Vibration of Hydraulic Machinery
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Springer, New York NY USA, (2013)
500 pp., hardbound, 179 USD, ISBN 978-94-007-6421-7

The theme of this book is utilizing numerical modeling methods to predict vibration in hydraulic machinery, such as turbines and pumps. The book provides latest development and case studies in this area. In this context, the term “Hydraulic Machinery” in the title refers to large water turbines or pumps used in hydro power plants. Unlike *Noise Control of Hydraulic Machinery* by Skaistis, this book does not cover hydraulically powered machinery such as heavy construction equipment.

This book tends to be oriented towards research rather than to practical applications such as vibration control. The targeted readers of this book are researchers and students with solid physics and math background. Most equations in this book are concise, with minimum derivation. However, the authors provide appropriate references in each section for further reading.

The first part of this book (chapters 1 through 4) summarizes fundamentals in mechanical vibration, numerical modeling methods and rotor dynamics. It lays out the foundation for the later chapters which deal with advanced numerical analysis. Chapter 2 “Fundamental of Mechanical Vibration” reviews mechanical vibration of linear discrete system and continuous system. Chapter 3 “Numerical Model of Dynamics” provides theoretical concepts and formulation of finite element method (FEM) and fluid–structure interaction (FSI). Chapter 4 introduces rudimentary concepts of rotor dynamics, from simple lumped mass model to flexible MDOF model. This chapter prepares readers for rotor dynamic simulation in Chapter 9. The presentation of the material in these chapters is structured and concise.

The second part (chapters 5 and 6) introduces major vibration excitations in turbines, including mechanical, magnetic and hydraulic excitations. Mechanical excitations covered in Chapter 5 include imbalance of rotating mass and oil-film instability in bearing. The authors also briefly discussed the unbalanced magnetic force excitation caused by eccentricity. The mathematical models of these excitations are constructed and analyzed in this chapter. Chapter 6 is the largest chapter and expands on a broad range of hydraulic excitations that induce vibration in hydraulic machinery. For example, pressure pulsation in Francis turbines can be induced by unstable flows in the runner, or by vortices shedding from blades and vanes. Other hydraulic excitations covered in this chapter include cavitation, self-excited vibration and flow instability produced by rotor–stator interaction. Frequency signature of each hydraulic excitation mechanism is given by either analytical or empirical formula. Chapters 5 and 6 also briefly discussed the mechanical and hydraulic excitations in centrifugal pumps.

The third part (chapters 7 through 9) is concerned with utilizing the numerical methods described in Part 1 to simulate hydraulic pressure fluctuation, structural vibration and rotor dynamics in hydraulic machinery. In Chapter 7, main computational fluid dynamics (CFD) approaches are briefly introduced. A few simulation examples are used to demonstrate turbulence modeling methods. Reynolds-Averaged Navier-Stokes (RANS) model is adopted to simulate the unsteady flow through a Kaplan turbine. The pressure pulsation results obtained from simulation are in good agreement with experimental results. The same approach is also used to model the flow through a high speed centrifugal pump. The Detached Eddy Simulation (DES) approach is applied to turbulent flow simulation of a Francis turbine used in the Three-Gorge hydroelectric plant (the world's largest hydroelectric plant). Chapter 8 focuses on utilizing Fluid–Structure Interaction (FSI) approaches to simulate structure's behavior when subjected to hydraulic loading. Examples include modal analysis of a Francis turbine in still/moving water and dynamic stresses analysis of Kaplan turbine blades. Chapter 9 expands on the fundamentals established in chapter 4 and applies rotor dynamic modeling in hydraulic machinery. In this chapter, both lumped parameter method and Finite Element Method (FEM) are used to calculate turbine natural frequencies and its transient vibration response. Same approaches are also adopted to compute critical shaft speed of an ultra-high pressure multi-stage centrifugal pump.

The fourth part (chapters 10 and 11) reviews instability analysis and vibration-based condition monitoring of hydraulic turbine system. In Chapter 10, hydraulic and electrical parts are coupled together to investigate the impact of the hydraulic machinery to the hydroelectric plant system instability. A few case studies are used to demonstrate hydro power plant stability models. Chapter 11 introduces condition monitoring to maintain hydraulic machinery health and performance. The system utilizes the measured vibration data to monitor the following major parameters: pressure pulsation, shaft swing and structural vibration.

As a summary, this book provides a comprehensive overview of vibration modeling for hydraulic machinery. Although the modeling is focused on hydro turbine and centrifugal pumps, the methodologies adopted in this book can be useful for some noise control applications. For example, the Fluid–Structure Interaction (FSI) analysis can be used in vibration or fluid-borne noise simulation of hydraulically powered machines. The book is a good reference to researchers and students who are interested in hydraulic machinery, CFD or fluid–structure coupled analysis.

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