

# Finite Element Analysis for Design Engineers

## List of Chapters

### Preface

### Chapter 1 Introduction

- 1.1 What Is Finite Element Analysis?
- 1.2 What Is “FEA for Design Engineers?”
- 1.3 Note on Hands-On Exercises and Illustrations in This Book

### Chapter 2 From CAD Model to Finite Element Analysis Results

- 2.1 Formulation of the Mathematical Model
- 2.2 Selecting the Numerical Method to Solve the Mathematical Model
  - 2.2.1 Numerical Methods in Engineering Analysis
  - 2.2.2 Reasons for the Dominance of the Finite Element Method
- 2.3 The Finite Element Model
  - 2.3.1 Meshing
  - 2.3.2 Formulation of Finite Element Equations
  - 2.3.3 Errors in FEA Results

### Chapter 3 Major Concepts of the Finite Element Model

- 3.1 Formulation of a Finite Element
  - 3.1.1 Shape Functions, Degrees of Freedom, and Element Order
  - 3.1.2 Requirements to Be Satisfied by Shape Functions
  - 3.1.3 Artificial Constraints
  - 3.1.4 The Choices of Discretization
- 3.2 Types of Finite Elements
  - 3.2.1 Element Dimensionality
  - 3.2.2 Analysis Dimensionality
  - 3.2.3 Element Shape
  - 3.2.4 Element Order and Element Type
  - 3.2.5 Element Modeling Capabilities

### Chapter 4 Controlling Discretization Errors

- 4.1 Convergence Process
  - 4.1.1 h-Convergence Process
  - 4.1.2 Convergence Error
  - 4.1.3 Solution Error
  - 4.1.4 p-Convergence Process

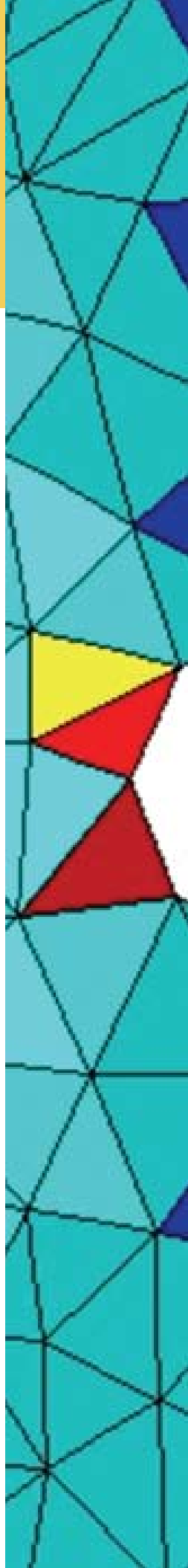
- 4.1.5 Variations in Convergence Processes
- 4.2 Problems with Convergence
  - 4.2.1 Stress Singularity
  - 4.2.2 Displacement Singularity
- 4.3 Hands-On Exercises
  - 4.3.1 Tensile Strip with a Circular Hole
  - 4.3.2 L-Shaped Bracket
  - 4.3.3 Spot-Welded Cantilever

### Chapter 5 Finite Element Mesh

- 5.1 Meshing Techniques
  - 5.1.1 Manual Meshing
  - 5.1.2 Semi-Automatic Meshing
  - 5.1.3 Automatic Meshing
- 5.2 Mesh Compatibility
  - 5.2.1 Compatible Elements
  - 5.2.2 Incompatible Elements
  - 5.2.3 Forced Compatibility
- 5.3 Common Meshing Problems
  - 5.3.1 Element Distortion
  - 5.3.2 Not Enough Elements to Represent Model Stiffness
  - 5.3.3 Incorrect Mapping to Geometry
  - 5.3.4 Incorrect Conversion to Shell Model
- 5.4 Hands-On Exercises
  - 5.4.1 Hollow Cantilever Bracket
  - 5.4.2 Beam in Bending

### Chapter 6 Modeling Process

- 6.1 Modeling Steps
  - 6.1.1 Definition of the Objective of Analysis
  - 6.1.2 Selection of the Units of Measurement
  - 6.1.3 Geometry Creation
  - 6.1.4 Defining Material Properties
  - 6.1.5 Defining Boundary Conditions
- 6.2 Some Useful Modeling Techniques
  - 6.2.1 Taking Advantage of Symmetry and Anti-Symmetry
  - 6.2.2 Axial Symmetry
  - 6.2.3 Realignment of Degrees of Freedom
- 6.3 Hands-On Exercises
  - 6.3.1 Cantilever Bracket with Symmetry Boundary Conditions



# Finite Element Analysis for Design Engineers

- 6.3.2 Cantilever Bracket with Anti-Symmetry Boundary Conditions
- 6.3.3 Shaft in Torsion
- 6.3.4 Plate in Bending
- 6.3.5 Ring in Bending
- 6.3.6 Pin-Supported Link

- 7.6.7 U-Shaped Support Bracket
- 7.6.8 Unsupported and Hinge-Supported Beam
- 7.6.9 Hollow Cantilever Bracket, Modes Separation
- 7.6.10 Beam in Compression

## Chapter 7 Types of Finite Element Analysis

- 7.1 Thermal Analysis
  - 7.1.1 Heat Flow Induced by Prescribed Temperatures
  - 7.1.2 Heat Flow Induced by Heat Load and Convection
  - 7.1.3 Modeling Considerations in Thermal Analysis
- 7.2 Nonlinear Analysis
  - 7.2.1 Nonlinear Material
  - 7.2.2 Nonlinear Geometry
  - 7.2.3 Contact Stress Analysis
- 7.3 Modal Analysis
  - 7.3.1 Differences Between Modal and Static Analyses
  - 7.3.2 Interpretation of Displacement and Stress Results in Modal Analysis
  - 7.3.3 Modal Analysis with Rigid Body Modes
  - 7.3.4 Importance of Supports in Modal Analysis
  - 7.3.5 Applications of Modal Analysis
  - 7.3.6 Pre-Stress Modal Analysis
  - 7.3.7 Symmetry and Anti-Symmetry Boundary Conditions in Modal Analysis
  - 7.3.8 Convergence of Modal Frequencies Results
  - 7.3.9 Meshing Considerations for Modal Analysis
- 7.4 Buckling Analysis
  - 7.4.1 Buckling Load Factor
  - 7.4.2 Interpretation of Results of Buckling Analysis
- 7.5 Dynamic Analysis
  - 7.5.1 Modal Superposition Method
  - 7.5.2 Time Response Analysis
  - 7.5.3 Frequency Response Analysis
- 7.6 Hands-On Exercises
  - 7.6.1 Crossing Pipes
  - 7.6.2 Radiator
  - 7.6.3 Cantilever Bracket, Elasto-Plastic Material
  - 7.6.4 Slender Cantilever Beam in Bending
  - 7.6.5 Round Membrane Under Pressure
  - 7.6.6 Tuning Fork

## Chapter 8 Design Optimization

- 8.1 Topological Optimization
- 8.2 Structural Optimization
  - 8.2.1 Factors Defining an Optimization Process
  - 8.2.2 Sensitivity Studies

## Chapter 9 Using Finite Element Analysis in the Design Process

- 9.1 Differences Between CAD and FEA Geometries
  - 9.1.1 Defeaturing
  - 9.1.2 Idealization
  - 9.1.3 Cleanup
  - 9.1.4 Common Meshing Problems
  - 9.1.5 Mesh Inadequacy
- 9.2 Integration of CAD and FEA Software
  - 9.2.1 Standalone FEA Software
  - 9.2.2 Integrated FEA Software
- 9.3 FEA Implementation
  - 9.3.1 Positioning of CAD and FEA Activities
  - 9.3.2 Personnel Training
  - 9.3.3 Software Selection Criteria
  - 9.3.4 Building Confidence in the FEA
  - 9.3.5 Expected Return on Investment
- 9.4 FEA Projects
  - 9.4.1 Major Steps in an FEA Project
  - 9.4.2 FEA Report
  - 9.4.3 Importance of Documentation and Backups
  - 9.4.4 Contracting Out FEA Services
  - 9.4.5 Common Errors in FEA Management

## Chapter 10 Some Misconceptions and Frequently Asked Questions

- 10.1 FEA Quiz
- 10.2 Frequently Asked Questions About FEA

## Chapter 11 Finite Element Analysis Resources

## Chapter 12 Glossary of Terms

## Index

## About the Author

