Hydraulic Systems Volume 7

Modeling and Simulation for Application Engineers

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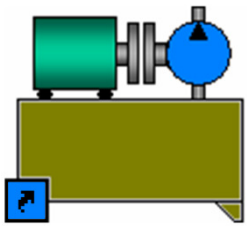

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Modeling and Simulation for Application Engineers

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PREFACE

Modeling and simulation techniques are essential tools for dynamic systems design and production. This book introduces an overview of common mathematical modeling techniques in t-domain and s-domain, various types of physical systems, and challenges of modeling them.

This book is targeting industry professionals who oversee modeling machine at large rather than modeling a single component. This book is also a great resource for mechanical engineering graduate students for their research work.

The book adopted lumped modeling technique, using Matlab-Simulink, to model discrete hydraulic components that can be recharacterized and used repeatedly in system models. The book isn't intended to present a model for every hydraulic component, it rather applies the lumped modeling concept on hydraulic fluids, transmission lines, pumps, motors, cylinders, pressure relief valves, flow control valves, proportional valves, and servo valves. This book uses the component lumped models to assemble an electrohydraulic cylinder position control system and an electrohydraulic motor speed control as case studies.

More than 60 models are presented. This book provides a comprehensive explanation on how these models are structured, validated, and used for analyzing system performance. These models are available to download when you purchase the book.

The author is working hard to finish his goal of supporting fluid power professional education by developing the following series of volumes and relevant software:

- Hydraulic Systems Volume 1: Introduction to Hydraulics for Industry Professionals.
- Hydraulic Systems Volume 2: Electro-Hydraulic Components and Systems.
- Hydraulic Systems Volume 3: Hydraulic Fluids and Contamination Control.
- Hydraulic Systems Volume 4: Hydraulic Fluids Conditioning. Under Development (UD)
- Hydraulic Systems Volume 5: Safety and Maintenance. UD
- Hydraulic Systems Volume 6: Troubleshooting and Failure Analysis. UD
- Hydraulic Systems Volume 7: Modeling and Simulation for Application Engineers.
- Hydraulic Systems Volume 8: Design Strategies of Hydraulic Systems. UD
- Hydraulic Systems Volume 9: Design Strategies of Electro-Hydraulic Systems. UD

Hydraulic Systems Volume 10: Hydraulic Components Modeling and Simulation. UD

Dr. Medhat Kamel Bahr Khalil

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This book was written during the hardship of Covid-19 Virus.

All praise is to Allah who granted me the knowledge, resources and health to finish this work

To the soul of my parents who taught me the values of ISLAM

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To my family: wife, sons, daughters in law, and grandson “Adam”

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- Kamara Sheku, Dean of Applied Researches at Milwaukee School of Engineering.
- Tom Wanke, CFPE, Director of Fluid Power Industrial Consortium and Industry Relations at Milwaukee School of Engineering.

ABOUT THE BOOK

Book Description:

This book is targeting system design engineers who oversee hydraulic control system design whether for industrial or mobile applications. This book introduces conceptual methodology to build lumped models for hydraulic components and assemble them to form a system. This book is also a great resource for mechanical engineering graduate students for their research work. The book presents models for hydraulic fluids, transmission lines, pumps, motors, cylinders, pressure relief valves, flow control valves, proportional valves, and servo valves.

This book is colored and has the size of standard A4. The book is associated with a separate colored workbook. The workbook contains printed power point slides, chapter reviews and assignments. This book is the seventh in a series that the author plans to publish to offer complete and comprehensive teaching references for the fluid power industry. The book contains a total of eleven chapters distributed over 320 pages with very demonstrative figures and tables. The contents of the book are brand non-biased and intends to introduce the latest technologies related to the subject of the book.

Book Objectives:

Chapter 1: Introduction to Physical Systems Modeling and Simulation

Modeling and simulation are essential tools in today's system design process. This chapter introduces the subject matter overviewing, the importance, historic background, and the challenges in physical systems modeling and simulation. The chapter also provides a brief overview of the common techniques used for mathematical modeling of physical systems in t-domain and s-domain. The chapter also presents the typical forcing functions used to simulate physical systems performance analysis under various load conditions or commands.

Chapter 2: Modeling and Simulation of First-Order Dynamic Systems

In this chapter, methods and theories presented in Chapter 1 are applied to First-Order dynamic systems. The chapter presents mathematical modeling for first-order systems in t-domain and s-domain. This chapter also presents the response of first-order systems to the typical forcing functions including, step, ramp, and harmonic inputs. The chapter discusses the measured characteristics of first-order step response and how to develop the transfer function of the system based on existing dynamic characteristics.

Chapter 3: Modeling and Simulation of Second-Order Dynamic Systems

In this chapter, methods and theories presented in Chapter 1 are applied for Second-Order dynamic system. The chapter presents mathematical modeling for second-order systems in t-domain and s-domain. This chapter also presents the response of second-order systems to the

typical forcing functions including, step, ramp, and harmonic inputs. The chapter discusses measured characteristics of second-order step response and how to develop the transfer function of the system based on existing dynamic characteristics.

Chapter 4: Modeling Approaches for Hydraulic Components and Systems

This chapter explores the different approaches when modeling a hydraulic component versus modeling a hydraulic system at large. The chapter presents the basic idea and the structure of lumped modeling, an adopted modeling approach for application engineers.

Chapter 5: Modeling of Fluid Properties

This chapter presents different techniques to model hydraulic fluid properties based on available information. Properties considered in this chapter are bulk modulus, density, specific gravity and viscosity. In modeling such properties, effects of working temperature and pressure are considered. Case studies are presented, and Matlab-Simulink models were built and validated based on given information.

Chapter 6: Modeling of Hydraulic Transmission Lines

This chapter presents modeling transmission lines, fittings and orifices. Model for a transmission line considers compressible fluid so that effect of line capacitance can be investigated. Developed models were validated based on other software.

Chapter 7: Modeling of Hydraulic Pumps

This chapter presents the lumped modeling concept as applied for fixed and variable displacement pumps. This chapter considers situations where a pump works under a constant or variable pressure and driving speed. Models for pressure-compensated, displacement-controlled, and torque-limited pumps are developed.

Chapter 8: Modeling of Hydraulic Motors

This chapter presents the lumped modeling concept as applied for fixed and variable displacement motors. This chapter considers situations where a motor works under a constant or variable torque and inlet flow. Models for two-position control, proportional control, and torque-limited motors are developed.

Chapter 9: Modeling of Hydraulic Cylinders

This chapter presents the lumped modeling concept as applied for double-acting hydraulic cylinders. This chapter considers situations where a cylinder works under a constant or variable external load and inlet flow. Calculations for cylinder slowing due to leakage, cylinder drift due to oil compressibility, and pressure increase due to thermal expansion are presented.

Chapter 10: Modeling of Hydraulic Valves

This chapter presents the lumped modeling concept as applied for hydraulic valves. This chapter considers modeling at least one pressure control valve, one flow control valve, and one

directional control valves. Models for electro-hydraulic proportional and servo valves are also developed.

Chapter 11: Modeling of Hydraulic Control Systems

This chapter utilizes the lumped component models previously built to build system models. In this chapter, there is no additional math models to be developed. This chapter assembles system models from component models. After validating system models, they can be used as reference models for purposes of system design or investigating effects of operating conditions on system performance. This chapter presents models for electrohydraulic cylinder position control, electrohydraulic motor speed control, and hydraulic loading system.

Book Statistics:

The table shown below contains interesting statistical data about the textbook:

Chapter #	Pages	Figures	Models	Equations	Tables	Lines	Words	Characters
Chapter 1	38	19	0	12	5	390	8218	46847
Chapter2	29	27	9	16	0	192	4044	23057
Chapter 3	45	36	13	27	0	245	5172	29484
Chapter 4	13	7	0	2	0	131	2757	15720
Chapter 5	23	19	5	20	3	189	3990	22749
Chapter 6	20	20	4	15	0	119	2520	14369
Chapter 7	57	68	12	7	0	344	7244	41292
Chapter 8	36	41	7	6	0	234	4926	28080
Chapter 9	17	18	1	12	1	130	2752	15691
Chapter 10	24	28	6	7	0	157	3323	18946
Chapter 11	16	21	5	0	0	98	2074	11826
Other	39	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total	**357**	**304**	**62**	**124**	**9**	**2229**	**47020**	**268061**

ABOUT THE AUTHOR

Medhat Khalil, Ph.D. is Director of Professional Education & Research Development at the Applied Technology Center, Milwaukee School of Engineering, Milwaukee, WI, USA. Medhat has consistently been working on his academic development through the years, starting from bachelor's and master's Degrees in Mechanical Engineering in Cairo Egypt and proceeding with his Ph.D. in Mechanical Engineering and Post-Doctoral Industrial Research Fellowship at Concordia University in Montreal, Quebec, Canada. He has been certified and is a member of many institutions such as: Certified Fluid Power Hydraulic Specialist (CFPHS) by the International Fluid Power Society (IFPS); Certified Fluid Power Accredited Instructor (CFPAI) by the International Fluid Power Society (IFPS); Member of Center for Compact and Efficient Fluid Power Engineering Research Center (CCEFP); Listed Fluid Power Consultant by the National Fluid Power Association (NFPA); and Listed Professional Instructor by the American Society of Mechanical Engineers (ASME). Medhat has balanced academic and industrial experience. Medhat has a vast working experience in the field of Mechanical Engineering and more specifically hydraulics, having developed and taught fluid power system training courses for industry professionals, being quite aware of the technological developments in the field of fluid power and motion control and the production program of the leading fluid power companies. In addition, Medhat had worked for several world-wide recognized industrial organizations such as Rexroth in Egypt and CAE in Canada. Medhat had designed several hydraulic systems and developed several analytical and educational software. Medhat also has considerable experience in modeling and simulation of dynamic systems using Matlab-Simulink.

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