Preface

Machinists are highly skilled professionals. 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. The latest geometric dimensioning and tolerancing (GD&T) standards from ASME Y14.5 are also covered.

Machining Fundamentals has many features that make it easy to read and understand. The headings in each chapter are numbered to quickly locate specific information within a chapter. A chapter outline lists major chapter headings at the beginning of each chapter. Learning outcomes are also presented in the chapter opener, along with a list of selected technical terms that are 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. 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. *Tech Tip* features give students valuable knowledge that will help them as they progress toward their professional machining or manufacturing careers.

Each chapter closes with a chapter review containing a summary and review questions. The summary reiterates and expands on the learning outcomes given in the chapter opener. Review questions reinforce key learning outcomes and offer students the opportunity to check their understanding. Apply and Analyze and Critical Thinking questions encourage students to think critically about the value and purpose of their new knowledge and apply what they have learned to practical work situations.

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

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About the Authors

John Templeton has 30 years of experience in manufacturing and CNC machining, including industry and technical education. As a manufacturing instructor, he has developed curriculum in CNC programming, CAD/CAM, machining processes, and quality assurance. Mr. Templeton's journey began with a four-year apprenticeship in the United Kingdom while also studying at Darlington College of Technology. After graduating, he progressed through a variety of fields in the machining industry, with positions of note including work as a Tool & Die Maker; CNC Programmer; Lead Machinist; and Prototype/R&D Machinist working with advanced aerospace metals, composites, and polymers. Mr. Templeton also provides consulting services and customized training programs for machine shops and related manufacturing industries. Mr. Templeton currently teaches the Advanced Manufacturing CTE pathway in the Downey Unified School District in California. He has also previously taught in post-secondary education, as well as apprenticeship classes.

Bob Dixon is a former 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.

John R. Walker is the author of 13 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 five 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.

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New to This Edition

This new edition of *Machining Fundamentals* brings the content up to date with the latest standards and industry practices. End-of-chapter reviews have been improved, with summary points and review questions tied directly to the main heading sections within the chapters. Apply and Analyze and Critical Thinking questions allow students to apply the knowledge from the chapters in practical scenarios and contemplate and expand on the importance and usefulness of what they have learned. Details of the new elements in this edition include:

- Updated content includes new photos and illustrations and reflects industry changes in technology, as well as practical workplace skills and troubleshooting tips.
- CNC programming coverage has been expanded, including sample coding projects in Chapter 23: *CNC Milling* and Chapter 24: *CNC Turning*.
- New Chapter 4: *Math Review* provides numerous practice problems and review questions to allow students to get up to speed with the math skills they need to pursue a career in machining.

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Credentialing Partners and Support

Goodheart-Willcox appreciates the value of industry credentials, certifications, and accreditation. We are pleased to partner with leading organizations to support students and programs in achieving credentials. Integrating industry-recognized credentialing into a career and technical education (CTE) program provides many benefits for the student and for the institution. By achieving third-party certification, students gain confidence, have proof of a measurable level of knowledge and skills, and earn a valuable achievement to include in their résumés. For educators and administrators, industry-recognized credentials and accreditation validate learning, enhance the credibility of programs, and provide valuable data to measure student performance and help guide continuous program improvement.

Machining Fundamentals is correlated to the Level I Machining Credentials offered by NIMS and to the Manufacturing Technology and Precision Machining NOCTI Certifications.

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Goodheart-Willcox is pleased to partner with NOCTI and Nocti Business Solutions (NBS), a leading provider of industry certification solutions for skill verification across the nation. With over 55 years of experience, NOCTI/NBS is a valuable partner within both the CTE community and industry to improve America's workforce. Goodheart-Willcox has created correlations between select products and the standards and competencies that are the basis for NOCTI/NBS credentials, to the benefit of states, instructors, and students working toward NOCTI/NBS credentials.

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To see how *Machining Fundamentals* correlates to credentialing and certification standards, visit the Correlations tab at www.g-w.com/machining-fundamentals-2028.

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Features of the Textbook

The instructional design of this textbook includes student-focused learning tools to help you succeed. This visual guide highlights these features.

Chapter Opening Materials

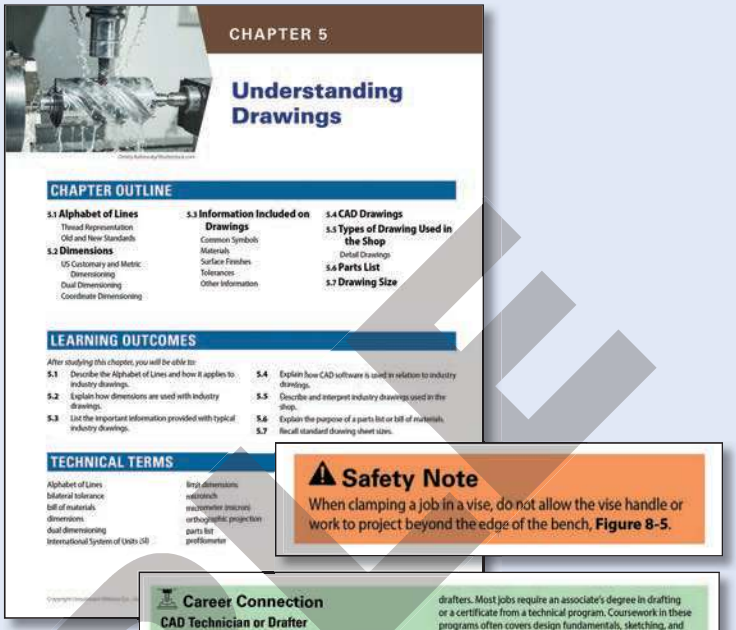
Each chapter opener contains a chapter outline, a list of learning outcomes, and a list of technical terms. The **Chapter Outline** summarizes the topics that will be covered in the chapter. **Learning Outcomes** clearly identify the knowledge and skills to be gained when the chapter is completed. These outcomes are labeled and correlated to related assessment elements to facilitate reporting and remediation. **Technical Terms** list the key words to be learned in the chapter.

Additional Features

Additional features are used throughout the body of each chapter to further learning and knowledge. **Safety Notes** alert you to potentially dangerous materials and practices. **Career Connection** features provide information about a variety of paths to career success. **Workplace Skills** features highlight the professional behaviors and traits that employers want and expect. **Pro Tips** provide advice and guidance that is especially applicable for on-the-job situations.

Illustrations

Illustrations have been designed to clearly and simply communicate the specific topic. Illustrations have been completely replaced and updated for this edition. Photographic images have been updated to show the latest equipment.


CHAPTER 5

Understanding Drawings

CHAPTER OUTLINE

5.1 Alphabet of Lines
Thread Representation
Old and New Standards
5.2 Dimensions
US Customary and Metric Dimensioning
Dual Dimensioning
Coordinate Dimensioning
5.3 Information Included on Drawings
Common Symbols
Materials
Surface Finishes
Tolerances
Other Information
5.4 CAD Drawings
5.5 Types of Drawing Used in the Shop
Detail Drawings
5.6 Parts List
5.7 Drawing Size

LEARNING OUTCOMES

After studying this chapter, you will be able to:
5.1 Describe the Alphabet of Lines and how it applies to industry drawings.
5.2 Explain how dimensions are used with industry drawings.
5.3 List the important information provided with typical industry drawings.
5.4 Explain how CAD software is used in relation to industry drawings.
5.5 Describe and interpret industry drawings used in the shop.
5.6 Explain the purpose of a parts list or bill of materials.
5.7 Recall standard drawing sheet sizes.

TECHNICAL TERMS

Alphabet of Lines
bilateral tolerance
bill of materials
dimensions
dual dimensioning
International System of Units (SI)
limit dimensions
micrometer
micrometer (microm)
orthographic projection
parts list
profilometer

Safety Note

When clamping a job in a vise, do not allow the vise handle or work to project beyond the edge of the bench, **Figure 8-5**.


Career Connection

CAD Technician or Drafter

What does a CAD technician do?

CAD technicians, also known as CAD drafters, work with engineers, architects, and other designers to convert designs into digital technical drawings. They use computer-aided drafting (CAD) to draw and structure designs digitally. Building information modeling (BIM) is also used to render interactive 3D models from the original technical specifications. Once designs become digital technical drawings or models, they can be stored, shared, and edited via computer as the project progresses. Information collected with BIM can even be used to maintain a structure during its lifetime.

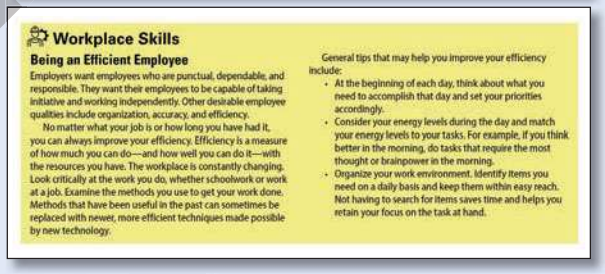
What education and skills are needed to be a CAD technician?

Highly specialized training from technical schools or community colleges is required for CAD technicians or drafters. Most jobs require an associate's degree in drafting or a certificate from a technical program. Coursework in these programs often covers design fundamentals, sketching, and creating drawings with CAD. High school students interested in drafting should prepare themselves with courses in mathematics, science, computer technology, drafting, and design.

What is it like to be a CAD technician?

CAD technicians or drafters most often work in the architectural, engineering, manufacturing, and construction industries. While they primarily work in offices, CAD technicians may travel to jobsites to monitor projects and refine designs, if needed.

According to the *Occupational Outlook Handbook*, the median annual wage for a CAD technician or CAD drafter was $65,380 in May 2024.


Workplace Skills

Being an Efficient Employee

Employers want employees who are punctual, dependable, and responsible. They want their employees to be capable of taking initiative and working independently. Other desirable employee qualities include organization, accuracy, and efficiency.

No matter what your job is or how long you have had it, you can always improve your efficiency. Efficiency is a measure of how much you can do—and how well you can do it—with the resources you have. The workplace is constantly changing. Look critically at the work you do, whether schoolwork or work at a job. Examine the methods you use to get your work done. Methods that have been useful in the past can sometimes be replaced with newer, more efficient techniques made possible by new technology.

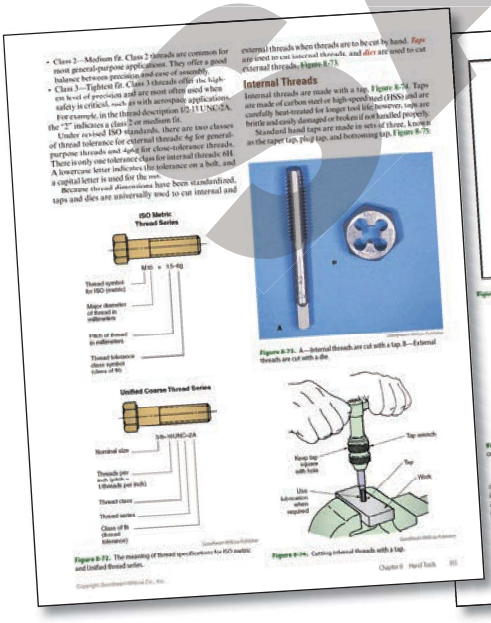
General tips that may help you improve your efficiency include:

- At the beginning of each day, think about what you need to accomplish that day and set your priorities accordingly.
- Consider your energy levels during the day and match your energy levels to your tasks. For example, if you think better in the morning, do tasks that require the most thought or brainpower in the morning.
- Organize your work environment. Identify items you need on a daily basis and keep them within easy reach. Not having to search for items saves time and helps you retain your focus on the task at hand.

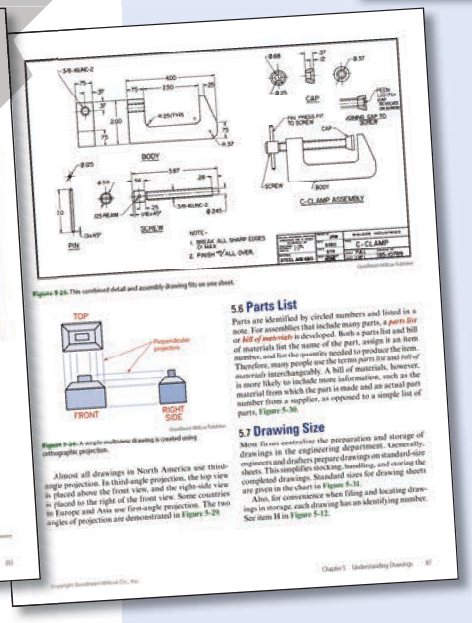

Pro Tip

Tungsten Carbide Scrap

Machine shops collect and store worn-out tungsten carbide drills for resale. Industry recyclers pay high rates for scrap tungsten carbide and recycle it into raw material ready for new uses. Tungsten carbide is one of the most sought-after ceramic scraps because of its strength and suitability for reuse. Reselling these old tungsten carbide drills benefits shops economically while also saving resources.


Internal Threads

Internal threads are made with a tap. **Figure 8-74.** Taps are made of carbon steel or high-speed steel (HSS) and are carefully heat-treated for longer tool life; however, taps are brittle and easily damaged or broken if not handled properly. Standard hand taps are made in sets of three, known as the taper tap, plug tap, and bottoming tap. **Figure 8-75.**


5.6 Parts List

Parts are identified by circled numbers and listed in a note. For assemblies that include many parts, a *parts list* or *bill of materials* is developed. Both a parts list and bill of materials list the name of the part, assign it an item number, and list the quantity needed to produce the item. Therefore, many people use the terms *parts list* and *bill of materials* interchangeably. A bill of materials, however, is more likely to include more information, such as the material from which the part is made and an actual part number from a supplier, as opposed to a simple list of parts, **Figure 5-30.**

5.7 Drawing Size

Most firms centralize the preparation and storage of drawings in the engineering department. Accurately engineers and drafters prepare drawings on standard-size sheets. This simplifies stocking, handling, and storing the completed drawings. Standard sizes for drawing sheets are given in the chart in **Figure 5-31.**

Also, for convenience when filing and locating drawings in storage, each drawing has an identifying number. See item H in **Figure 5-12.**

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Chapter 20 Review

SUMMARY

- Precision grinding operates by removing a small amount of material through abrasive action to generate a smooth, accurate surface. The two basic types of precision grinders are planar and rotary surface grinders. (20.1)
- Workholding devices for surface grinding include magnetic and electromagnetic chucks, parallels and blocks for nonferrous materials, a universal vise, an indexing head with centers, clamps, a precision vise, and double-faced masking tape. (20.2)
- ANSI/UAMA B74.13-2016 standardizes grinding wheel markings and is used by all grinding wheel manufacturers. Use the markings when selecting, mounting, dressing, and truing a grinding wheel. (20.3)
- Cutting fluids help reduce wear on the grinding wheel, maintain accurate dimensions and finish quality, and remove heat generated during the grinding operation. Cutting fluids used for grinding operations include water-soluble chemical fluids, neosynthetic coolants with polymers, and water-soluble oil fluids. (20.4)
- The first steps in a surface grinding procedure are to select and mount a suitable grinding wheel, true and dress the wheel with a diamond dressing tool, mount the workholding device, and check the coolant system to be sure it is operating satisfactorily. (20.5)
- Most problems with precision surface grinding can be identified and corrected by carefully checking the machine settings and characteristics of the wheel. (20.6)
- All safety guidelines must be followed when surface grinding to ensure the safety of the operator and any bystanders. (20.7)
- A universal tool and cutter grinder is primarily used to sharpen cutters, such as milling cutters, to specified tolerances. Attachments permit straight, spiral, and helical cutters to be sharpened accurately. (20.8)
- A grinding procedure can be used to sharpen various types of cutter and machine tool. (20.9)
- Straight, taper, and form grinding operations are possible with cylindrical grinding. Two variations of cylindrical grinding are traverse grinding and plunge grinding. (20.10)
- Internal grinding is done to produce a fine surface finish with high accuracy on inside diameters. (20.11)
- Centerless grinding is used when large quantities of the same part are required. There are four variations of centerless grinding: through-feed, infeed, end-feed, and internal centerless grinding. (20.12)
- In form grinding, the grinding wheel is shaped to produce the required contour on the work, such as for thread grinding. (20.13)
- Industry makes considerable use of other abrasive processes, including abrasive belt grinding, electrolytic grinding, and grinding using computer numerical control (CNC) grinders. (20.14)

REVIEW QUESTIONS

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

Know and Understand

1. On the ideal grinding wheel, the bonding material will wear away _____. (20.1)
   A. slowly enough to get the maximum use from the individual abrasive grains
   B. quickly enough for dull abrasive particles to drop off and expose new particles
   C. Both A and B are correct.
   D. None are correct.
2. Industry classifies surface grinding as the grinding of _____ surfaces. (20.1)
   A. contoured
   B. flat
   C. cylindrical
   D. angled
3. *True or False?* Much of the work machined on a surface grinder is held in position by a magnetic chuck. (20.2)
4. Which of the following is not one of the five distinguishing characteristics of a grinding wheel? (20.3)
   A. abrasive type
   B. glazing
   C. grain size
   D. bond type
5. Why are cutting fluids or coolants necessary for grinding operations? (20.4)
   A. They help maintain accurate dimensions.
   B. They help ensure a high-quality surface finish.
   C. They remove heat generated during the grinding operation.
   D. All are correct.
6. _____ can be added to water-soluble oil fluids to keep them from turning rancid. (20.4)
   A. Bleach
   B. Ammonia
   C. Bacteriostats
   D. Denatured alcohol

12. A _____ is a grinding machine designed to support cutters (usually milling cutters) while they are being sharpened. (20.8)
    A. creep feed grinder
    B. slabbing cutter
    C. universal tool and cutter grinder
    D. cylindrical grinder
13. When grinding plain milling cutters, set up the cutter so the wheel _____. (20.9)
    A. grinds into the cutting edge of the tooth
    B. grinds away from the tooth cutting edge
    C. is held against the tooth rest
    D. None are correct.
14. With _____ grinding, work wider than the face of the grinding wheel can be ground. (20.10)
    A. plunge
    B. form
    C. traverse
    D. creep
15. _____ grinding is done to produce a fine surface finish with high accuracy on inside diameters. (20.11)
    A. Form
    B. Creep
    C. Traverse
    D. Internal
16. In _____ grinding, it is not necessary to support work between centers or mount work in a chuck while it is being rotated against the grinding wheel. (20.12)
    A. surface
    B. cylindrical
    C. internal
    D. centerless
17. Thread grinding is an example of _____ grinding. (20.13)
    A. form
    B. centerless
    C. internal
    D. creep
18. *True or False?* Electrolytic grinding is actually an electrochemical machining process. (20.14)
19. *True or False?* Abrasive belts run cool and require light contact pressure, reducing the possibility of metal distortion caused by heat. (20.14)
20. The best method to precisely grind contoured surfaces is to use a _____. (20.14)
    A. surface grinder
    B. cylindrical grinder
    C. centerless grinder
    D. CNC grinder

Apply and Analyze

1. Name three workholding devices used to hold work for surface grinding. (20.2)
2. A(n) _____ dressing tool is usually used to true and dress wheels for precision grinding. (20.3)
3. Explain the process of checking a grinding wheel for soundness, including what should be done when a grinding wheel that is unfit for use is found. (20.5, 20.7)
4. What is the difference between conventional grinding and creep grinding? (20.5)
5. What is the purpose of a tooth rest? (20.9)
6. List the two variations of cylindrical grinding. (20.10)
7. What is the primary purpose of internal grinding? (20.11)
8. Briefly describe form grinding. (20.13)
9. The grinding technique that uses a belt on which abrasive particles are bonded for stock removal, finishing, and polishing operations is known as _____. (20.14)
10. Describe the machining process involved in electrolytic grinding. (20.14)

Critical Thinking

1. Consider the following grinding wheel marking and explain what each letter and number means. (20.3)
   A 60 J 8 V
2. If a colleague is experiencing irregular scratches while grinding, what would you recommend to troubleshoot the problem? (20.6)

End-of-Chapter Content

End-of-chapter material provides an opportunity for review and application of concepts. A concise **Summary** provides an additional review tool and reinforces key learning outcomes. This helps you focus on important concepts presented in the text. **Know and Understand** questions enable you to demonstrate knowledge, identification, and comprehension of chapter material. **Apply and Analyze** questions extend learning and develop your abilities to use learned material in new situations and to break down material into its component parts. **Critical Thinking** questions develop higher-order thinking and problem-solving abilities.

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
- Workholding and tool-holding devices
- Fasteners
- Abrasives
- Fluids
- Miscellaneous
- Direction or force arrows, dimensional information

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