QUALITY AND RELIABILITY IN ENGINEERING

Quality and Reliability in Engineering provides an integrated approach to quality specification, quality control and monitoring, and reliability. Examples and exercises stress practical engineering applications. Steps in the development of the theory are implemented in the form of complete, self-contained computer programs. The book serves as a textbook for upper-level undergraduate courses in quality and reliability in mechanical engineering, manufacturing engineering, and industrial engineering programs. It can be used as a supplement to upper-level capstone design courses, short courses for quality training, and as a learning resource for practicing engineers.

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To Henry M. Rowan

"A detailed attention to quality and reliability is vital to the growth and success of a company."

Henry M. Rowan

Henry M. Rowan is the founder and chairman of Inductotherm Industries, Inc., located in Rancocas, New Jersey. He built his company's first furnace in his backyard; from that humble beginning, Inductotherm has become the world's largest designer and manufacturer for induction melting, heat treating, and welding. Inductotherm is currently a global enterprise of more than eighty companies with facilities in fifteen nations around the world.

A native of Raphine, Virginia, Rowan grew up in Ridgewood, New Jersey. After serving as a pilot in the Army Air Corps during World War II, he earned his B.S. in electrical engineering from Massachusetts Institute of Technology. Rowan took major steps in customer service by creating a highly mobile service team organized around a fleet of company-owned aircraft to ensure maximum uptime of each customer's installation. In 1992, Rowan endowed Glassboro State College with $100 million. It is now known as Rowan University. Rowan's triumphs and tribulations are presented in his autobiography, *The Fire Within* (Penton Publishing, 1995).

Contents

Preface

The text material evolved out of teaching a course on quality and reliability in an undergraduate program in mechanical engineering. This is a required course in the second semester of our junior year. I have taught the course every year for the past ten years. I received positive feedback from the students who took the course and from the managers in industry who employed them. These positive interactions provided the motivation to develop the course material into a book. This book is a culmination of more than forty years of my experience as a design and manufacturing engineer, teacher, researcher, and consultant.

The underlying philosophy of the book is that a quality product results from the specification of quality at the design stage; measurement, monitoring, and control of quality at the production stage; and quality performance at the final stage. A course on quality and reliability covering all three aspects is needed in every mechanical engineering or manufacturing engineering program. Practicing engineers in design, manufacturing, and quality engineering need to have this material handy in one place. Industrial engineering students also need an exposure to quality specification. There are many excellent books on each of the three areas, but books integrating the three areas are not available.

This book is intended as a textbook for an upper-level course in mechanical engineering, manufacturing engineering, and industrial engineering programs. The book can be used as a reference book for upper-level capstone design courses, and also as a learning resource for practicing engineers. Each chapter introduces the underlying concepts and attempts to explain the origin of some of the data in the tables. As an example, the estimation of the standard deviation in terms of the sample range used in various process control charts is shown to come from order statistics. These and other relationships have been implemented in generating the tables available in the Appendix. The corresponding tables provided on the CD included with this book have active formulas.

Complete computer programs that implement and parallel the theory have been provided. These programs are in Microsoft Excel and are available on the CD included with the book. Several full-fledged programs have spreadsheet simplicity. Pressing Alt+F11 will show the modules and functions that have been developed. Several programs have interactive features using the spin buttons in Microsoft Excel. All tables given in the Appendix are available on the CD in the form of spreadsheets or programs.

The book is organized as follows: Chapter 1 gives definitions of quality and reliability providing a brief historical development. Quality philosophies are presented. Chapter 2 develops the concept of preferred numbers before introducing the international tolerance system. The relationship of manufacturing processes and tolerances is presented. Tolerance selection and tolerance allocation decisions are also discussed. Chapter 3 gives an overview of geometric dimensioning and tolerancing. Tolerances of form, profile, orientation, location, and runout are discussed. Evaluation aspects of form tolerances – straightness, flatness, circularity, and cylindricity – are discussed, and several computer programs are included.

Chapters 4, 5, and 6 provide the key concepts of probability and statistics, sampling concepts, and data presentation tools. Chapter 7 introduces the concepts of order statistics and other preliminaries and goes on to present various control charts for variables and attributes. Operating characteristic curves are given for both variables and attributes. Chapter 8 discusses process capability, measurement system analysis, error propagation, and tolerance intervals. Chapter 9 presents acceptance sampling for attributes and variables. Interactive programs are provided for the design of sampling plans for both attributes and variables.

Chapter 10 gives concepts of experimental design. Completely randomized single-factor experiments, randomized block experiments, two-factor factorial experiments, and 2^k factorial experiments are discussed. Chapter 11 introduces reliability concepts, and various failure distributions are presented. The evaluation of system reliability of series and parallel systems, K-of-N systems, and standby systems are discussed. Chapter 12 discusses parameter estimation aspects for Weibull and lognormal distributions and sampling procedures for reliability life testing.

Programs in mechanical engineering and manufacturing engineering are expected to cover all chapters. Chapter 6 may be covered through some discussion followed by assignments. Some topics in Chapters 7, 8, 9, and 12 may be left as reading material. A course on quality improvement in industrial engineering programs may use Chapter 2 as optional reading material and skip Chapter 3. Needed material from Chapters 4 and 5 may be reviewed. Chapters 6, 7, 8, 9, and 10 should be covered in their entirety. Chapters 11 and 12 may be used as needed. A first course on reliability may cover Chapters 1, 4, 5, 6, 10, 11, and 12, and other chapters may be used as needed.

Junior- or senior-level capstone design and project-based courses in mechanical and manufacturing engineering may use this book as a study reference, with students expected to study Chapters 1, 2, 3, 4, 5, 6, 10, and 11. Some testing aspects of Chapter 12 may also be used.

Training programs in the areas of quality and reliability may use relevant chapters and programs for short courses. Practicing professionals should find the book useful for self-learning.

The use of computer programs must be stressed; the included Excel programs should serve well for this purpose. I would like to get your feedback concerning the included software (you may contact me at Chandrupatla@rowan.edu). Use of software such as MINITAB and other commercial software is encouraged.

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I would like to thank several reviewers who gave many constructive suggestions. In particular, I would like to thank Dr. Srinivas Chakravarty, Professor of Operations Research and Statistics, Department of Industrial and Manufacturing Engineering, Kettering University, Flint, Michigan, who has been a continuing source of encouragement for many years as a colleague and friend. I cherish all the interesting discussions on statistics, quality, and reliability that we had. I am deeply indebted to Dr. Prabhaker R. Gangasani, Technical Director, Dura-Bar, a division of Wells Manufacturing Company, Woodstock, Illinois, for providing me with valuable insight through his review. I express my sincere thanks to Dr. Ashok D. Belegundu, Professor, Department of Mechanical Engineering, Pennsylvania State University, who, as coauthor of my previous books, always encouraged me to write this book. I thank all the students who took the course and provided many valuable suggestions.

I express my deep gratitude to Mr. Henry M. Rowan of the Inductotherm Group of companies, who has been a constant source of inspiration. I also thank Dr. Dianne Dorland, Dean, College of Engineering at Rowan University, for her encouragement and support in this endeavor. The encouragement received from the entire faculty in the College of Engineering at Rowan is highly appreciated.

I express my sincere thanks to Mr. Peter Gordon, Engineering Editor at Cambridge University Press. He handled the project efficiently and with great speed. I would like to express my thanks to the copyeditor, Ms. Heather Phillips, the project manager, Ms. Peggy M. Rote, and the production team for the fine job that they accomplished.

I would like to thank my wife, Suhasini; my sons, Sreekanth and Hareesh; my daughter-in-law, Vandana; and my grandchildren, Sumanth and Sriya. They all turned this major undertaking into a pleasant chore.

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