

Contents

Preface	xi
About the Author.....	xv
About the Cover	xvii
Acknowledgements.....	xix

CHAPTER 1 Introduction to e-Design	1
1.1 Introduction.....	2
1.2 The e-Design Paradigm.....	5
1.3 Virtual Prototyping	7
1.3.1 Parameterized CAD Product Model	7
1.3.2 Product Performance Analysis.....	11
1.3.3 Product Virtual Manufacturing.....	13
1.3.4 Tool Integration	14
1.3.5 Design Decision Making.....	15
1.4 Physical Prototyping.....	19
1.4.1 Rapid Prototyping.....	19
1.4.2 CNC Machining.....	22
1.5 Example: Simple Airplane Engine.....	23
1.6 Example: High-Mobility Multipurpose Wheeled Vehicle.....	27
1.7 Summary.....	36
Questions and Exercises.....	36
References.....	36
Sources.....	38

CHAPTER 2 Virtual Machining.....	39
2.1 Introduction.....	41
2.2 NC Part Programming	42
2.2.1 Basics of NC Machines.....	42
2.2.2 Basic Concept of Part Programming	46
2.2.3 Computer-Assisted Part Programming.....	48
2.2.4 CAD/CAM Approach.....	51
2.3 Virtual Machining Simulations	51
2.3.1 Basic Machining Simulations.....	52
2.3.2 Advanced Machining Simulations	56
2.3.3 Turning Simulations	61
2.4 Practical Aspects in CNC Machining	62
2.4.1 Jigs and Fixtures.....	63
2.4.2 Cutters and Machining Parameters	64
2.4.3 Setting a CNC Sequence.....	67

2.5	Commercial Machining Simulation Software.....	69
2.5.1	General-Purpose Machining Software.....	69
2.5.2	Special-Purpose Machining Software.....	70
2.6	Case Study and Tutorial Examples.....	72
2.6.1	Case Study.....	72
2.6.2	Tutorial Examples.....	76
2.7	Summary.....	80
	Questions and Exercises.....	81
	References.....	83
	Appendix A Sample Address Codes.....	84
	Appendix B Sample G- and M-Codes.....	85
	Appendix C HAAS Mini-Mill.....	86
CHAPTER 3	Toolpath Generation.....	95
3.1	Introduction.....	96
3.2	Inclined Flat Surface.....	98
3.3	Ruled Surface.....	105
3.3.1	5-Axis Mill with Ball-Nose Cutter.....	106
3.3.2	3-Axis Mill with Flat-End Cutter.....	115
3.3.3	3-Axis Mill with Ball-Nose Cutter.....	118
3.3.4	4-Axis Mill with Flat-End Cutter.....	122
3.4	Cylindrical Surface of Bézier Curve.....	124
3.5	Summary.....	128
	Questions and Exercises.....	128
	References.....	131
CHAPTER 4	Sheet Metal Forming Simulation.....	133
4.1	Introduction.....	135
4.2	Fundamentals of Sheet Metal Forming.....	137
4.2.1	Sheet Forming Processes.....	137
4.2.2	Plane Stress and Material Properties.....	140
4.2.3	Yield Criteria.....	146
4.2.4	Forming Limit Diagram.....	150
4.2.5	Springback Analysis.....	151
4.2.6	Numerical Implementations.....	156
4.3	Process Planning and Tooling Design.....	159
4.3.1	One-Step Simulation for Formability Study.....	160
4.3.2	Die Design.....	162
4.3.3	Incremental Forming Analysis.....	167
4.3.4	Springback Analysis and Die Compensation.....	169
4.4	Commercial Forming Simulation Software.....	173
4.4.1	Overview of Simulation Software.....	173
4.4.2	HyperForm.....	175
4.4.3	DynaForm.....	176

4.5	Case Studies.....	177
4.5.1	Core Panel	179
4.5.2	Wheel Fairing	180
4.6	Summary.....	187
	Questions and Exercises.....	188
	References.....	189
CHAPTER 5	Rapid Prototyping.....	191
5.1	Introduction.....	193
5.2	RP Process and Tutorial Example.....	194
5.2.1	General Process	194
5.2.2	Engine Block Example.....	195
5.3	Rapid Prototyping Systems	198
5.3.1	Liquid-Based Systems.....	198
5.3.2	Solid-Based Systems	199
5.3.3	Powder-Based Systems.....	200
5.4	Advanced RP Systems.....	202
5.4.1	Solidica	202
5.4.2	Electron Beam Melting	203
5.4.3	Laser Engineered Net Shaping.....	205
5.4.4	Micro-Manufacturing RP Systems.....	205
5.5	Rapid Prototyping Applications	207
5.5.1	Design Applications	208
5.5.2	Manufacturing Applications.....	209
5.5.3	Art Applications	209
5.5.4	Medical Applications	211
5.5.5	Bioengineering Applications.....	216
5.5.6	Personal RP	219
5.5.7	Other Applications.....	219
5.6	Case Study: RP for Complex Assembly.....	221
5.6.1	Single-Piston Engine	221
5.6.2	Formula SAE Racecar.....	223
5.7	Summary.....	232
	Questions and Exercises	232
	References.....	233
CHAPTER 6	Product Cost Estimating.....	237
6.1	Introduction.....	239
6.2	Fundamentals of Cost Analysis.....	242
6.2.1	Elements in the Cost Estimate	243
6.2.2	Type of Costs.....	244
6.2.3	Overhead Costs.....	247
6.2.4	Cost-Estimating Techniques.....	248

6.3	Manufacturing Cost Models	252
6.3.1	Manufacturing Cost Elements for In-House Parts	253
6.3.2	Machining Cost Model	254
6.3.3	Injection Molding Cost Model	260
6.3.4	Sheet Metal Stamping Cost Model	266
6.3.5	Assembly Cost Model	269
6.4	Commercial Software for the Cost Estimate	270
6.4.1	CAD-Based Costing Software	270
6.4.2	General-Purpose Costing Software	271
6.4.3	Special-Purpose Costing Software	273
6.4.4	Web-Based Costing Tools	273
6.5	Case Studies	274
6.5.1	Machining Costing Using SolidWorks	274
6.5.2	Sheet Metal Costing Using SolidWorks	279
6.5.3	Cost Estimate for a BWMD Using SEER-DFM	282
6.6	Summary	287
	Questions and Exercises	288
	References	290
	Appendix A Calculations of Material Removed for Standard Features	291

Project S4: Machining Simulation Using CAMWorks	295
Project P4: Machining Simulation Using Pro/MFG	375
Project M4: Machining Simulation Using Mastercam	471
Index	539