Innovative Conceptual Design

Conceptual design, along with need identification and analysis, make up the initial stage of the design process. Need analysis transforms the often vague statement of a design task into a set of design requirements. Conceptual design encompasses the generation of concepts and integration into system-level solutions, leading to a relatively detailed design.

This book is devoted to the crucial initial stage of engineering design. In particular, it focuses on parameter analysis, a systematic yet flexible methodology that leads the user through the design process, helping to identify critical issues (parameters) of the design and propose configuration-specific solutions to these issues. To illustrate the principles discussed, the text presents numerous examples and a variety of real-world case studies. The emphasis throughout is on innovation. The ideas developed by the authors encourage the derivation of original solutions to new design problems or fundamental improvements to existing designs.

*Innovative Conceptual Design* will be a useful text for advanced undergraduate and graduate students, as well as a handy reference for practicing engineers, architects, and product development managers.

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Innovative Conceptual Design

Theory and Application of Parameter Analysis

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To Our Families  —EK, SSC, DGJ
# Contents

## Preface  
page xi

## 1 Introduction  
1.1 What Is Conceptual Design?  
1.2 Parameter Analysis: A Conceptual Design Methodology  
1.3 Overview of the Engineering Design Process  
1.4 Structure of the Book  
1  

## 2 Need Identification and Analysis  
2.1 The Importance of Need Identification  
2.2 Need Identification in Practice  
2.3 The Need Analysis Methodology  
2.4 Performance Considerations in Need Analysis  
2.5 Value Considerations in Need Analysis  
2.6 Size Considerations in Need Analysis  
2.7 Safety Considerations in Need Analysis  
2.8 Special Considerations in Need Analysis  
2.9 Development of Design Requirements  
2.10 Discussion and Summary  
2.11 Thought Questions  
2.12 Bibliography  
2  

## 3 Need Identification and Analysis Case Study:  
Packing Factor of Sand in Electrical Fuses  
3.1 Background  
3.2 The Initial Need  
3  

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## Contents

3.3 Need Identification 43  
3.4 Need Analysis 44  
3.5 Design Requirements 49  
3.6 Discussion and Summary 50  
3.7 Thought Questions 51  
3.8 Bibliography 52  

4 Introduction to Parameter Analysis 53  
4.1 A Look at an Invention 53  
4.2 The Nature of Conceptual Design 56  
4.3 Theoretical Model of Conceptual Design 61  
4.4 Parameter Analysis as a Conceptual Design Methodology 64  
4.5 Discussion and Summary 68  
4.6 Thought Questions 69  
4.7 Bibliography 70  

5 Parameter Analysis Put to Work 71  
5.1 Parameter Analysis Process Overview 71  
5.2 Technology Identification 73  
5.3 Parameter Identification 75  
5.4 Creative Synthesis 86  
5.5 Evaluation 90  
5.6 Parameter Analysis Revisited 95  
5.7 Discussion and Summary 102  
5.8 Thought Questions 103  

6 Conceptual Design Case Study: HVAC Airflow Sensor 105  
6.1 The Initial Need 105  
6.2 Abbreviated Need Analysis 106  
6.3 Some Design Requirements 108  
6.4 Technology Identification 108  
6.5 Parameter Analysis 111  
6.6 Discussion and Summary 117  
6.7 Thought Questions 120  
6.8 Bibliography 121  

7 Conceptual Design Case Study: Cut-Edge Sensor for Flooring Removal 123  
7.1 The Initial Need 123
Contents

10.7 Parameter Analysis of Conceptual Design II 199
10.8 Discussion and Summary 204
10.9 Thought Questions 205

11 Technology Observation 207
11.1 Improving Design Abilities 207
11.2 Domestic Gas Water Heaters Example 208
11.3 Discussion and Summary 214
11.4 Thought Questions 215
11.5 Bibliography 215

12 Conclusion 216
12.1 The Essence of the Methodology 216
12.2 Cognitive Aspects of Parameter Analysis 217
12.3 Relation to Other Design Methodologies 220
12.4 What’s Next? 222
12.5 Bibliography 225

Index 227
Over the past several years, we have taught project-based courses on product design to mechanical engineering students at several universities. We have used a variety of textbooks, but mainly our own sets of teaching notes. At the same time, we have been doing research in the area of design theory and methodology. Although most textbooks and design classes offer a decent coverage of the relevant topics, their main weakness is in handling the conceptual design stage. This is the most important phase of the design process, yet the books fall short in providing the readers with a consistent and systematic methodology to apply for different design tasks. Our lecture notes and research into parameter analysis as an approach to conceptual design are the basis of this book.

Innovative Conceptual Design: Theory and Application of Parameter Analysis is both an undergraduate- and graduate-level textbook for design courses in engineering programs. Practicing engineers, managers, and other product development professionals will also find the book valuable. Although our experience is with teaching the material primarily to mechanical engineering students, the applicability of the book is broad so that it may be used for teaching advanced problem solving and design in various contexts, such as other engineering disciplines and architecture.

The text focuses on the initial stages of the design process, namely, need identification and analysis and conceptual design. We define need analysis as the process of transforming an often vague state-
Preface

mentation of a design task into a set of design requirements. In this transformation process, the designer develops substantial insight into the design task, in terms of both functionality and constraints. Under conceptual design we encompass much more than other authors do. We include the generation of concepts, the integration of these concepts into system-level solutions, and the realization of the designs as solid and concrete working configurations. Our conceptual design phase ends with a relatively detailed design, which has been shown to satisfy the requirements of the need. Our emphasis throughout the text is on innovation. We encourage the derivation of original solutions to design problems that have not been solved before. If solutions already exist, we accentuate the need for substantial and fundamental improvements.

Most existing design books guide the reader to various search and enumeration methods in order to generate a multitude of ideas on how to solve the design task. These books refer the designer to patent and literature surveys to identify potential solutions that may be adapted to solve the task at hand. Because these approaches rely heavily on previously generated solutions, they do not foster innovation. Furthermore, they fail to provide the designer with a starting point in a totally new design situation.

Most books also offer variations of brainstorming techniques whose purpose is to organize the generation of ideas. Although these techniques provide a useful starting point for the designer, they do not help to transform an initial, rough idea into a good conceptual design. An innovative design is a synergy of a number of good ideas, not just a single good idea. Brainstorming techniques, however, do not help in identifying ideas and integrating them into a cohesive solution.

Because this book focuses on the parameter analysis methodology to conceptual design, it eliminates the frequent sight of design students and designers staring at a blank sheet of paper and desperately trying to create a workable design. Parameter analysis is a systematic, yet flexible, methodology that leads the user through the design process. It helps the user identify the critical issues (parameters) of the design and propose configuration-specific solutions to these issues. Parameter analysis fosters innovation by requiring the
designer to continually incorporate new ideas into the design. It is also beneficial as a tool for educating designers to think in a systematic and creative manner.

The content of the book is ideal for project-based courses on engineering design. Such courses are already prevalent at the senior and graduate levels, and the current trend is toward earlier teaching of design methodologies. The engineering accreditation agency, ABET, and other authoritative bodies have been advocating for some time the integration of design across the entire engineering curriculum. As a result, engineering departments are struggling to find appropriate teaching materials for design. The present volume uses an approach to educating designers that is not limited to a specific level of studies. We have taught parameter analysis, the main thrust of the book, mainly at the senior and graduate levels; however, one of us (S. C.) has taught the methodology to second-year students.

Faculty who teach design at a higher level than machine elements rarely adopt a textbook author’s philosophy in its entirety. Rather, they assemble their courses from articles, case studies, and miscellaneous textbook chapters. This style is common in engineering schools within the field of design. The perspective that guides our book will enable faculty either to adopt it as the sole textbook for a comprehensive and in-depth coverage of conceptual design or to use it as a resource on conceptual design if the class also deals with other topics. In both cases, the focus of our book on conceptual design will fill an existing void at both the undergraduate and graduate levels.

The parameter analysis methodology was developed by Y. T. Li and his colleagues at the Massachusetts Institute of Technology (MIT), including David G. Jansson. Dr. Jansson and his colleagues at MIT and later at Texas A&M University, including the other authors of this book, carried out further developments and refinements. In particular, for a number of years, Dr. Jansson taught a graduate class at MIT, called “Invention,” with Prof. A. Douglas Carmichael. Parameter analysis was a primary part of that course. Dr. Jansson is indebted to Dr. Carmichael for the many hours of discussion, interchange of ideas, refinement of examples, and improvements in teaching methodology that were the fruit of this partnership.
Preface

Dr. Condoor and Dr. Kroll have been teaching parameter analysis at Texas A&M University, Saint Louis University, The University of Missouri–Columbia/Kansas City, Ort Braude College, and the Technion–Israel Institute of Technology. They are grateful to the many undergraduate and graduate students, academic colleagues, and professionals from industry and government who have contributed both directly and indirectly to this book.