Metal cutting is one of the most widely used methods of producing the final shape of manufactured products. The technology involved in metal cutting operations has advanced considerably in recent years, along with developments in materials, computers, and sensors.

This book treats the scientific principles of metal cutting and their practical application to solving problems encountered in manufacturing. The subjects of mathematics, physics, computers, and instrumentation are discussed as integration tools in analyzing or designing machine tools and manufacturing processes.

The book begins with the fundamentals of metal cutting mechanics. The basic principles of vibration and experimental modal analysis are applied to solving problems on the shop floor. A special feature is the in-depth coverage of chatter vibrations, a problem experienced daily by practicing manufacturing engineers. The essential topics of programming, design, and automation of computer numerically controlled (CNC) machine tools, numerically controlled (NC) programming, and computer-aided design/computer-aided manufacturing (CAD/CAM) technology are discussed. The text also covers the selection of drive actuators, feedback sensors, the modeling and control of feed drives, the design of real-time trajectory generation and interpolation algorithms, and CNC-oriented error analysis in detail. Each chapter includes examples drawn from industry, design projects, and homework problems.

Advanced undergraduate and graduate students, and practicing engineers, as well, will find in this book a clear and thorough way to learn the engineering principles of metal cutting mechanics, machine tool vibrations, CNC system design, sensor-assisted machining, and CAD/CAM technology.

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MANUFACTURING AUTOMATION

METAL CUTTING MECHANICS, MACHINE TOOL VIBRATIONS, AND CNC DESIGN

Second Edition

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Metal cutting is one of the most widely used manufacturing processes to produce the final shape of products, and its technology continues to advance in parallel with developments in materials, computers, sensors, and actuators. A blank is converted into a final product by cutting extra material away by turning, drilling, milling, broaching, boring, and grinding operations conducted on computer numerically controlled (CNC) machine tools. The second edition of this book helps students and engineers understand the scientific principles of metal cutting technology and the practical application of engineering principles to solving problems encountered in manufacturing shops. The book reflects the author's industrial and research experience, and his manufacturing engineering philosophy as well.

Engineers can learn best by being shown how to apply the fundamentals of physics to actual machines and processes that they can feel and visualize. Mathematics, physics, computers, algorithms, and instrumentation then become useful integration tools in analyzing or designing machine tools and machining processes.

Metal cutting operations take place between a cutting tool and workpiece material mounted on a machine tool. The motion of the machine tool is controlled by its CNC unit, and the numerically controlled (NC) commands to CNC are generated on computer-aided design/computer-aided manufacturing (CAD/CAM) systems. The productivity and accuracy of the metal removal operation depend on the preparation of NC programs, planning of machining process parameters and cutting conditions, cutter geometry, work and tool materials, machine tool rigidity, and performance of the CNC unit. Manufacturing engineers who are involved in machining and machine tool technology must be familiar with each of these topics. It is equally important to link them and to be able to apply them in an interdisciplinary fashion to solve machining problems.

The beginning chapters of this book provide detailed mathematical models of metal cutting, milling, turning, and drilling operations. The macromechanics of cutting, which is applicable to solving problems on the shop floor and in machine tool design, is emphasized. Although required in work and tool material design – the micromechanics of cutting – basic principles of machinability, tool wear mechanisms, and chipping are briefly introduced to provide a complete picture. The design of machine tools requires knowledge of structures, mechanics of solids, vibrations, and kinematics, subjects that are covered
PREFACE

in dedicated mechanical engineering texts. This text builds on that knowledge, applying the principles of vibration and experimental modal analysis to machine tools and metal cutting. Mathematical methods are simplified so that they can be easily used to solve machining vibration problems. Chatter vibrations in machining are treated in depth in this text because the problem is experienced daily by practicing manufacturing engineers.

The last three chapters of the book are dedicated to programming, design, and automation of CNC machine tools. Numerically controlled programming and CAD/CAM technology are briefly covered, but with sufficient explanation so that the reader can start programming and using CNC machine tools. The selection of drive actuators, feedback sensors, modeling and analysis of feed drives, the design of real-time trajectory generation and interpolation algorithms, and CNC-oriented error analysis are presented in more detail than can be found in other texts. Open CNC design philosophy and improvement of accuracy and productivity by adding sensors and algorithms to CNC machine tools are also covered.

Students learn best by dealing with real manufacturing problems. The contents of this book are based on experimentally proven engineering principles that are widely used in applied research laboratories and industry. The examples and problems presented in each chapter originate from the research and industrial problems solved by the author and his graduate students. Interdisciplinary problems are posed as industrial projects so that readers can apply all the necessary techniques simultaneously. They solve the basic metal cutting mechanics problem first, followed by milling mechanics, static deflection of end mills and corresponding surface-form error modeling, and vibration model of the end mill and chatter stability. For example, the chain of knowledge is exercised in solving problems associated with milling of an aircraft structure, a project that originated from industry. Similarly, in another project, the reader is guided step by step through the programming, real-time modeling, and control of a CNC machine tool. Because all the projects were tried in the author's laboratory, a number of teaching and research setups are provided in the book to aid instructors.

The book is intended as a text for senior undergraduate and graduate students and practicing manufacturing engineers who wish to learn the engineering principles of metal cutting, machine tool vibration, experimental modal analysis, NC programming and CAD/CAM technology, CNC system design, and sensor-based machining. The book can also be used by researchers who wish to study metal cutting mechanics, machine tool vibrations, feed drive design and control, and CNC and sensor-based machining.

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