rotating beams; coupled torsional-lateral-axial vibration analysis; coupled torsional-flexural vibration analysis; finite elements for shaft modelling.

Rotating elements under consideration: rotating beams and shafts; Timoshenko beams; filleted shafts; D-shaped shafts; geared shaft systems; flexible links; circular plates with solid shafts; bladed disc-shaft assemblies; disc-shaft assemblies; composite beams/ shafts.

2.4. Spindles

Topics included: dynamic modelling of spindles; modal analysis; identification of modal parameters; vibration and deformation analyses.

Rotating elements/systems: spindles; spindle-bearing systems; lathe-spindle assembly; cutting machine tool spindles; grinding machine tool spindles; hydrostatic gas bearing spindles; air-spindles.

2.5. Blades

This subsection deals with topics such as: dynamic modelling of rotating blades; modal analysis; linear and nonlinear vibration analysis; deformation analysis; forced response analysis; damping considerations; vibration analysis of pre-twisted blades; aeroelastic response analysis.

The following components are included: blades; blades with flexible coupling; blades with small holes; blade arrays; composite rotor blades.

3. Fracture mechanics and fatigue

Rotating machinery components are prone to cracking and failure caused by creep, fatigue and their interaction. Fatigue crack growth studies are central to damage-tolerance approaches. Mathematical models of cracked rotor systems have been developed to predict the change in vibrational behavior due to crack growth. The main subject of this section are finite element, linear and nonlinear, studies of various aspects of vibration of rotating machinery with a crack.

This section deals with finite element analysis of rotating crack models. Included are topics such as: vibration analysis; modal parameters identification; crack initiation and propagation; dynamic failure analysis; damage analysis and detection; environmental and mechanical fatigue; fretting fatigue; fatigue crack growth and propagation; creep-fatigue modelling; creep crack initiation; surface flaw behaviors; lifetime evaluation; probabilistic fracture mechanics; sensitivity analysis; stress intensity factor computations.

The following cracked components are under consideration: rotors; shafts; discs; turboalternator rotors; helicopter rotors; turbine blades; turbine rotors; compressor blades; aeroengine discs; rotor-bearing systems.

4. Contact and contact-impact problems

The contact in rotating systems has long been recognized as a major contributor to their failures. Developing adequate contact models and incorporating them into the dynamic finite element analysis of rotating machinery are key issues in order to understand the mechanisms and in this way to predict accurately the phenomena. Many rotors also contain components stacked and held together. When the rotor whirls, working joints are causing the friction damping which is a potential source of instability.

Types of contact and contact-impact problems that are analyzed/simulated in this section are, for example: rotor-stator contact problems; rotor-bearing contacts; shaft-hub connections; gear-shaft connections; shaft-cone connections; blade-disc connections; joints of hollow shafts; shaft couplings for rotor wheels; joints of aeroengine discs; rotor-foundation interaction; frictional heating in shaft-bush system; contact analysis of turbine blades; impact behavior of rotor dynamic systems; crashworthy rotorcraft design; blast loading of discs; helicopter rotor blade-droop stop impacts.

5. Stability analysis

Rotors should not be working in the unstable regime. The instability is induced by fluid-solid interaction and can be seen as a spontaneous growth in whirl amplitude upon reaching some threshold speed. The sources of instability are bearings and seals, passive forces in turbines or impellers, internal friction, etc.

Vibration and dynamic stability/instability problems are the subjects of this section. The following components/systems have been analyzed by finite element methods: discs; rotating shafts; cracked shafts and rotating beams; rotating blades; turbomachinery blades; Timoshenko shafts; composite shafts; non-symmetric rotors on distributed bearings; pre-twisted rotors; rotor-bearing systems. The aeroelastic stability of helicopter rotor blades is also included.

6. Specific industrial applications

Specific industrial applications in this last section include finite element analyses and design considerations of: compressor rotors; gas turbine rotors and blades; turbogenerator rotors; rotorcraft transmissions; helicopter rotors and blades; rotors of gyroscopes and centrifuges; bearingless helicopter rotors; rotor-fuselage systems; cam engine shaft systems; wing drive shafts; multiblade fan shaft systems; turbine blades; wind turbine blades; aircraft turbine blades; turbine blade rows; centrifugal and hydraulic pumps.

Readers interested in the finite element literature in general are referred to [3] or to the author's Internet Finite Element Book Bibliography (http://www.solid.ikp.liu.se/fe/index.html). The solutions of rotordynamic problems in general can be found in many books, for example in [4–9]. A list of references on finite element analysis of machine elements where bearings and seals are included can be found in [10], and the active vibration control is a part of the [11].

Acknowledgement

The bibliography presented is by no means complete but it gives a comprehensive representation of different finite element applications on the subjects. The author wishes to apologize for the unintentional exclusions of missing references and would appreciate receiving comments and pointers to other relevant literature for a future update.

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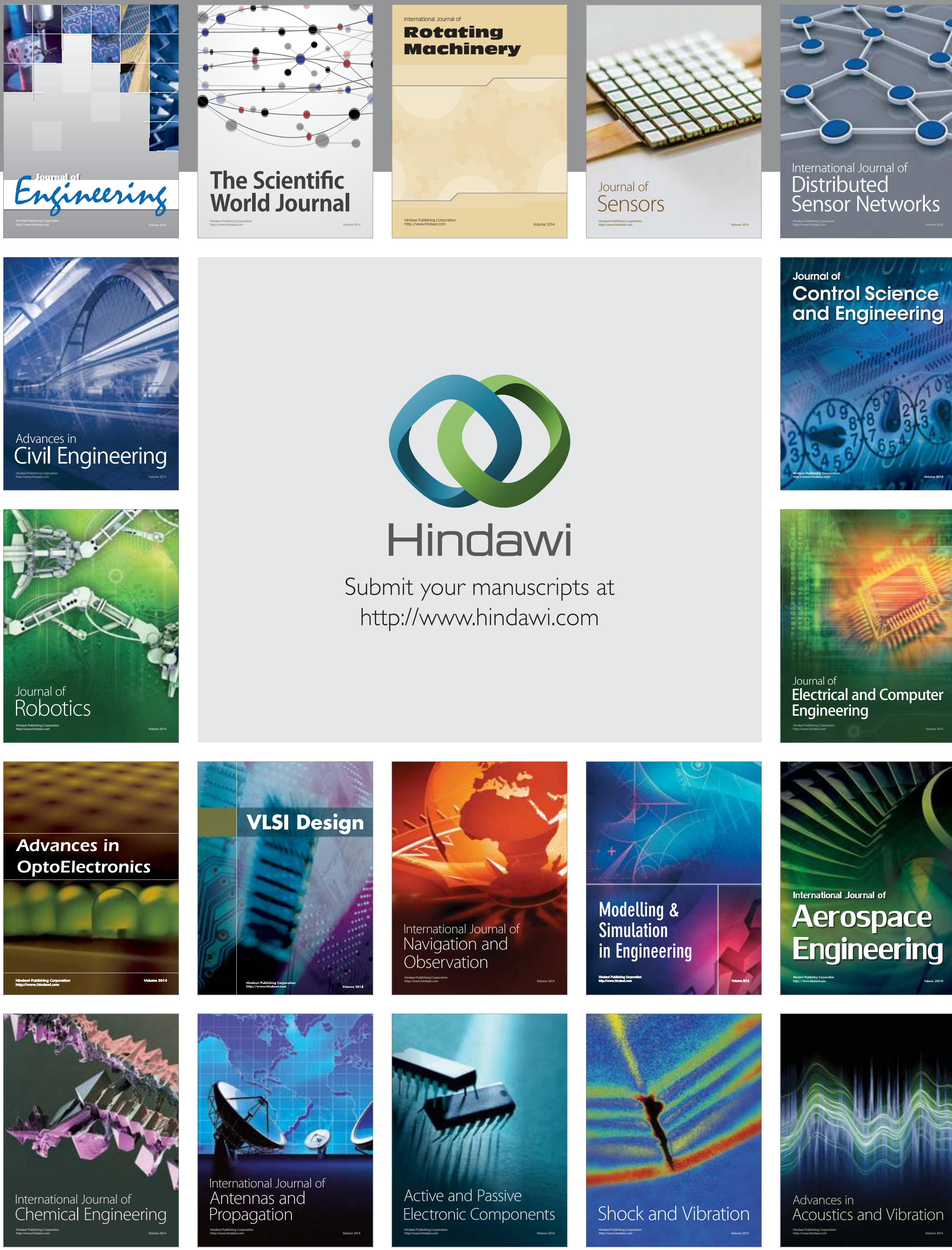
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