G-W PUBLISHER

Machining Fundamentals

10TH EDITION

JOHN R. WALKER | BOB DIXON

Machining Fundamentals

10TH EDITION

by

JOHN R. WALKER
Bel Air, Maryland

BOB DIXON
Walters State Community College
Morristown, Tennessee

Publisher
The Goodheart-Willcox Company, Inc.
Tinley Park, IL
www.g-w.com

Manufactured in the United States of America.

Library of Congress Catalog Card Number 2017046452

ISBN 978-1-63563-208-8

1 2 3 4 5 6 7 8 9 – 19 – 23 22 21 20 19 18

Cover image: Dmitry Kalinovsky/Shutterstock.com
Cover background: tomertu/Shutterstock.com
Back cover image: Pixel B/Shutterstock.com

Library of Congress Cataloging-in-Publication Data

Names: Walker, John R., author. | Dixon, Bob (Bob A.)
Title: Machining fundamentals / by John R. Walker, Bob Dixon.
Description: 10th edition. | Tinley Park, IL : The Goodheart-Willcox Company, Inc., [2019] | Includes index.
Identifiers: LCCN 2017046452 | ISBN 9781635632088
Subjects: LCSH: Machine-shop practice. | Machining.
Classification: LCC TJ1160 .W25 2019 | DDC 671.3/5--dc23 LC record available at https://lccn.loc.gov/2017046452

Introduction

Machinists are highly skilled men and women. They use drawings, hand tools, precision measuring tools, drilling machines, grinders, lathes, milling machines, and other specialized machine tools to shape and finish metal and nonmetal parts. Machinists must have a sound understanding of basic and advanced machining technology, which includes:

- Proficiency in safely operating machine tools of various types (manual, automatic, and computer controlled).
- Knowledge of the working properties of metals and nonmetals.
- The academic skills (such as math, science, English, print reading, and metallurgy) needed to make precision layouts and machine setups.

Machining Fundamentals provides an introduction to these important areas of manufacturing technology. The text explains the "how, why, and when" of numerous machining operations, setups, and procedures. Through it, you will learn how machine tools operate and when to use one particular machine instead of another. The advantages and disadvantages of various machining techniques are discussed, along with their suitability for particular applications.

Machining Fundamentals details the many common methods of machining and shaping parts to meet given specifications. It also covers more advanced processes, such as laser machining, waterjet cutting, high-energy-rate forming (HERF), cryogenics, chipless machining, electrical discharge machining (EDM), electrochemical machining (ECM), robotics, and rapid prototyping. The importance of computer numerical control (CNC) in the operation of most machine tools and its role in automated manufacturing is explored thoroughly. A new chapter expands coverage of geometric dimensioning and tolerancing (GD&T).

Machining Fundamentals has many features that make it easy to read and understand. The heads in each chapter are numbered to quickly locate specific information within a chapter. A chapter outline lists all chapter heads and subheads at the beginning of each chapter. Learning objectives are also presented in the chapter opener, along with a list of selected technical terms important to understanding the material in that chapter.

Throughout the text, technical terms are highlighted in bold italic type as they are introduced and defined. These terms are also listed and defined in the *Glossary* at the end of the text.

The extensive illustrations, photographs, and other visuals throughout ***Machining Fundamentals*** clarify and reinforce machining operations, procedures, and applications. A color key is used to indicate different materials and types of equipment. Features visually highlight and expand textual content by giving it practical value. *Workplace Skills* and *Career Connection* features introduce students to machining-related careers and the qualities employers are seeking. *Green Machining* features expose students to recent trends in environmentally friendly manufacturing.

Each chapter closes with a chapter review containing a summary and review questions. The summary reiterates and expands on the learning objectives given in the chapter opener. Review questions reinforce key learning objectives and offer students the opportunity to check their understanding.

Machining Fundamentals is a valuable guide to anyone interested in machining, since the procedures and techniques presented have been drawn from all areas of machining technology. Students will gain a strong foundation in machining to support practical skills.

About the Authors

John R. Walker is the author of thirteen textbooks and has written numerous magazine articles. Mr. Walker completed his undergraduate studies at Millersville University and has a master's degree in Industrial Education from the University of Maryland. He taught industrial arts and vocational education for more than 32 years, including 5 years as Supervisor of Industrial Education. He also worked as a machinist for the US Air Force and as a draftsman at the US Army Aberdeen Proving Grounds.

Bob Dixon is a Professor and Head of the Engineering Technology Department at Walters State Community College in Morristown, Tennessee. Dr. Dixon holds bachelor's and master's degrees in Engineering Technology from East Tennessee State University, a master's degree in Industrial Engineering from the University of Tennessee, and a doctorate in Educational Leadership from East Tennessee State University. Prior to entering the education field, Dr. Dixon spent over 20 years in industry working in a variety of machining, manufacturing, and engineering positions. He is an ATMAE Certified Senior Technology Manager and recipient of the 2005 ATMAE Outstanding Faculty of Industrial Technology Award for Region 3.

Reviewers

The authors and publisher wish to thank the following industry and teaching professionals for their valuable input into the development of ***Machining Fundamentals***.

Terry Anselmo
Sun Area Technical Institute
Northumberland, Pennsylvania

Marte Arreola
British Columbia Institute of Technology
Burnaby, British Columbia

George Beauchemin
Bay Path Regional Vocational High School
Worcester, Maryland

Paul Bois
Milford High School and Applied Technology Center
Somersworth, New Hampshire

Mark Bosworth
Southwestern Illinois College
Belleville, Illinois

Craig Brazil
Sheridan College
Oakville, Ontario

Michael Buechler
Santa Ana College
Santa Ana, California

Jason S. Carpenter
Tennessee College of Applied Technology
Morristown, Tennessee

Dr. Chesley Chambers
Floyd County College & Career Academy
Cedartown, Georgia

Donald Dean
C-TEC
Newark, Ohio

Rose M. DeNunzio
Eastfield College, Dallas County Community College District
Mesquite, Texas

Bruce Dirks
Owatonna High School
Owatonna, Minnesota

David Eledge
Metropolitan Community College
Council Bluffs, Iowa

Gottfried Georgi
William Horlick High School
Mount Pleasant, Wisconsin

John Glenn
Clinton Technical School
Clinton, Missouri

Howard Gray
Sault College
Sault Ste. Marie, Ontario

Richard Grossen
Blackhawk Technical College
Cottage Grove, Wisconsin

Garth Hansen
Dixie Applied Technology College
Saint George, Utah

Henry Hatem
Renton Technical College
Carnation, Washington

Troy Hayes
TCAT Crossville
Crossville, Tennessee

Michael Hilber
Anoka-Hennepin Secondary Technical Education Program
East Bethel, Minnesota

Jeremy Hodkiewicz
Shawano High School
Clintonville, Wisconsin

Roger Holland
Minnesota State College Southeast
La Crescent, Minnesota

Bruce Jacobs
Mt. Bauer Middle School
Puyallup, Washington

Bart Jenkins
Georgia Northwestern Technical College
Rome, Georgia

Stephen B. Jenkins
Parkside High School and Wor-Wic Community College
Salisbury, Maryland

Mike Koppy
Lake Superior College
Hermantown, Minnesota

David Laton
Alabama Department of Postsecondary Education
Montgomery, Alabama

Danny Lester
Somerset Community College
Somerset, Kentucky

Tom Livingstone
The Pennsylvania College of Technology
Williamsport, Pennsylvania

William J. McCracken, Jr.
Colorado Mesa University/Western Colorado Community College
Grand Junction, Colorado

Dale Miller
Lebanon County Career and Technology Center
Lebanon, Pennsylvania

Daniel J. Miller
SUNY Canton
Canton, New York

Daniel Morales
South Texas College
McAllen, Texas

Brian Nelson
Dunwoody College of Technology
West Saint Paul, Minnesota

James Niehaus
Southern Indiana Career & Technical Center
Evansville, Indiana

Shan Packer
Central Mountain High School
Howard, Pennsylvania

Samuel Ray
The Williamson Free School of Mechanical Trades
Saint Michaels, Maryland

Edward Schmidt
Trenton Central High School
Philadelphia, Pennsylvania

Preet Singh
Donna High School
Pharr, Texas

Bruce Smith
Tulsa Technology Center
Claremore, Oklahoma

Marty Snagg
Heritage High School
Conyers, Georgia

Paul Sorenson
Minnesota State College Southeast
Winona, Minnesota

James Standing
Algonquin College
Ottawa, Ontario

Steve Stayton
Colbert County Schools
Tuscumbia, Alabama

Daniel Wagner
HACC, Central Pennsylvania's Community College
Hegins, Pennsylvania

Roger Wensink
Lakeshore Technical College
Sheboygan Falls, Wisconsin

Olaf Wick
Wisconsin Indianhead Technical College
New Richmond, Wisconsin

Dr. John Wren
Fanshawe College, St. Thomas Campus
St. Thomas, Ontario

Dr. John Wyatt
Mississippi State University
Starkville, Mississippi

Nick Yates
Patterson High School
Baltimore, Maryland

Jim Zeleny
Confederation College
Thunder Bay, Ontario

Andy Zwanch
Johnson College
Scranton, Pennsylvania

Acknowledgments

The authors and publisher would like to thank the following companies, organizations, and individuals for their contribution of resource material, images, or other support in the development of ***Machining Fundamentals***.

3D Systems
3M Company
Alden Corp.
American Foundrymen's Society
American Society of Mechanical Engineers
AMT—The Association for Manufacturing Technology
Autocon Technologies, Inc.
Baldor
Bethlehem Steel Co.
BIG Kaiser Precision Tooling Inc.
Bill Hannan
Bird-Johnson Company
Bob Walker
Bridgeport Machines, Inc.
Buehler, a division of ITW Company
C. & E. FEIN GmbH
Carboloy
Carl Zeiss, Inc.
Carpenter Steel Co.
Chicago-Latrobe
Chick Machine Tool, Inc.
Cincinnati Milacron
CITCO Div., Western Atlas, Inc.
Clausing Industrial, Inc.
CNC Software, Inc.
Coated Abrasive Manufacturers Institute
Cogsdill Tool Products, Inc.
Compositek Corporation
Dake Corporation
Dapra Corporation
Delcam International
DoALL Co.
duMont Corp.
DuPont Co.
Engis Corporation
EZFeatureMILL—Engineering Geometry Systems
Fanuc Robotics North America, Inc.
Federal Products Co.
FEIN Power Tools, Inc.
Flow International Corp.
Ford Motor Co.
Fowler High Precision
General Dynamics Corp.
General Motors Corp.
Giddings & Lewis, Inc.
Greenfield Industries
Grizzly Industrial, Inc.
Haas Automation, Inc.
Hardinge, Inc.
Heli-Coil Corp.
Helisys, Inc.
Hertel Cutting Technologies, Inc.
Heule Precision Tools
Hirata Corporation of America
Honeywell, Inc., Industrial Automation and Control
Hougen Manufacturing, Inc.
Hydromat, Inc.
IBAG North America
IBM
Iscar Metals, Inc.
Jenoptik
Jergens, Inc.
Jet Equipment & Tools
John Winter
Jones & Lamson Machine Co.
Justrite Manufacturing Company
K.O. Lee Co.
Kennametal
KEO Cutters
Klein Tools, Inc.
Komet of America, Inc.
L. S. Starrett Co.
Landis Div. of Western Atlas
LeBlond Makino Machine Tool Co.
Library of Congress, Prints & Photograph Division
Light Beam Technology, Inc.
Lockwood Products, Inc.
Lovejoy Tool Company, Inc.
Lufkin Rule Co.
Lumonics Corp.

Mack Molding Co.
MAG IAS, LLC
Magnaflux Corp.
Mahr Federal Inc.
Makita USA, Inc.
Manufacturing Technology, Inc.
Marposs Corp.
Master Lock Co.
Maswerks, Inc.
Mazak
Metal Powder Industries Federation
MHI Machine Tool U.S.A., Inc.
Microphoto, Inc.
MIFCO McEnglevan Industrial Furnace Co., Inc.
Millersville University
Mitsubishi Materials USA Corporation
Mitutoyo/MTI Corp.
Morse Tool Co.
NASA
National Broach & Machine Co.
NEYTECH
Northrop-Grumman Corp.
Norton Co.
NSK America
O.S. Walker Co.
OSG Tap & Die, Inc.
PA&E Bonded Metals Division
Parker-Kalon
Parlec, Inc.
Precision Castparts Corp.
Quality Vision International, Inc.
Radyne
Rem Sales, Inc.
Renishaw, Inc.
Republic-Lagun Machine Tool Co.
Revolution Tool Company
Rofin-Sinar, Inc.
Rohm and Haas
Royal Products, Division of Curran Manufacturing Corporation
Rush Machinery, Inc.
Sandvik Coromant Co.
Sharnoa Corp.
Sharp Industries, Inc.
SpeedFam
Standard Tool Co.
Stratasys, Inc.
Sulzer
Sunnen Products Company
Tibor Machine Products
Tornos-Bechler S.A.
Tri-Tool, Inc.
Union Carbide Corp.
US Air Force
US Air Force Thunderbirds
US Amada, Ltd.
US Army
US Navy
US Navy Mass Communication Specialist 2nd Class Andrea Perez
Valenite, Inc.
Vermont Machine Tool and the Bryant Grinder Division
W.J. Savage Co.
Waldes Kohinoor Inc.
Webber Gage Div., L. S. Starrett Co.
Webster Instrument, Inc.
Weiler Corporation
Westech Products Group/Gantrex Machine Tool Loaders
William Schotta, Millersville University
Willis Machinery and Tools Corp.
Wilson Instruments/Instron Corporation
WMW Machinery Company, Inc.
www.mini-lathe.com
Yukiwa Seiko USA, Inc.

G-W Integrated Learning Solution

Together, We Build Careers

At Goodheart-Willcox, we take our mission seriously. Since 1921, G-W has been serving the career and technical education (CTE) community. Our employee-owners are driven to deliver exceptional learning solutions to CTE students to help prepare them for careers. Our authors and subject matter experts have years of experience in the classroom and industry. We combine their wisdom with our expertise to create content and tools to help students achieve success. Our products start with theory and applied content based on a strong foundation of accepted standards and curriculum. To that base, we add student-focused learning features and tools designed to help students make connections between knowledge and skills. G-W recognizes the crucial role instructors play in preparing students for careers. We support educators' efforts by providing time-saving tools that help them plan, present, assess, and engage students with traditional and digital activities and assets. We provide an entire program of learning in a variety of print, digital, and online formats, including economic bundles, allowing educators to select the right mix for their classroom.

Student-Focused Curated Content

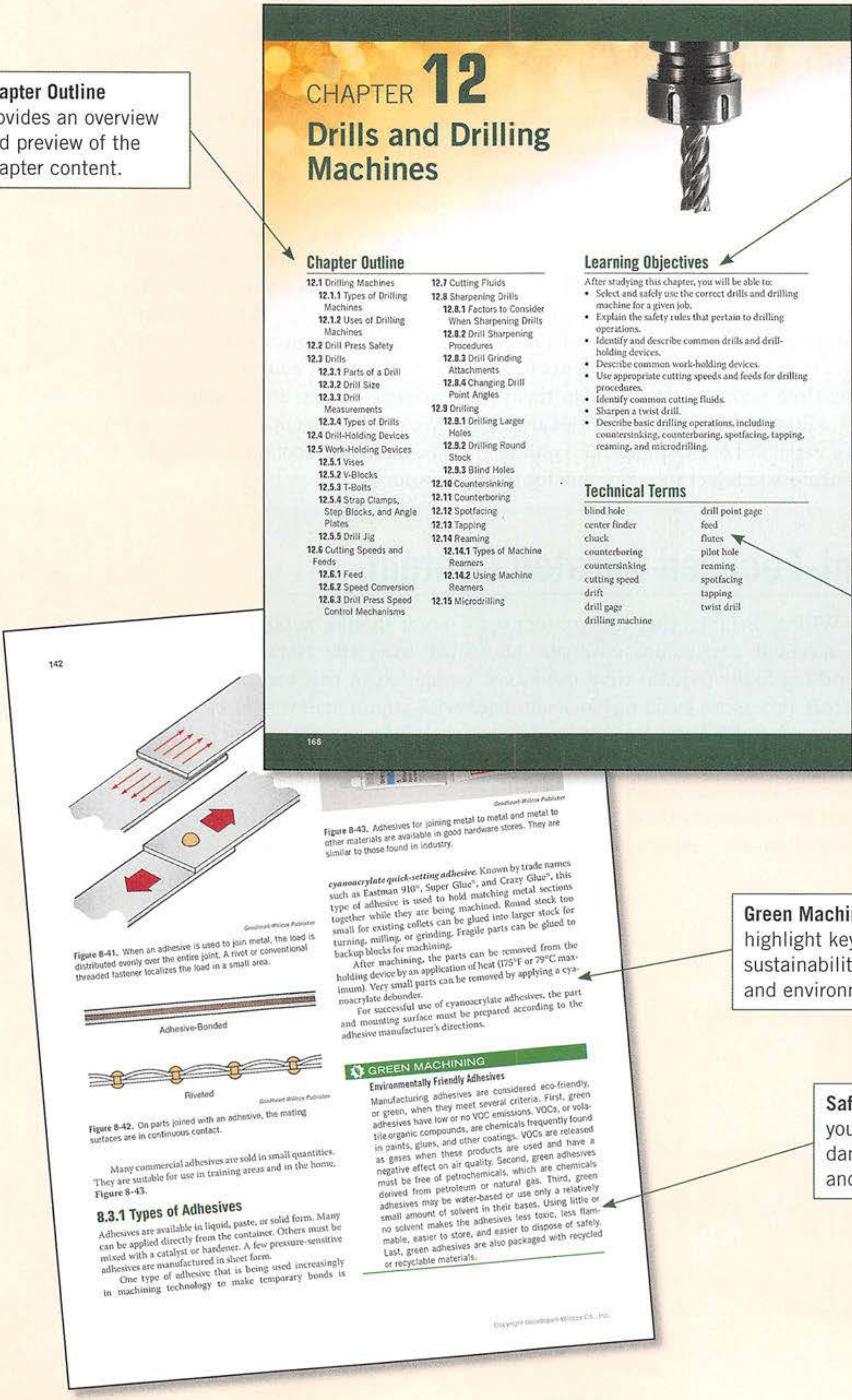
Goodheart-Willcox believes that student-focused content should be built from standards and accepted curriculum coverage. Standards from the National Institute for Metalworking Skills (NIMS) were used as a foundation in this text. ***Machining Fundamentals*** also uses a building block approach with attention devoted to a logical teaching progression that helps students build upon their learning. We call on industry experts and teachers from across the country to review and comment on our content, presentation, and pedagogy. Finally, in our refinement of curated content, our editors are immersed in content checking, securing and sometimes creating figures that convey key information, and revising language and pedagogy.

Features of the Textbook

Features are student-focused learning tools designed to help you get the most out of your studies. This visual guide highlights the features designed for the textbook.

Chapter Outline provides an overview and preview of the chapter content.

Learning Objectives clearly identify the knowledge and skills to be obtained when the chapter is completed.



CHAPTER 12

Drills and Drilling Machines

Chapter Outline

12.1 Drilling Machines
12.1.1 Types of Drilling Machines
12.1.2 Uses of Drilling Machines
12.2 Drill Press Safety
12.3 Drills
12.3.1 Parts of a Drill
12.3.2 Drill Size
12.3.3 Drill Measurements
12.3.4 Types of Drills
12.4 Drill-Holding Devices
12.5 Work-Holding Devices
12.5.1 Vises
12.5.2 V-Blocks
12.5.3 T-Bolts
12.5.4 Strap Clamps, Step Blocks, and Angle Plates
12.5.5 Drill Jig
12.6 Cutting Speeds and Feeds
12.6.1 Feed
12.6.2 Speed Conversion
12.6.3 Drill Press Speed Control Mechanisms
12.7 Cutting Fluids
12.8 Sharpening Drills
12.8.1 Factors to Consider When Sharpening Drills
12.8.2 Drill Sharpening Procedures
12.8.3 Drill Grinding Attachments
12.8.4 Changing Drill Point Angles
12.9 Drilling
12.9.1 Drilling Larger Holes
12.9.2 Drilling Round Stock
12.9.3 Blind Holes
12.10 Countersinking
12.11 Counterboring
12.12 Spotfacing
12.13 Tapping
12.14 Reaming
12.14.1 Types of Machine Reamers
12.14.2 Using Machine Reamers
12.15 Microdrilling

Learning Objectives

After studying this chapter, you will be able to:
- Select and safely use the correct drills and drilling machine for a given job.
- Explain the safety rules that pertain to drilling operations.
- Identify and describe common drills and drill-holding devices.
- Describe common work-holding devices.
- Use appropriate cutting speeds and feeds for drilling procedures.
- Identify common cutting fluids.
- Sharpen a twist drill.
- Describe basic drilling operations, including countersinking, counterboring, spotfacing, tapping, reaming, and microdrilling.

Technical Terms

blind hole
center finder
chuck
counterboring
countersinking
cutting speed
drift
drill gage
drilling machine
drill point gage
feed
flutes
pilot hole
reaming
spotfacing
tapping
twist drill

168

142

Figure 8-41. When an adhesive is used to join metal, the load is distributed evenly over the entire joint. A rivet or conventional threaded fastener localizes the load in a small area.

Adhesive-Bonded

Riveted

Figure 8-42. On parts joined with an adhesive, the mating surfaces are in continuous contact.

Many commercial adhesives are sold in small quantities. They are suitable for use in training areas and in the home. Figure 8-43.

8.3.1 Types of Adhesives

Adhesives are available in liquid, paste, or solid form. Many can be applied directly from the container. Others must be mixed with a catalyst or hardener. A few pressure-sensitive adhesives are manufactured in sheet form.

One type of adhesive that is being used increasingly in machining technology to make temporary bonds is

Figure 8-43. Adhesives for joining metal to metal and metal to other materials are available in good hardware stores. They are similar to those found in industry.

cyanoacrylate quick-setting adhesive. Known by trade names such as Eastman 910®, Super Glue®, and Crazy Glue®, this type of adhesive is used to hold matching metal sections together while they are being machined. Round stock too small for existing collets can be glued into larger stock for turning, milling, or grinding. Fragile parts can be glued to backup blocks for machining.

After machining, the parts can be removed from the holding device by an application of heat (175°F or 79°C maximum). Very small parts can be removed by applying a cyanoacrylate debonder.

For successful use of cyanoacrylate adhesives, the part and mounting surface must be prepared according to the adhesive manufacturer's directions.

GREEN MACHINING

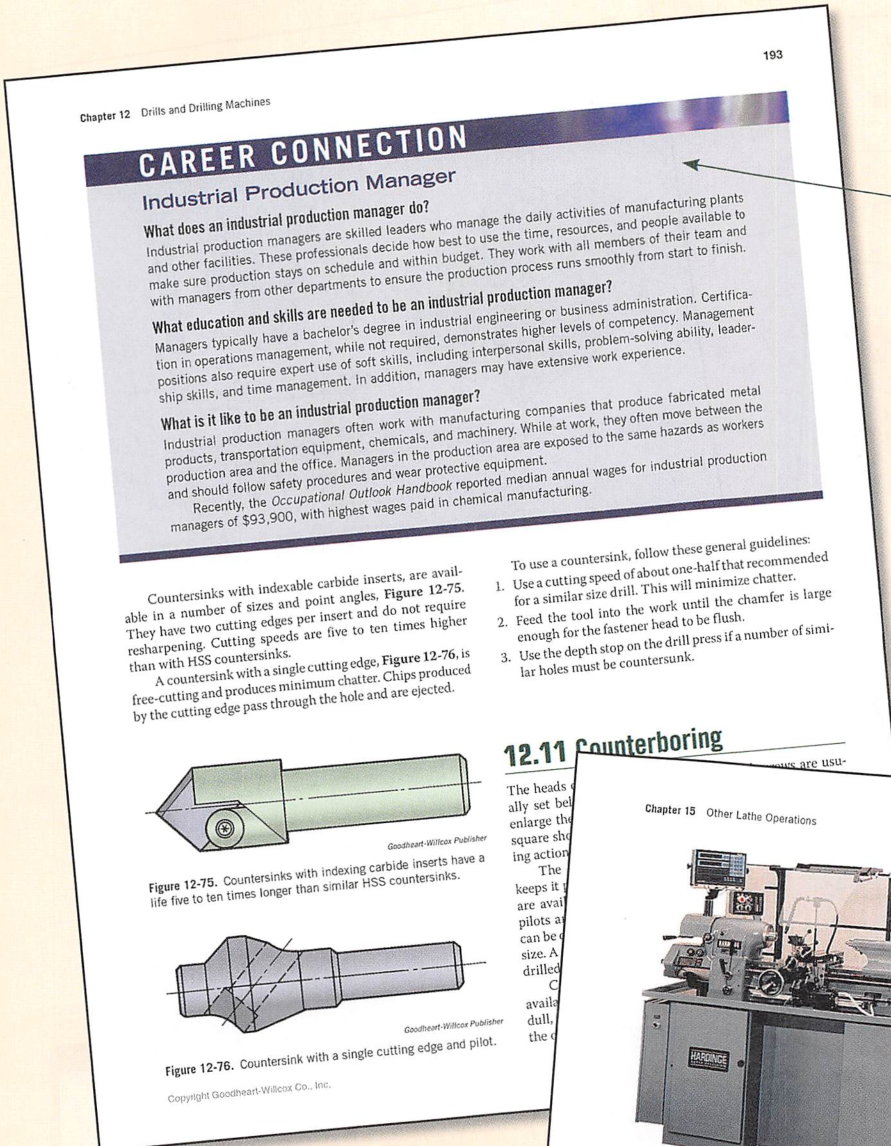
Environmentally Friendly Adhesives

Manufacturing adhesives are considered eco-friendly, or green, when they meet several criteria. First, green adhesives have low or no VOC emissions. VOCs, or volatile organic compounds, are chemicals frequently found in paints, glues, and other coatings. VOCs are released as gases when these products are used and have a negative effect on air quality. Second, green adhesives must be free of petrochemicals, which are chemicals derived from petroleum or natural gas. Third, green adhesives may be water-based or use only a relatively small amount of solvent in their bases. Using little or no solvent makes the adhesives less toxic, less flammable, easier to store, and easier to dispose of safely. Last, green adhesives are also packaged with recycled or recyclable materials.

Technical Terms list the key terms to be learned in the chapter.

Green Machining features highlight key items related to sustainability, energy efficiency, and environmental issues.

Safety Notes alert you to potentially dangerous materials and practices.



Chapter 12 Drills and Drilling Machines

193

CAREER CONNECTION

Industrial Production Manager

What does an industrial production manager do?

Industrial production managers are skilled leaders who manage the daily activities of manufacturing plants and other facilities. These professionals decide how best to use the time, resources, and people available to make sure production stays on schedule and within budget. They work with all members of their team and with managers from other departments to ensure the production process runs smoothly from start to finish.

What education and skills are needed to be an industrial production manager?

Managers typically have a bachelor's degree in industrial engineering or business administration. Certification in operations management, while not required, demonstrates higher levels of competency. Management positions also require expert use of soft skills, including interpersonal skills, problem-solving ability, leadership skills, and time management. In addition, managers may have extensive work experience.

What is it like to be an industrial production manager?

Industrial production managers often work with manufacturing companies that produce fabricated metal products, transportation equipment, chemicals, and machinery. While at work, they often move between the production area and the office. Managers in the production area are exposed to the same hazards as workers and should follow safety procedures and wear protective equipment.

Recently, the *Occupational Outlook Handbook* reported median annual wages for industrial production managers of $93,900, with highest wages paid in chemical manufacturing.

Countersinks with indexable carbide inserts, are available in a number of sizes and point angles, **Figure 12-75.** They have two cutting edges per insert and do not require resharpening. Cutting speeds are five to ten times higher than with HSS countersinks.

A countersink with a single cutting edge, **Figure 12-76,** is free-cutting and produces minimum chatter. Chips produced by the cutting edge pass through the hole and are ejected.

To use a countersink, follow these general guidelines:

1. Use a cutting speed of about one-half that recommended for a similar size drill. This will minimize chatter.
2. Feed the tool into the work until the chamfer is large enough for the fastener head to be flush.
3. Use the depth stop on the drill press if a number of similar holes must be countersunk.

12.11 Counterboring

Goodheart-Willcox Publisher

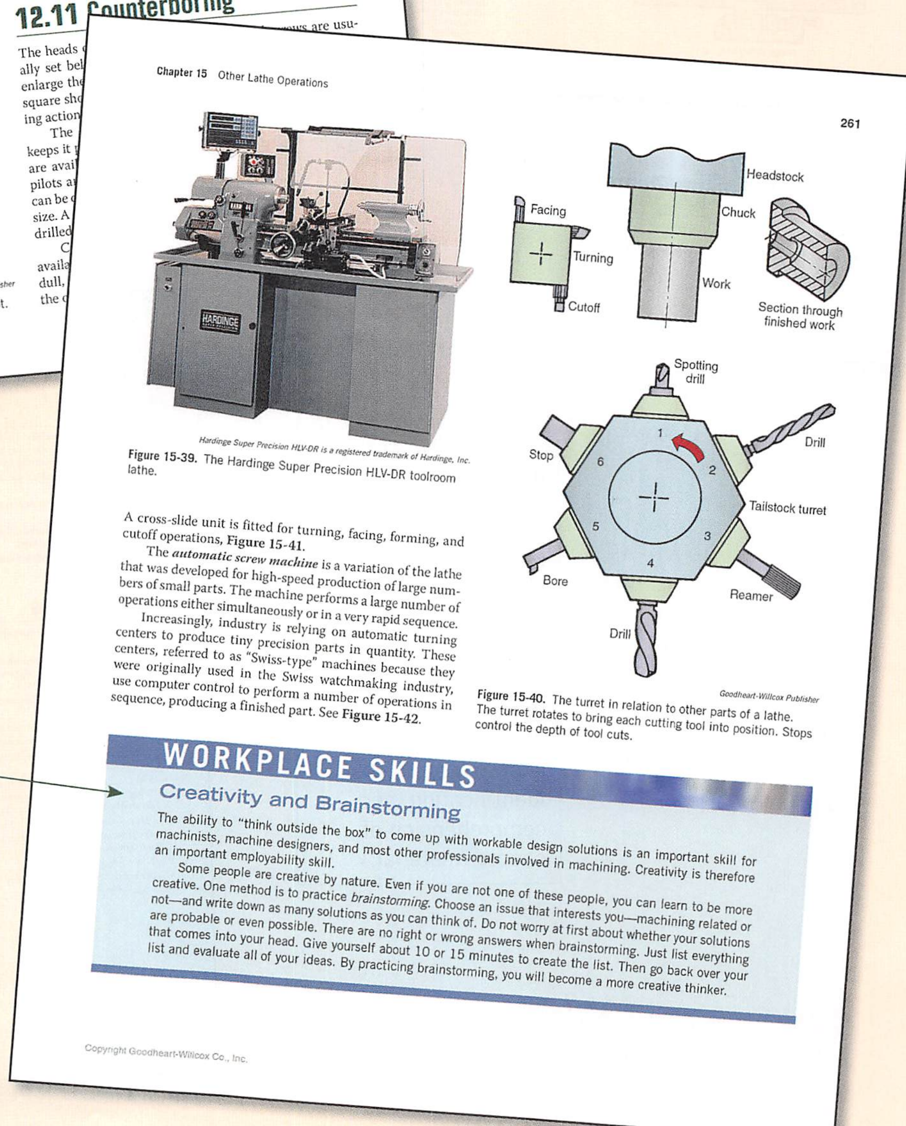
Figure 12-75. Countersinks with indexing carbide inserts have a life five to ten times longer than similar HSS countersinks.

Goodheart-Willcox Publisher

Figure 12-76. Countersink with a single cutting edge and pilot.

Copyright Goodheart-Willcox Co., Inc.

Career Connection features and profiles can provide a path for career success.



Chapter 15 Other Lathe Operations

261

Hardinge Super Precision HLV-DR is a registered trademark of Hardinge, Inc.

Figure 15-39. The Hardinge Super Precision HLV-DR toolroom lathe.

Goodheart-Willcox Publisher

Figure 15-40. The turret in relation to other parts of a lathe. The turret rotates to bring each cutting tool into position. Stops control the depth of tool cuts.

A cross-slide unit is fitted for turning, facing, forming, and cutoff operations, **Figure 15-41.**

The ***automatic screw machine*** is a variation of the lathe that was developed for high-speed production of large numbers of small parts. The machine performs a large number of operations either simultaneously or in a very rapid sequence.

Increasingly, industry is relying on automatic turning centers to produce tiny precision parts in quantity. These centers, referred to as "Swiss-type" machines because they were originally used in the Swiss watchmaking industry, use computer control to perform a number of operations in sequence, producing a finished part. See **Figure 15-42.**

WORKPLACE SKILLS

Creativity and Brainstorming

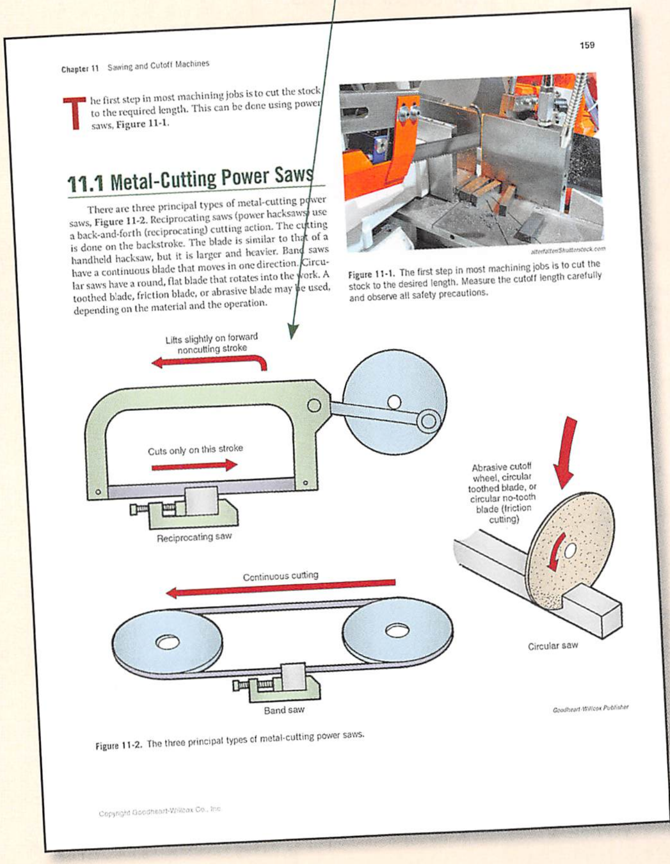
The ability to "think outside the box" to come up with workable design solutions is an important skill for machinists, machine designers, and most other professionals involved in machining. Creativity is therefore an important employability skill.

Some people are creative by nature. Even if you are not one of these people, you can learn to be more creative. One method is to practice *brainstorming.* Choose an issue that interests you—machining related or not—and write down as many solutions as you can think of. Do not worry at first about whether your solutions are probable or even possible. There are no right or wrong answers when brainstorming. Just list everything that comes into your head. Give yourself about 10 or 15 minutes to create the list. Then go back over your list and evaluate all of your ideas. By practicing brainstorming, you will become a more creative thinker.

Copyright Goodheart-Willcox Co., Inc.

Workplace Skills highlight the professional behaviors and traits that employers want.

Illustrations have been designed to clearly illuminate key concepts, equipment, and methods and enhance the text with visuals for different learning styles.


Chapter 11 Sawing and Cutoff Machines

159

The first step in most machining jobs is to cut the stock to the required length. This can be done using power saws, **Figure 11-1**.

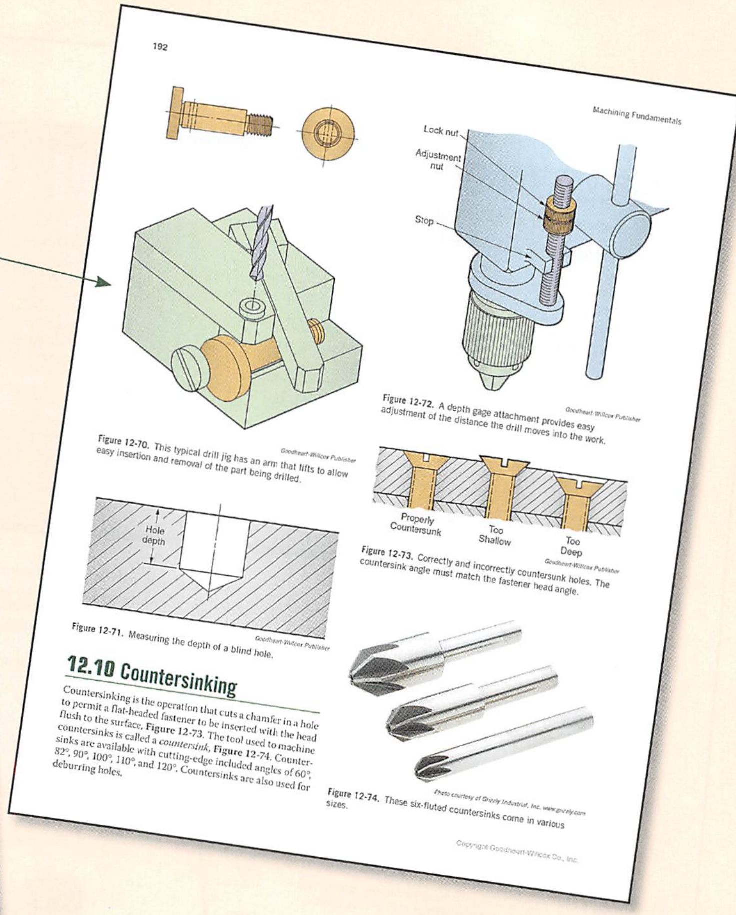
11.1 Metal-Cutting Power Saws

There are three principal types of metal-cutting power saws, **Figure 11-2**. Reciprocating saws (power hacksaws) use a back-and-forth (reciprocating) cutting action. The cutting is done on the backstroke. The blade is similar to that of a handheld hacksaw, but it is larger and heavier. Band saws have a continuous blade that moves in one direction. Circular saws have a round, flat blade that rotates into the work. A toothed blade, friction blade, or abrasive blade may be used, depending on the material and the operation.

Figure 11-1. The first step in most machining jobs is to cut the stock to the desired length. Measure the cutoff length carefully and observe all safety precautions.

Figure 11-2. The three principal types of metal-cutting power saws.

Copyright Goodheart-Willcox Co., Inc.


192

Machining Fundamentals

Figure 12-70. This typical drill jig has an arm that lifts to allow easy insertion and removal of the part being drilled.

Figure 12-71. Measuring the depth of a blind hole.

Figure 12-72. A depth gage attachment provides easy adjustment of the distance the drill moves into the work.

Figure 12-73. Correctly and incorrectly countersunk holes. The countersink angle must match the fastener head angle.

12.10 Countersinking

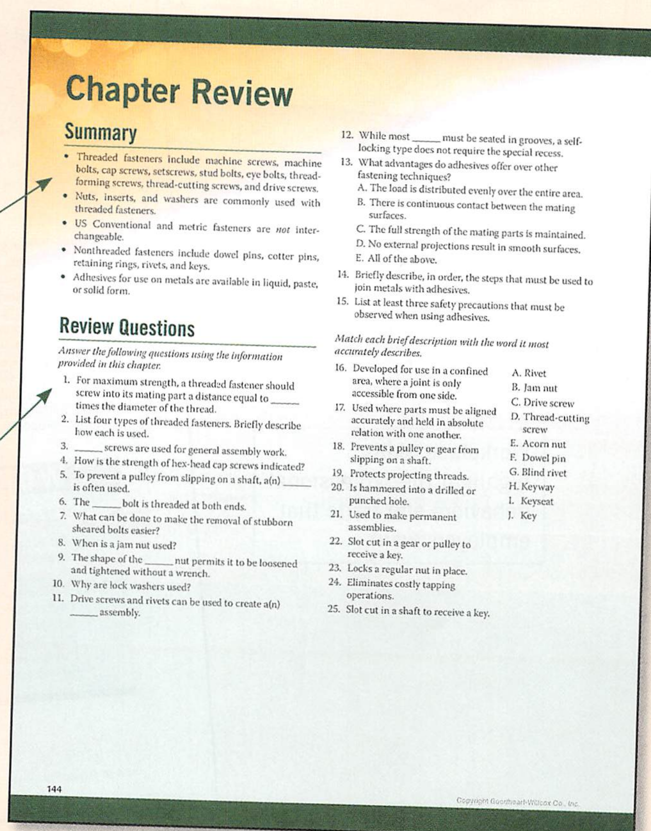
Countersinking is the operation that cuts a chamfer in a hole to permit a flat-headed fastener to be inserted with the head flush to the surface, **Figure 12-73**. The tool used to machine countersinks is called a *countersink*, **Figure 12-74**. Countersinks are available with cutting-edge included angles of 60°, 82°, 90°, 100°, 110°, and 120°. Countersinks are also used for deburring holes.

Figure 12-74. These six-fluted countersinks come in various sizes.

Copyright Goodheart-Willcox Co., Inc.

Summary feature provides an additional review tool for you and reinforces key learning objectives.

Review Questions allow you to demonstrate knowledge, identification, and comprehension of chapter material.


Chapter Review

Summary

- Threaded fasteners include machine screws, machine bolts, cap screws, setscrews, stud bolts, eye bolts, thread-forming screws, thread-cutting screws, and drive screws.
- Nuts, inserts, and washers are commonly used with threaded fasteners.
- US Conventional and metric fasteners are *not* interchangeable.
- Nonthreaded fasteners include dowel pins, cotter pins, retaining rings, rivets, and keys.
- Adhesives for use on metals are available in liquid, paste, or solid form.

Review Questions

Answer the following questions using the information provided in this chapter.

1. For maximum strength, a threaded fastener should screw into its mating part a distance equal to _____ times the diameter of the thread.
2. List four types of threaded fasteners. Briefly describe how each is used.
3. _____ screws are used for general assembly work.
4. How is the strength of hex-head cap screws indicated?
5. To prevent a pulley from slipping on a shaft, a(n) _____ is often used.
6. The _____ bolt is threaded at both ends.
7. What can be done to make the removal of stubborn sheared bolts easier?
8. When is a jam nut used?
9. The shape of the _____ nut permits it to be loosened and tightened without a wrench.
10. Why are lock washers used?
11. Drive screws and rivets can be used to create a(n) _____ assembly.
12. While most _____ must be seated in grooves, a self-locking type does not require the special recess.
13. What advantages do adhesives offer over other fastening techniques?
    A. The load is distributed evenly over the entire area.
    B. There is continuous contact between the mating surfaces.
    C. The full strength of the mating parts is maintained.
    D. No external projections result in smooth surfaces.
    E. All of the above.
14. Briefly describe, in order, the steps that must be used to join metals with adhesives.
15. List at least three safety precautions that must be observed when using adhesives.

Match each brief description with the word it most accurately describes.

16. Developed for use in a confined area, where a joint is only accessible from one side.
17. Used where parts must be aligned accurately and held in absolute relation with one another.
18. Prevents a pulley or gear from slipping on a shaft.
19. Protects projecting threads.
20. Is hammered into a drilled or punched hole.
21. Used to make permanent assemblies.
22. Slot cut in a gear or pulley to receive a key.
23. Locks a regular nut in place.
24. Eliminates costly tapping operations.
25. Slot cut in a shaft to receive a key.

A. Rivet
B. Jam nut
C. Drive screw
D. Thread-cutting screw
E. Acorn nut
F. Dowel pin
G. Blind rivet
H. Keyway
I. Keyseat
J. Key

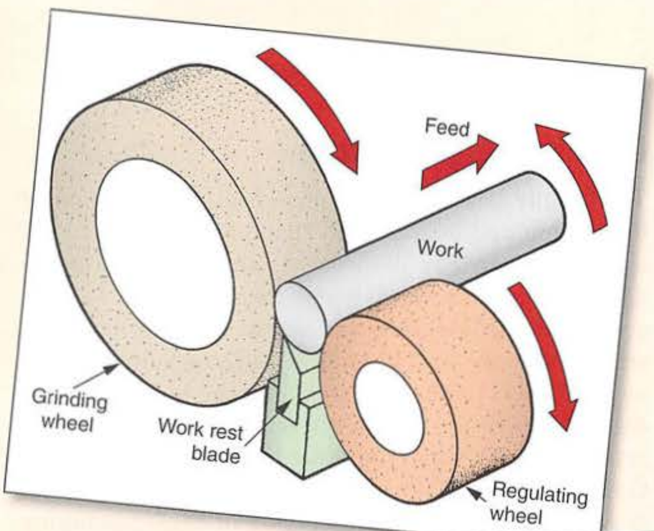
144

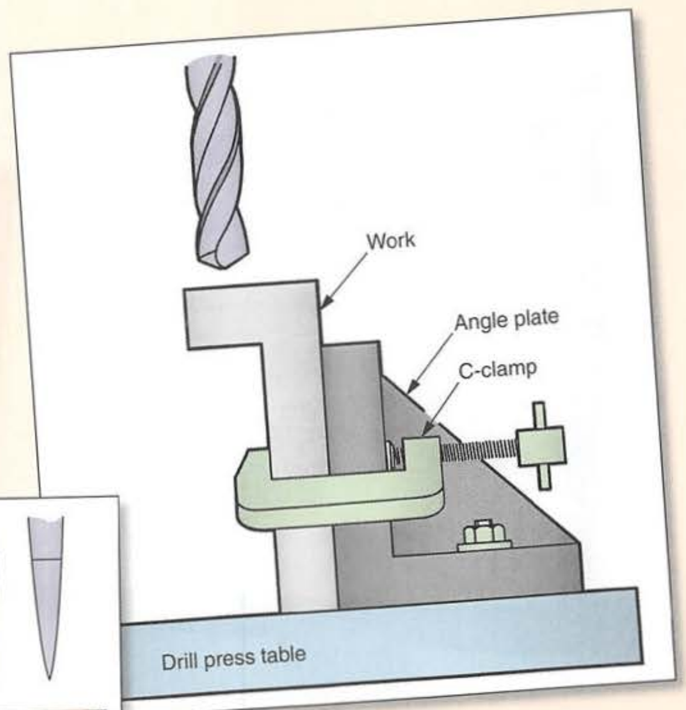
Copyright Goodheart-Willcox Co., Inc.

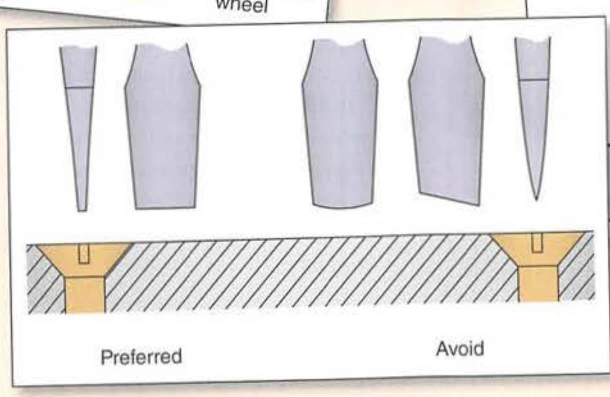
Machining Fundamentals Color Code

A consistent color code is used in the line illustrations throughout ***Machining Fundamentals*** to help you better visualize the machining operations and procedures. Specific colors are used to indicate different materials and equipment features. The following key shows what each color represents:

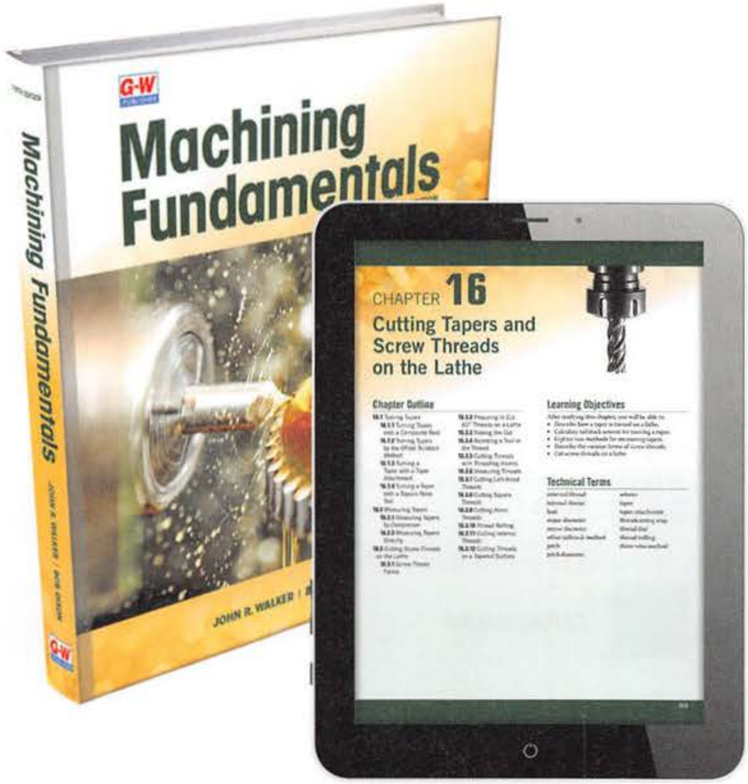
- **Metals**
- **Alternate metal**
- **Machines/machine parts**
- **Tools**
- **Cutting edges**
- **Work-holding and tool-holding devices**
- **Fasteners**
- **Abrasives**
- **Fluids**
- **Miscellaneous**
- **Direction or force arrows, dimensional information**







Student Resources



Textbook

The *Machining Fundamentals* textbook provides an exciting, full-color, and highly illustrated learning resource. The textbook is available in print and online versions.

Workbook

The student Workbook provides questions that reinforce and review textbook content. Organized to follow the textbook on a chapter-by-chapter basis, the Workbook assignments help you engage with the textbook content and aid in effective retention of key facts, ideas, and concepts.

Online Learning Suite

The Online Learning Suite provides the foundation of instruction and learning for digital and blended classrooms through any device with an Internet browser. All student instructional materials are found on a convenient online bookshelf and are accessible at home, at school, or on the go. The Online Learning Suite includes an interactive online textbook, student workbook with digital form fields, vocabulary activities, drag-and-drop activities, and a variety of other learning activities. The Online Learning Suite also contains 30 video clips that provide dynamic visual instruction of basic machining practices. Scripted by an expert machinist, shot in an actual manufacturing facility and loaded with practical hands-on demonstrations, these live-action videos help provide students with the essential knowledge and skills required for entry-level employment in today's manufacturing industry. The Online Learning Suite effectively brings digital learning to students and is easy for instructors to use.

Online Learning Suite/Student Textbook Bundle

Looking for a blended solution? Goodheart-Willcox offers the Online Learning Suite bundled with the printed text in one easy-to-access package. Students have the flexibility to use the print version, the Online Learning Suite, or a combination of both components to meet their individual learning style. The convenient packaging makes managing and accessing content easy and efficient.

Video Clip Library

Live-action videos provide students with solid information on 30 machining topics. High-quality video footage and crisp narrations enable visual learners to clearly understand the content.

Instructor Resources

Instructor resources provide information and tools to support teaching, grading, and planning; class presentations; and assessment.

Instructor's Presentations for PowerPoint®

Presentations for PowerPoint® are designed to support instructors and visually reinforce the textbook content. These time-saving and customizable presentations include objectives, key concepts, terms, and images from each chapter. Instructors can customize each presentation by modifying and adding slides and images to better meet classroom needs.

ExamView® Assessment Suite

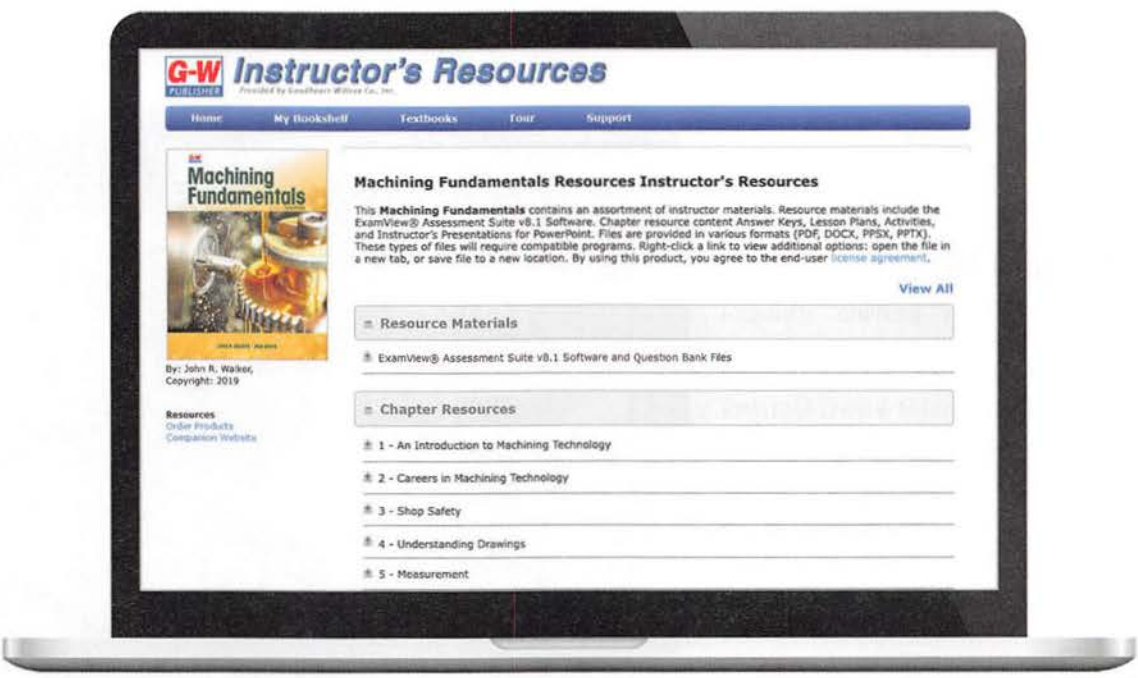
The ExamView® Assessment Suite allows instructors to quickly and easily create, administer, and score tests, both in print and online. Create many versions of formative and summative exams, multiple versions of a single test, and automatically generate answer keys. For additional versatility, instructors can easily modify existing questions and add new questions to fit course needs.

Instructor's Resource CD

A variety of time-saving teaching support tools are provided in the Instructor's Resource for ***Machining Fundamentals***. Answer keys are included for both the textbook and student Workbook. Customizable lesson plans provide chapter-specific instructional resources, tools for practice and assessment, and other resources available for teaching the chapter content. An overview of the products in the teaching package is provided, as well as correlation to NIMS Duties and Standards for Machining Skills Level I.

Online Instructor Resources

Online Instructor Resources are comprehensive, time-saving teaching tools organized in a convenient, easy-to-use online bookshelf. Lesson plans, answer keys, a correlation to NIMS Duties and Standards for Machining Skills Level I, Presentations for PowerPoint®, ExamView® Assessment Suite software, and other resources are available on demand, 24/7 from home or school.



Brief Contents

Contents

Feature Contents

WORKPLACE SKILLS

CAREER CONNECTION

GREEN MACHINING

CHAPTER 1

An Introduction to Machining Technology

Chapter Outline

1.1 The Evolution of Machine Tools
- **1.1.1** Early Machine Tools
- **1.1.2** Power Sources

1.2 Basic Machine Tool Operation
- **1.2.1** Sawing Machines
- **1.2.2** Drill Press
- **1.2.3** Grinding Machines
- **1.2.4** Milling Machine
- **1.2.5** Broaching Machines

1.3 Nontraditional Machining Processes

1.4 Automating the Machining Process
- **1.4.1** The Development of Numerical Control
- **1.4.2** Computer Numerical Control

1.5 The Evolving Role of the Machinist

1.6 Acquiring Machining Skills and Knowledge

Learning Objectives

After studying this chapter, you will be able to:

- Discuss how modern machine technology affects the workforce.
- Give a brief explanation of the evolution of machine tools.
- Provide an overview of machine tool operations.
- List nontraditional machining processes.
- Explain how CNC machining equipment operates.
- Describe the role of the machinist.
- Explain how machinists are trained and certified.

Technical Terms

broaching machine
computer numerical control (CNC)
drill press
grinding machine
lathe
machine tools
machinist
milling machine
numerical control (NC)
sawing machine
skill standards
turning

A study of technology will show that industry has progressed from a time when everything was made by hand to recent advances resulting in the fully automated manufacturing processes used today. Machine tools have played an essential role in all technological advances.

Without machine tools, **Figure 1-1**, there would be no airplanes, automobiles, television sets, or computers. Many of the other industrial, medical, recreational, and domestic products we take for granted would not have been developed. For example, if machine tools were not available to manufacture tractors and farming implements, farmers might still be plowing with oxen and hand-forged plowshares.

It is difficult to name a product that does not require, either directly or indirectly, the use of a machine tool somewhere in its manufacture. Today, no country can hope to compete successfully in a global economy without using the most advanced machine tools available. No industry or country can hope to take advantage of the most advanced machine tools without the aid of a ***machinist***—a person highly skilled in the use of machine tools and capable of creating the complex machine setups required for modern manufacturing.

CNC Software, Inc. ©Copyright 1983–2013. All rights reserved.

Figure 1-1. Machine tools have made it possible to manufacture parts with the precision and speed necessary for low-cost mass production. Without machine tools, most products on the market today would not be available or affordable.

These high-paying skilled jobs in manufacturing, such as tool and die making and precision machining, require aptitudes comparable to those of college graduates. Jobs that require few or no skills have almost disappeared.

1.1 The Evolution of Machine Tools

Machine tools are machines that can be used to manufacture other tools, including other machine tools. There are many variations of each type of machine tool, and they are available in many sizes. Tools range from those small enough to fit on a bench top to machines weighing several hundred tons.

The evolution of machine tools evokes the old question, "Which came first, the chicken or the egg?" You could also ask, "How could there be machine tools when there were no machine tools to make them?"

1.1.1 Early Machine Tools

The first machine tools, the bow lathe and bow drill, were handmade and human-powered. They have been dated back to about 1200 BC. Until the end of the seventeenth century, the lathe could be used only to turn softer materials, such as wood, ivory, or at most, soft metals such as lead or copper. Eventually, the bow lathe, with its reciprocating (back-and-forth) motion, gave way to treadle power, which made possible work rotation that was continuous in one direction. Later, machines were powered by a "great wheel" turned by flowing water or by a person or animal walking on a treadmill. Power was transmitted from the wheel to one or more machines by a belt and pulley system.

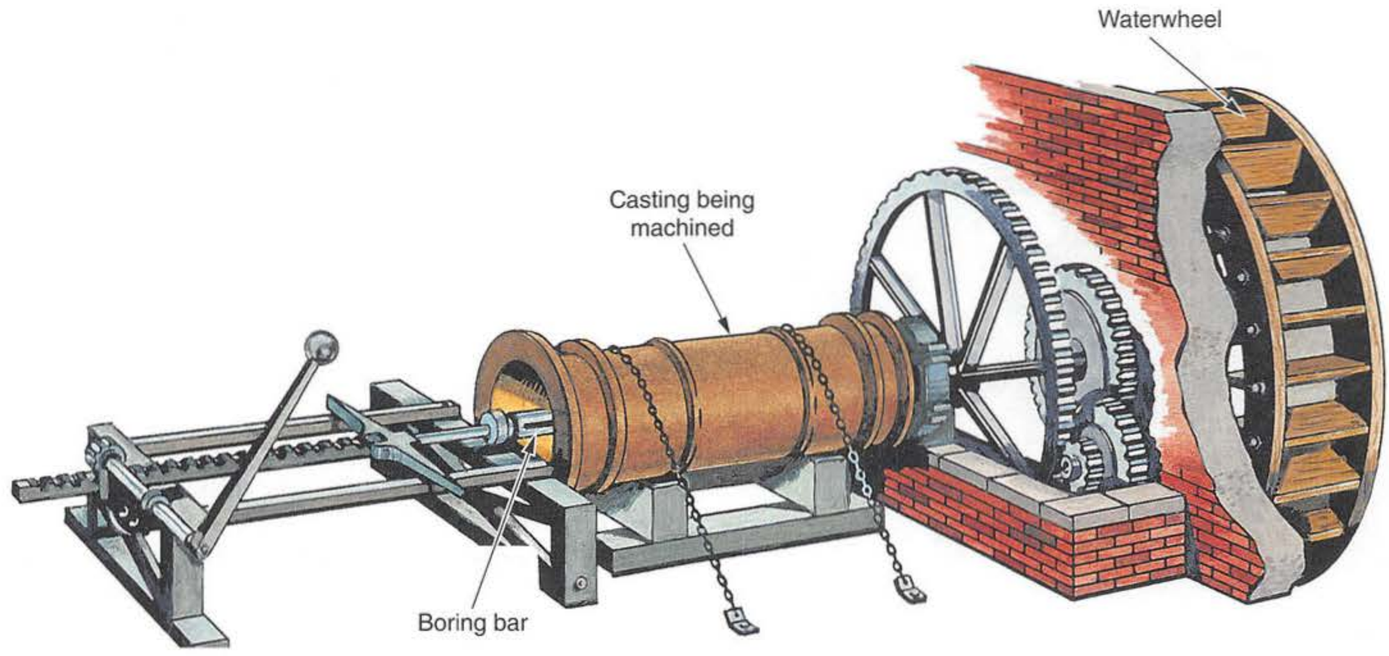
Boring Mill

When inventor James Watt first experimented with his steam engine, the need for perfectly bored cylinders soon became apparent. This brought about the development of the first true machine tool. It was a type of lathe and was called a "boring mill," **Figure 1-2**. The water-powered tool was developed in 1774 by Englishman John Wilkinson.

This machine was capable of turning a cylinder 36″ in diameter to an accuracy of a "thin-worn shilling" (an English coin about the size of a modern US quarter). However, operation of the boring mill, like that of all metal cutting lathes at the time, was hampered by the lack of tool control. The "mechanic" (the first machinist) had to unbolt and reposition the cutting tool after each cut.

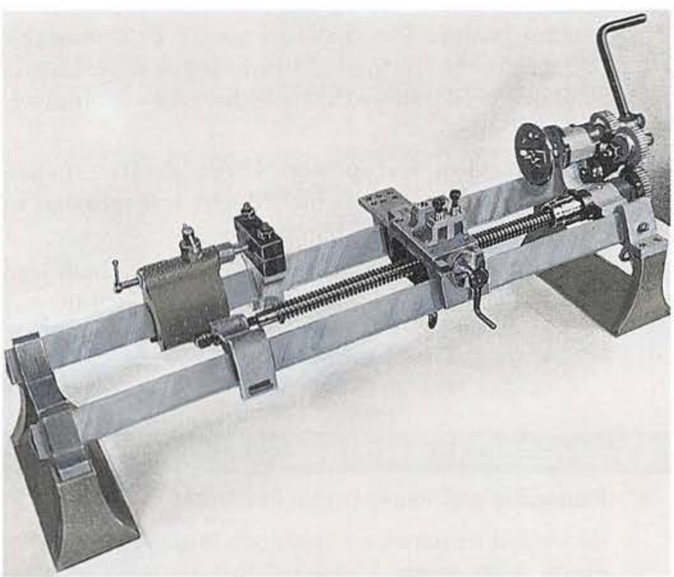
Lathe

The first lathe capable of cutting accurate screw threads was designed and constructed by Henry Maudslay, an English master mechanic and machine toolmaker, in about 1800. As shown in **Figure 1-3**, a handmade screw thread was geared



DoALL Co.

Figure 1-2. The first true machine tool is thought to be the boring mill invented by John Wilkinson in 1774. It enabled James Watt to complete the first successful steam engine. The boring bar was rigidly supported at both ends and was rotated by waterpower. It could bore a 36" diameter cylinder to an accuracy of less than 1/16".



DoALL Co.

Figure 1-3. Henry Maudslay's screw-cutting lathe. This machine tool, constructed on a heavy frame, combined a master lead screw and a movable slide rest. The lead screw had to be changed when a different thread pitch was required.

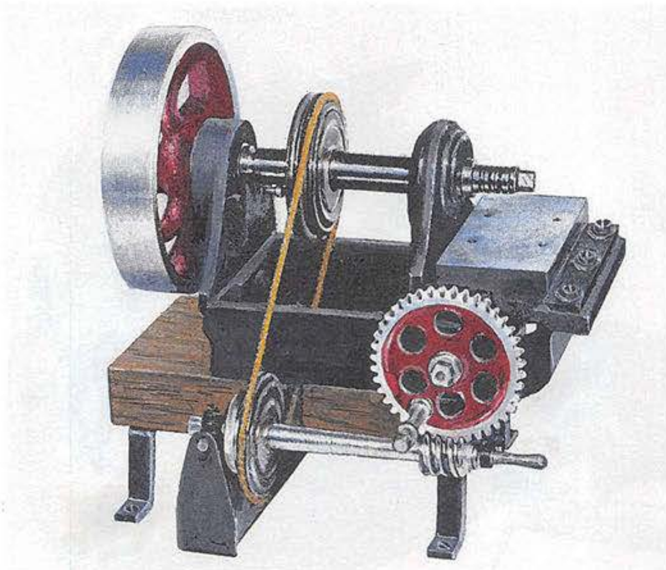
to the spindle and moved a cutting tool along the work. Maudslay also devised a slide rest and fitted it to his lathe. This allowed the cutting tool to be repositioned accurately after each cut. Maudslay's lathe is considered the "granddaddy" of all modern chip-making machine tools.

The Industrial Revolution could not have taken place if there had not been a cheap, convenient source of power: the steam engine. Until the advent of the steam engine, industry had to be located near a source of water power. This was often some distance from raw materials and workers. With cheap power, industry could be located where workers were plentiful and where the products they produced were needed. The steam engine, in turn, would not have been possible without machine tools. Until the boring mill and lathe were developed to the point that metal could be machined with some degree of accuracy, there could be no steam engine.

Milling Machine

The milling machine was the next important development in machine tools. It also evolved from the lathe. In 1820, Eli Whitney, an American inventor and manufacturer, devised a system to mass-produce muskets (guns). Whitney began using a milling machine, **Figure 1-4**, to make interchangeable musket parts. Until then, muskets were made individually by hand, so parts from one musket would not fit in another. Whitney's milling machine even had power feed, but it had one defect. There was no provision to raise the worktable. The part had to be raised by shimming after each cut. Since each machine was used to produce the same part again and again, this shortcoming was not a great problem, and it was soon corrected.

Whitney had another problem, however. His ideas were used in several armories producing gun parts. There was no standard of measurement at that time, so parts made in one



DoALL Co.

Figure 1-4. One of the first practical milling machines manufactured in America. Eli Whitney used this and similar machines to mass-produce interchangeable musket parts.

armory were not interchangeable with parts made in another armory. It was not until the mid-1860s that the United States adopted a standard measuring system.

Shaper

Another early machine tool that was important in the early machine shop was the shaper. The operation of early shapers was relatively simple. A single-point tool, much like those used in lathes, was held in a toolholder. The workpiece was clamped onto a table that was moved back and forth under the cutter. As the workpiece moved under the tool, the tool shaved material away from the workpiece. The toolholder was hinged so that, on the return stroke of the table, the tool was free to ride on top of the workpiece. When the tool cleared the workpiece, the toolholder dropped back into position. After the tool cleared the workpiece, the table moved sideways in preparation for another cutting stroke.

Later models used a hydraulic ram to move the tool in a linear motion for the cutting stroke. Another important innovation was the addition of electric limit switches that controlled the length of the stroke and the side-to-side indexing distance.

The primary use of the original shaper was to machine keyway slots and dovetails for linear slide control. It was also used to cut splines and teeth into gears. The addition of limit switches allowed the shaper to be used to clean up and reduce thicknesses of flat stock without direct supervision. This freed the worker to do other tasks while the shaper machined the workpiece.

By 1875, basic machine tools, such as the lathe, upright drill, and milling machine, **Figure 1-5**, were capable of attaining accuracies of one one-thousandth of an inch. This proficiency in machining and manufacturing would help America greatly during World War II. Factories were rapidly converted to produce military hardware instead of consumer goods. Of special importance to the war effort was the opening up of heavy industry professions to women. This supplied the labor needed to produce the large quantities of guns, ammunition, tanks, planes, and ships necessary to win the war, **Figure 1-6**.

1.1.2 Power Sources

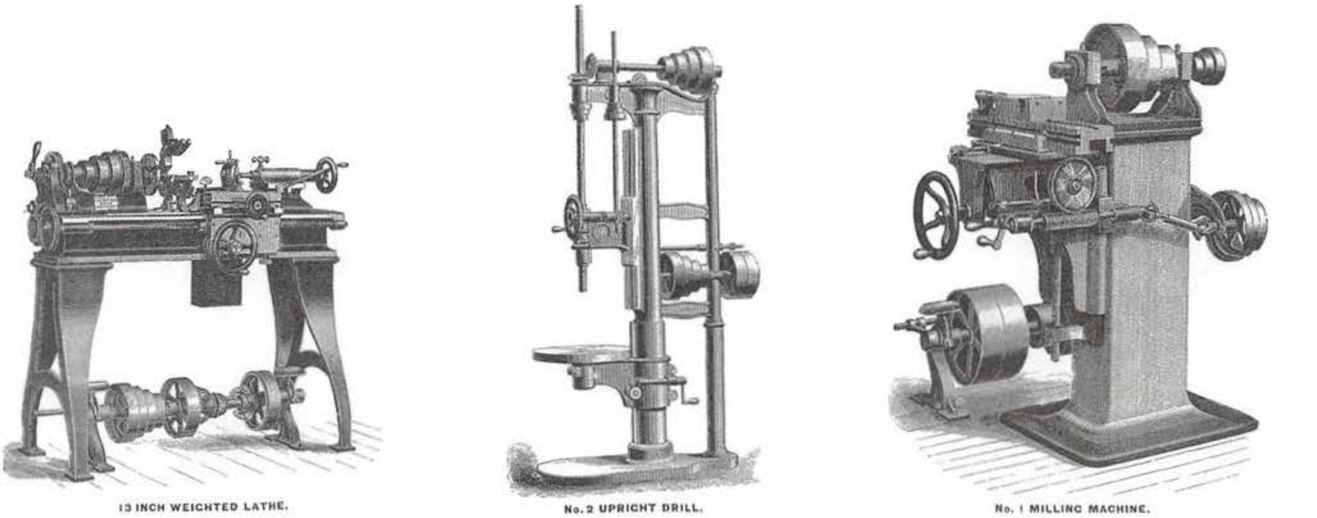
As machine tools were improved, so was the way they were powered. At first, the changes were very slow, occurring over hundreds of years. The greatest changes have come only in the last 150 years or so. The following are the various power sources used by machine tools throughout history in the order they evolved:

- **Hand power.** The bow lathe and bow drill are examples. The direction of rotation changed at each stroke of the bow.
- **Foot power.** A treadle or a treadmill made possible continuous rotation of the work in one direction.
- **Animal power.** Treadmills were used to power early devices for boring cannon barrels. Human foot power was not strong enough for this work.
- **Water power.** Not always dependable as a power source, because of lack of water during dry seasons.
- **Steam power.** The first real source of dependable power. A centrally located steam engine turned shafts and overhead pulleys that were belted to the individual machines.
- **Central electrical power.** Large electric motors replaced the steam engines. Power transmission to the machines did not change.
- **Individual electrical power.** Motors were built into the individual machine tools. Overhead belting was eliminated.

GREEN MACHINING

Renewable and Nonrenewable Resources

Renewable resources are resources, such as water, solar energy, wind energy, and wood, that are replaced naturally and fairly quickly. Humans can use these resources repeatedly because nature provides a steady supply. Nonrenewable resources take much longer to produce. Their rate of consumption (how quickly we use them) outpaces their rate of production (how quickly they are made). When possible, industrial applications now favor environmentally friendly renewables over nonrenewable resources like coal, natural gas, petroleum, and rare earth minerals. Renewable energy sources, such as wind or solar power, offer long-term environmental and economic benefits to manufacturing over nonrenewable fossil fuels.



Goodheart-Willcox Publisher

Figure 1-5. Illustrations of Pratt & Whitney machine tools from an 1876 advertisement. Built from heavy iron castings, the machines were driven by overhead pulleys and belting. A central steam engine or large electric motor powered the overhead pulleys in factories until the 1920s.

Library of Congress, Prints & Photograph Division, FSA-OWI Collection, LC-DIG-fsac-1a34951

Figure 1-6. Lathe operator machining parts for transport planes at the Consolidated Aircraft Corporation plant in Fort Worth, Texas.

Photo courtesy of Grizzly Industrial, Inc. www.grizzly.com

Figure 1-7. A modern lathe featuring chuck safety guard, foot brake, coolant system, inch/metric dials, and a universal gearbox capable of cutting inch, metric, and diametral threads. Except those tools that perform nontraditional machining operations, all machine tools have evolved from the lathe.

1.2 Basic Machine Tool Operation

Almost all machine tools have evolved from the ***lathe***, **Figure 1-7**. This machine tool performs one of the most important machining operations, ***turning***. It operates on the principle of rotating work against the edge of a cutting tool, as shown in **Figure 1-8**. Many other operations—drilling, boring, threadcutting, milling, and grinding—can also be performed on a lathe. The most advanced version of the lathe is the CNC turning center.

1.2.1 Sawing Machines

A ***sawing machine***, **Figure 1-9**, or saw, makes use of a multitoothed saw blade to cut away material. Sawing machines come in a variety of forms. All sawing machines perform one of two basic operations:

- **Cutoff sawing.** Sawing and cutoff machines cut stock material into more manageable lengths in preparation for other machining operations.
- **Band machining.** A vertical band saw uses a continuous saw blade. Chip removal is rapid and accuracy can be held to close tolerances, eliminating or minimizing many secondary machining operations.

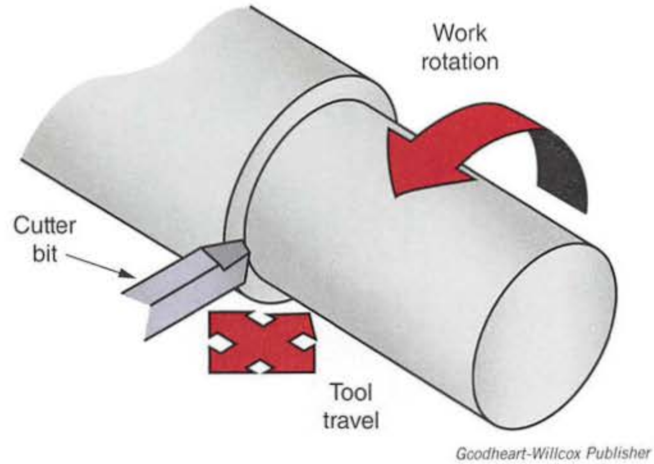


Figure 1-8. The lathe operates by rotating the work against the edge of a cutting tool.

Photo courtesy of Grizzly Industrial, Inc. www.grizzly.com

Figure 1-9. Sawing machines, like this horizontal band saw, make use of a continuous saw blade, with each tooth functioning as a precision cutting tool.

1.2.2 Drill Press

A ***drill press*****, Figure 1-10**, rotates a cutting tool (drill) against the material with sufficient pressure to cause the tool to penetrate the material. It is primarily used for cutting round holes. See **Figure 1-11**. Drill presses are available in many versions. Some are designed to machine holes as small as 0.0016" (0.04 mm) in diameter.

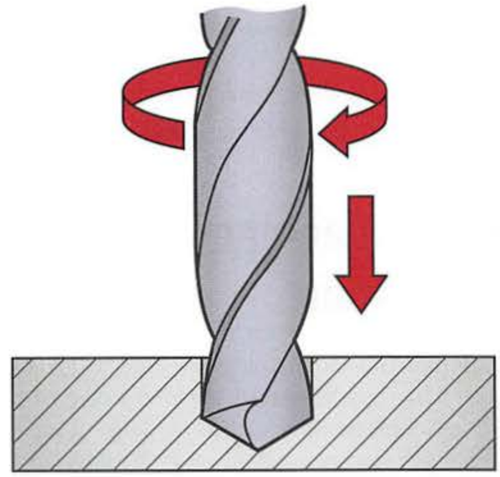
1.2.3 Grinding Machines

A ***grinding machine*****, Figure 1-12**, or grinder, removes metal by rotating a grinding wheel or abrasive belt against the work. The process falls into two basic categories:

- **Offhand grinding.** Work that does not require great accuracy is handheld and manipulated until ground to the desired shape.

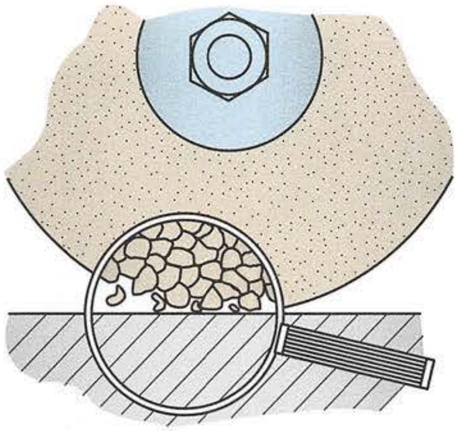
Willis Machinery and Tools Corp.

Figure 1-10. A typical 20" variable-speed gearhead drill press with power feed. It can drill holes up to 1 1/2" in diameter in cast iron.



Goodheart-Willcox Publisher

Figure 1-11. A drill press operates by rotating a cutting tool (drill) against the material with sufficient pressure to cause the tool to penetrate the material.



Goodheart-Willcox Publisher

Figure 1-12. Grinding is a cutting operation, like turning, drilling, milling, or sawing. However, instead of the one, two, or multiple-edge cutting tools used in other applications, grinding uses an abrasive tool composed of thousands of cutting edges.

- **Precision grinding.** Only a small amount of material is removed with each pass of the grinding wheel, so that a smooth, accurate surface is generated. Precision grinding is a finishing operation.

1.2.4 Milling Machine

A ***milling machine*** rotates a multitoothed cutter into the work, **Figure 1-13**. A variety of cutting operations can be performed on milling machines, including machining flat or contoured surfaces, slots, grooves, recesses, threads, gears, and spirals. Milling machines are available in more variations than any other family of machine tools, **Figure 1-14**, and are well suited to computer-controlled operation. The most advanced version of a milling machine is the CNC milling center.

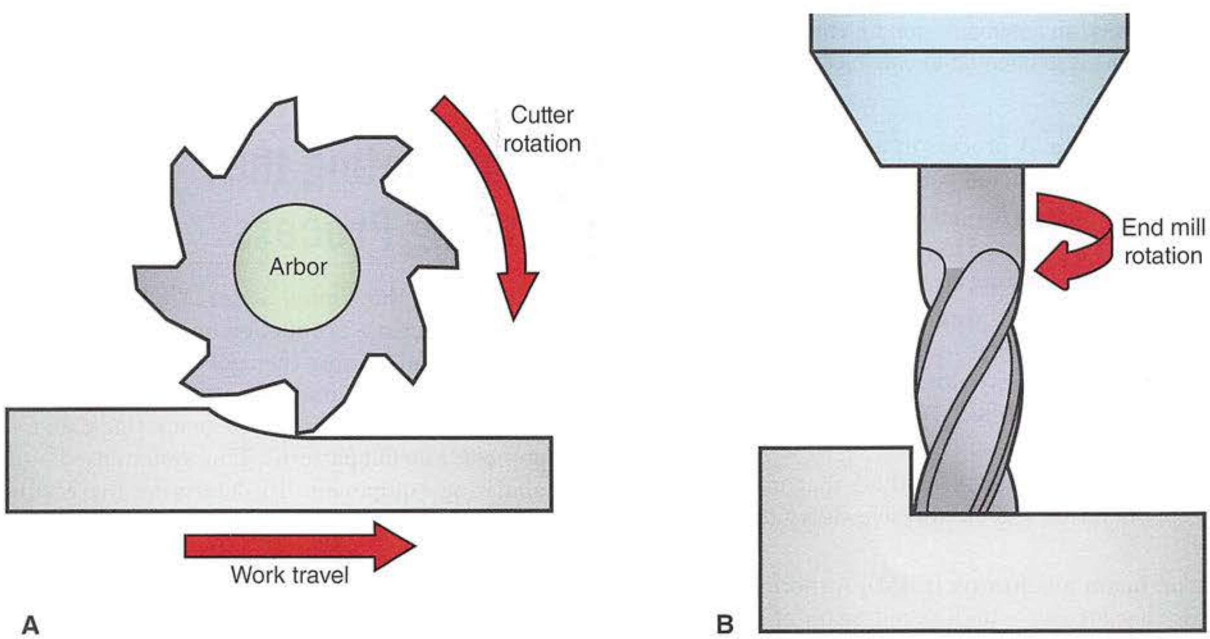
1.2.5 Broaching Machines

A ***broaching machine*** is designed to push or pull a multitoothed cutter across the work, **Figure 1-15**. Each tooth of the broach (cutting tool) removes only a small amount of the material being machined.

1.3 Nontraditional Machining Processes

A number of machining operations have not evolved from the lathe. They are classified as nontraditional machining processes. These processes include the following:

- **Electrical discharge machining (EDM).** An advanced machining process that uses a fine, accurately controlled electric spark to erode metal.
- **Electrochemical machining (ECM).** A method of material removal that shapes a workpiece by removing electrons from its surface atoms. In effect, ECM is exactly the opposite of electroplating.



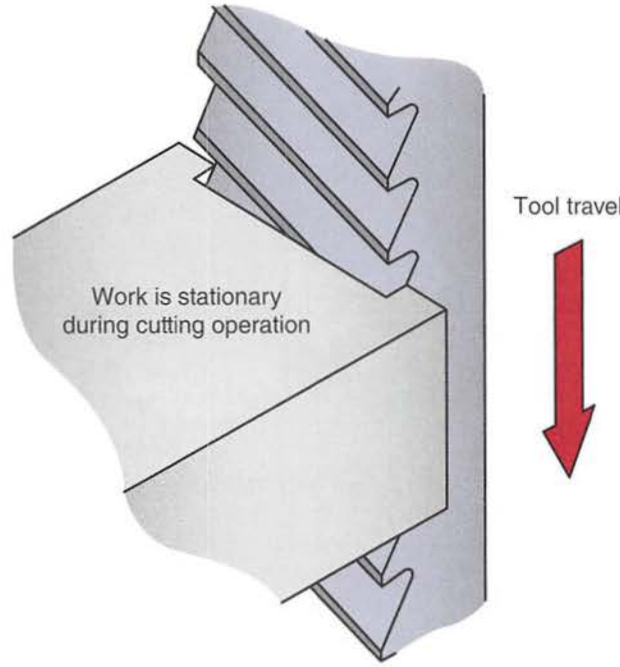
Goodheart-Willcox Publisher

Figure 1-13. Milling removes material by rotating a multitoothed cutter into the work. A—In peripheral milling, the surface being machined is parallel to periphery of the cutter. B—End mills have cutting edges on the circumference and the end of the cutter.

Photo courtesy of Grizzly Industrial, Inc. www.grizzly.com

Figure 1-14. A modern milling machine featuring power feed, variable speed controls, an automatic stop function, coordinate display, and selectable resolution up to one micrometer.

- **Chemical milling.** A process in which chemicals are used to etch away selected portions of metal.
- **Chemical blanking.** A material removal method in which chemicals are used to produce small, intricate, ultrathin parts by etching away unwanted material.
- **Hydrodynamic machining (HDM).** A computer-controlled technique that uses a 55,000 psi water jet to cut complex shapes with minimum waste. The work can be accomplished with or without abrasives added to the jet.
- **Ultrasonic machining.** A method that uses ultrasonic sound waves and an abrasive slurry to remove metal.
- **Electron beam machining (EBM).** A thermoelectric process that focuses a high-speed beam of electrons on the workpiece. The heat that is generated vaporizes the metal.



Goodheart-Willcox Publisher

Figure 1-15. A broach is a multitoothed cutting tool that moves against the work. Each tooth removes only a small portion of the material being machined. The cutting operation may be on a vertical or horizontal plane.

- **Laser machining.** The laser produces an intense beam of light that can be focused onto an area only a few microns in diameter. It is useful for cutting and drilling.

1.4 Automating the Machining Process

In the late 1940s, the United States Air Force was searching for ways to increase production on complex parts for the new jet aircraft and missiles then going into production. The Parsons Corporation, a manufacturer of aircraft parts, had developed a two-axis technique for generating data to check helicopter blade airfoil patterns. This system used punched-card tabulating equipment. To determine the accuracy of the data, a pattern was mounted on a Bridgeport milling machine. With a dial indicator in place, the X and Y points were called out to a machinist operating the machine's X-axis handwheel and another machinist who controlled the Y-axis handwheel. With enough reference points established, the generated data proved accurate to ±0.0015″ (0.038 mm).

1.4.1 The Development of Numerical Control

Parsons realized that the technique might also be developed into a two-axis, or even three-axis, machining system. With an Air Force contract to manufacture a contoured, integrally stiffened aircraft wing section, the Parsons Corporation subcontracted with the Servomechanism Laboratory at the Massachusetts Institute of Technology (MIT) to design a three-axis machining system. MIT eventually took over the entire development project.

By 1952, MIT had designed a control system and mounted it on a vertical spindle machine tool. The system operated on instructions coded in the binary number system on punched (perforated) tape. Programming required the use of an early computer on which MIT was also experimenting.

Later in that year, MIT demonstrated the first machine tool capable of executing simultaneous cutting tool movement on three axes. Since mathematical information was the basis of the concept, MIT coined the term ***numerical control (NC)***. The first NC machines became available to industry in 1955.

1.4.2 Computer Numerical Control

In the mid-1970s, with the introduction of the microchip, the use of onboard computers on individual machine tools became possible. This led to the introduction of ***computer numerical control (CNC)***, **Figure 1-16**.

CNC machine tools are much easier to use than manually controlled machines. They have menu-selectable displays, advanced graphics (the multifunction screen displays the full operational data as a part is being machined), and a word address format for programming. The program is made up of sentence-like commands. Programs can be entered at the machine or downloaded from an external computer. Programs on punched tapes are no longer used. A modern CNC machining center is shown in **Figure 1-17**.

WORKPLACE SKILLS

Joining Organizations

Belonging to a student or professional organization can help you reach your career goals. You will find student and professional organizations focused on almost every career topic. They will help you learn more about career options and meet other students and professionals who can help you establish a career. They will also help you learn teamwork skills that are needed in the workplace. Organizations that may help you prepare for a career in machining include the following:

- *SkillsUSA* is an organization for students preparing for technical, trade, and skilled-service occupations. Its goal is to create a strong American workforce. SkillsUSA programs include the Professional Development Program, which builds employability skills, such as communication and teamwork. The Work Force Ready System offers assessments for career and technical education, including areas such as technical drafting, residential wiring, and plumbing.
- *National Institute for Metalworking Skills (NIMS)* is an organization for students seeking training for a career in the machining and metalworking industries. NIMS accredits machining and metalworking programs and offers students credentials to prove their skills to future employers. NIMS offers credentials in manual milling, turning operations, and CNC machining among numerous other metalworking skills.
- *Society of Manufacturing Engineers (SME)* is a professional organization that supports manufacturing education. SME offers membership to students who have an interest in a STEM (science, technology, engineering, and mathematics) field or a career in the manufacturing industry. SME also recognizes and financially supports outstanding high school manufacturing programs.

Becoming involved in student and professional organizations now can help you land a job in your chosen field after completing your training. Your membership shows employers that you are already involved in the organization and serious about a career in a specific area.

Other professional organizations with student members include the National Society of Professional Engineers (NSPE), American Society for Quality (ASQ), American Welding Society (AWS), and ASM International. To be a student member of these organizations, you must be enrolled in a certain number of courses that will lead to a career in the given area. There is also a fee, which is usually less than a professional membership fee.