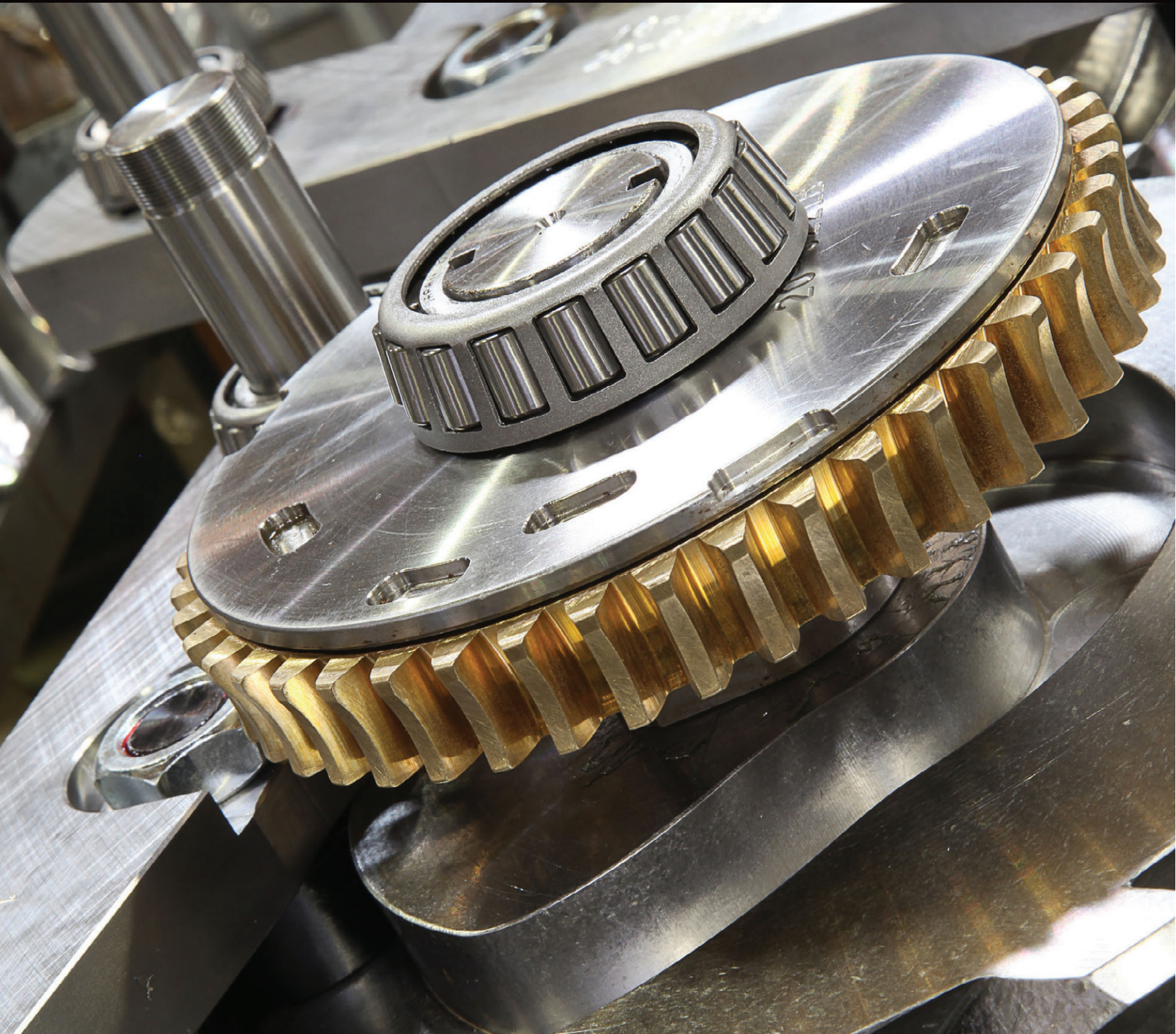


Michael Fitzpatrick

Machining and CNC Technology

Third Edition

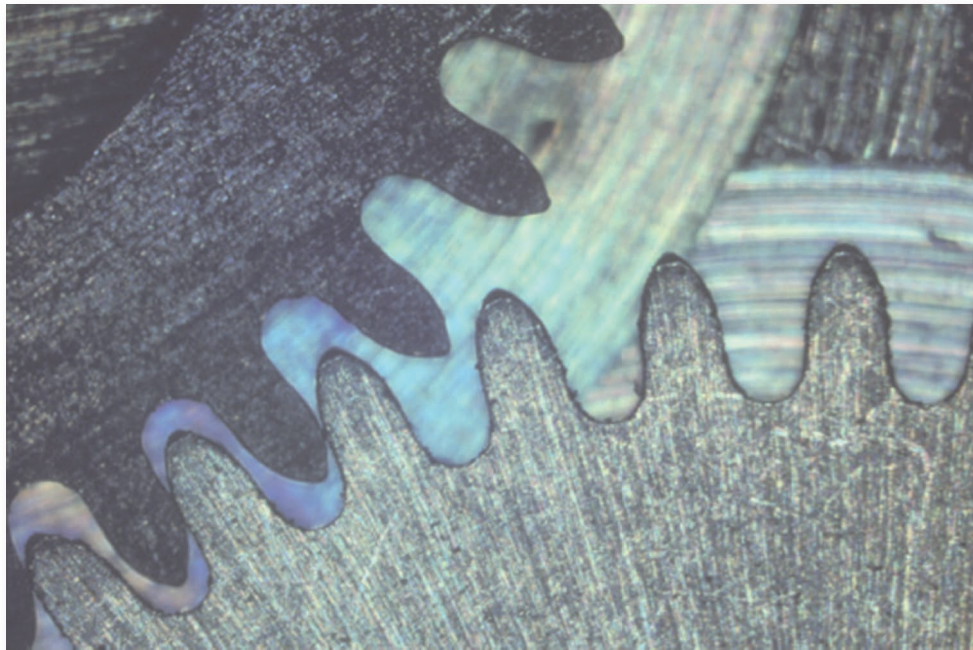


Machining and CNC Technology



Machining and CNC Technology

Third Edition



Michael Fitzpatrick





MACHINING AND CNC TECHNOLOGY, THIRD EDITION

Published by McGraw-Hill, a business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY, 10020. Copyright © 2014 by The McGraw-Hill Companies, Inc. All rights reserved. Printed in the United States of America. Previous editions © 2011 and 2005. No part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written consent of The McGraw-Hill Companies, Inc., including, but not limited to, in any network or other electronic storage or transmission, or broadcast for distance learning.

Some ancillaries, including electronic and print components, may not be available to customers outside the United States.

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 0 DOW/DOW 1 0 9 8 7 6 5 4 3

ISBN 978-0-07-337378-2

MHID 0-07-337378-8

Senior Vice President, Products & Markets: *Kurt L. Strand*

Vice President, General Manager, Products & Markets: *Martin J. Lange*

Vice President, Content Production & Technology Services: *Kimberly Meriwether David*

Managing Director: *Thomas Timp*

Director: *Michael D. Lange*

Global Publisher: *Raghothaman Srinivasan*

Director of Development: *Rose Koos*

Development Editor: *Vincent Bradshaw*

Global Publisher: *Curt Reynolds*

Project Manager: *Jean R. Starr*

Buyer II: *Debra R. Sylvester*

Designer: *Matt Backhaus*

Cover/Interior Designer: *Matt Backhaus*

Cover Image: *Courtesy Haas Machine Tools USA*

Senior Content Licensing Specialist: *Jeremy Cheshareck*

Manager, Digital Production: *Janean A. Utley*

Media Project Manager: *Cathy L. Tepper*

Typeface: *10.5/13 Times*

Compositor: *MPS Limited*

Printer: *R. R. Donnelley*

All credits appearing on page or at the end of the book are considered to be an extension of the copyright page.

Cataloging-in-Publication Data has been requested from the Library of Congress.

The Internet addresses listed in the text were accurate at the time of publication. The inclusion of a website does not indicate an endorsement by the authors or McGraw-Hill, and McGraw-Hill does not guarantee the accuracy of the information presented at these sites.

While there were countless others along the way, these four made all the difference in my career and life. Without them I question whether this book would have been.

To Linda, my wife

for never complaining about the time taken from us to do this, for believing, giving, and forgiving.

To Jan Carlson

for demonstrating with acts, what a caring professional should be, and especially for the encouraging space to grow.

To Bill Simmons

for trusting me with more than just your tool box, for your gentle guidance. We all miss you, Uncle Bill.

To Bill Coberley

for marketing me in the beginning and for being a lifelong friend.

Contents

About the Author	ix
Preface	x
Acknowledgements	xii
Walkthrough	xiv

PART 1 Introduction to Manufacturing

Chapter 1	Professionalism in Manufacturing	2
Chapter 2	Math Skills Self-Review	26
Chapter 3	Reading Technical Drawings	38
Chapter 4	Introduction to Geometrics	53
Chapter 5	Before and After Machining	79
Chapter 6	The Science and Skill of Measuring—Five Basic Tools	145
Chapter 7	Single-Purpose Measuring Tools, Gages, and Surface Roughness	182
Chapter 8	Layout Skills and Tools	218

PART 2 Introduction to Machining

Chapter 9	Cutting Tool Geometry	237
Chapter 10	Drilling and Operations and Machines	260
Chapter 11	Turning Operations	307
Chapter 12	Mills and Milling Operations	391
Chapter 13	Precision Grinding Operations and Machines	446
Chapter 14	Screw Thread Technology	489
Chapter 15	Metallurgy for Machinists—Heat Treating and Measuring Hardness	509
Chapter 16	Job Planning	539

PART 3 Introduction to Computer Numerical Control Machining

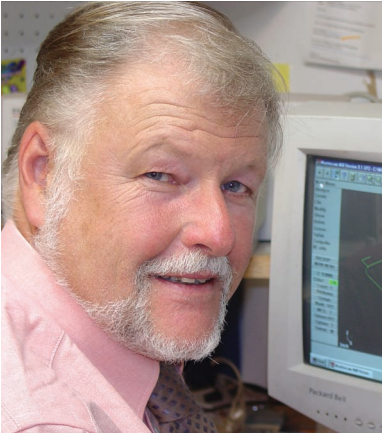
Chapter 17	Coordinates, Axes, and Motion	557
Chapter 18	CNC Systems	589
Chapter 19	CNC Controls	614
Chapter 20	Operating a CNC Machine	629
Chapter 21	Program Planning	655
Chapter 22	Level-One Programming	674
Chapter 23	Level-Two Programming	699
Chapter 24	Setting Up a CNC Machine	716

PART 4 Advanced and Advancing Technology

Chapter 25	Design for CNC Manufacturing—Solid Modeling	752
Chapter 26	CAM Mill Programming for CNC Machinists	757
Chapter 27	Tool Life, Productivity, and Advancing Technology	768
Chapter 28	Statistical Process Control (SPC)	792
Chapter 29	Computer Coordinate Measuring	805

Appendices	824
Credits	835
Index	839

About the Author



As if it was yesterday, I remember carrying my new toolbox down the aisle at Kenworth Trucks of Seattle. Scotty, the crusty drill press operator, stepped away from his machine and planted himself right in front of me. Without a welcome, he raised his bushy eyebrows, poked two fingers into my chest, and said “You see all these men here?” He waited. At eighteen, I recall only nodding, unable to speak. He went on, “Each one of us will show you everything we know if you pay attention. We’ll give you lifetimes of experience, but know this, lad, it comes with an obligation. Someday you’ll pass it on.”

Hello, I’m Mike Fitzpatrick, your machining instructor in print. Since you’ve honored me by studying my book, I thought it might be a confidence builder to tell a little about why I’m qualified to pay forward to you what Scotty and countless other fine craftsmen taught me.

I began that apprenticeship on the first Monday after high school graduation, in 1964. A year or so later, I was given the life-altering opportunity to be their first employee to run the first Numerical Control (NC) machine brought to the Seattle area, other than the ones at the Boeing Aircraft Company. Nothing like the computerized machines you’re about to learn, that NC machine was a turret head drill press, run by paper tapes. Not far from a music box in its technology, it was primitive compared to the machines in your training lab. Still, it was enough to hook me for life. So, with a year of applications and interviews, I transferred to Boeing, where I completed my machining certificate. There I learned to run programmed machines that had basements, and ladders to get up to the cutter head!

Passing the tough final with a 100% score, I qualified to take the even tougher test to become a tool and die apprentice. I made it and finished my training in 1971. That totaled 12,000 hours of rigorous on-the-job training under a whole army of skilled people. It also came with many hours of technical classes. Since then I’ve either been a machinist/tool maker or taught others for my entire adult life. For the last 25 years I’ve taught manufacturing in technical schools, private industry, a high-school skills center, a junior high school, and in two foreign countries.

Today I can stand in front of anyone and say with pride, “I’m a journeyman tool and die maker and a master of my trade.” Nearing the end of my journey, Scotty’s imprint calls me to pass it forward. But don’t forget, what we instructors and machinists give you comes with the same obligation.

One trait we clearly see you’ll need far more than we did is adaptability. Beyond imparting skills and competencies, this book has a mission: to start its readers down the long, ever-accelerating technology path. Clearly, the machinist of the future is one who can see and adapt to a changing future. When you do pass the baton forward, the trade won’t be anything like that found in this book. But I’m confident it will be passed, because machinists have a long history of adaptation.

Preface

Programmed machine tools now represent nearly 100 percent of manufacturing and, of greater impact to you, of new jobs. *Entry-level people usually start in the shop as CNC operators.* Flexible and friendly, the machines and programming systems are so quick and easy to learn that they are now practical even for one-of-a-kind work such as mold making and die work, as well as production. *Schools integrate and teach CNC as an entry-level subject—starting from the first lesson on the first day.*

This book was specifically written to serve this type of modern student. To do so, subjects have been grouped into four large career partitions:

Part 1 Introduction to Manufacturing

Manufacturing is a world of its own. Chapters 1 through 8 are designed to open the door. They provide the background needed to fit into the shop, to understand the rules, to read and interpret the drawings, to be comfortable with extreme accuracy, and especially to be safe.

Part 2 Introduction to Machining

Chapters 9 through 16 teach how to cut metal the right way. These lessons assume that you'll eventually perform them on CNC equipment, but will probably practice first on manually operated machines because they are a simple, safe place to learn setups and operations.

Part 3 Introduction to CNC

Now we get to the text core: how to apply Parts 1 and 2 to setting up, programming, and running CNC machine tools. In Chapters 17 through 24, we will learn how to professionally manage a CNC world. Because they move at lightning speed with lots of power behind them, safety must be integrated into everything we study.

Part 4 Advanced and Advancing Technology

Chapters 25 through 29 set the tone for your career after graduation. The best is yet to come, so let's get started!

So, many thanks to those who are using my book to start your manufacturing careers. It's an honor to be your instructor. Here's what I can pass on about our trade.

The Third Edition has been revised to include a number of new features:

- **New Chapters on Mastercam and SolidWorks**
- **Access to Mastercam Version X6 and SolidWorks** A free version of Mastercam Version X6 is available on the Student DVD that is packaged with this textbook. New for this edition: instructors can grant an access code to download the latest version of Solidworks student version. After a brief introduction in the text, students go to the Online Learning Center at <http://www.mhhe.com/fitzpatrick3e> for a step-by-step lesson in designing solids for CNC programs. Connecting that lesson, they can then install a version of Mastercam X to create the same solid in MC-X then write CNC code based upon it. The SolidWorks code will be housed on the password-protected Instructor's Side of the Online Learning Center for *Machining* (www.mhhe.com/fitzpatrick3e).
- **An index to help you map this book to any national machining standard** Recognizing the growing trend toward standardized instruction, this textbook is now skill mapped and indexed to help fit it to any national machining standard. The full index can be found on the Online Learning Center at www.mhhe.com/fitzpatrick3e, and the three-digit codes will help you cross-reference the index with the material in the book. A **glossary of terms** can also be found on the Online Learning Center.
- **Made Right Here Chapter-Opening Profiles** Where might your student's careers be going? Many fine companies discuss their unique products and own brand of success. Offered to encourage career choices in manufacturing, they highlight that the trade is alive and well right here!
- **Two new interactive chapter features** There have been many advances in mobile technology since the

last edition, and this new textbook incorporates many of them. Students can now use their mobile devices to view interesting websites, videos, and articles when they scan the special codes at the back of the book. Think of these **Xcursions** as a virtual field trip of

material that will enhance their understanding of the text. In addition, students can quiz themselves on the vocabulary of each chapter using their mobile devices. Just scan the special code at the end of the chapter to access the **Terms Toolbox Challenge**.

Acknowledgements

My deepest gratitude goes to these major contributors, without whom this book would not have been possible:

CNC Software, Inc. Mastercam *Mark Summers, President; Dan Newby, Training Director*

Thank you, Mark, for believing in education, and Dan, for your editing and guidance, and many thanks to your entire team for improving our trade and supporting education worldwide.

Milwaukee Area Technical College (*Milwaukee, Wisconsin*) *Dale Howser & Patrick Yunke, Lead Instructors*

Offering a nationally recognized, two-year tool-and-die-making diploma. MATC graduates learn die and mold making and qualify for Wisconsin's apprenticeship certificate. Thus they often serve full apprenticeships in the highly paid tooling area of manufacturing.

Dale Howser Sr.: Apart from 28 years of journeyman tool-making experience, with 15 years of teaching these subjects, Dale holds degrees in tool and die making from Milwaukee Area Technical College and in Vocational Education from Stout University. He also develops and works on educational materials for the Precision Metalforming Association and Wisconsin's Apprenticeship programs.

Patrick Yunke: A graduate of Wisconsin's Madison Area Technical College die making program and Stout University for Vocational Education, Patrick brings many years of experience in all aspects of precision die, metal, and plastic mold making to MATC, where he has taught for 15 years. He has also been a consultant to industry for manufacturing and custom educational programs.

Many thanks to you both for your expertise and for supplying great photos from your beautifully organized shop.

NTMA—National Tooling and Machining Association *Dick Walker, President*

Many thanks for being at the root of this new book in the beginning, for investing time and energy in it, and for the 45 drawings donated from your training materials.

NTMA Training Centers, California *Max Hughes, Dean of Instruction*

Thanks, Max, for the assistance with the CNC portion of this book.

Haas Automation, Inc. (*Oxnard, California*) *Scott Rathburn, Marketing Manager, Sr. Editor CNC Machining*

Thanks, Scott, for your commitment to machine tool education (see cover and copyright page), and for contributing support, time, energy, and many photos to this book.

Boeing Commercial Airplane Co. *Apprentice Instructor*

Thank you for giving me the best education possible when I began my career, and to Tim for your ongoing support of quality apprenticeship, for help in planning and executing this book, and for being a lifelong friend.

Brown and Sharpe Corp. (*Rhode Island*) *Metrology Equipment*

For your commitment to education in metrology in technical schools and colleges.

Kennametal Inc. *Kennametal University, dedicated to finding better methods and to educating wherever machining is taught or applied.*

Thanks for the data, advanced tooling photos, text, and charts.

Iscar Metals *Bill Christensen, Advanced Tooling Photos and Text*

Advancing knowledge through research and education; thank you, Bill, for the HSM article.

Sandvik Coromant

Thank you for photos from *Modern Metal Cutting*.

SME—Society of Manufacturing Engineers

Westech Machine Tool and Productivity Exposition

In addition, I would like to thank the following instructors who reviewed this textbook and provided suggestions for improvement:

Bob Dixon *Walters State Community College*

Bret Holmes *Ogden Weber Applied Tech Center*

Mike Wyckoff *Grand Rapids Community College*

Mike Cannon *Pensacola State College*

Dean Duplessis *Northern Maine Community College*

Mark Dodge *Nashua Community College*

Arthur Martz Thomas Wertman *Kaplan Career Institute*

Jim Kitchen *Pensacola State College*

Samuel Obi *San Jose State University*

Andrew Zwanch *Johnson College*

Patrick Mason *Morehead State University*

Michael Mattson *Clackamas Community College*

Dexter Hulse *University of Cincinnati-Batavia*

Richard Buhnerkemper *Gateway Technical—Elkhorn*
Thanks to the following individuals for recommending companies for the “Made Right Here” opening segments in this book:

Gerald Berry *Wayne County Community College District*

Herbert Skinner *Southeast Technical Center*


Ismail Fidan *Tennessee Tech University*

Erica Matthew *Florida Career College*

Teje Sult *Jackson State University*

Machining and CNC Technology, Third Edition, provides the most up-to-date approach to Machine Tool technology available, with totally integrated coverage of manual and Computer Numerical Control-based equipment.

Every other chapter opens with a **Made Right Here** profile. This profile contains a photo and brief text describing a company or product manufactured today. It is meant to inspire students and show them all of the opportunities available to them in the industry.



HUMAN IMMERSIVE LABORATORY
Real-World Solutions from Virtual Reality

Enter the world of a large-scale, immersive virtual reality system developed by Lockheed Martin. The Human Immersive Laboratory (HIL) was first used as a simulation tool to facilitate design and test of the fifth generation F-35 Light reality system, including a virtual reality room, designers and explore modeling data that were solved early in the design process. When F-35 production began, the Marine Corps' F-35B Delivery delays on a schedule slip. As a result, they could re-sequence the F-35's engine production to be main. Working with the simulation to verify necessary access for the assembly team. By putting assembles the assembly team process could be successful. production delays. Se



Xcursion. How much torture did your safety glasses endure to get that Z87 approval? For more information and video of the ballistic testing of safety glasses, scan here.



XCURSIONS are special codes students can scan using their mobile devices to view interesting videos, websites, and articles. An icon in the chapter alerts students to scan the code to access the additional material.

The **Terms Toolbox Challenge** allows students to review the vocabulary terms using their mobile devices. Students can scan the code to access the flashcard-like exercise.

TRADE TIP

Besides using letters to track revisions, in your shop, drawing revisions can also be tracked by number or by the date on which they were updated.

Check the Revision Box Look in the upper right corner of the drill gage drawing (Fig. 5-2). There have been no revisions; this is a NEW release drawing. It may be a very old design, but it has never been revised. The second print 203B-605 is at Rev A. It has been updated once, probably when the saw was improved. Brief notes in the Rev box give clues as to what those changes were. Normally you needn't worry about what the changes were; they are history as far as you are concerned. They have been incorporated onto the print. The important thing to ensure is that the next key points are followed.

KEYPOINT

When receiving a job, always verify that

- The part number matches the WO.
- The drawing revision level and work order revision level agree.

SHOPTALK

Replacement Parts Keep in mind, shops also produce replacement parts for older products—*not the latest version!* In that case, a lot of detective work must be done. The changes made over time must be backtracked from the current Rev level back to the ones ordered. Each change must be investigated to see if it is compatible with the latest parts. Will they interchange or does the

Terms Toolbox

Chips Metal particles of waste removed from the workpiece by machining.

Natural fibers Cotton or wool cloth, which tends to resist hot chip damage and melting, thus protecting the wearer from burns.

Synthetic fibers Plastic cloth such as nylon and polyester, which tends to melt when hot chips touch it.

Z87 or Z87.1 The mark found on safety glasses approved for shop work, which means they will protect your eyes from the front and side in a dangerous environment.

***Review the key terms in the Terms Toolbox Challenge!** Just scan the code in every Chapter Review, or go to www.mhhe.com/fitzpatrick3e.

MOTIVATIONAL CHAPTER FEATURES such as *Key Points*, *Trade Tips*, and *Shop Talk* are included to show students the practical side of the subject.

All topics in the textbook have been **indexed for programs needing to offer standard skills certificates**. The complete index can be found on the instructor side of the Online Learning Center (www.mhhe.com/fitzpatrick3e). The topics are noted in text with a three-digit numbering system.

2.4.1 Bilateral Tolerances

Easy to understand but not always easy to accomplish! That's how we earn our pay! For example, on the engineering drawing you read that a hole diameter specification is to be 0.6250 diameter; then, in the table below, you see the tolerance for a four-place number is " ± 0.0010 ."

Question: So, what size range would be acceptable?

Answer: 1.624 in. on the low and 1.626 in. on the high.

Expressing it as a plus/minus range is called a **bilateral tolerance**, meaning its acceptable range extends both directions from nominal.

2.4.2 Unilateral Tolerance

Expressing the tolerance in one direction from nominal is a **unilateral tolerance**. Look at the 1.50-in. width dimension in Fig. 2-13.

$$01.50 \begin{matrix} +.000 \\ -.000 \end{matrix}$$

And now what is the range? Answer 1.500 to 1.490 in.

You cannot machine the width larger than 1.50 in., but ten thousandths smaller is OK.

2.4.3 Limits

Sometimes the designer will express the tolerance as **limits** of size; for example, the bottom width:

2.995 in.

2.305 in.

That means there is no specific quality target—any result within the limited range is OK.

Final point: No matter how it's expressed, your task will be to machine and measure the controlled feature well within the tolerance!



Figure 1-7 Hair does catch on moving machinery. Keep it out of harm's way.

Full-color **photos and illustrations** make concepts easier for students to understand and apply to the information presented.

TOOL & DIE STEEL

A 2 Annealed Air Hardening 5% Chrome		D 2 Annealed Air Hardening High Carbon/Chrome		O 6 Annealed Oil Hardening Graph-Mo®	
A 6 Annealed Air Hardening Low Temperature		H 13 Annealed Air Hardening Hot Work		S 5 Annealed Oil Hardening Shock Resisting	
A 10 Annealed Air Hardening Graph-Air®		O 1 Annealed Oil Hardening		S 7 Annealed Air Hardening Shock Resisting	

Figure 1-13 Correctly stored and color-code-identified raw materials.

MASTERCAM STUDENT VERSION EXERCISES AND A FREE VERSION OF THE SOFTWARE are provided on the free DVD. The exercises provide CAD/CAM programming experience for students. Also available are student exercise for SolidWorks and access to a version of the software can be found on the Instructor Side of the OLC.

THE ONLINE LEARNING CENTER (WWW.MHHE.COM/FITZPATRICK3E) contains a wealth of resources for instructors, including an Instructor's Manual with teaching tips and handouts, an EZ Test computerized Test Bank, and enhanced PowerPoint slides with videos.

Machining and CNC Technology



Part 1

Introduction to Manufacturing

This book is about getting a job in a machine shop. But, it's also about keeping that job advancing career responsibility and pay. For career success, you need to know what is expected of you from the very first day. Like any workplace, there are tasks, procedures, and rules to be followed. Some are formal skills or rules, while some are informal and generally accepted by your fellow workers.

Part 1 is designed to impart basic manufacturing knowledge and skills and to clarify trade expectations to help you

Chapter 1 Know how to look, act, and be professional 2

Chapter 2 Understand, use, and speak the precision numbers of the trade 26

Chapter 3 Read early lab drawings and be ready for more engineering drawing instruction 38

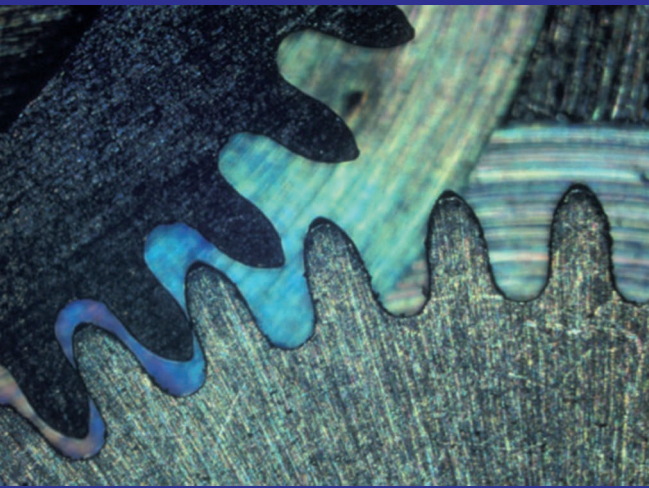
Chapter 4 Identify and use geometric dimensioning and tolerancing (GDT) found on drawings 53

Chapter 5 Work with the materials, documents, and processes before and after the machining occurs 79

Chapter 6 Use five basic measuring tools, the right way always with the best repeatability 145

Chapter 7 Use specialized measuring tools when the five basic tools aren't the right choice 182

Chapter 8 Perform simple part layout and know when it's right or wrong for the job 218



Chapter 1

Professionalism in Manufacturing

Learning Outcomes

1-1 Dressing for Career Success (Pages 3–6)

- Select the correct protective equipment for a machine shop
- Select the correct clothing

1-2 Handling Materials (Pages 6–10)

- Safely lift heavy objects correctly and explain why bending your knees is the right thing to do, but the last resort for heavy lifting
- Safely move metals within the shop
- Store metals and machine accessories

1-3 Handling Shop Supplies (Pages 10–14)

- List the six possible dangers of shop chemicals
- Ask for and read MSDS sheets when in doubt about handling new chemicals

- Handle and store lubricants, solvents, and coolants
- Know how to correctly dispose of waste

1-4 Maintaining Equipment and the Work Environment (Pages 15–22)

- Lubricate complex machinery
- Safely remove metal chips
- Understand what a lean green shop means
- Review fire prevention and safety

INTRODUCTION

This book represents a manufacturing world where computer-aided design/computer-aided manufacturing (CAD/CAM) and computer numerical control (CNC) have changed everything. Planned by a group of industry leaders and instructors, we used today's job market and tomorrow's career needs as our guide. To make room for the new subjects needed for career success, every effort was made to eliminate old technologies and skills no longer relevant to mainstream employment. Our goal was to equip you, the beginning machinist, with the competencies to get and keep that vital first job.

But we also knew that students often breeze past the usual opening chapters to get to the "real training." So why start with a chapter on professionalism and safety?

Because a critical part, perhaps the most critical part, of your training has nothing to do with measuring, reading prints, and

running programs on machines, yet getting it right will have everything to do with your success! It might be called work ethic, team spirit, or job readiness. It's often called attitude on an employee evaluation or a grade report. No matter what you call it, it adds up to how you walk the walk of a skilled craftsman. A large part of the separation between ordinary and skilled workers is a professional attitude.

While a whole lot more could be said on the subject, these units are enough to get you started fitting into a machine shop environment and starting the lifelong process of being a skilled professional. Taken to heart, the message of this chapter will make a real difference in your career.

Unit 1-1 Dressing for Career Success

Introduction: In Fig. 1-1, which person would you want making precision parts for your new car or outboard motor? In truth, they might all be good machinists but—well, you get the picture. The concern here isn't styles of clothing or grooming, it's about being right for a precision shop environment.

Terms Toolbox

Chips Metal particles of waste removed from the workpiece by machining.

Natural fibers Cotton or wool cloth, which tends to resist hot chip damage and melting, thus protecting the wearer from burns.

Synthetic fibers Plastic cloth such as nylon and polyester, which tends to melt when hot chips touch it.

Z87 or Z87.1 The mark found on safety glasses approved for shop work, which means they will protect your eyes from the front and side in a dangerous environment.

***Review the key terms in the Terms Toolbox Challenge!** Just scan the code in every Chapter Review, or go to www.mhhe.com/fitzpatrick3e.

1.1.1 Getting Ready for the Work Environment—Eye Protection Always

Figure 1-2 shows several types of eye protection. Most shops supply one or more varieties. The best choice is the one you find comfortable and tend to leave on 100 percent of the time! Many prefer full-vision, wraparound lenses because they are all clear material so you don't see a frame.



Figure 1-1 Which machinist looks right for the job—and more importantly, for a career?



Figure 1-2 The best choice for eye protection is the one you find most comfortable and tend to leave on.

KEYPOINT

Safety glasses will bear the mark **Z87** or **Z87.1** on the ear piece if they have passed strict testing and are acceptable for shop work.



Xcursion. How much torture did your safety glasses endure to get that Z87 approval? For more information and video of the ballistic testing of safety glasses, scan here.



Clear or Yellow

Either lens color is acceptable. Yellow lenses offset the blue of common fluorescent lighting and many feel that the correction boosts their ability to read precision tools. Never select dark glasses unless you must work near electric welding flashes because they dull your ability to see details.

Prescription Eyewear

Most wraparound safety glasses can be worn over prescription glasses. But the law requires prescription glass lenses to be made from tempered glass or high-impact plastic, so it is acceptable to wear them alone as long as side shields are added. It's a fact that many eye injuries occur from the side rather than straight on, so shatterproof front lenses aren't enough protection by themselves.

Extreme Danger Areas

When performing tasks such as disk grinding with lots of flying debris, protect your eyes by adding a full-face shield over safety glasses.

Just Do It!

Be a trendsetter—wear safety glasses even when others don't. Modern CNC equipment usually has containment

shielding so the operator feels safe from flying metal particles, but don't forget you must occasionally walk through the shop past other unprotected machines. Make safety glasses a habit by putting them on when entering the shop. Here's an attitude check: you've got it right when you feel strange without your safety glasses. No kidding, I've gone home still wearing them! If those provided aren't comfortable, then find an industrial safety supplier and buy a pair just right for you—that's the kind of pro we're talking about.

1.1.2 Hearing Protection

Machine shops can be noisy places. Some operations are loud enough to cause hearing loss over time. Prevent permanent damage right now while your hearing is good. Get in the habit of wearing ear protection (Fig. 1-3) where noise gets above moderate—see the chart. The two common types of hearing protection are expandable foam inserts that fit every ear shape and the muff type that fit over your ears.



Figure 1-3 Machinists protect their hearing when shop noise is loud or high pitched.

TRADE TIP

Hearing Is Your Primary Control Protecting your hearing is more than personal. Just as when driving a car, the machinist almost always hears a problem developing before seeing it, especially on fast CNC equipment.

Earplugs remove the loud spikes but allow controlled hearing. For extreme situations, earmuffs are supplied by your employer. Either way, don't give away your most immediate

control sense by not protecting it. And by the way, to control your machine it is important to not use personal music earphones—sorry, but they're out when running a machine.

1.1.3 Shop Clothing

The main danger of loose clothing is that it can be caught by moving machinery—but you already knew that. While Fig. 1-4 was set up, really being caught in a machine is no fun—think about it! Nothing loose—sleeves, necklaces, untucked shirts—nothing! Well-fit, **natural fibers** such as cotton or wool, without pockets or tie cords hanging out, are essential.

Typical Range of Common Sounds

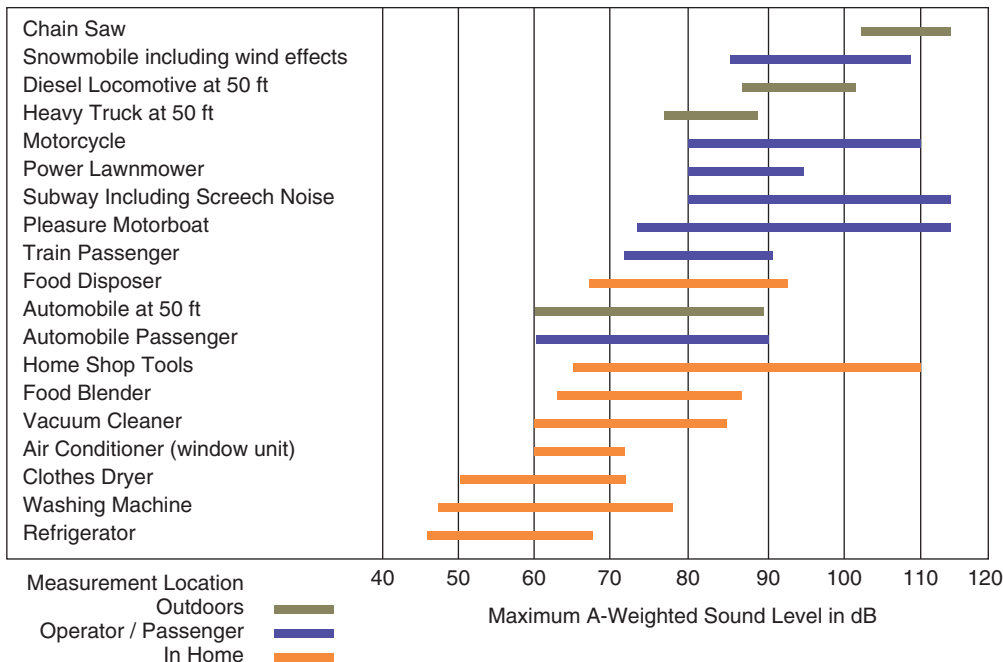




Figure 1-4 Seriously, loose clothing does get caught in moving machinery!

Why Natural Fibers?

The shavings made when cutting metal are called **chips**. They're hot, as much as 1,000 degrees. While today's CNC machines won't operate with the safety guard open, many older machines will. Flying hot chips must be dealt with. As we study machine operation we'll see several ways to control them, but one action the pro takes is the kind of fabrics worn on the job.

When hot chips contact **synthetic fibers** such as polyester, rayon, or nylon, they stick, then melt through (Fig. 1-5). So your shirt or pants are ruined and the hot metal is held against your skin. Ouch! Not only that, but that makes it hard to concentrate on the task at hand.

KEYPOINT

Where hot chips cannot be contained by any other method, *wearing* natural fibers such as cotton denim or wool can work. They will just bounce off your clothing.



Figure 1-5 Two hot chips melted onto this nylon windbreaker while the center one went completely through to possibly burn the person within!

Aprons and Shop Coats

An apron or shop coat can be a good choice. But be aware that not all are designed for machining. Some are made for lab work, where machinery won't grab loose ties or pockets. Find one with internal pockets and no loose belts tied in front. Long sleeves are not smart for obvious reasons. A professional approach is to keep a short-sleeved work shirt in your locker.

How About Shoes?

Your work shoes have three safety aspects. I'll bet the third will surprise you. Work shoes provide

- Protection for your feet from falling objects.
- Nonslip soles designed for a shop where chips, coolants, and oils are often on the floor.
- Protection from fatigue.

Athletic shoes are a poor choice. Even though comfortable, they aren't designed to stand up to a shop environment.

Steel Toes Shoes or boots with steel toe caps are better than shoes without and may be required on the job. No matter how careful you are, there's always the inevitable falling heavy object. Don't fall for the old tale that someone knows someone who had their toes severed by the steel insert collapsing when something really heavy fell on it. Think about it: if the thing was that heavy, it would have done the same damage with or without the steel protection!

SHOPTALK

Quality Could be Linked to Good Work Shoes or Boots

Boots As a machinist, you're going to be on your feet all day, usually on concrete. Guess when most folks make the most mistakes. That's right, at the end of the day when they're tired. Good-quality work shoes offset some of the problems and help keep your mind sharp.