The Computer Aided Engineering Design Series

Product Performance Evaluation using CAD/CAE

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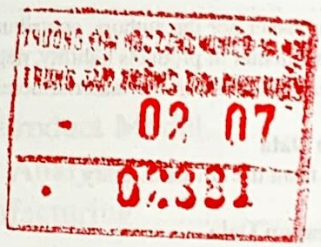

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Preface

The conventional product development process employs a design-build-test philosophy. The sequentially executed product development process often results in a prolonged lead time and an elevated product cost. The e-Design paradigm presented in the *Computer Aided Engineering Design* series employs IT-enabled technology, including computer-aided design, engineering, and manufacturing (CAD/CAE/CAM) tools, as well as advanced prototyping technology to support product design from concept to detailed designs, and ultimately manufacturing. This e-Design approach employs virtual prototyping (VP) technology to support a cross-functional team in analyzing product performance, reliability, and manufacturing costs early in the product development stage and in conducting quantitative trade-offs for design decision making. Physical prototypes of the product design are then produced using rapid prototyping (RP) technique mainly for design verification. The e-Design approach holds potential for shortening the overall product development cycle, improving product quality, and reducing product cost.

The *Computer Aided Engineering Design* series intends to provide readers with a comprehensive coverage of essential elements for understanding and practicing the e-Design paradigm in support of product design, including design method and process, and computer-based tools and technology. The book series consists of four books: *Product Design Modeling using CAD/CAE, Product Performance Evaluation using CAD/CAE, Product Manufacturing and Cost Estimating using CAD/CAE,* and *Design Theory and Methods using CAD/CAE*. The *Product Design Modeling using CAD/CAE* book discusses virtual mockup of the product that is first created in the CAD environment. The critical design parameterization that converts the product solid model into parametric representation, enabling the search for better designs, is an indispensable element of practicing the e-Design paradigm, especially in the detailed design stage. The second book, *Product Performance Evaluation using CAD/CAE*, focuses on applying numerous computer-aided engineering (CAE) technologies and software tools to support evaluation of product performance, including structural analysis, fatigue and fracture, rigid body kinematics and dynamics, and failure probability prediction and reliability analysis. The third book, *Product Manufacturing and Cost Estimating using CAD/CAE*, introduces computer-aided manufacturing (CAM) technology to support manufacturing simulations and process planning, RP technology and

computer numerical control (CNC) machining for fast product prototyping, as well as manufacturing cost estimate that can be incorporated into product cost calculations. The product performance, reliability, and cost calculated can then be brought together to the cross-functional team for design trade-offs based on quantitative engineering data obtained from simulations. Design trade-off is one of the key topics included in the fourth book, *Design Theory and Methods using CAD/CAE*. In addition to conventional design optimization methods, the fourth book discusses decision theory, utility theory, and decision-based design. Simple examples are included to help readers understand the fundamentals of concepts and methods introduced in this book series.

In addition to the discussion on design principles, methods, and processes, this book series offers detailed review on the commercial off-the-shelf software tools for the support of modeling, simulations, manufacturing, and product data management and data exchanges. Tutorial style lessons on using commercial software tools are provided together with project-based exercises. Two suites of engineering software are covered: they are Pro/ENGINEER-based, including Pro/MECHANICA Structure, Pro/ENGINEER Mechanism Design, and Pro/MFG; and SolidWorks-based, including SolidWorks Simulation, SolidWorks Motion, and CAMWorks. These tutorial lessons are designed to help readers gain hands-on experiences to practice the e-Design paradigm.

The book you are reading, *Product Performance Evaluation using CAD/CAE*, is the first book of the *Computer Aided Engineering Design* series, but is the first of the series to publish. The objective of this book is to provide readers with fundamental understanding in product performance evaluation, and to enable them to apply the principles, methods, and software tools to support practical design applications. In Chapter 1, a brief introduction to the e-Design paradigm and tool environment will be given. Following this introduction, important topics in product performance evaluation, including structural performance of critical components, kinematics and dynamics of mechanical systems, fatigue and fracture, as well as product reliability analysis at both component and system levels will be discussed.

Chapter 2 focuses on structural analysis, including both analytical methods and finite element analysis (FEA), in which the essential elements in using FEA for modeling and analysis of structural performance are discussed. In addition, two companion projects are included: Project S3 Structural FEA and Fatigue Analysis Using SolidWorks Simulation and Project P3 Structural FEA and Fatigue Analysis Using Pro/MECHANICA Structure. These two projects offer tutorial lessons that should help readers to learn and be able to use the software tools for solving problems that are beyond hand calculations using analytical methods. Example files needed for going through the tutorial lessons are available for download from the book's website: http://booksite.elsevier.com/9780123984609. The goal of this chapter is to help readers become confident and competent in using FEA for creating adequate models and obtaining reasonably accurate results to support product design.

Chapter 3 provides an overview on motion analysis. Again, both analytical and computer-aided methods, that is, the so-called computer-aided kinematic and dynamic analyses, are included. General concept and process in carrying out motion simulation for kinematic and dynamic analysis are included in this chapter. In order to support readers to use the computer-aided analysis capability for general design applications, we have provided two companion projects: Project S2 Motion Analysis Using SolidWorks Motion and Project P2 Motion Analysis Using Pro/ENGINEER Mechanism Design. Tutorial lessons of these two projects should help readers to carry out motion simulations. Again, the goal of this chapter is to help the reader become confident and competent in using motion software tools for engineering design.

Chapter 4 offers a brief discussion on structural fatigue and fracture, which is one of the most technically challenging issues facing aerospace and mechanical engineers. In addition to basic theory, this chapter provides a brief review on the computational methods that support structural fatigue and fracture analysis in various stages. Similar to the previous chapters, tutorial lessons that provide details in using SolidWorks Simulation and Pro/MECHANICA Structure for crack initiation calculations are offered. You may find these lessons in Projects S3 and P3. The goal of this chapter is to enable readers to create adequate models and obtain reasonable results that support design involving fatigue and fracture.

In engineering design, there are uncertainties we must consider. Uncertainties exist in loading, material properties, geometric size, and material strength. Mechanical engineers must understand the importance of the probabilistic aspect in product design and must be able to apply adequate reliability analysis methods to solve engineering problems. Chapter 5 provides a brief overview on reliability analysis, which calculates failure probability of a prescribed performance measure considering uncertainties. This chapter also touches on design from a probabilistic perspective and compares the effectiveness of the probabilistic approach with conventional methods, such as safety factor and worst-case scenario. The goal of this chapter is to provide basic probabilistic theory and reliability analysis methods that enable readers to deal with basic engineering problems involving uncertainties.

As you may notice, any individual chapter included in this book can easily be expanded to a full textbook. Please keep in mind, this book is not intended to provide you an in-depth and thorough discussion on the respective subjects, but offer readers the concept and process of applying the computer-aided engineering technology and software tools to solve various aspects of engineering problems.

This *Product Performance Evaluation using CAD/CAE* book should serve well for a half-semester (8 weeks) instruction in engineering colleges of general universities. Typically, a three-hour lecture and one-hour laboratory exercise per week are desired. This book

(and the book series) aims at providing engineering senior and first-year graduate students a comprehensive reference to learn advanced technology in support of engineering design using IT-enabled technology. Typical engineering courses that the book serves include Engineering Design, Integrated Product and Process Development, Concurrent Engineering, Design and Manufacturing, Modern Product Design, Computer-Aided Engineering, as well as Senior Capstone Design. In addition to classroom instruction, this book should support practicing engineers who wish to learn more about the e-Design paradigm at their own pace.

Resources available with this book:

For Instructors using this book for a course, an instructor manual and set of powerpoint slides are available by registering at www.textbooks.elsevier.com.

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