Introduction to Finite Element Analysis

٠	4	
1	1	٠

Table of Contents

Preface Acknowledgments	i ii
Introduction	
Introduction Development of Finite Element Analysis FEA Modeling Considerations Types of Finite Elements Finite Element Analysis Procedure Matrix Definitions Getting Started with SolidWorks Starting SolidWorks Units Setup SolidWorks Screen Layout Menu Bar Toolbar Menu Bar Pull-down Menus Heads-up View Toolbar Features Toolbar Sketch Toolbar Command Manager Feature Manager Design Tree Graphics Area Reference Triad Origin Confirmation Corner Graphics Cursor or Crosshairs Message and Status Bar Basic Functions of Mouse Buttons [Esc] — Canceling Commands On-Line Help Leaving SolidWorks Creating a CAD Files Folder	Intro-2 Intro-2 Intro-3 Intro-4 Intro-6 Intro-6 Intro-9 Intro-9 Intro-11 Intro-13 Intro-13 Intro-14 Intro-14 Intro-14 Intro-17 Intro-18 Intro-19 Intro-19 Intro-20
Chapter 1 The Direct Stiffness Method	
Introduction One-dimensional Truss Element Example 1.1 Example 1.2	1-2 1-3 1-5 1-7

Basic Solid Modeling using SolidWorks The Adjuster Design	1-10 1-10
Starting SolidWorks	1-10
Step 1: Creating a Rough Sketch	1-12
Graphics Cursors	1-12
Geometric Relation Symbols	1-14
Step 2: Apply/Modify Relations and Dimensions	1-15
Changing the Dimension Standard	1-16
Viewing Functions – Zoom and Pan	1-17
Modifying the Dimensions of the Sketch	1-18
Step 3: Completing the Base Solid Feature	1-19
Isometric View	1-20
Rotation of the 3D Model – Rotate View	1-20
Rotation and Panning – Arrow Keys	1-22
Dynamic Viewing – Quick Keys	1-23
Viewing Tools – Heads-up View Toolbar	1-25
View Orientation	1-26
Display Style	1-27
Orthographic vs. Perspective	1-27
Customizing the Heads-up View Toolbar	1-27
Sketch Plane	1-28
Step 4-1: Adding an Extruded Boss Feature	1-30
Step 4-2: Adding an Extruded Cut Feature	1-33
Save the Part and Exit	1-35
Questions	1-36
Exercises	1-37
Chapter 2 Truss Elements in Two-Dimensional Spaces	
	2.2
Introduction	2-2
Truss Elements in Two-Dimensional Spaces	2-2
Coordinate Transformation	2-5
EXAMPLE 2.1	2-9
Solution	2-10
Global Stiffness Matrix	2-10
EXAMPLE 2.2	2-13
Solution	2-13
Questions	2-19
Exercises	2-20

2D Trusses in MS Excel and Truss Solver	
Direct Stiffness Matrix Method using Excel EXAMPLE 3.1 Establish the Global K Matrix for each Member Assembly of the Overall Global Stiffness Matrix Solving the Global Displacements Calculating Reaction Forces Determining the Stresses in Elements The Truss Solver and the Truss View Programs The Truss View Program Questions Exercises	3-2 3-2 3-3 3-8 3-10 3-16 3-18 3-23 3-30 3-32 3-33
Chapter 4 Truss Elements in SolidWorks Simulation	
One-dimensional Line Elements Starting SolidWorks Units Setup Creating the CAD Model – Solid Modeling Approach A CAD Model is NOT an FEA Model The SolidWorks Simulation Module Creating an FEA Model Assign the Element Material Property Applying Boundary Conditions - Constraints Applying External Loads Create the FEA Mesh and Run the Solver Viewing the Stress Results Viewing the Displacement Results Questions Exercises	4-2 4-4 4-5 4-6 4-15 4-16 4-17 4-19 4-20 4-23 4-25 4-26 4-28 4-29 4-30
Chapter 5 SolidWorks Simulation Two-Dimensional Truss Analy	/sis
Finite Element Analysis Procedure Preliminary Analysis Starting SolidWorks Units Setup Creating the CAD Model – Structural Member Approach Creating Structural Members in SolidWorks Weldment Profiles Activate the SolidWorks Simulation Module Setting Up Truss Elements	5-2 5-3 5-4 5-5 5-6 5-8 5-9 5-12 5-14

vi Introduction to Finite Element Analysis

Assign the Element Material Property Applying Boundary Conditions - Constraints and Loads Applying External Loads Create the FEA Mesh and Run the Solver Viewing the Stress results Viewing the Internal Loads of All members Questions Exercises	5-15 5-16 5-21 5-23 5-24 5-26 5-27 5-28
Chapter 6 Three-Dimensional Truss Analysis	
Three-Dimensional Coordinate Transformation Matrix Stiffness Matrix Degrees of Freedom Problem Statement Preliminary Analysis Starting SolidWorks Units Setup Creating the CAD Model – Structural Member Approach Creating Weldments Profiles in SolidWorks Creating Structural Members using the New Profile Editing the Dimensions of the New Profile Activate the SolidWorks Simulation Module Setting Up Truss Elements Assign the Element Material Property Applying Boundary Conditions - Constraints Applying External Loads Create the FEA Mesh and Run the Solver Using the Probe Option to View Individual Stress Viewing the Internal Loads of All Members Questions Exercises	6-2 6-3 6-3 6-5 6-5 6-5 6-7 6-8 6-9 6-12 6-16 6-18 6-19 6-21 6-22 6-23 6-24 6-26 6-27 6-28 6-29 6-30
Chapter 7 Basic Beam Analysis	
Introduction Modeling Considerations Problem Statement Preliminary Analysis Starting SolidWorks Units Setup Creating the CAD Model – Structural Member Approach	7-2 7-2 7-3 7-3 7-6 7-7 7-8

	Table of Contents	vii
Creating a Rectangular Weldment Profile	7-10	
Creating Structural Members using the New Profile	7-14	
Adjusting the Orientation of the Profile	7-15	
Adding a Datum Point for the Concentrated Load	7-16	
Activate the SolidWorks Simulation Module	7-18	
Assign the Element Material Property	7-20	
Applying Boundary Conditions - Constraints	7-21	
Applying Concentrated Point Loads	7-24	
Applying the Distributed Load	7-26	
Create the FEA Mesh and Run the Solver	7-28	
What Went Wrong?	7-29	
Directions 1 and 2 in Shear and Moment Diagrams	7-32	
Questions	7-34	
Exercises	7-35	
Chapter 8 Beam Analysis Tools		
Introduction	8-2	
Problem Statement	8-2	
Preliminary Analysis	8-3	
Stress Components	8-4	
Starting SolidWorks	8-6	
Creating the CAD Model – Structural Member Approach	8-7	
Creating a Rectangular Weldment Profile	8-9	
Creating Structural Members using the New Profile	8-13	
Adjusting the Orientation of the Profile	8-14	
Adding a Datum Point	8-15	
Activate the SolidWorks Simulation Module	8-17	
Assign the Element Material Property	8-19	
Applying Boundary Conditions - Constraints	8-20	
Applying the Distributed Load	8-23	
Create the FEA Mesh and Run the Solver	8-25	
Shear and Moment Diagrams	8-26	
Using the Probe Option to Examine Stress at Point1	8-28	
Questions	8-29	
Exercises	8-30	
Chapter 9		
Statically Indeterminate Structures		
Introduction	9-2	
Problem Statement	9-3	
Preliminary Analysis	9-3	

Table	of Contents
1 4 10 10	or Configura

12-16 12-17

12-18

12-21

12-22 12-23

	4	7
	п	ä

Starting SolidWorks	9-6
Creating the CAD Model	9-7
Creating a Circular Weldment Profile	9-9
Creating Structural Members using the New Profile	9-13
Adding a Datum Point for the Concentrated Load	9-14
Activate the SolidWorks Simulation Module	9-16
Assign the Element Material Property	9-18
Applying Boundary Conditions - Constraints	9-19
Applying the Concentrated Point Load	9-23
Create the FEA Mesh and Run the Solver	9-24
Viewing the Internal Loads of All members	9-25
Shear and Moment Diagrams	9-26
Questions	9-28
Exercises	9-29
Exercises	<i>y</i> = <i>y</i>
Chapter 10	
Two-Dimensional Surface Analysis	
Tito Billionolollar Gartago Fatary Co.	
Introduction	10-2
Problem Statement	10-3
Preliminary Analysis	10-3
Maximum Normal Stress	10-3
Maximum Displacement	10-4
Geometric Considerations of Finite Elements	10-5
Starting SolidWorks	10-6
Creating a CAD Model in SolidWorks	10-7
Activate the SolidWorks Simulation Module	10-10
Defining A Surface Model	10-12
Assign the Element Material Property	10-13
Applying Boundary Conditions - Constraints	10-14
	10-17
Applying the External Load H-Element versus P-Element	10-20
Create the first 2D Mesh –Coarse Mesh	10-21
Run the Solver	10-23
Refinement of the Mesh– Global Element Size 0.10	10-25
Refinement of the Mesh– Global Element Size 0.16 Refinement of the Mesh– Global Element Size 0.05	10-23
	10-27
Refinement of the Mesh-Global Element Size 0.03	10-29
Refinement of the Mesh– Global Element Size 0.02	10-31
Comparison of Results	10-32
Questions	10-33
Exercises	10-33

Chapter 11		
Three-Dimensional	Solid	Elements

Run the Solver and View the Results

Starting a New 3D Surface Model

Starting a New FEA Study

Refinement of the Mesh-Global Element Size 0.0125

Completing the Definition of the Surface Model
Assign the Element Material Property

Three-Dimensional Solid Elements	
Introduction	11-2
Problem Statement	11-3
Preliminary Analysis	11-4
Starting SolidWorks	11-7
Creating a CAD Model in SolidWorks	11-8
> Define the Sweep Path	11-8
> Define the Sweep Section	11-10
> Create the Swept Feature	11-12
> Create a Cut Feature	11-13
Activate the SolidWorks Simulation Module	11-15
Assign the Element Material Property	11-17
Applying Boundary Conditions - Constraints	11-18
Applying the External Load	11-19
Create the first FEA Mesh Coarse Mesh	11-20
Run the Solver	11-22
Refinement of the Mesh– Global Element Size 0.10	11-24
Refinement of the FEA Mesh – Mesh Control Option	11-26
Refinement of the FEA Mesh – Automatic Transition	11-29
Comparison of Results	11-31
Notes on FEA Linear Static Analyses	11-32
Questions	11-33
Exercises	11-34
Chapter 12	
3D Thin Shell Analysis	
Introduction	12-2
Problem Statement	12-4
Preliminary Analysis	12-4
Starting SolidWorks	12-6
Creating a CAD Model in SolidWorks	12-7
Activate the SolidWorks Simulation Module	12-9
Assign the Element Material Property	12-11
Applying Boundary Conditions - Constraints	12-12
Applying the External Pressure	12-14
Create the first FEA Mesh –Coarse Mesh	12-15

Introduction to Finite Element Analysis

Applying Boundary Conditions - Constraints Applying the External Pressure Create the first FEA Mesh - Coarse Mesh Run the Solver and View the Results Refinement of the Mesh- Global Element Size 0.010 Questions Exercises	12-24 12-28 12-29 12-30 12-31 12-32 12-33
Chapter 13 Dynamic Modal Analysis	
Introduction Problem Statement Preliminary Analysis The Cantilever Beam Modal Analysis Program Starting SolidWorks Creating a CAD Model in SolidWorks Activate the SolidWorks Simulation Module Assign the Element Material Property Create the first FEA Mesh View the Results Refinement of the Mesh—Global Element Size 0.15 Adding an Additional Mass to the System One-Dimensional Beam Frequency Analysis Conclusions Questions Exercises	13-2 13-3 13-3 13-6 13-9 13-10 13-12 13-15 13-16 13-18 13-21 13-23 13-27 13-28 13-29 13-30

Index