

**Dynamic Analysis
of Centrifugal Machines Rotors
with Combined Using 3D and 2D
Finite Element Models**

by

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Lüdenscheid, Germany
RAM-VERLAG
2018

The monograph is aimed at developing methods for the identification of dynamic characteristics of rotor oscillations by combined using 3D and 2D finite element models. General approach is stated for solving dynamic problems for turbopump units, as well as for multistage centrifugal pumps and compressors. The virtual rotor balancing procedure is proposed. Special attention is paid to the investigation of rotor dynamics with taking into account nonlinearities of bearing characteristics. The monograph will be useful for engineers, researchers, students and postgraduate students of higher educational institutions.

The monograph was reviewed by three reviewers.

Edition of Scientific and Technical Literature

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This monograph was prepared with support by the Project of the Structural Funds of the EU, ITMS code 26220220103 and it was recommended for publication by the Academic Council of Sumy State University as a scientific monograph (minutes No. 4 of 14.12.2017).

ISBN 978-3-942303-64-4
UDC 534.13:[621.22+621.515.1]

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Preface

Intensification of the development in the field of power engineering occurs by using the modern energy-intensive equipment, an essential role of which is performed by multistage rotor machines. Permanently raising their parameters leads to increasingly significant problems of vibration reliability. Furthermore, the problem of investigation of dynamics of flexible rotors is based on determination of the critical frequencies and corresponding mode shapes. This problem is currently actual due to the impossibility of absolutely accurate dynamic rotor balancing.

General approaches are used for investigation of the rotor dynamics, that are closely intersected with the issues of strength of materials and the theory of elasticity, the theory of linear and nonlinear oscillation of mechanical systems, as well as the problems for the identification of mathematical models of dynamic systems. Most problems can be solved in combination of 2D and 3D formulation by using modern software. Therefore, skills should be gained in the field of numerical solving problems of rotor dynamics and identification of parameters for dynamic systems.

The monograph is intended for engineers at pumps and compressors manufacturing enterprises, for researchers in the field of rotor dynamics, as well as for students and postgraduate students of engineering majors at higher educational institutions. It is devoted to investigate the dynamic problems of flexible rotors on bearing supports. Special attention is paid to the investigation of rotor dynamics with taking into account nonlinearities of bearing characteristics.

The monograph consists of five chapters, arranged in the order of presentation of the research material for turbopump units, multistage centrifugal pumps and turbocompressors. The list of symbols and the subject index located at the beginning

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and at the end of the monograph, will help to accelerate the search for the necessary material.

Each chapter concludes the material based on authors' experience in mathematical modelling and numerical simulation of rotor dynamics commissioned by the Ministry of Education and Science of Ukraine, Yuzhnoye State Design Office, PJSC "Sumy Machine-Building Science-and-Production Association", JSC "Nasosenergomash Sumy", JSC "Research and Design Institute for Atomic and Power Pumpbuilding" and Space Systems Engineering. Particularly, the first three chapters are created within the recent research works of the authors at the Department of General Mechanics and Machine Dynamics of Sumy State University:

1. Numerical simulation of rotor dynamics for liquid rocket engines with considering dynamic characteristics of bearings and seals, No. 0115U000679.
2. Development of the new mathematical models of centrifugal machines rotors and methods of their diagnosis, No. 0113U001522.
3. Investigation of oscillations of entrifugal machines rotors associated with nonlinearity reactions in gap bearings and seals, and their vibration diagnosis, No. 0115U000549.
4. Development of methods for numerical simulation and optimization of hydrodynamic characteristics for gap and labyrinth seals, and investigation of their impact on the rotordynamics for centrifugal machines, No. 0106U001385.
5. Numerical simulation and optimization of gas-dynamics and vibration characteristics for turbochargers of gas-pumping units and their components, No. 0109U001937.
6. Rotordynamic research for the turbopumps of the liquid rocket engines, No. 51.24-01.15.SP.

The last two chapters are written as a result of close cooperation between the Faculty of Technical Systems and Energy Efficient Technologies of Sumy State University (Ukraine) and the Faculty of Manufacturing Technologies with a seat in Prešov of Technical University of Košice (Slovak Republic) within the National Scholarship Programme of the

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Slovak Republic and the corresponding research internship “Interdisciplinary research in the field of dynamic and strength of mechanical systems”. Practical examples from the authors’ experience of calculations of turbopumps are especially valuable in this monograph.

The part of the results are achieved within the project “Development and implementation of energy efficient modular separation devices for oil and gas purification equipment” (No. 0117U003931, No. 15.01.06-01.17/20.ZP) due to the close cooperation between the Department of General Mechanics and Machine Dynamics, Process and Equipment of Chemical and Petroleum-Refineries Department, and the Department of Manufacturing Engineering, Machines and Tools.

The entire material of the monograph will be useful for higher educational institutions within the subjects “Problems for the identification of mathematical models of dynamic systems”, “Theory of oscillations”, “Theory of Elasticity” for students of engineering majors (e. g. “Dynamics and strength”, “Computational mechanics”, “Computational engineering in mechanics”).

The main material of the monograph has been approved within the Erasmus+ program at the lecture courses for M.Sc. students “Dynamic analysis of centrifugal machines rotors by using finite element method”, “Fundamentals of mechanical engineering” and “Mathematical modelling of mechanical systems” at the Faculty of Mechanical Engineering and Management of Poznań University of Technology (Poland).

The authors sincerely hope that the material presented in this monograph will be quite clear for understanding, and new ideas can be gained for the further scientific growth.

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