Precision Machine Design

Alexander H. Slocum
Massachusetts Institute of Technology

Society of Manufacturing Engineers
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Preface

History has shown that precision machines are essential elements of an industrial society. Indeed, modern industry is critically dependent on precision machines ranging from those for the manufacture of integrated circuits, to machines for the manufacture of optical components, to machines for the manufacture of automobiles. There are many fine texts on the design of machine elements, and this book assumes that the reader is familiar with their concepts. However, a precision machine is an integrated system that relies on the attributes of one component to augment the weaknesses of another component. Therefore, in this book, emphasis is placed on the design of mechanical and structural precision machine components and their integration with sensor and control systems to maximize performance. In the discussion of the design of components and assemblies, emphasis is placed on how the design will affect the overall accuracy, repeatability, and resolution of the machine.

No single text can adequately cover the detailed design of mechanical, sensor, and control system components. This text is primarily concerned with the design and integration of precision mechanical components and machines. Thus with respect to sensor and control systems, basic operating principles are first discussed. Examples are then given of commercially available sensors' characteristics. Control system design is discussed in the context of how the selection of a component affects the controllability of the machine.

Design is a mixture of analysis and creative thought, and it is my intent to provide the reader with a sound theoretical background and then provide the means for the reader to experiment. When teaching design courses in the past, I always dreaded having to arrange for students to have the proper catalogs required for a hands-on design course. In addition, when working on a design, often at a client's site, I was also often frustrated when I did not have a catalog I needed in order to complete a design layout. Thus in this text, examples are given of the characteristics of commercially available components that I have found to be quite useful. I would gladly accept recommendations for additions to the examples provided.

The book begins with a discussion of design philosophies for precision machines and presents in-depth case studies on the design of a machine tool and a coordinate measuring machine. Chapter 2 presents a detailed discussion on the physics of errors in machines and how such knowledge can be used to build an error budget for a machine. Chapters 3 and 4 discuss types of analog and optical sensors for use in precision machine tools.[1] Chapter 5 discusses sensor mounting methods. Chapter 6 is a detailed case study on the mapping of geometric and thermal errors in a machine tool. Chapter 7 discusses system design considerations. Chapters 8 and 9 discuss all types of linear and rotary bearings used in machine tools. Emphasis is placed on discussing fundamental properties of bearings and how the bearings behave in the machine. Chapter 10 discusses how to define actuator requirements and then discusses in detail many types of linear and rotary actuators and transmissions commonly used in precision machines.

This book is intended as a textbook for senior-level or graduate design courses and as a reference book for practicing engineers. As a textbook it assumes that the student has the level of maturity required to investigate concepts in more detail when an unfamiliar one is only briefly mentioned. Because this book in many ways is the first design book of its kind, it should be valuable to the practicing engineer as a reference and review book. In many cases detailed derivations of formulas are provided, because often the concept of the derivation helps to provide insight into the nature of the problem. The application of formulas is often illustrated with the use of spreadsheets.

[1] Chapters 3 and 4 present sensors in alphabetical order, rather than based on operating principle (e.g., inductive), because real-world engineers I queried liked the format better. In the end, the information content is the same. I welcome further comments from readers on this format.

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