

CONTENTS

Preface xi

CHAPTER 1

Why Study the Design Process? 1

- 1.1 Introduction 1
- 1.2 Measuring the Design Process with Product Cost, Quality, and Time to Market 3
- 1.3 The History of the Design Process 8
- 1.4 The Life of a Product 11
- 1.5 The Many Solutions for Design Problems 14
- 1.6 The Basic Actions of Problem Solving 16
- 1.7 Knowledge and Learning During Design 17
- 1.8 Summary 18
- 1.9 Sources 19
- 1.10 Exercises 19

CHAPTER 2

Describing Mechanical Design Problems and Process 21

- 2.1 Introduction 21
- 2.2 Decomposition of Mechanical Systems 21
- 2.3 Importance of Product Function, Behavior, and Performance 24
- 2.4 Different Types of Mechanical Design Problems 26
- 2.5 Languages of Mechanical Design 33
- 2.6 Constraints, Goals, and Design Decisions 34
- 2.7 The Value of Information 35
- 2.8 Design as Refinement of Abstract Representations 36
- 2.9 Summary 38

2.10 Sources 39

2.11 Exercises 39

CHAPTER 3

Designers and Design Teams 41

- 3.1 Introduction 41
- 3.2 A Model of Human Information Processing 42
- 3.3 Mental Processes That Occur During Design 49
- 3.4 Characteristics of a Creative Designer 55
- 3.5 Engineering Design Teams 58
- 3.6 Summary 63
- 3.7 Sources 63
- 3.8 Exercises 64

CHAPTER 4

The Design Process 67

- 4.1 Introduction 67
- 4.2 Overview of the Design Process 67
- 4.3 The Design Process: Designing Quality into Products 74
- 4.4 Simple Design Process Examples 76
- 4.5 A More Complex Example: Design Failure in the Space Shuttle *Challenger* 78
- 4.6 Communication During the Design Process 81
- 4.7 Introduction of a Sample Design Problem 84
- 4.8 Summary 85
- 4.9 Sources 85
- 4.10 Exercises 85

CHAPTER 5**Project Definition and Planning 87**

- 5.1 Introduction 87
- 5.2 Project Definition 87
- 5.3 Project Planning 89
- 5.4 ISO 9000 90
- 5.5 Background for Developing a Design Project Plan 91
- 5.6 Planning for Deliverables 97
- 5.7 The Five Steps in Planning 98
- 5.8 A Design Plan for Mass-Produced Products: Xerox Corporation 105
- 5.9 A Design Plan for Mass-Produced Products: The BikeE Rear Suspension 107
- 5.10 Summary 110
- 5.11 Sources 110
- 5.12 Exercises 110

CHAPTER 6**Understanding the Problem and the Development of Engineering Specifications 111**

- 6.1 Introduction 111
- 6.2 Step 1: Identify the Customers: *Who Are They?* 116
- 6.3 Step 2: Determine the Customers' Requirements: *What Do the Customers Want?* 118
- 6.4 Step 3: Determine Relative Importance of the Requirements: *Who versus What* 127
- 6.5 Step 4: Identify and Evaluate the Competition: *How Satisfied Is the Customer Now?* 128
- 6.6 Step 5: Generate Engineering Specifications: *How Will the Customers' Requirements Be Met?* 130
- 6.7 Step 6: Relate Customers' Requirements to Engineering Specifications: *How to Measure What?* 132

6.8 Step 7: Set Engineering Targets: *How Much Is Good Enough?* 132

6.9 Step 8: Identify Relationships Between Engineering Requirements: *How Are the Hows Dependent on Each Other?* 133

6.10 Further Comments on QFD 134

6.11 Summary 134

6.12 Sources 135

6.13 Exercises 135

CHAPTER 7**Concept Generation 137**

7.1 Introduction 137

7.2 Understanding the Function of Existing Devices 139

7.3 A Technique for Designing with Function 148

7.4 Concept Generation Methods 155

7.5 Basic Methods of Generating Concepts 157

7.6 The Morphological Method 162

7.7 Logical Methods for Concept Generation 166

7.8 Communication During Concept Generation 173

7.9 Summary 173

7.10 Sources 173

7.11 Exercises 174

CHAPTER 8**Concept Evaluation 177**

8.1 Introduction 177

8.2 Information Representation in Concept Evaluation 179

8.3 Evaluation Based on Feasibility Judgment 181

8.4 Evaluation Based on Go/No-Go Screening 182

8.5 Evaluation Based on a Basic Decision Matrix 185

- 8.6 Robust Decision Making 189
- 8.7 Evaluation Based on an Advanced Decision Matrix 197
- 8.8 Product Safety and Liability 201
- 8.9 Communication During Concept Evaluation 205
- 8.10 Summary 206
- 8.11 Sources 207
- 8.12 Exercises 207

CHAPTER 9

The Product Design Phase 209

- 9.1 Introduction 209
- 9.2 The Importance of Drawings 211
- 9.3 Drawings Produced During Product Design 212
- 9.4 Rapid Prototyping 217
- 9.5 Bills of Materials 217
- 9.6 Product Data Management 218
- 9.7 Summary 219
- 9.8 Sources 220
- 9.9 Exercises 220

CHAPTER 10

Product Generation 221

- 10.1 Introduction 221
- 10.2 Form Generation 223
- 10.3 Materials and Process Selection 240
- 10.4 Vendor Development 242
- 10.5 Generating Product Designs for the BikeE Suspension 243
- 10.6 Summary 249
- 10.7 Sources 250
- 10.8 Exercises 250

CHAPTER 11

Product Evaluation for Performance and the Effects of Variation 251

- 11.1 Introduction 251

- 11.2 The Importance of Functional Evaluation 251
- 11.3 The Goals of Performance Evaluation 252
- 11.4 Accuracy, Variation, and Noise 256
- 11.5 Modeling for Performance Evaluation 262
- 11.6 Tolerance Analysis 266
- 11.7 Sensitivity Analysis 272
- 11.8 Robust Design by Analysis 275
- 11.9 Robust Design Through Testing 277
- 11.10 Summary 282
- 11.11 Sources 283
- 11.12 Exercises 283

CHAPTER 12

Product Evaluation for Cost, Manufacture, Assembly, and Other Measures 285

- 12.1 Introduction 285
- 12.2 Cost Estimating in Design 285
- 12.3 Value Engineering 296
- 12.4 Design for Manufacture 297
- 12.5 Design-for-Assembly Evaluation 298
- 12.6 Design for Reliability (DFR) 319
- 12.7 Design for Test and Maintenance (DFTM) 322
- 12.8 Design for the Environment 323
- 12.9 Summary 325
- 12.10 Sources 326
- 12.11 Exercises 326

CHAPTER 13

Launching and Supporting the Product 329

- 13.1 Introduction 329
- 13.2 Documentation and Communication 331
- 13.3 Support 333
- 13.4 Engineering Changes 334
- 13.5 Patent Applications 334
- 13.6 Sources 338

APPENDIX A**Properties of 25 Materials Most Commonly Used in Mechanical Design** 339

- A.1 Introduction 339
- A.2 Properties of the Most Commonly Used Materials 340
- A.3 Materials Used in Common Items 353
- A.4 Sources 354

APPENDIX B**Normal Probability** 357

- B.1 Introduction 357
- B.2 Other Measures 361
- B.3 Sources 361

APPENDIX C**The Factor of Safety as a Design Variable** 363

- C.1 Introduction 363

C.2 The Classical Rule-of-Thumb Factor of Safety 364

C.3 The Statistical, Reliability-Based, Factor of Safety 366

C.4 Sources 373

APPENDIX D**Human Factors in Design** 375

D.1 Introduction 375

D.2 The Human in the Workspace 376

D.3 The Human as Source of Power 379

D.4 The Human as Sensor and Controller 379

D.5 Sources 386

APPENDIX E**Triz** 387**APPENDIX F****Belief Map Masters** 397

Index 399