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
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