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Precision Machining TECHNOLOGY

Third Edition

NIMS®

Peter Hoffman • Eric Hopewell

Precision Machining Technology

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Third Edition

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***Precision Machining Technology*, Third Edition**
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PREFACE

Precision Machining Technology introduces students, both at the secondary and postsecondary levels, to the exciting world of precision machining technology as it is practiced in the 21st century. In writing this text, the authors' main goal is to provide a deep understanding of the fundamental and intermediate machining skills needed for career success in a rapidly changing manufacturing environment. In line with this objective, the author team has taken special care to ensure that the text:

- Has a down-to-earth, practical orientation that covers what students need to know about the field of precision machining as it is practiced today
- Develops modern interpersonal skills that are demanded by the job market
- Covers current career information and trends
- Includes modern shop practices
- Contains specific instructions and examples, with images showing many step-by-step applications
- Provides in-depth knowledge as a base for strong foundational skills without becoming difficult to read or comprehend
- Includes current computer numerical control (CNC) content with various programming examples.

This text is written for students of precision machining at the secondary and postsecondary levels who have the opportunity and desire to learn skills required by the precision machining industry and to obtain NIMS certifications. The book is written in such a way that the student needs no prior knowledge of machining to benefit.

Precision Machining Technology has been sponsored and endorsed by NIMS. The text and its supporting supplements fill the need of comprehensively covering all of the material encountered by a student during the NIMS certification process, and were written with the Machining Level I Standards in mind. The text's close adherence to NIMS's nationally recognized skills standards will be especially useful for schools and school districts that wish to comply with the funding requirements of the Carl D. Perkins Career and Technical Education Act of 2006 (Perkins IV).

How the Text Was Developed

In order to create a truly new set of teaching and learning tools, *Precision Machining Technology* was launched with no preconceived notion of how the text should be designed. A large number of instructors at NIMS-accredited programs participated in the initial development of the table of contents, which then led to the recruitment of the author team, also from NIMS-accredited programs. During the development of the project, over a dozen instructors reviewed drafts of the manuscript and provided useful feedback to the authors. Their input has played a major role in improving the final product. Last, the publisher and NIMS committed to an extra developmental step, class-testing the manuscript at multiple institutions, in order to assure the highest level of accuracy and teaching effectiveness. Reviewers and class-testers are listed in the Acknowledgments section.

To enhance the teaching and learning experience, the authors developed the text with the following objectives in mind:

- Achieve an easy-to-read writing style that assumes the student has no prior knowledge of machining and takes the student all the way through to the intermediate stage
- Include many images to clarify explanations and procedures so students can make visual connections
- Identify key and secondary terms throughout the text to guide students to important points

- Assume that students are taking or have already taken basic geometry, basic algebra, and have good proficiency in computation of fractions, decimals, and order of operations
- Allow for the companion *Workbook/Projects Manual* to provide a beneficial measure of practice to prepare the student for NIMS product creation and the knowledge examination

Organization of the Text

In designing *Precision Machining Technology*, the authors followed the typical progression through the NIMS certifications. For many of the sections, a student should have sufficient knowledge to obtain a NIMS certification at the completion of the sections.

The text is divided into eight major sections, as follows:

Section 1—Introduction to Machining
Section 2—Measurement, Materials, and Safety
Section 3—Job Planning, Benchwork, and Layout
Section 4—Drill Press
Section 5—Turning
Section 6—Milling
Section 7—Grinding
Section 8—Computer Numerical Control (CNC)

Each section of the text contains multiple "bite-sized" units, which provide the following teaching and learning aids: learning objectives, key terms, caution safety checks, chapter summary, and review questions.

Special care was taken to make each unit progress in a logical presentation of content for someone with no prior knowledge. The authors took steps to ensure that no new terminology was presented prior to a complete explanation of each term. Each unit builds on another, and many sections build on previous sections. As the text progresses, topics are explored more deeply. Previous knowledge is reinforced through new application of previous information.

What's New in This Edition

- Increased CNC programming content including additional canned cycles
- CNC programming examples with graphics presented in both Fanuc and Haas formats, two of the most widely used industry formats
- Multi-step procedures modified to a bulleted format to make following steps easier
- Expanded details in many areas including optical comparator use, hazardous materials, key and keyseat machining, and more
- Updated images to complement textual content
- This edition of Precision Machining Technology is also correlated to Precision Exams' Machining I and Machining II exams, part of the Manufacturing Career Cluster's Production Pathway.

A Note for Students: How to Use This Text

Do not become overwhelmed with all of the information. The text is arranged so that you may take each piece step by step. Pause and think about key and secondary terms while reading.

Supplements

Workbook and Projects Manual

The student Workbook and Projects Manual contains helpful review material to ensure that students have mastered key concepts in the text, and guided practice operations and projects on a wide range of machine tools that will enhance their NIMS credentialing success. All projects are keyed to NIMS Duties and Standards.

Instructor Companion Website

The Instructor Companion Website, found on cengage.com, includes the following components to help minimize instructor preparation time and engage students:

PowerPoint® lecture slides, which present the highlights of each chapter.

An **Image Gallery,** which offers a database of hundreds of images in the text. These can easily be imported into the PowerPoint® presentations.

An **Answer Key** file for the Core text and Workbook, which provides the answers to all end-of-chapter questions and the questions in the Workbook.

Cengage Learning Testing Powered by Cognero—a flexible online system that allows you to:

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MindTap for Precision Machining Technology

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- *Measure Skills and Outcomes*: Analytics and reports provide a snapshot of class progress, time on task, engagement, and completion rates.

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Eric Hopewell

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INTRODUCTION TO MACHINING SECTION 1

- Unit 1
  Introduction to Machining

- Unit 2
  Careers in Machining

- Unit 3
  Workplace Skills

UNIT 1 Introduction to Machining

Learning Objectives

After completing this unit, the student should be able to:

- Define the term *machining*
- Define a machine tool
- Discuss the evolution of machining and machine tools
- Identify the role of machining in society
- Discuss the principles of the basic types of machining processes

Key Terms

Abrasive machining
Computer Numerical Control (CNC)
Drill press
Electrical Discharge Machining (EDM)
End product
Laser machining
Lathe
Machine tool
Machining
Manufacturing
Milling machine
Numerical Control (NC)
Sawing machine
Water jet machining

INTRODUCTION

The word *machining* probably has very little meaning to the typical person today. However, nearly all people depend on that word more than they could ever imagine. How can that be? What *is* machining and how does it influence everyday life?

The answers to these questions, and many others that will come up along the journey to discover the world of machining, involve exploring several different related topics.

First, the terms *machining* and *machine tool* need to be defined and many details of their definitions explained.

Next, a realization of how machining is connected to people's daily lives is needed. Connections will be made to a wide variety of consumable and durable goods and even services used by millions of people worldwide.

Discussion of the equipment, tools, processes, and technology used in the world of machining is necessary to begin to understand the role of machining in society. A brief history of machining and how it has progressed over time also helps to portray the importance of the machining field in the past, present, and future.

Once an overview of these topics is complete, the journey into the complex world of machining will have begun.

MACHINING DEFINED

What is *machining*?

Merriam-Webster's Dictionary defines **machining** in this way:

"to process by or as if by machine; especially: to reduce or finish by or as if by turning, shaping, planing, or milling by machine-operated tools."[1]

This definition may not give a very clear picture of machining. It is from the year 1853, and its basic meaning is still correct, but that definition does not tell the whole story of machining.

Beginning with Merriam-Webster's definition is a fine start. First, "to process by machine" means to use a machine to perform a task.

The second part of this definition, "to reduce or finish," means to change size and/or shape by cutting a piece of material. Turning, shaping, planing, and milling are cutting methods. Materials that are machined are usually metals, but other materials, including plastics and graphite, can also be machined.

Finally, the "machine-operated tools" used to perform the cutting are called **machine tools**.

[1]By permission. From Merriam-Webster's Collegiate® Dictionary, 11th Edition © 2013 by Merriam-Webster, Inc. (http://www.merriam-webster.com/).

All of these factors add to a definition of machining that is well suited for the topics discussed throughout this text:

Machining: Using machine tools to cut materials to desired sizes and shapes.

HISTORY OF MACHINING

Humans have used machine tools for centuries, beginning with very primitive forms and advancing to the high levels of technology, precision, and efficiency that exist today. The earliest machine tools were hand powered, and progressed to being powered by animals or water, then steam, and finally electricity.

Simple Machine Tools

The bow drill is the simplest and most likely the first machine tool. The cord of a bow was wrapped around a round cutting tool and, when the bow was moved back and forth, the cutting tool rotated and produced a hole. Similar to the bow drill is another hand-powered machine tool called the pump drill. It was developed around the time of the Roman Empire and was common until the 18th century. In the pump drill, a cord still rotates the round cutting tool, but motion is up and down and more easily creates rotary cutting action to produce holes. **Figure 1.1.1** shows these simple hand-powered tools.

The spring pole lathe was developed in the 13th century to produce cylindrical wooden parts. One end of a rope was connected to the part being cut and the other end to a spring pole, and power was produced by use of a foot

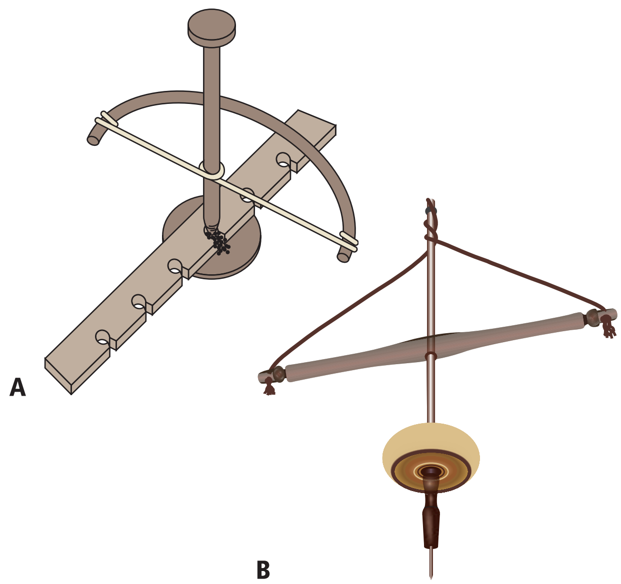


FIGURE 1.1.1 Examples of the earliest hand-powered machine tools. (A) The bow drill; and (B) the pump drill.

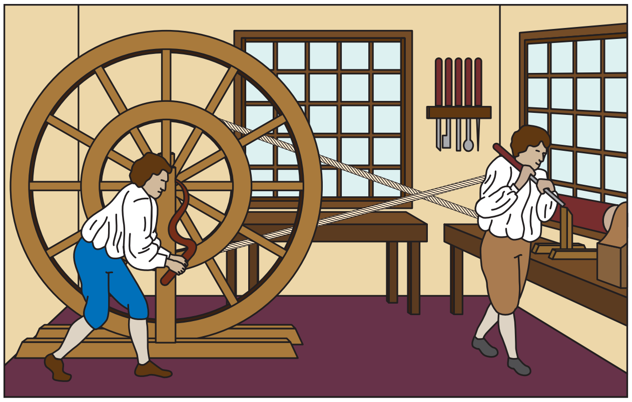


FIGURE 1.1.2 The Great Wheel lathe.

pedal. Cutting tools were then held against the rotating part to create cylindrical surfaces. Early settlers in North America used live saplings to build this type of machine tool at their home sites. Later a metal cutting version was developed.

The spring pole lathe had one drawback: its motion was not continuous. In the mid-18th century, John Smeaton developed the Great Wheel lathe that was powered by a drive cord or belt attached to a large wheel. One person spun the wheel to create power, and another performed the machining. **(See Figure 1.1.2.)**

Industrial Revolution

Machine tools began to drastically improve with the beginning of the Industrial Revolution in the late 18th century. More products were being produced from metals, and better machine tools were needed.

In England in 1775, John Wilkinson developed a water wheel–powered boring machine to machine the inside of cannons. **(See Figure 1.1.3.)** Soon the machine began to bore cylinders for Boulton and Watts's steam engines. That began the era of steam-powered machine tools.

In 1797, Henry Maudslay developed a machine that was able to accurately cut screw threads. This revolutionized manufacturing because interchangeable threaded parts could be produced.

In 1818, Eli Whitney produced the first milling machine. This machine tool was able to produce flat surfaces

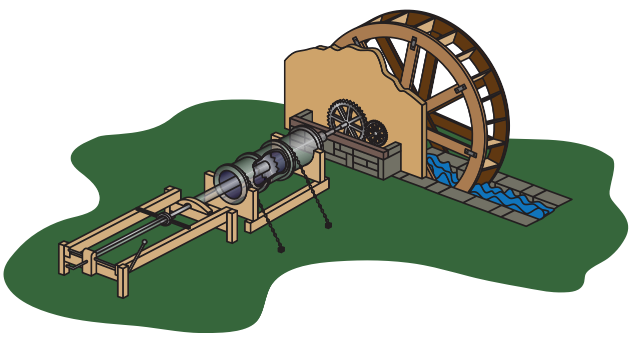
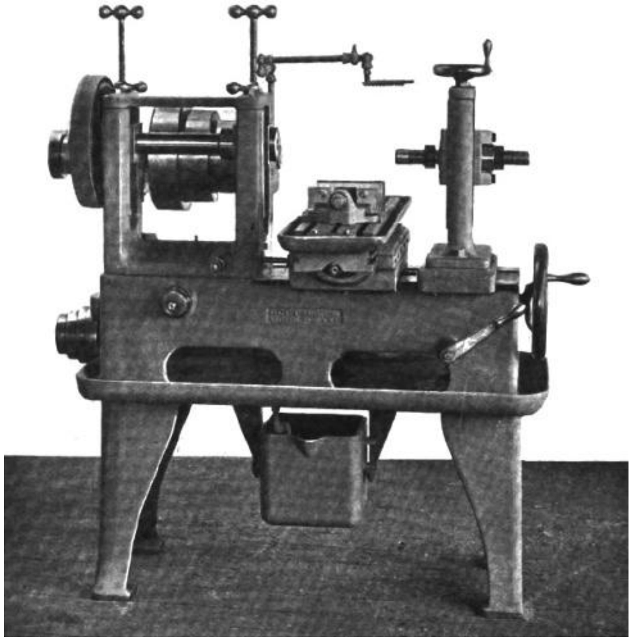


FIGURE 1.1.3 John Wilkinson's boring machine. It was first used to machine cannon bores, then cylinders for steam engines.



Horner, Joseph Gregory. Modern Milling Machines, C. Lockwood and Son,© 1906

FIGURE 1.1.4 An early milling machine from around 1860. Horner, Joseph Gregory. Modern milling machines.

more easily than by hand with filing and scraping tools. Over the next several years, several individuals made improvements on Whitney's machine and different models became available. **Figure 1.1.4** shows an early milling machine from around 1860.

The post drill produced holes by turning a crank by hand. The crank turned gears that rotated the cutting tool and advanced it into the part being drilled. It was commonly used into the early 20th century before electricity became widely available.

Throughout the 18th and 19th centuries, steam-powered machine tools were driven by a series of belts that were connected to a large centralized wheel powered by a steam engine. During the Industrial Revolution, many companies began producing machine tools as metal cutting operations became more common.

20th-Century Machining

In the early part of the 20th century, electric power began to replace steam power, and machine tools continued to become more complex, more precise, and more efficient. Better machine tools were able to produce more accurate parts, which in turn produced even better machine tools, in a cycle of constant improvement.

In the early 1900s, Henry Ford's creation of the assembly line for mass production of automobiles relied heavily on machining. Parts needed to be machined efficiently to keep up with automobile assembly.

World War I and World War II both created huge growth in the machining industry in the United States as the country produced war-related materials.

Up until the 1940s, machine tool movements were controlled by levers, hand wheels, and geared transmissions. After World War II, great economic growth took place in the United States. Consumerism began, and the machining industry needed to become more efficient to support manufacturing. The invention of **numerical control (NC)** greatly improved machine tool performance. A language of machine code was developed and loaded on a punch card or tape and then fed into the machine tool to automatically guide the motions of the machine and change tools without the need of an operator.

In the 1970s, the NC punch card or tape began to be replaced with **computer numerical control (CNC)**. Instead of machine code being punched on the tape or card, code was entered through an integrated computer on the machine tool. Continued advancement in computer technology and machine tool construction has resulted in machine tools that can produce intricate, complex shapes with extreme accuracy and efficiency. When properly configured, they can also perform many operations with many different types of cutting tools while running without the need of an operator. **Figure 1.1.5** shows an ultra-modern CNC machine tool in operation.

Courtesy of Haas Automation, Inc

FIGURE 1.1.5 Today's state-of-the-art CNC machine tools can be programmed to run unattended and machine extremely complex shapes.

THE ROLE OF MACHINING IN SOCIETY

Nearly every person depends either directly or indirectly on machining in some way. Without machining, very few goods and services used every day would exist. How is that possible? Some exploration is needed to find the answer.

People, Manufacturing, and Machining

Many think of manufacturing in terms of big-ticket items like cars and televisions, but everyone uses manufactured items every day. **Manufacturing** simply means to produce something. Paper is a manufactured item. Plastic bags are manufactured items. So are tissues, clothing, and many foods. **End products** are final manufactured items used by consumers. The machining industry produces end products and components that are assembled as end products, and supports manufacturing for the products used by people throughout the world every day.

Machining also normally involves producing sizes and shapes to high levels of precision. Some machining operations can produce sizes with variations of 0.0001 inch or less of the desired size. This one ten-thousandth of an inch (0.0001) is approximately 1/50 of the *thickness* of an ordinary piece of paper. Why do parts need to be produced with such precision? The answer is performance and interchangeability of parts. When mating parts are assembled, high accuracy ensures proper fit and long life. Further, mating parts can be mass produced and interchangeable because they are manufactured to standard sizes, instead of needing to be custom fit to each other.

Some common connections to machining can be made fairly easily, while others require more careful investigation. It is more obvious that machining is connected to manufacturing of durable goods in a wide variety of industries, such as automotive, aerospace, and motor-sports, than to the paper, computer, or food industries.

Manufacturing in the United States

Recent history has convinced the vast majority of people that manufacturing is a dead industry in the United States. While it is certainly true that manufacturing has experienced some decline since the last several years of the 20th century, the United States is still the leading manufacturing nation of the world. U.S. manufacturing was valued at $2.1 trillion in 2016. There were only eight other countries in the world whose entire economies were larger than the U.S. manufacturing sector. Further, more than three-fourths of the research and development activities conducted in the

United States are performed by manufacturing companies, leading the way for technological advancements in many different fields.

Manufacturing also plays a major role in supporting the American workforce. U.S. Bureau of Labor and Statistics 2017 data show that there are more than 12.5 million people directly employed in manufacturing jobs in the United States. With a total workforce of approximately 154 million, manufacturing provides employment to over 8 % of all U.S. workers. At the end of the first quarter of 2018, the average American worker in the manufacturing sector earned an hourly wage of $26.86. That equates to more than $55,600 annually based on the average 40.8-hour workweek. When benefits such as health insurance and retirement plans are included, the average manufacturing worker's hourly wage rises to just under $39. That equates to slightly more than $81,000 annually. These figures show that manufacturing is alive and well in the United States, the country is still a global leader in manufacturing, and manufacturing careers provide excellent salaries and benefits.

Aerospace, Automotive, and Motorsports

Automotive and aerospace industries rely heavily on machining and machine tools. Consider cars and planes as examples. These highly complex and technologically advanced vehicles contain parts that were produced by machining operations. Engine, drive-train, and suspension components, as well as wheels, gears, and instrumentation, are just a few examples, not to mention the countless variations of nuts, bolts, and washers used for assembly. Machining operations produce all of these parts precisely. The motor-sports industry also uses many of the same types of parts as those used in the automotive and aerospace industries. **(See Figure 1.1.6.)**

Courtesy of Penske Racing Shocks

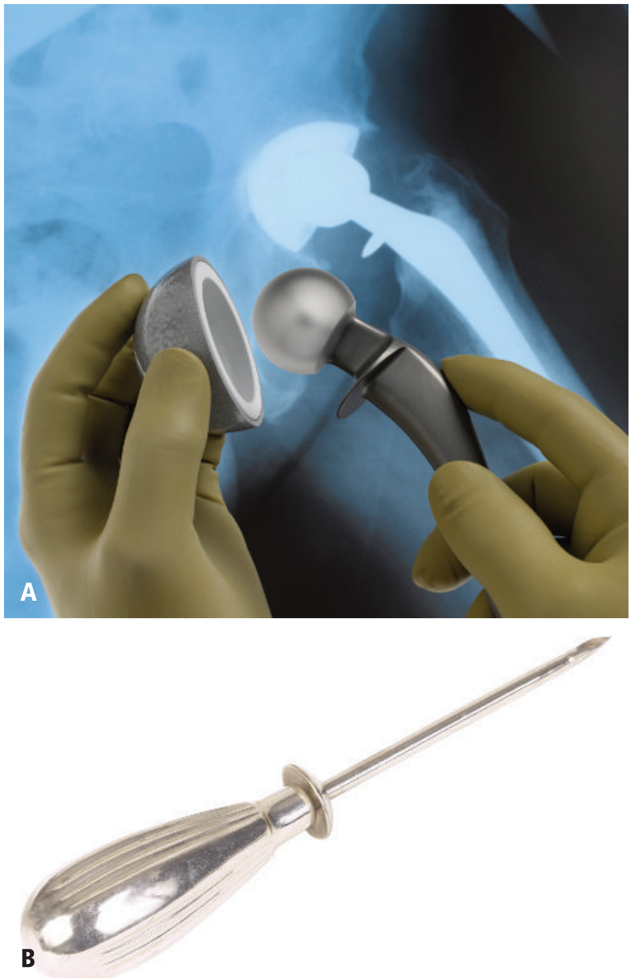
FIGURE 1.1.6 Machined shock absorber components and an assembled shock absorber used in motorsports racing.

Medical Fields

Other high-tech fields that are not easily seen as related to machining still depend on machining and machine tools for their existence. The medical field is one major example. Machine tools produce many medical devices that are used in today's high-tech surgical procedures. Surgical and dental tools, heart catheters; intravenous and hypodermic needles; joint replacement parts for knees, hips, and elbows; replacement discs for the spinal cord; and even artificial hearts are produced by high-tech machining operations. By manufacturing these types of components, machining operations and machine tools play key roles in medical and surgical advancements. **Figure 1.1.7** shows some machined parts used in the medical industry.

Plastics

In today's society, plastic plays a role in nearly every aspect of life. Electronic items such as CD and DVD players, televisions, portable digital music players, mobile phones, and computers all contain plastic parts. Plastic bottles, cups, and other containers are everywhere. Most children's toys are plastic. All of these objects depend on the machining



© Don Farrall/Getty Images

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FIGURE 1.1.7 (A) Machining produces medical products such as this hip implant and (B) surgical tool.

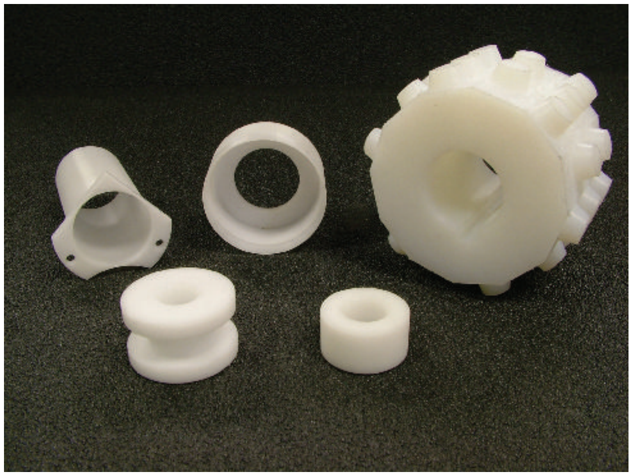
Courtesy of Trimetric Mold and Design

FIGURE 1.1.8 One-half of a machined mold and the plastic molded part produced by the mold.

industry. Many finished plastic parts are produced from molds when high numbers are required and sizes do not need to be extremely precise. Molds contain cavities that are made to the shape of the desired part and then filled with molten plastic. When the plastic cools, the mold is opened and the part is removed. Machine tools machine the molds for these types of plastic parts that are used by millions every day. **Figure 1.1.8** shows a mold and a molded plastic part. Plastic parts that require very precise sizes or those produced in low numbers are often machined from solid pieces of plastic instead of being molded. **Figure 1.1.9** shows some machined plastic components.

Other Durable Goods

Products in daily use, such as hand tools, metal cans, metal pans, and drinking glasses, as well as countless metal components used throughout the world, also need the machining industry to exist. Molds similar to those for plastics are used to create glass products. Tools called dies are used to cut or form sheet metal into desired shapes. Cans and pans are examples of parts made with one type of die called a forming die. A flat piece of metal is squeezed between two parts of the die to stretch it to the desired shape. Forging dies use great force to form



Courtesy of Pernell Parts, LLC

FIGURE 1.1.9 Some machined plastic components.

hot pieces of metal into countless products, including wrenches, hammers, gears, crankshafts, hitches, and door hardware. Blanking and piercing dies punch out sheet metal products using the same principle as a paper hole punch. Sometimes several dies that pierce and form metal are mounted in one assembly called a progressive die. At each stage, operations are performed on the part, resulting in a finished end product. The components of these types of dies are made with machine tools. **Figure 1.1.10** shows a progressive die assembly and the part produced by the die.

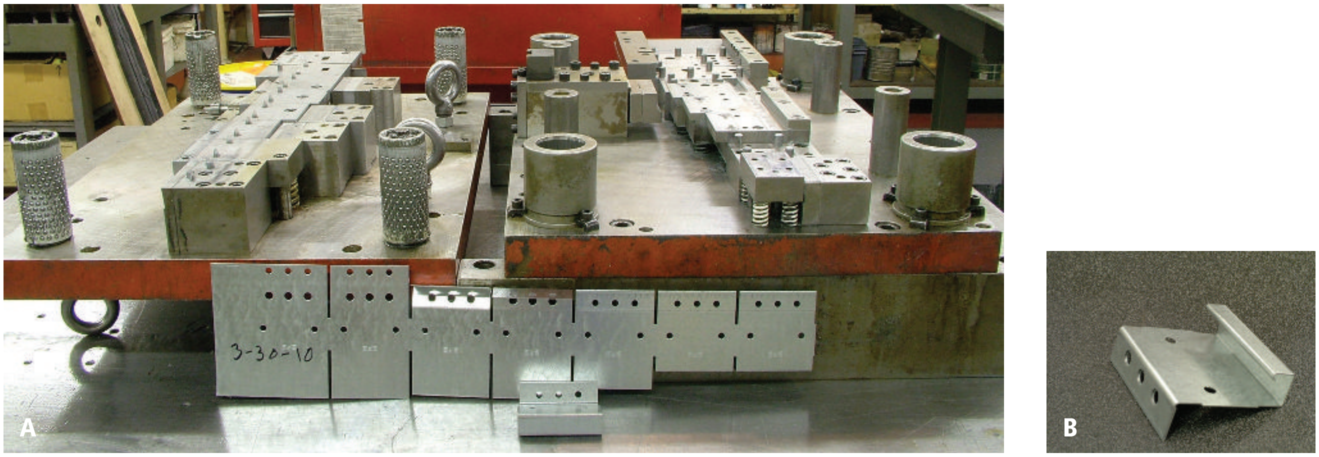
Consumable Goods

It is becoming clearer how machining is connected to durable goods that are manufactured, but how does machining relate to consumable items such as food, paper, and clothing? The plastic packaging that holds many food items is made in molds **(see Figure 1.1.11)**, and molds also actually form the shape of some foods, such as ravioli and snack foods.

Other consumables such as clothing and paper rely on machining indirectly, just like durable goods do. The equipment and machinery that produce clothing, paper, or any manufactured consumable product are built from parts that were created through machining processes. Hydraulic cylinders, shafts, conveyor rollers, and bearings are a few examples of machined components used to produce equipment that in turn produces every manufactured product used today.

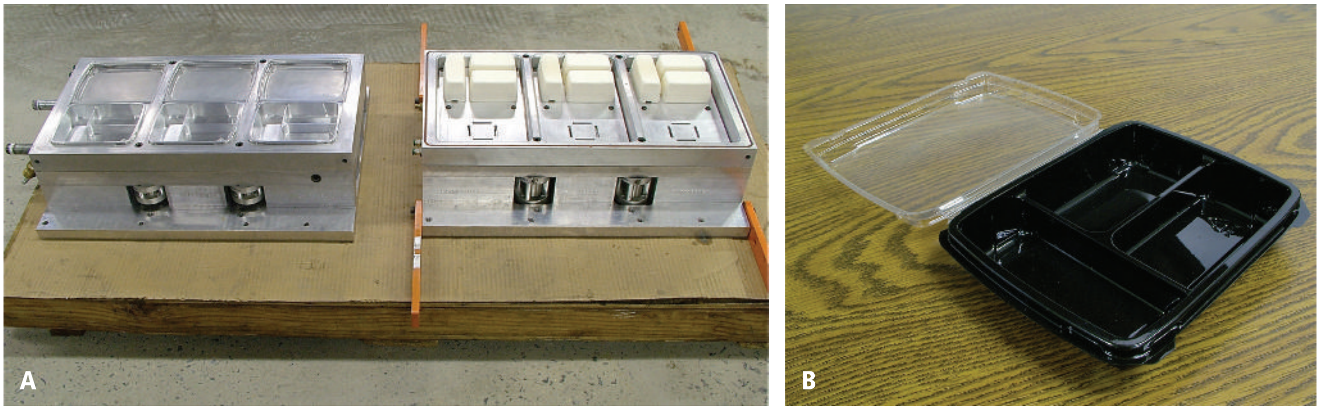
MAJOR MACHINE TOOLS

There are some basic types of machine tools or machining operations. Each is designed and suited for specific applications. Many are greatly improved versions of the earliest handheld and hand-powered tools using the same basic principles of operation.



Courtesy of SFS Intec

FIGURE 1.1.10 (A) This progressive die has eight stages. Each stage shapes the part further from a strip of material. At the final stage, the die cuts the finished part off the strip. (B) The final product.



Courtesy of Tray-Pak Corporation

FIGURE 1.1.11 (A) Machining produced this mold that forms plastic food packaging. (B) The package produced by the mold.

Others are completely different technologies that have been developed recently. Machine tools are referred to as either conventional (or manual) or CNC types. Conventional machine tools require an operator to use hand-operated wheels or levers or engage geared transmissions to perform machining operations. They can usually perform only straight-line movements in one plane, or direction, at a time. Movements of CNC machine tools are directed by computerized controls. They can produce intricate, complex shapes with extreme accuracy and efficiency. When properly configured, they can also perform many operations with many different types of cutting tools while running without the need of an operator. Some types of machine tools are available in either conventional or CNC versions, while others are strictly CNC versions.

Sawing Machines

Sawing machines, often just called saws, use multi-tooth saw blades to perform cutting. These machines are usually used to cut material to rough lengths or to remove large sections of material quickly in preparation for other machining operations. Two types of blades are generally used. Band saws use a band-type blade and are available in horizontal or vertical machine types, as shown in **Figure 1.1.12**. **Figure 1.1.13** shows a saw that uses a circular-type blade. Some saws can be equipped with CNC controls to automatically cut multiple pieces of material very efficiently, as shown in **Figure 1.1.14**.

The Drill Press

The **drill press** performs holemaking operations by feeding various types of rotating cutting tools into the work. It is normally used when precise hole locations are not necessary. **Figure 1.1.15** shows a typical conventional drill press.

The Lathe

The **lathe** is used to produce cylindrical parts and operates on the principle of moving a cutting tool across the surface of a rotating piece of material. Operations that can be performed on the lathe include machining of external and internal diameters, lengths, threads, grooves, and

FIGURE 1.1.12 (A) A horizontal band-sawing machine; and (B) a vertical band-sawing machine.

Courtesy of Behringer Saws, Inc

FIGURE 1.1.13 A circular-blade-type sawing machine.

Courtesy of Behringer Saws, Inc

FIGURE 1.1.14 A CNC-controlled sawing machine.

tapers. **Figure 1.1.16** shows conventional and CNC lathes and a few sample parts produced by these machine tools.

The Milling Machine

Milling machines use rotating cutters moved across a part to remove material. These machine tools can use either a vertical spindle or a horizontal spindle and are available in conventional or CNC versions. Conventional types perform accurate holemaking operations and produce primarily flat surfaces. CNC versions can cut curves and contours. **Figure 1.1.17** shows conventional and CNC milling machines and some examples of the types of parts produced by these machines.

Abrasive Machining

Abrasive machining refers to using grinding wheels in either a nonprecision or precision manner. Noncritical operations are usually performed by hand on pedestal- type grinders like the one shown in **Figure 1.1.18**.

Precision grinders produce very accurate dimensions and very smooth surfaces. The most common types are surface grinders and cylindrical grinders. Surface grinders produce flat surfaces like milling machines, but with higher precision. Cylindrical grinders produce cylindrical parts like lathes, but with higher precision. Both surface and cylindrical grinders are available in conventional and CNC versions. **Figure 1.1.19** shows two types of precision grinders.

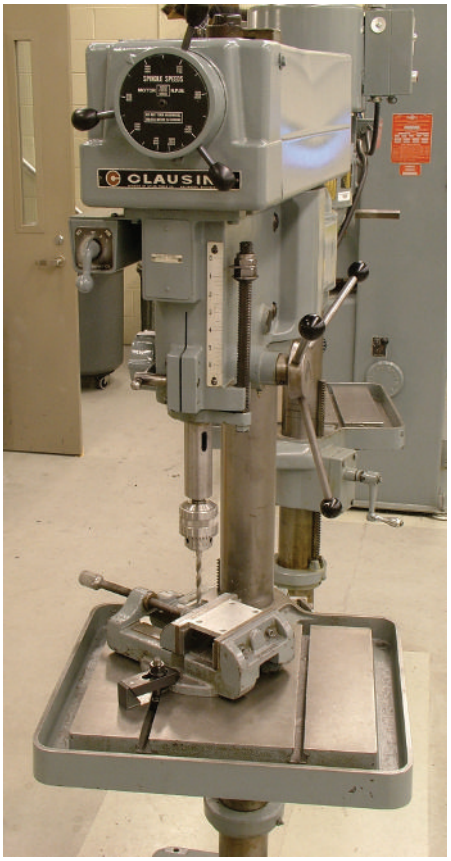


FIGURE 1.1.15 The drill press is often used for holemaking operations.

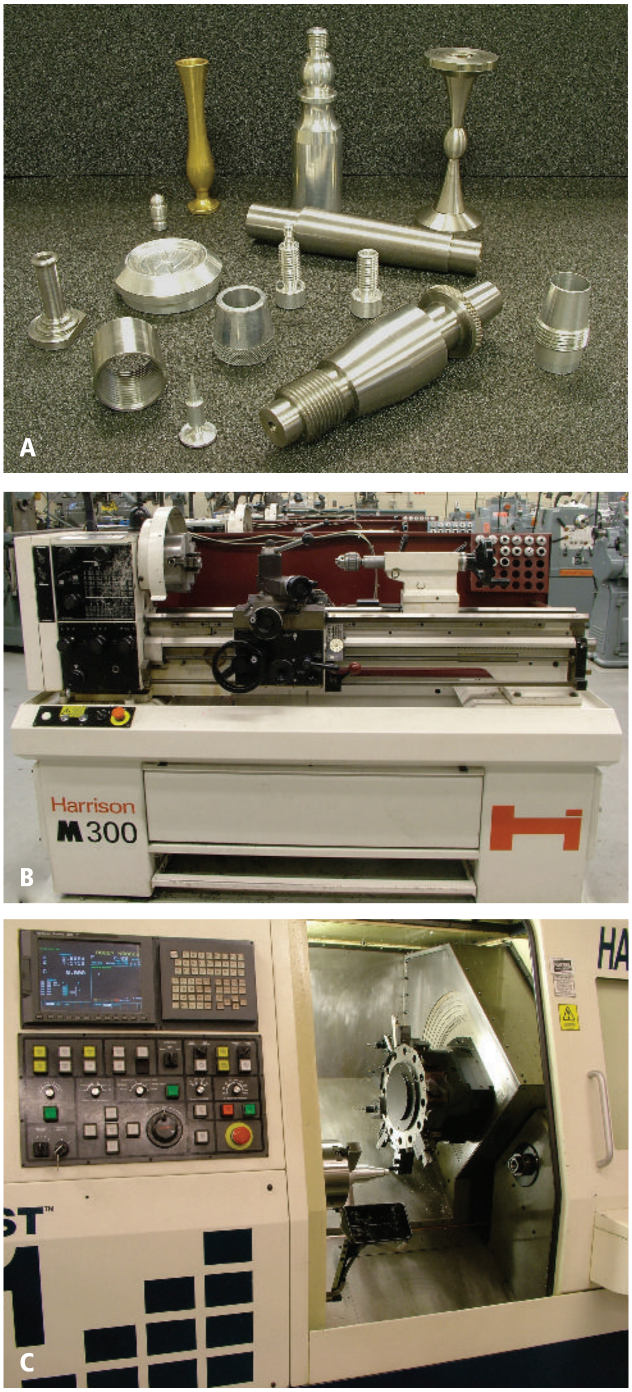


FIGURE 1.1.16 (A) Cylindrical parts are normally machined on either a (B) conventional lathe, or (C) a CNC lathe.

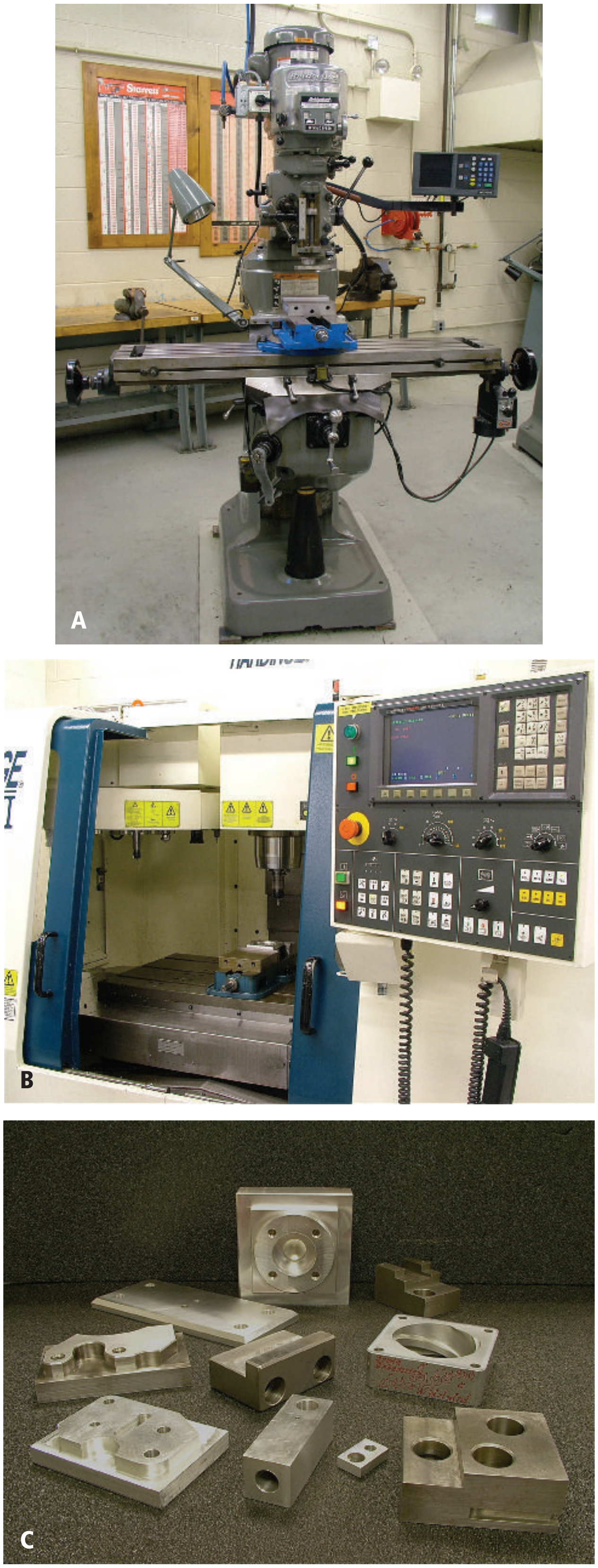


FIGURE 1.1.17 (A) A conventional vertical spindle milling machine and (B) a CNC vertical spindle milling machine. (C) Some parts produced on milling machines.

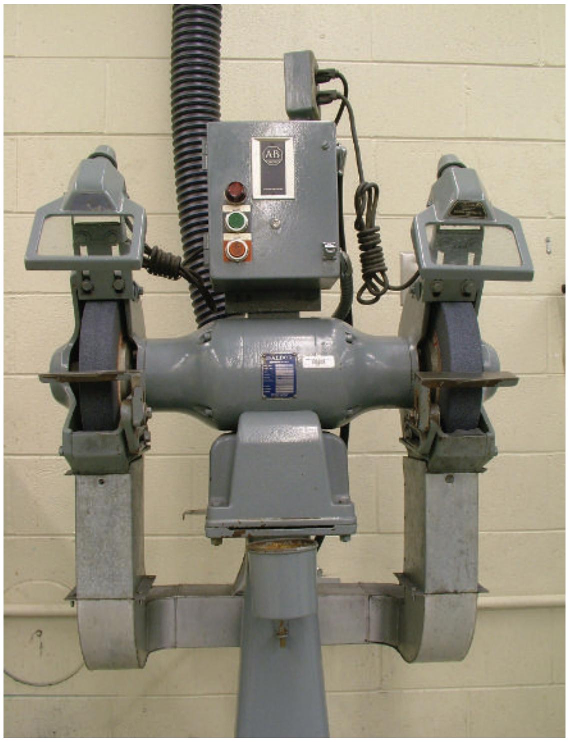


FIGURE 1.1.18 A pedestal grinder can be used to perform shaping operations when high accuracy is not needed.

Electrical Discharge Machining

Electrical discharge machining, or **EDM**, uses electrical current to machine any material that will conduct electricity. No contact is made between tool and the part, but material is eroded away by the spark created when the tool comes in close proximity to the part. The ram- or sinker-type EDM uses an electrode that is the opposite of the form desired. It is commonly employed in mold making because a mold often requires a small internal radius, or a narrow feature, that cannot be machined by other methods. However, the opposite form can often be easily machined on the electrode in a milling machine or a lathe. Then the electrode can be used to produce the final desired shape in the mold. **(See Figure 1.1.20.)** The wire-type EDM uses a small-diameter wire to produce very intricate shapes and sharp inside corners that could not be machined by other methods. Its ability to maintain those shapes through relatively thick material is another added benefit. **(See Figure 1.1.21.)** EDM machines are classified as CNC machine tools, but some sinker/ram types perform only simple movements. A sinker/ram EDM can create pockets that do not pass entirely through a part. Features produced by wire EDM must pass completely through the part because the wire must be able to pass from a spool, through the part, and then be collected in a container. One disadvantage of the EDM is that the process is generally much slower than using lathes and milling machines.

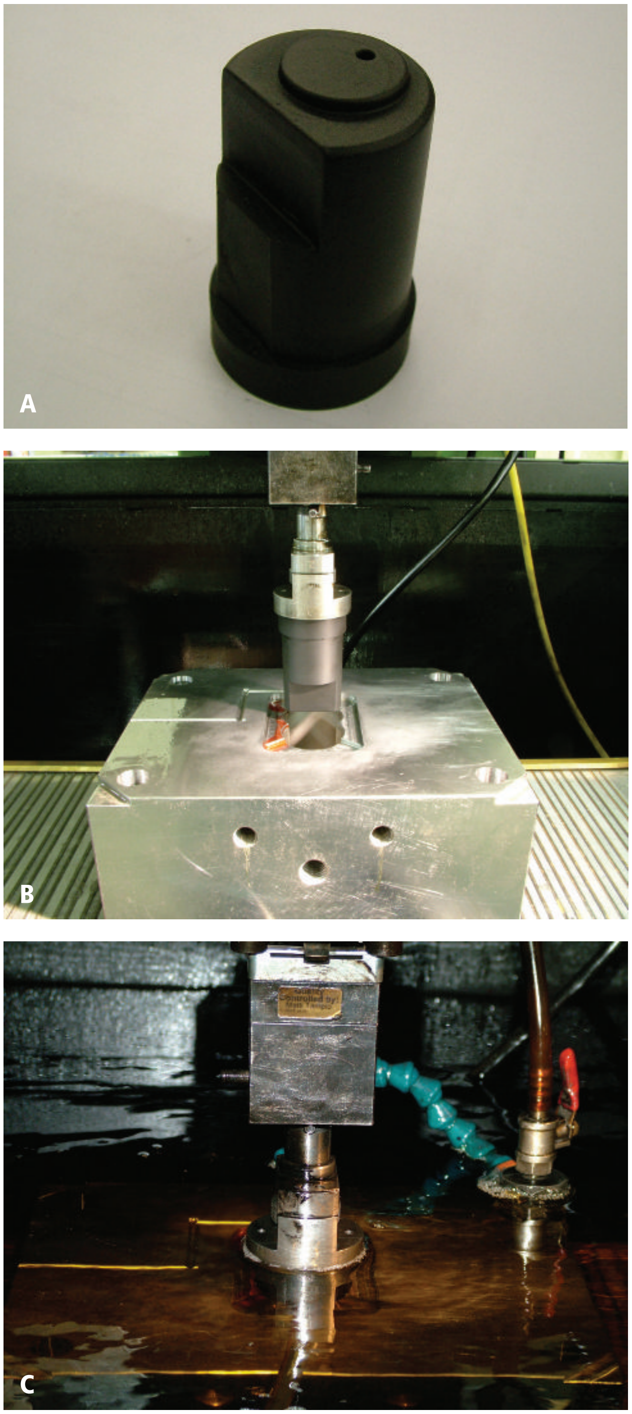
Courtesy of TruTechSystems/Harig Products

A

B

Courtesy of Weldon Solutions

FIGURE 1.1.19 (A) A conventional surface grinder. (B) A CNC cylindrical grinder.



Courtesy of Trimetric Mold and Design

FIGURE 1.1.20 (A) A machined graphite electrode that acts as the cutting tool in a sinker EDM. (B) The electrode mounted in the EDM to produce a mold cavity. (C) The work being machined by the EDM must be submerged in a liquid called dielectric fluid during operation.

Courtesy of Trimetric Mold and Design

FIGURE 1.1.21 (A) The wire EDM uses a very small-diameter electrically charged wire to cut through material. A flow of water helps to wash away the eroded material. (B & C) Examples of intricate parts than can be produced by the wire EDM.

Laser Machining

Laser machining uses a highly concentrated beam of light with temperatures up to 75,000°F to cut, groove, or engrave metals. Lasers are classified as CNC machine tools and can cut very hard materials easily. **Figure 1.1.22** shows a laser cutting operation.

Water Jet Machining

In **water jet machining**, abrasive grit is introduced into a very high-pressure, focused jet of water to perform cutting. Such jets can cut through 6 inches of steel. This type of machine tool was developed in the 1960s but is becoming more widely used in the machining industry. **Figure 1.1.23** shows a water jet cutting operation.

© Chris Fertnig/Getty Images

FIGURE 1.1.22 A laser machine tool in operation.

Courtesy of Flow International Corporation

FIGURE 1.1.23 A water jet machine uses a high-pressure water stream containing an abrasive to cut materials.

SUMMARY

- The machining industry is a widespread and complex, but little-known, field. It uses machine tools to machine, or cut, material to desired shapes and sizes.
- Manufacturing is simply the production of durable and consumable goods used by everyone, and machining has an impact on nearly every manufacturing process.
- Machining can directly produce end products or components used in end products. Machining can also produce components of other machines or equipment required for the manufacture of end products.
- Simple, hand-powered machine tools have existed for centuries and have been improved over time into highly efficient pieces of equipment capable of achieving extreme levels of precision.
- Several major machine tools are widely used today, and many are controlled by integrated computerized controls that allow them to perform complex operations with little human input once they are set up.
- Even though machining is not well understood, it has a great impact on many aspects of our lives.

REVIEW QUESTIONS

1. Define the term *machining*.
2. What is a machine tool?
3. What is manufacturing?
4. List four industries that depend on machining.
5. What does the abbreviation *CNC* stand for?
6. What is the purpose of the drill press?
7. What machine tool produces cylindrical parts?
8. Briefly describe the primary purpose of sawing machines.
9. What machine tool is available with either horizontal or vertical spindle orientation and uses rotating cutting tools to primarily produce flat surfaces?
10. Abrasive machining makes use of ________________ to remove material.
11. What does the abbreviation *EDM* stand for?
12. What are the two types of EDM machines?
13. _________________ uses a high-pressure stream of water containing abrasive particles to cut material.
14. Briefly describe the principle of laser machining.

UNIT 2 Careers in Machining

Learning Objectives

After completing this unit, the student should be able to:

- Identify and discuss careers in the machining industry
- Identify and discuss careers in fields related to machining
- Discuss the job outlook in the machining field
- Understand and explain effective job-seeking skills

Key Terms

CNC machinist
Computer-Aided Design (CAD)
Computer-Aided Manufacturing (CAM)
Conventional machinist
Die maker
Engineering drawing
Industrial salesperson
Inspector
Machine tool service technician
Machinist
Manufacturing engineer
Manufacturing engineering technician
Mechanical designer
Mechanical engineer
Mechanical engineering technician
Metrology
Mold maker
Operator
Print
Programmer
Quality control technician
Set-up technician
Supervisor/manager
Toolmaker

INTRODUCTION

Throughout the Industrial Revolution and into the early part of the 20th century, people who worked with machine tools were usually referred to as mechanics. Their jobs were varied, as they performed manual labor in addition to operating machinery. With the great requirement for hands-on skills, these mechanics were highly skilled craftspeople.

As the machining industry grew through the 20th century, the term **machinist** replaced *mechanic*. The new term connected the person with the machine tool. The machinist was one who made a living at and was skilled in the use of machine tools.

Work for the machinist into the early 20th century was a combination of physical labor and mental effort, and working conditions were often dangerous and dirty.

As time progressed, machine tools, machining, and related industries became more complex. Specialty jobs in different areas of machining started to develop. Today, the title of machinist is often misunderstood and brings to mind antiquated visions of hard physical labor in dark, dangerous, sweatshop environments.

MODERN MACHINING CAREERS

Careers in the modern machining industry still require a combination of hands-on and mental skills but are far safer and far less physically demanding. Jobs are frequently in very clean, climate-controlled, high-tech environments. Workers in today's machining industry are highly skilled professionals with a combination of hands-on and theoretical talent.

Due to an aging workforce in the machining field, there are shortages of qualified candidates in many fields of durable and consumable goods manufacturing. Those shortages equal opportunities for good-paying jobs with benefits and excellent working conditions. According to the Occupational Outlook Handbook website prepared by the U.S. Bureau of Labor Statistics (BLS), there should be good job opportunities for CNC programmers and operators and tool and die makers through the year 2026, largely due to few people pursuing those career paths. This means that there should be more openings than qualified candidates. These conditions create an environment ripe with career opportunities.

Today there are many different jobs in the machining field and many jobs in related fields that require knowledge of machine tool operations and capabilities. All of these jobs require at least some knowledge of reading **engineering drawings** or **prints**. These are the drawings of parts to be machined and show shapes, sizes, and specifications that must be met. **Figure 1.2.1** shows an example of some engineering drawings.

The next sections give brief descriptions of primary responsibilities and tasks of these jobs. It must be stressed that there is frequently an overlap of skills, depending on the particular position and company. All of these jobs may be available in three basic roles: large-scale production manufacturing, small-volume custom manufacturing, and support positions for manufacturing.

The following websites are resources that can provide additional information and details about careers connected to machining, as well as national statistics about career outlook and wage data.

http://online.onetcenter.org/ is the home page of **O*NET**, the Occupational Information Network (O*NET) developed under the sponsorship of the U.S. Department of Labor/Employment and Training Administration (USDOL/ETA).

http://www.careeronestop.org/ is the home page of **Career One Stop**, another website that is also sponsored by the U.S. Department of Labor.

http://www.bls.gov/audience/jobseekers.htm is a page of the BLS, which is also a part of the U.S. Department of Labor.

http://www.dol.gov/dol/location.htm lists links to individual state agencies that provide career and employment data and resources specific to each U.S. state and territory.

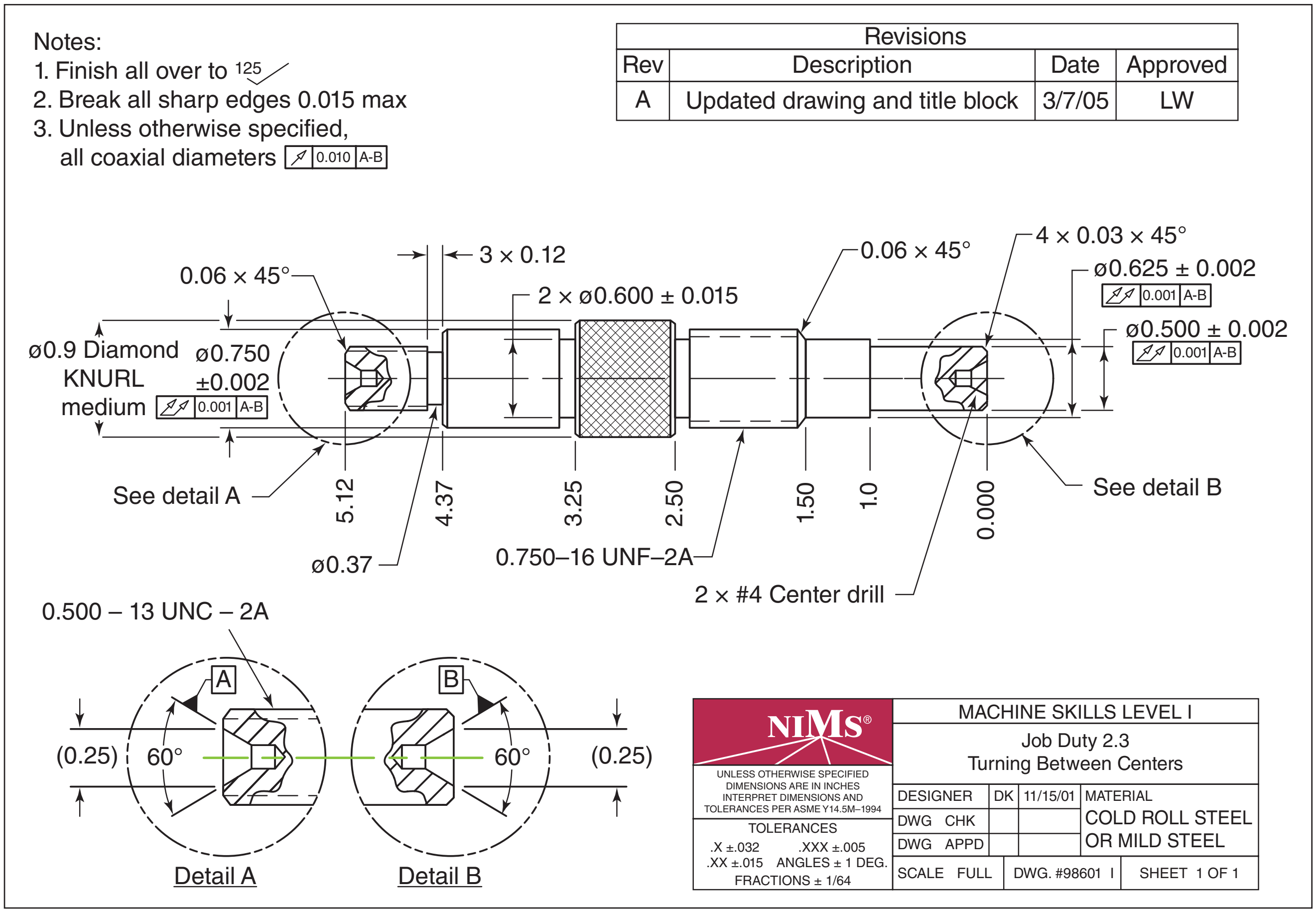
Operator

Operator positions are available in both conventional and CNC machining environments but are more common in CNC facilities. They are often filled by entry-level employees who are beginning careers in machining, and they require little prior knowledge of machining. **Operators** place parts in machines and continually run a set operation or group of operations. They are often also responsible for measuring sizes to ensure parts meet specifications shown on engineering drawings.

Depending on the environment, operators may be responsible for keeping more than one machine tool running and checking measurements on parts from each machining process.

Set-up Technician

Set-up technicians prepare or set up machine tools so that operators can run them. These positions are more common in CNC environments than in conventional machining facilities. Set-up technicians may specialize in preparing only one type of machine tool, such as the lathe or milling machine. Others may be skilled in setting up multiple types of machine tools. In some jobs, set-up technicians may be responsible for a certain number or group of machines. Set-up positions require previous



Courtesy of NIMS

FIGURE 1.2.1 An example of some engineering drawings, or prints, showing the shape and specifications of components to be produced by machining operations.

machining experience and/or education provided by secondary career and technical education (CTE) programs or certificate or associate degree programs.

Set-up technicians select proper cutting tools and devices to hold parts and mount them in the machine tool. They will often load computer programs into CNC machine tools and modify machining operations or replace tools as needed to maintain part specifications. Set-up technicians work closely with operators who run CNC machines as well as those who program CNC machines. **Figure 1.2.2** shows a set-up technician at work.

Conventional Machinist

Conventional machinists, or manual machinists, are highly skilled workers who usually have experience running almost every type of conventional machine tool. They normally do not specialize in one type of machine tool and work in environments where they must use many different machines to complete specific projects. **Figure 1.2.3** shows a conventional machinist.

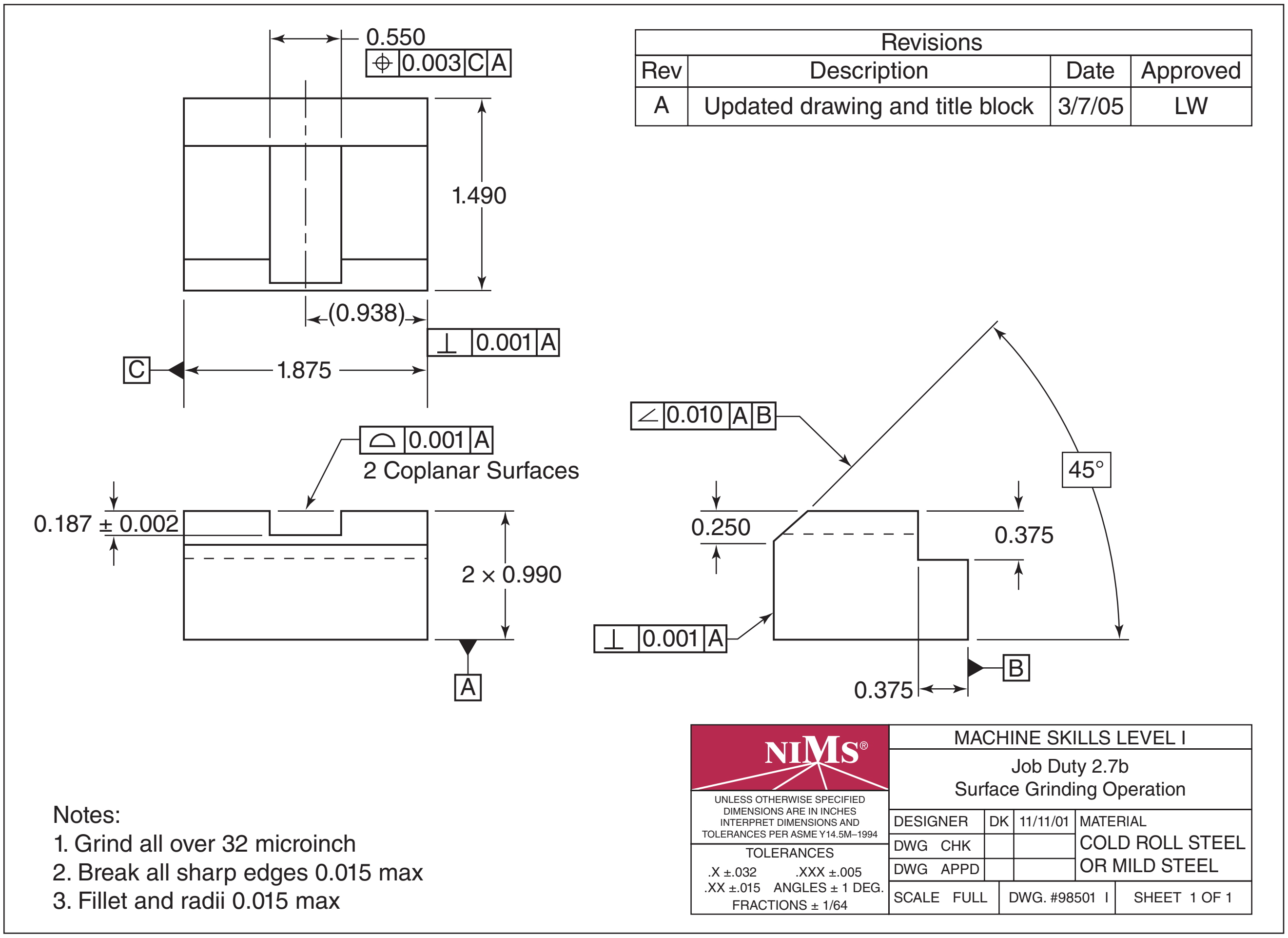
Conventional machinists will examine prints, select materials, establish process plans, and then perform all of the machining operations needed to complete a project to meet print specifications. Training through high school vocational education programs, certificate or associate degree programs, or apprenticeships is often needed for these jobs.

CNC Machinist

CNC machinists are very similar to conventional machinists except that they are normally skilled in the set-up and operation of CNC machine tools. They possess the skills of both the set-up technician and the operator. CNC machinists, like set-up technicians, may specialize in the use of one type or multiple types of CNC machine tools.

Many CNC machinists will, like conventional machinists, study prints, select material, and establish plans for machining operations. They will then use CNC machine tools to perform those machining operations and measure machined parts to ensure engineering drawing specifications are met.

Usually, but not always, CNC machinists will have experience in conventional machining, set-up, and operation as well and may use both conventional and CNC machines to perform their duties. Training for CNC machinists begins like that for conventional machinists, but also requires additional training in CNC applications.



Courtesy of NIMS

FIGURE 1.2.1 *continued.*

Courtesy of Penske Racing Shocks

FIGURE 1.2.2 This set-up technician is setting up the cutting tools on a CNC lathe.

FIGURE 1.2.3 This machinist is cutting an internal thread in a custom part on a conventional lathe.

Programmer

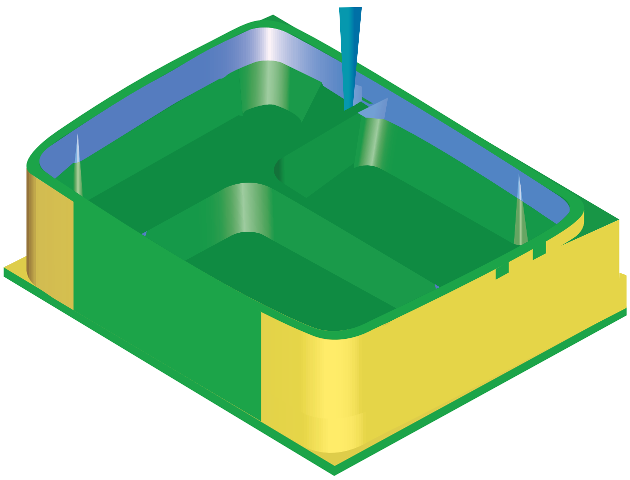
Programmers, sometimes called CNC or NC programmers, are the people who write programs consisting of machine code for CNC machine tools. They typically have previous experience as operators, set-up technicians, or CNC machinists and have advanced into programming positions. Programmer training is also similar to that needed by conventional and CNC machinists, but with additional training required in understanding machine programming languages.

Programmers may enter code directly into the machine tool using the machine's computerized control or write programs with a typical word processing program that can then be loaded into the machine's control system.

More complicated CNC programs require the use of **computer-aided manufacturing (CAM)** software. The programmer uses the computer software to select tools and cutting operations using a computer-generated virtual model of a part. **(See Figure 1.2.4**.) The CAM software then automatically generates the complex machine code that can be downloaded into the machine tool's computerized control.

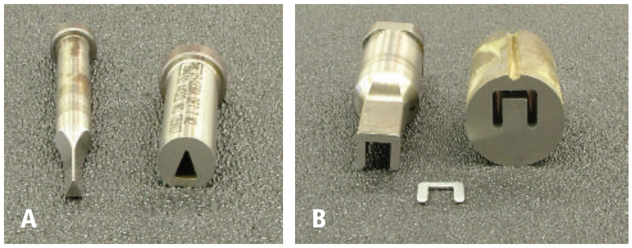
Die Maker, Mold Maker, Toolmaker

Die makers, mold makers, and toolmakers are very highly skilled specialists in the machining field. They are nearly always expert machinists, either in the use of conventional machine tools or both conventional and CNC machine tools. Those with CNC experience will likely be able to perform CNC programming online or offline using CAM software. They may also use **computer-aided design (CAD)** software to design some of their projects. Assembly and troubleshooting of dies, molds, and tools are also responsibilities in these positions. Formal training through certificate degree programs, associate degree programs, or apprenticeships prepares die makers, mold makers, and toolmakers.



Courtesy of Tray-Pak Corporation

FIGURE 1.2.4 CNC programmers often use CAM software to create complex programs for CNC machining operations. This software is simulating the program for the machining of a mold.



Courtesy of SFS Intec

FIGURE 1.2.5 A die maker machined these punch and die components that pierce out small pieces of sheet metal. They are part of a larger die assembly.

Die Makers

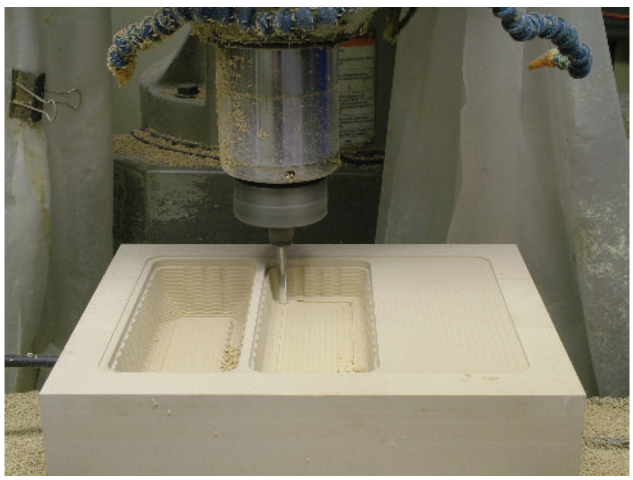
Die makers specialize in making cutting tools consisting of punches and dies that are used to either bend, form, or pierce metal parts. **Figure 1.2.5** shows some typical punch and die components machined by a die maker.

Mold Makers

Mold makers specialize in machining molds and mold components for either plastic or die-cast metal parts. Molds contain cavities that are made in sections, which when assembled will have either molten plastic or metal forced into the molds. When the material cools, the mold is opened and the parts are removed. **Figure 1.2.6** shows machining of a mold on a CNC milling machine.

Toolmakers

Toolmakers specialize in machining complex tools, jigs, fixtures, or machinery used to manufacture other parts. Jigs are devices that hold parts and guide tools for manufacturing processes. Fixtures hold parts for manufacturing



Courtesy of Tray-Pak Corporation

FIGURE 1.2.6 CNC machining of this prototype mold is typical of the type of work performed by mold makers.

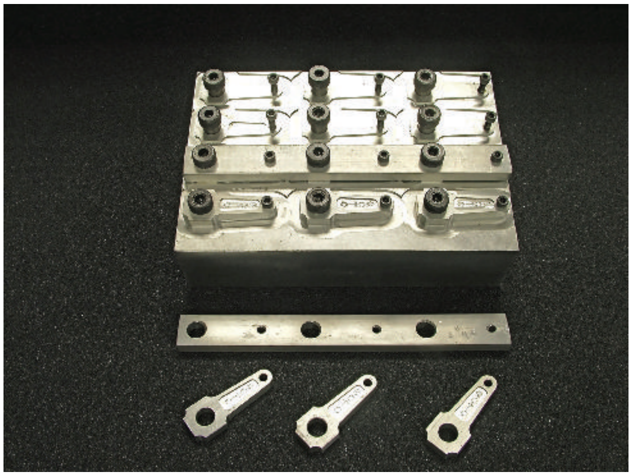


FIGURE 1.2.7 A fixture used for holding parts that was designed and machined by a toolmaker. A strip of material is mounted on the fixture and a CNC milling machine cuts the profile of the finished parts.

processes. **Figure 1.2.7** shows an example of a fixture designed and machined by a toolmaker.

Die makers, mold makers, and toolmakers typically work from highly detailed engineering drawings, plan and perform required machining operations, and then perform the final assembly and fitting of all the machined components to ensure that the final die, mold, or tool performs as required. Die makers and toolmakers are often called tool and die makers, as their work is very closely related, and many toolmakers and die makers are experienced in both specialty areas.

Supervisory Positions

After sufficient practical experience is gained in the machining field, there can be opportunities for advancement into a position of a **supervisor** or **manager**. People in these positions normally do not perform machining operations, but are responsible for planning, scheduling, purchasing, budgeting, and personnel issues.

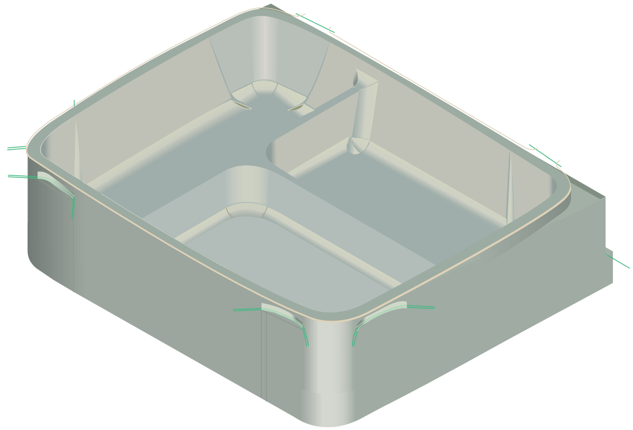
RELATED CAREERS

There are some careers that are closely related to or that support machining. They include design, engineering, service, sales, and inspection positions.

Mechanical Designer

Mechanical designers use CAD software to draw models or engineering drawings that are used as reference for machining operations. **(See Figure 1.2.8.)** Designers are normally given overall parameters or specifications from engineers, and then they design components or subassemblies for use in larger assemblies.

A general knowledge of machining capabilities is important to the designer so designs can be machined or



Courtesy of Tray-Pak Corporation

FIGURE 1.2.8 A mechanical designer used CAD software to design this mold used to produce plastic food storage containers.

manufactured efficiently and economically. Mechanical designer positions usually require at least an associate's degree and often require a 4-year degree.

Engineering Positions

Mechanical Engineer

Mechanical engineers understand the theory of many topics, including selection and properties of materials. They usually design overall projects, assemblies, or systems using high-end computer software. An understanding of machining is helpful for the same reason as it is important to the mechanical designer.

Mechanical engineers can also work in areas of machine tool, cutting tool, or machine tool accessory design. Mechanical engineers usually need to have completed a bachelor's degree.

Manufacturing Engineer

Manufacturing engineers establish manufacturing processes and continually study and improve on those processes. Often these are high-tech automated production lines. If a process includes machining operations, it is crucial that manufacturing engineers understand machining operations. If manufacturing engineers understand machining, they will be more efficient in determining needed components to build production lines. These engineers will often work with machinists and/or toolmakers and die makers who produce components for manufacturing equipment.

Engineering Technician

Mechanical engineering technicians and **manufacturing engineering technicians** could be considered a cross between mechanical engineers and manufacturing engineers. The engineers work more with theory and design, but engineering technicians work in the actual construction or testing of mechanisms, machinery, and equipment. Engineering technician jobs usually require an associate's degree, and some require bachelor's degrees.

These technicians will, like manufacturing engineers, frequently work with machinists and toolmakers and die makers when building equipment. Basic machining knowledge is important so they can interact with those types of people and complete needed tasks accurately and efficiently.

Sometimes engineering technicians will actually have machining backgrounds and may perform some machining operations as they construct projects. In these cases, working knowledge of machine tools is even more important.

Machine Tool Service Technician

Given the variety and number of machine tools in service in the machining industry, there is certainly the need for repairs to the pieces of equipment. **Machine tool service technicians** travel into the field to perform repairs as needed. They are like the appliance repairpersons of the machining industry. Service technicians frequently complete apprenticeships and may receive specialized training provided by machine tool manufacturers.

Machine tool service technicians can specialize in one type or many types of machines. They may work for a particular machine tool manufacturer or for a company that services many different manufacturer brands. Depending on the employer, machine tool service technicians may travel around the country or the world. These service technicians need to have troubleshooting and problem-solving skills as well as understand the function and repair of mechanical, electrical, electronic, hydraulic, and pneumatic systems.

Quality Control Technician/ Inspector

Whenever and wherever machining operations are being performed, there is always a need for inspection of parts to be sure they meet specifications. Some companies employ **quality control technicians** or **inspectors** skilled in **metrology**, the science or practice of measurement, to perform this function. Training for these positions can vary greatly depending on the complexity of the job. Some may require only company training while others require 4-year degrees in metrology.

Inspectors may move from machine to machine to inspect parts or parts may be brought to a station or an inspection lab. The inspector's job is to confirm all specifications and report to the person responsible for maintaining those specifications. Inspectors will often work closely with operators or set-up technicians to quickly identify errors so corrections can be made. They often use highly specialized measuring equipment. **(See Figure 1.2.9.**)

FIGURE 1.2.9 A quality control technician uses specialized measuring instruments to inspect machined components.

Industrial Salesperson

Sales jobs exist in a few different areas. Machine tool manufacturers, cutting tool or machine accessory manufacturers, and industrial suppliers can employ salespeople. In each case the **industrial salesperson** visits customers and prospective customers to discuss their needs in order to gain their business. They may travel locally or nationally and often deal with supervisors, managers, machinists, and toolmakers and die makers.

SUMMARY

- Many different careers are available in machining and related fields. These occupations have evolved from mostly hands-on jobs to those that also require the use of new technology.
- The machining and related career fields offer many different jobs requiring different levels of skill and education. Jobs in these fields often offer opportunities for career advancement.
- Today many careers in the machining industry pay well and offer excellent working environments and there are currently opportunities for successful careers in the machining field in the United States.
- Because of the wide variety of industries and jobs that rely on machining, the field can provide a variety of rewarding careers.

REVIEW QUESTIONS

1. What is an engineering drawing and what is its purpose?
2. What is the primary duty of a machine tool operator?
3. What occupation involves preparing tools and machines for machining operations?
4. Briefly describe a CNC programmer's responsibilities.
5. What is CAM software?
6. What is CAD software?
7. What career advancement opportunities exist for employees in the machine tool industry?
8. What career area related to machining deals with designing, establishing, and improving products and/or manufacturing processes?
9. What occupation requires knowledge of several different types of systems in order to troubleshoot and repair machine tools?
10. What is metrology?

UNIT 3 Workplace Skills

Learning Objectives

After completing this unit, the student should be able to:

- Identify and understand personal skills needed for success in the machining field
- Identify and understand technical skills needed for success in the machining field
- Show understanding of training opportunities and methods available to gain skills required for the machining field
- Create a career plan
- Create a resume
- Create a cover letter
- Compile a list of references
- Create a thank-you letter
- Describe a portfolio and its importance
- Use different methods to find job opportunities
- Conduct a practice interview

Key Terms

Apprentice
Apprenticeship
Associate degree
Baccalaureate degree
Career and Technical Education (CTE)
Certificate
Journeyperson
National Institute for Metalworking Skills (NIMS)
On-the-Job Training (OJT)
Personal skills
Technical skills
Vocational education

INTRODUCTION

Every career requires certain skills for success, and careers in the machining field are no different. Since there is often a lack of understanding of machining careers, there is also often a lack of understanding of the skills and knowledge needed to be a successful professional in the industry. All machining careers require a combination of mental and hands-on skills, although the blend may differ in different positions. Many of these abilities can be labeled as personal skills, or soft skills, that are largely part of someone's personality or nature but that can be honed and improved over time with practice. Others are technical skills, or practical skills, that are largely learned through various methods of formal and informal training and practice. There is, however, some overlap between personal and technical skills.

Once someone has the skills that are needed for industry employment, the search for a job must begin. There are several steps to take along this path, and there are some key job-seeking activities to pursue.

This unit will discuss the personal and technical skills commonly needed for success in machining careers and provide some job-seeking suggestions that can help someone find the job that is a good fit.

Once again, the following resources can provide additional information about skills required for specific jobs as well as data on wages and the outlook for machining jobs.

http://online.onetcenter.org/ is the home page of **O*NET**, the Occupational Information Network (O*NET) developed under the sponsorship of the U.S. Department of Labor/Employment and Training Administration (USDOL/ETA).

http://www.careeronestop.org/ is the home page of **Career One Stop**, another website that is also sponsored by the U.S. Department of Labor.

http://www.bls.gov/audience/jobseekers.htm is a page of the Bureau of Labor and Statistics, which is also a part of the U.S. Department of Labor.

http://www.dol.gov/dol/location.htm lists links to individual state agencies that provide career and employment data and resources specific to each U.S. state and territory.

PERSONAL SKILLS

Personal skills are largely part of an individual's personality or natural ability, but they can be honed or improved with practice. Some are purely physical, some are purely psychological, and some are a combination of both. All play a key role in achieving success in machining careers.

Mechanical Aptitude

Mechanical aptitude is a combined mental and physical skill. It refers to the ability to visualize and understand basic laws of how things work and move. That includes the relationship between moving parts and the concept of cause and effect.

This skill is critical in the machining field, as there are many relationships occurring at the same time between machine tools, cutting tools, and the materials they cut. Those kinds of connections also exist in complex tool or machinery assembly. The talent to assess many factors and predict results is a daily occurrence for many machinists, mold makers, toolmakers, and die makers, and it is important for success in those machining jobs.

Manual Dexterity and Eye-Hand Coordination

Manual dexterity and eye-hand coordination describe the physical ability to precisely control hand motions. Performing intricate operations involving small movements to make fine adjustments is common in the machining field. This occurs during hand tool and machine tool operations as well as during assembly procedures.

Problem-Solving, Troubleshooting, and Decision-Making Skills

Problem solving, or troubleshooting, means being able to recognize when something is incorrect and then making corrections to fix errors. Because of the complexity of many processes in machining, it is not always easy to identify causes of problems. It is also an asset to be able to look at a situation and predict areas where problems might arise before they occur. This skill can be improved by training in machining principles, but the base capability of making judgments using many pieces of information is largely an instinctive skill.

Once problems are identified, decisions need to be made to correct them. To make good decisions, analyze as much information as is available. Then identify possible solutions. By projecting and comparing the outcomes of each possible solution, you can make decisions that provide the best expected result.

Focus and Concentration with Attention to Detail

To become successful in the machining industry, the machine tool professional must have a high level of concentration as well as an eye for detail. Because of the high-precision nature of machining, even small lapses in attention can lead to large errors and huge losses of time and money. The complexity of normal daily tasks also calls for attention to minor details to ensure that specifications and goals are being met.

! CAUTION

Because of the highly automated and powerful equipment used today, loss of concentration and attention can create unsafe situations leading to personal injury or even death.

Persistence and Patience

Machine tool professionals must have the mind-set to stay on task until projects are complete. They also must take the time and precautions to make sure that work is done correctly. There are many tasks, especially in intricate part machining, programming, and mold, die, and toolmaking, that take long periods of time to complete, and often little visible progress is seen on a daily basis. Instant gratification and completion is not usually the norm for those in the machining field, so it is necessary to possess or develop long-term vision and goals and be able to persist at work that can be time consuming and tedious.

Personal Responsibility and Reliability

People in positions such as set-up technician; programmer; machinist; die, mold, and toolmaker; and especially manager are frequently given responsibility for progress and project completion with very little supervision along the way. For this reason, these jobs require personal accountability to meet both short-term and long-term goals. These people must strictly meet specifications and ensure that final products are correct, so it is necessary for a person to take ownership of his or her own work.

Ability to Perform Multi-Step Processes

Due to the lengthy procedures and multiple steps needed to perform even common everyday operations, the machining industry worker must be capable of performing those steps accurately. Following written or verbal instructions is also crucial to complete daily duties.

Ability to Use Technical Reference Materials

Machine tool technical manuals and complex reference books are very common in the field, so the skill of finding information in these different forms is fundamental to accomplishing many machining objectives. Reference materials can be textbooks or technical manuals. The Internet is also a valuable resource for obtaining technical information through educational, manufacturer, and machining industry associations and forums. This skill can be partially learned by becoming familiar with terminology and the format of types of sources, but it also requires a solution- and detail-oriented mind-set to know what to search for.

Interpersonal Skills

In the machining field, there is often the need to work with others. Many times, you must work with people who are skilled in areas that you are not. There is a need to communicate effectively to share information. When working in a team setting, all members should value each other's input and cooperate to meet required goals and objectives. Respect for others and their opinions creates a positive environment that will promote continuous improvement and success.

Significant Memory Use

There is an incredibly large amount of information required to perform machining operations and become highly skilled and successful in the field. No one can remember every small piece of information, but there are many of these small, but very important, pieces of information that are used every day in the industry and are needed for even small tasks. There are certainly times when reference materials need to be used, but many, many mathematical formulas, machining principles, and concepts used on a daily basis need to become second nature in order for you to perform efficiently and effectively.

TECHNICAL SKILLS

Technical skills are those that can be learned and improved with practice. Many are the "hands-on" abilities that need to be combined with personal skills in order to build a successful career in machining.

Ability to Interpret Engineering Drawings

Engineering drawings or prints are the plans or maps to creating parts through machining operations. They are a two-dimensional representation of three-dimensional parts and contain many important facts about types of materials to be used, part dimensions, required degrees of precision, surface and finish requirements, and other engineering specifications.

A significant amount of time needs to be invested to become proficient in understanding the language of engineering drawings. This usually involves studying sample prints and performing mathematical calculations using decimal and fractional numbers.

Knowledge of English and Metric Systems of Measurement

In today's global economy, there is a great deal of manufacturing that must meet specifications in both the United States and other countries around the world. For that reason, workers in the machine tool industry need to be able to recognize, compare, and convert measurements between the English, or inch, system and the metric system. Fortunately there are many tables and conversion charts available, but the skilled machining professional should be able to learn to use memory to reasonably visualize sizes in both inches and millimeters.

Proficient Math Skills

Whether planning or performing machining operations or conducting measurements, math plays a major role in the daily duties of machining professionals. Fractional and decimal operations as well as conversions between the two are needed every day. Basic skills in algebra, geometry, and right-angle trigonometry are also vital to performing common tasks.

Use of Hand Tools, Measuring Tools, and Machine and Cutting Tools

Different projects have different requirements according to specifications given on engineering drawings; so different tools will be used depending on those specifications. There are a very large number of different specialty hand, measurement, and cutting tools and machines in the industry, so those in machining careers must be able to select the proper tool for any given situation. Most of the tools used in the machining field are also very expensive, and many are very delicate, so proper use and care is necessary to avoid damage that leads to loss of time and money. Learning about the many tools in machining also requires a major investment of time.

Understanding of Metals and Other Materials and Their Properties

Machined parts can be manufactured from many different types of metals or other materials such as plastics, graphite, carbon fiber, or fiberglass. Metallurgy is the science of metals, and the basics must be learned to understand the characteristics of many different types of metals and how they will react during machining operations. That knowledge can also be applied in selecting the proper metal for a given application. The same can be said for nonmetal materials. There are many different compositions and grades of plastic, graphite, carbon fiber, fiberglass, and other materials.

Knowledge and Skill in the Use of Computer Technology

The computer is becoming a larger part of more and more occupations today. It is understandable that CNC programmers, designers, engineers, and managers need computer skills. But many other machining jobs require computer use also. Software is used in the field to perform tasks such as communication via email between co-workers, companies, departments and divisions of larger companies, and customers. Computer programs can be used to track orders, hours, and projects as they progress through different stages. The Internet can be a valuable resource to find and order tools and materials. For these reasons, today's machining professionals would be wise to learn basic computer skills.

TRAINING OPPORTUNITIES/ METHODS

The technical skills required for successful machining careers can be learned through several different methods, ranging from programs provided by public schools, community colleges, and universities to employer provided education. Some of the methods also aid in developing and improving personal skills as a complement to technical training.

Secondary School (High School) Programs

Many public school districts in the United States offer opportunities for basic to intermediate training related to the machining industry. The major benefit of training provided by the public school system is that there is no tuition cost to the student. Some high schools offer very basic hand and machine tool exposure through technology educational programs. These courses usually take place during one daily class period and last for one quarter or one semester. They can provide a brief introduction of machining to students and act as a gateway to other options.

Career and technical education (CTE) or **vocational education** historically has provided hands-on training in the trades to high school students to prepare them for career paths in various industries. These types of programs can provide training that covers topics in the machine tool field more broadly and deeply. These elective programs offer far more hours of education than standard high school technical courses and are usually offered at a common location for students in a particular geographic region. These specialty schools have many different names, including career centers, career and technology centers, and vocational high schools, and operate in a few different formats. Some of these schools are part time, where students split their attendance between their regular high schools and these specialty schools on a split-day schedule or an alternating weekly schedule over a period of 2 to 3 years. Others utilize senior-year-only systems where students attend full time and spend most of the day in a machining lab and only one to two class periods daily in academic courses.

The major benefit of this type of training is that there is no tuition cost to students, and some CTE programs provide instruction that is comparable to the first year of some post-secondary technical education programs. Further, this type of education can provide a solid background for further education or immediate entry into the workforce with above-average wage earning potential.

Post-Secondary Training

Post-secondary education in machining skills is offered through technical schools and colleges, community colleges, and universities. Many different schools offer training programs ranging from general machining to specialty areas of CNC programming; die making, mold making, and toolmaking; metrology; engineering; and engineering technologies. These programs vary in length from approximately 18 months to 4 years or longer.

Technical Schools and Community Colleges

Technical schools and community colleges usually offer **certificate** and/or **associate degree** programs. Certificate programs focus primarily on practical lab application courses and applied or practical academics. Associate degree programs normally require the same lab courses, but also call for more theoretical academic courses than certificate programs. Both of these programs can generally be completed within 2 years.

Universities

Universities normally offer associate (2-year) and **baccalaureate** (4-year) **degrees**. The 4-year programs normally offer more theoretical education and training in the specialty areas such as engineering disciplines.

Employer-Provided Training

Some employers provide training to employees while they are receiving wages. Companies will sometimes hire inexperienced employees at low wage levels as operators and move them into different positions as their skills increase. Further, companies may also need to provide training for specific specialized areas and may send employees off-site or bring trainers on-site to meet that need. This type of education is called **OJT** or **on-the-job training**. OJT can either be unstructured or structured.

Unstructured employer training is when a company teaches an employee only the skills that are needed to perform his or her current job or perhaps a future job in the company. The instruction occurs during the course of the normal operations during the work day and is usually given to meet only immediate needs.

Structured training exists in companies that have more formal, established training programs, but again these programs are frequently specific to the individual company's needs. Employees may receive instruction over a specified time period, and when they learn and demonstrate new, higher-level skills, they will likely receive wage increases and different job titles.

Apprenticeships

Some companies' training programs are called **apprenticeships**. Company trainees, called **apprentices**, receive a certain number of hours of practical training in machining operations during normal working hours. Apprenticeships can be internal, or relating only to a company. Others are sponsored by either a state labor department or the U.S. Department of Labor.

Internal or Company-Provided Apprenticeships

These are similar to the structured training programs discussed earlier, but upon completion of these apprenticeships, the employee receives the title of a **journeyperson** and is expected to be able to perform any machining operation required by that company. Company apprenticeships may or may not require classroom training outside regular work hours. They can be as short as 1 year or as long as 5 years in duration. Skills learned through completion of a company-sponsored apprenticeship are usually recognized by other companies in the same local area, but completion may not carry as much weight as state or nationally sponsored programs.

State or Nationally Recognized Apprenticeships

These apprenticeships are more formal programs that combine theoretical and practical education for a person while the person is employed in the machining industry. Such apprenticeships are sponsored by and accountable to either a state's labor department or the U.S. Department of Labor. Companies agree to provide a certain number of hours of practical training in machining operations during normal working hours. Apprentices must also attend classes outside their working day to learn theoretical aspects of the machining field. These classes are usually offered at a local technical or community college. As apprentices progress through these programs, they receive wage increases. Upon successful completion of an apprenticeship, the apprentice earns the title of a journeyperson and is expected to have a strong set of skills and knowledge related to the profession as a whole, not just a particular company. They also receive certification from the state or the United States. Credentials earned through these apprenticeships are usually more widely accepted than those earned through a company's internal apprenticeship. Apprenticeships can vary in length, but they average between 4 and 6 years. They are available in general machining, as well as specialties such as CNC programming, mold making, and toolmaking and die making.

NIMS

The **National Institute for Metalworking Skills (NIMS)** is an organization that plays a vital role in training for the machining industry. NIMS has established national benchmarks, or standards, for performance and knowledge related to several different areas of the machining industry. Many educational institutions and machining companies across the United States offer opportunities for individuals to earn certifications in those areas. The certifications are competency based, which means a person will gain certification only if rigid standards of performance are met.

NIMS has also developed a competency-based apprenticeship program that requires apprentices to meet nationally recognized standards before receiving journeyperson status. This is different from many apprenticeships, where completion is based on the number of hours spent in the program instead of meeting any specific levels of achievement.

NIMS certifications can be an asset to any person desiring to build a successful career in the world of modern machining. The topics covered in this text address the knowledge and skill areas required to achieve competency in the field and earn NIMS machining certifications. To learn more about NIMS, visit http://www .nims-skills.org.

JOB SEEKING

Specific skills needed for success in machining careers and methods to gain those skills have been identified. Next, there are some key steps to finding the job that is right for you. The first step is to have a career plan. Creating a resume and cover letter, along with a list of references, summarizes your skills and goals. Then you must find opportunities, show your interest in those opportunities, and be prepared to pursue them.

Career Plan

The purpose of a career plan is to help you pursue a career path that will give you satisfaction, not frustration. The plan is an evaluation of yourself and a list of your career goals. A goal is like a target; if you do not have one, you will never hit it.

Keep the plan simple so you can actually use it. Being honest with yourself is important. No one else needs to see your career plan, but you could ask someone to review it if you like. Listing strengths and weaknesses is a good idea. Then you know where you can excel and where you need to improve. Everyone can improve in some areas.

Update your plan every year, because you and your goals will probably change over time. Referring back to your career plan will help guide you in the direction you want to go. Here are a few questions that should be answered in your career plan.

- What duties or tasks required in the industry do I like to do, and which ones do I not like?
- What duties or tasks do I perform best, and which ones do I need more practice at?
- Where do I want to work and live? What state or country? In a rural or urban setting?
- What kind of company do I want to work for? Large or small?
- Do I want to own my own business?
- Do I want to continue my education?
- Do I want to advance or move into other areas of the industry?
- Where do I want to be a year from now? Three years from now? Ten years from now?

By answering these types of questions, you will look for opportunities that fit your wants and needs. **Figure 1.3.1** shows an example of a simple career plan.

Resume

Everyone should have a resume to show skills and education that are relevant to their chosen career fields. It is best to limit your resume to one or two pages. Prospective employers are distracted by having to flip through multiple pages when reviewing resumes. Resumes can be written in many different styles, but they should all contain the same key parts. **Figure 1.3.2** shows a sample resume layout of someone with no work experience seeking a first job. Refer to it while reviewing the following resume elements.

Personal Information

Across the top of your resume, write your name, address, phone number, and possibly email address. Make your name the largest text on the resume for easy identification.

Career Objective

A career objective is a short statement about your career goal. It can also list one or two of your important skills. Wording your objective in a way that shows how

John Doe's Career Plan

Things I like to do:
- Precision Measuring/Inspection
- Lathe Operations
- Vertical Milling Operations
- CAM Programming
- CNC Lathe Set-up/Operation
- CNC Mill Set-up/Operation

Things I don't like to do:
- Hacksawing
- Filing
- Deburring
- Pedestal Grinding
- Assembly
- Cutting Raw Material
- Surface Grinding

What am I good at?
- Programming
- CNC Mill Set-up
- Short Projects
- Inspection

Where I do need more practice?
- CNC Lathe set-up
- Long projects-patience
- CAM programming

I want to live in a very rural area like Wyoming or Montana.
I want to work within a 45-minute drive of my home.
I only want to work a day-shift job.
I want to work for a small company with about 10–50 employees.
I want to get a 4-year degree in engineering or design.
Within 3 years, I want to start working on my 4-year degree.
Within 5 years, I want to become a foreman or lead person.
Within 10 years, I want to finish my 4-year degree and move into design.

FIGURE 1.3.1 Simple career plan.

you would benefit the potential employer is a good idea. Avoid overused phrases such as "hard-working" and "dedicated." An employer expects these qualities, and has probably seen those words on countless other resumes. Make yours different, so it stands out.

Skills/Work Experience

List your abilities here. Start with those that are directly related to the job. Then list additional skills that might set you apart from other candidates for the job. For example, even if you are applying for an entry-level machine operator position, you could list computer or communication skills. These might show an employer that you have skills that could lead to advancement.

If you have employment experience, list your jobs in reverse chronological order, starting with your current or most recent one. List the dates worked, company name and location (city and state), and job title. Then list your job responsibilities using action words.

Education

If you have formal education related to the job you are applying for, list that information next. Start with the current (or most recent). List the name of the institution (school, college, university, etc.), its location (city and state), what type of credential you earned—such as a diploma, certificate, or degree—and the date you earned that credential.

You can also list any special achievements you accomplished during your education, such as honor roll, dean's list, or extracurricular activities.

Other

If you have earned any special awards or certifications that are not related to the previous topics, list them here. Also include membership in organizations or clubs. Examples include those related to community, social, or religious organizations. This section can have a title such as "Achievements" or "Community Activities."

John Doe

123 Main Street • Anytown, ZZ 54321 • Phone: 123-456-7890 • E-Mail: johndoe@anyserver.com

Objective

Goal-oriented student seeking an entry-level CNC machining position with a company that will allow me to apply my training, grow with the company, and help the company succeed.

Skills

- Solid knowledge of g-code programming and program formats for CNC milling machines and lathes
- Ability to select proper tooling for CNC machining operations
- Capable of set-up and operation of CNC machine tools equipped with ABC and XYZ controls
- Skilled in the use of semi-precision and precision measuring tools
- Capable of following verbal and written instructions
- Working knowledge of word processing, spreadsheet, email, and Internet software

Education

Well-Known Technical College Bigtown, BB 2011–2014

- Received Associate Degree in CNC Machining Technology in June 2009
- Member of Student Machine Tool Safety Committee
- Earned NIMS Level 1 Machining Certifications in CNC Milling and CNC Turning

Anytown Career Center Anytown, ZZ 2009–2011

- Received Certificate in Precision Machining Technology in June 2007
- Member of National Student Organization
- Earned the following NIMS Level 1 Machining Certifications
  - Measurement, Materials, and Safety
  - Job Planning, Benchwork, and Layout
  - Drill Press Operations
  - Turning Between Centers Operations
  - Turning/Chucking Operations
  - Vertical Milling Operations

Community Service

- Volunteer at Anytown Retirement Community
- Member of Anytown Volunteer Fire Department

References

Available on request

FIGURE 1.3.2 Sample resume.

References

References are people you know who can provide positive information about your attitude, work ethic, and skills. References should be people who are not family members. Teachers, coaches, guidance counselors, pastors, and neighbors can all serve as references. Always ask permission before using someone as a reference and record their names, addresses, and phone numbers. Compile a list of about six references, because you may want to use different people as references for different jobs. Let your references know that you are actively seeking a job so if employers contact them, they will not be surprised and unprepared to answer questions about you. **Figure 1.3.3** shows a sample list of references.

Keep your list of references separate from your resume and write "References available on request" at the bottom of your resume.

References for John Doe

Dave Johnson
CNC Machining Instructor
Well-Known Technical College
1 Education Drive
Bigtown, BB
321-123-5555, Extension 105

Mike Davis
Machining Instructor
Anytown Career Center
100 Career Lane
Anytown, ZZ
123-321-4321, Extension10

John Smith
Guidance Counselor
Anytown Career Center
100 Career Lane
Anytown, ZZ
123-321-4321, Extension 12

Steve Michael
Science Instructor
Anytown High School
12 Main Street
Anytown, ZZ
123-321-1234, Extension 302

Tim Edwards
Director
Anytown Retirement Community
50 Country Road
Anytown, ZZ
123-321-1111, Extension 101

Bob Jones
Pastor
Anytown Community Church
4321 Pine Street
Anytown, ZZ
123-321-4444

Ron Thomas
Chief
Anytown Volunteer Fire Department
Anytown, ZZ
123-321-7777

FIGURE 1.3.3 Sample list of references.

Cover Letter

A cover letter introduces you to a prospective employer. It needs to create enough interest for the person reading it to look at your resume. A poor cover letter might prevent a resume from ever being read. Like resumes, cover letters can be written in many styles, but they should contain the same basic elements. A cover letter should always be typed or prepared using word processing software and printed. Never submit a handwritten cover letter. Refer to the sample cover letter in **Figure 1.3.4** while reviewing the following elements.

Greeting

Try to find out the name of the person receiving the letter. If it is not known, try searching for a company website and directory. You can also call the company and ask for the name of the person in charge of human resources or personnel. Personally addressing your cover letter is much better than using a generic greeting. Address the person as either Mr. or Ms., not by first name, and be sure to spell the name correctly. If the person's name cannot be determined, use a reference line and greeting like this:

RE: CNC Operator Position

Greetings:

Then begin the body of the letter. This may not be ideal, but it is better than the impersonal, outdated "Dear Sir or Madam" or "To whom it may concern."

Body

If you are applying for a specific job, refer to it in the first paragraph. Also state how you learned about the job. Write something specific about the company to show that you are interested in its business. A little research