

Preface

This book developed out of a collaboration by the authors at the Toyota Research Institute of North America, where multiphysics simulation and optimization is used on a daily basis for a variety of engineering studies related to electromechanical systems. Multiphysics simulation is a rapidly growing field, and the term itself is broad and may be applied to an extremely wide variety of coupled-physics problems. By nature, multiphysics simulation requires an array of technical skills in different intersecting disciplines. As such, this book aims to narrow down the topic by specifically focusing on multiphysics simulation for electromechanical systems, the original target application investigated by the authors. It is our hope that the collaborative aspects of such studies become apparent as the various technical topics throughout the book are presented.

Overview

Understanding and predicting the performance of electromechanical systems is of prime importance in the design of many of today's key products including computers, vehicles and consumer electronics. In these systems, increased efficiency and higher power density in a smaller package size is crucial. Success in design requires both analytical and numerical skills plus a foundation in mechanical and electrical engineering. Efficient analysis also necessitates an understanding of how best to build a numerical model that is accurate yet balances complexity and computational cost.

Beyond basic performance prediction, today's engineers and researchers are constantly seeking methods for optimizing complex electromechanical systems. The multiphysics aspects of these systems present constant challenges in terms of how best to arrive at an 'optimal solution.' Many optimization techniques exist, although the use of structural topology optimization is emphasized herein along with some aspects of discrete parameter optimization.

Organization and Features

Accordingly, this book highlights a unique combination of numerical tools including numerous strategies for handling the aforementioned simulation challenges. In [Chap. 1](#), the concept of design via simulation is introduced along with the role of multiphysics simulation in today's engineering environment. The importance of structural optimization techniques in the design and development of electromechanical systems is additionally discussed. From there, an overview of the physics commonly involved with electromechanical systems is provided ([Chap. 2](#)) for applications such as electronics, magnetic components, radio frequency components, actuators and motors. Governing equations for the simulation of related multiphysics problems are reviewed in [Chap. 3](#), while the relevant topology optimization and parametric size analysis methods for electromechanical systems are outlined in [Chap. 4](#). Several multiphysics simulation and optimization example studies in both two and three-dimensions are then described in detail throughout [Chap. 5](#). Extensions to new topics are suggested in [Chap. 6](#). Sample numerical code for a related electro-thermal topology optimization example is provided in the appendix in [Chap. 7](#).

A challenge in writing a book of this nature on the topic of multiphysics simulation is the preparation of the engineering nomenclature used for various physical constants, state variable, functions, etc. Specifically, the governing equations for the multitude of separate physical processes are often described using the same symbols for different variables. As such, every effort has been made to provide a comprehensive list of nomenclature with distinct variable usage wherever possible.

In addition to the above features, extensive references are provided at the end of each chapter. These references are related to prior research on multiphysics simulation and optimization methods, techniques, and application studies.

Target Audiences

It is our hope that the content presented in this book will serve as a reference for industry and academic researchers and engineers in the field of advanced electromechanical system design. The topics in this book are appropriate for undergraduate and graduate level students, although many of the design examples may be of interest to anyone curious about the unique design solutions that arise when optimization methods are coupled with multiphysics simulation strategies.

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