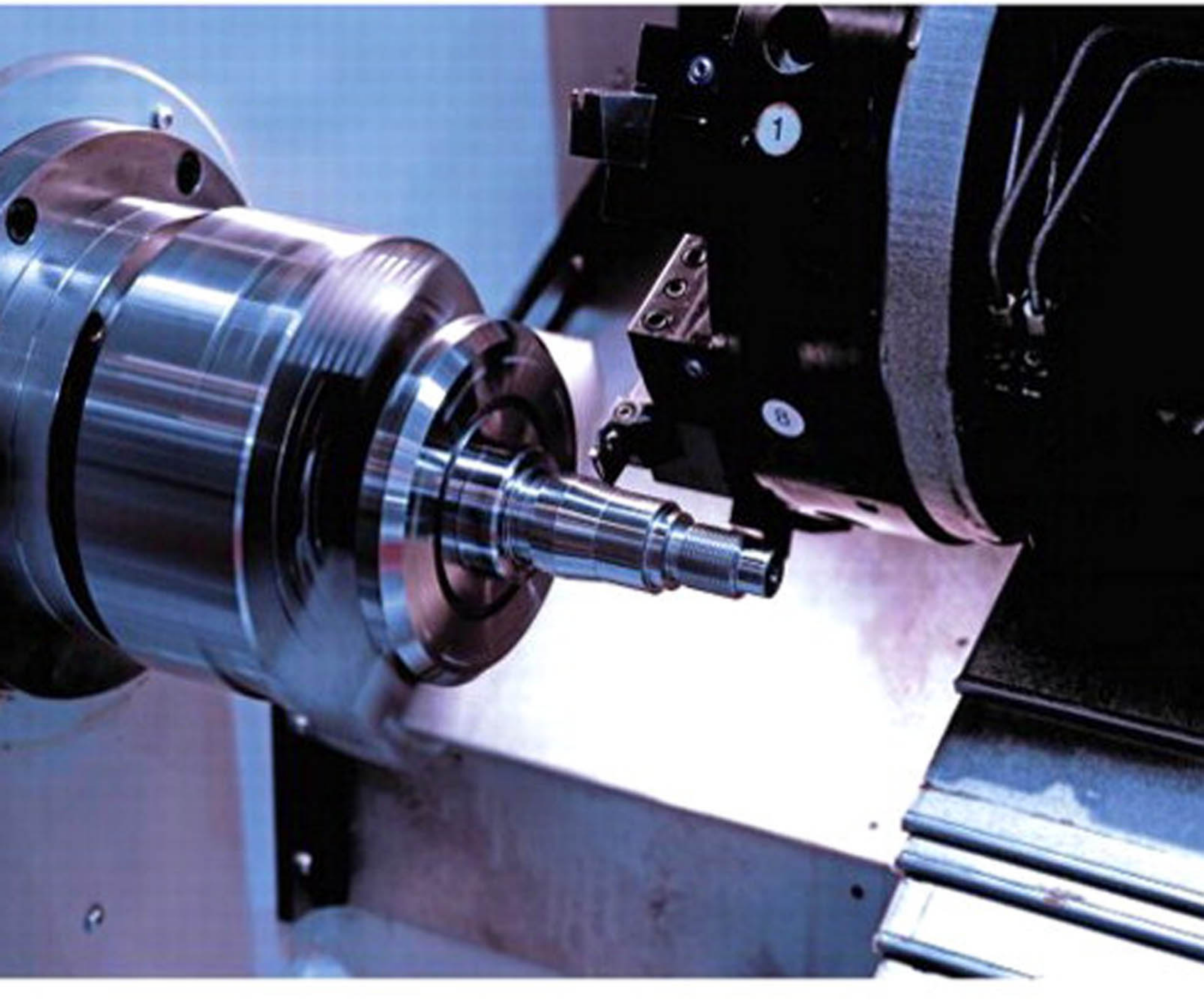
MACHINE TOOL PRACTICES

TENTH EDITION



RICHARD KIBBE | ROLAND MEYER | WARREN WHITE

JOHN NEELY | JON STENERSON | KELLY CURRAN

Machine Tool Practices

TENTH EDITION

RICHARD KIBBE

ROLAND MEYER

WARREN WHITE

JOHN NEELY

JON STENERSON

KELLY CURRAN

PEARSON

Boston Columbus Indianapolis New York San Francisco Hoboken
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Product Manager: Lindsey Gill
Program Manager: Maren Beckman
Project Manager: Rex Davidson
Editorial Assistant: Nancy Kesterson
Team Lead Project Manager: JoEllen Gohr
Team Lead Program Manager: Laura Weaver
Director of Marketing: David Gesell
Senior Marketing Coordinator: Stacey Martinez
Senior Marketing Assistant: Les Roberts
Procurement Specialist: Deidra M. Skahill
Media Project Manager: Noelle Chun
Media Project Coordinator: April Cleland
Creative Director: Andrea Nix
Art Director: Diane Y. Ernsberger
Cover Designer: Candace Rowley
Cover Image: sspopov/Shutterstock
Full-Service Project Management: Meeta Pendharkar, Lumina Datamatics
Composition: Lumina Datamatics
Printer/Binder: R.R. Donnelley & Sons
Cover Printer: Lehigh-Phoenix
Text Font: Minion

Credits and acknowledgments for materials borrowed from other sources and reproduced, with permission, in this textbook appear on the appropriate page within text.

Library of Congress Cataloging-in-Publication Data

Kibbe, Richard R.
Machine tool practices / Richard Kibbe, Roland Meyer, Warren White, John Neely, Jon Stenerson, Kelly Curran. — Tenth edition.
pages cm
Includes index.
ISBN 978-0-13-291265-5 (hardcover) — ISBN 0-13-291265-1 (hardcover)
1. Machine-tools. 2. Machine-shop practice. I. Title.
TJ1185.M224 2015
621.9'02—dc23

2014019329

10 9 8 7 6 5 4 3 2 1

PEARSON

ISBN 10: 0-13-291265-1
ISBN 13: 978-0-13-291265-5

Contents

SECTION L

Grinding and Abrasive Machining Processes, 573

SECTION M

Computer Numerical Control and Other Advanced Machining Processes, 645

APPENDIX 1

APPENDIX 2

APPENDIX 3

Preface

As a definitive text in the field for more than 30 years, *Machine Tool Practices*, 10th edition, is geared toward successfully training computer numerical control (CNC) and conventional machine operators, general machinists, and tool and die makers. It is ideal for those enrolled in apprenticeship training, community college courses, or vocational programs. Presented in a student-friendly manner, the book lends itself well to classes that take a combined lecture/laboratory approach, as well as to a self-paced instructional environment.

STRENGTHS AND UNIQUE SELLING POINTS

With more than 400 line drawings and 1,200 photographs, *Machine Tool Practices* is the best-illustrated book in this field. The text emphasizes practical shop knowedge and machine tool technology throughout and superbly illustrates the tools, equipment, and techniques that students are most likely to encounter in an actual industrial machine shop environment.

CLASSICAL PRACTICE/CURRENT TRENDS

Machine tools and machining practices have changed drastically over the past few years with advances in technology. This text has been aligned with standards that were developed by the National Institute of Metalworking Skills (NIMS). The National Institute for Metalworking Skills (NIMS) was formed in 1995 to develop and maintain a globally competitive American workforce. NIMS developed skills standards for industry, NIMS certifies individual skills against the standards and also accredits training programs that meet NIMS requirements. This text was developed for students studying machining who need to acquire the skills required by industry and to obtain NIMS certifications if they so desire. No matter what directions the field of machine tools and machining practices take in the future, *Machine Tool Practices* offers classical practice that is timely and essential to the basic foundation a student requires to participate effectively in the machining area of manufacturing technology. With the solid background in standard practice this text provides, students will confidently understand, appreciate, and operate computer-controlled and computer-supported machining as well as other high-tech manufacturing processes.

ORGANIZATION OF THE BOOK: TOTAL FLEXIBILITY TO SUIT YOUR TEACHING STYLE

The book is divided into 13 major sections and provides total flexibility to suit your teaching style. Appendix 1 contains Answers to Self-Tests, Appendix 2 offers practical General Tables, and Appendix 3 showcases Precision Vise Project Drawings. For the student, this project embodies many setups and techniques used in general precision machine shop work. The text also contains a Glossary and an Index. Many units are designed around specific projects that provide performance experience for students. The book structure makes it easy for instructors to include additional projects more applicable to specific individual programs.

NEW TO THIS EDITION

Updated to reflect the very latest trends and technology in the machine tool field, the tenth edition has been modernized to reflect the real-world environment and includes:

- New and updated color photos that depict the finer aspects of machine tools practice, including CNC
- Approximately 400 line drawings that provide easy comprehension and visually reinforce learning
- Expanded CNC content
- A self-test question set in each chapter
- A list of useful websites at the end of appropriate units that refer the reader to state-of-the-art information on cutting tools and machine shop equipment
- Improved readability for students

Guided Tour

Machine Tool Practices is divided into sections comprised of several units. To tool up, we invite you to take the Guided Tour.

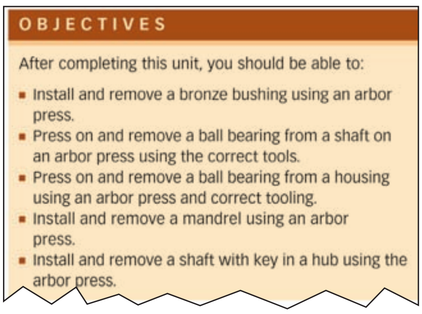
HALLMARK FEATURES

Introductory Overview

Introductions summarize and provide an overview of the main themes in each major section and help reinforce topics.

Objectives

Clearly stated objectives enable you to focus on what you should achieve by the end of each unit.



OBJECTIVES

After completing this unit, you should be able to:

- Install and remove a bronze bushing using an arbor press.
- Press on and remove a ball bearing from a shaft on an arbor press using the correct tools.
- Press on and remove a ball bearing from a housing using an arbor press and correct tooling.
- Install and remove a mandrel using an arbor press.
- Install and remove a shaft with key in a hub using the arbor press.

Photographs

Extensive use of color photographs provides you with views of actual machining operations.

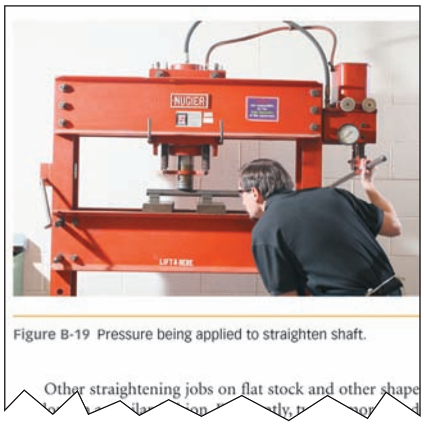


Figure B-19 Pressure being applied to straighten shaft.

Other straightening jobs on flat stock and other shape

Graphic Explanations

These detailed explanations highlight important concepts, common errors, and difficulties that machinists encounter.

Shop Tip

Shop Tip and **Shop Tip–Craftsmanship** boxes offer helpful tips and techniques to make the student a better and more intuitive machinist.

SHOP TIP

When reading any drawings in the machine shop, be sure to

1. Read any and all notes on the drawing.
2. Be sure that you are using the latest revision of a drawing. Errors can occur by machining parts to older drawing revisions. If you are unsure about the revision, check with your supervisor or instructor.

New Technology

Directs students to the latest technology in the field.

NEW TECHNOLOGY

Twist drills ordinarily do not produce a smooth hole. Often, reamers are used to produce a more dimensionally accurate hole with a smoother bore. However, this process will not produce a finish smooth enough for all purposes. Burnishing drills are available, designed not only to drill the hole, but also to finish it to size and increase the hole quality. They can be used for production drilling of cast iron, die-cast aluminum, and other nonferrous materials. Burnishing drills are presently used in the automotive, aerospace, compressor, and computer parts industries.

Professional Practice

Professional Practice provides tips from professional work environments.

PROFESSIONAL PRACTICE

The way a worker maintains his or her hand tools reveals the kind of machinist he or she is. Dirty, greasy, or misused tools carelessly thrown into a drawer are difficult to find or use the next time around. After a hand tool is used, it should be wiped clean with a shop towel and stored neatly in the proper place. If the tool was drawn from a tool room, the attendant may not accept a dirty tool.

Safety First

Safety First boxes provide safety warnings related to handling and working with various pieces of equipment.

SAFETY FIRST

The primary danger in operating the vertical band machine is accidental contact with the cutting blade. Workpieces are often hand guided. One advantage in sawing machines is that the pressure of the cut tends to hold the workpiece against the saw table. However, hands are often in close proximity to the blade. If you should contact the blade accidentally, an injury is almost sure to occur. You will not have time even to think about withdrawing your fingers before they are cut. Keep this in mind at all times when operating a band saw.

Always use a pusher against the workpiece whenever possible. This will keep your fingers away from the blade. Be careful when you are about to complete the cut: As the blade clears through the work, the pressure that you are applying is suddenly released, and your hand or finger can be carried into the blade. As you approach the end of the cut, reduce the feeding pressure as the blade cuts through.

Operating Tip

Advice on how to operate machinery students may come across in their studies or careers.

Self-Test

End-of-unit self-tests gauge how well you mastered the material.

SELF-TEST

1. What is the kerf?
2. What is the set on a saw blade?
3. What is the pitch of the hacksaw blade?
4. What determines the selection of a saw blade for a job?
5. Hand hacksaw blades fall into two basic categories. What are they?
6. What speed should be used in hand hacksawing?
7. Give four causes that make saw blades dull.
8. Give two reasons why hacksaw blades break.
9. A new hacksaw blade should not be used in a cut started with a blade that has been used. Why?

Internet References

The end of each unit lists pertinent Internet sites.

INTERNET REFERENCES

http://en.wikipedia.org/wki/Engineering_drawing
http://design-technology.info

COMPREHENSIVE TEACHING AND LEARNING PACKAGE

For the Instructor

Instructor's Guide with Lesson Plans

This handy manual contains suggestions on how to use the text for both conventional and competency-based education. It also includes unit post-tests and answer keys (ISBN–10: 0-13-291269-4).

PowerPoint Presentations

PowerPoint presentations feature topics of general interest to students of machine tool technology (ISBN–10: 0-13-291266-X).

TestGen (Computerized Test Bank)

TestGen contains text-based questions in a format that enables instructors to select questions and create their own examinations (ISBN–10: 0-13-291268-6).

To access supplementary materials online, instructors need to request an instructor access code. Go to **www.pearsonhighered.com/irc**, where you can register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail, including an instructor access code. Once you have received your code, log on to the site for full instructions on downloading the materials you wish to use.

Acknowledgments

The authors wholeheartedly thank the reviewers for the tenth edition for their insight and feedback:

Larry Crain
West Kentucky Community & Technical College

Jason Dixon
Bakersfield College

Billy Graham
Northwest Technical Institute

Raymond A. Miller
University of Cincinnati

Samuel Obi
San Jose State University

John Shepherd
Mt. San Antonio College

Ed VanAvery
Mid Michigan Community College

The authors would also like to thank Chris Banyai-Riepl of OMAX Corporation for his major contribution to the content on waterjet technology.

The authors would also like to thank Sandra McLain of OMAX Corporation for her assistance.

The authors would like to thank the following companies and schools for their contributions:

The 600 Group Plc.

Aloris Tool Technology Co. Inc.

American Iron and Steel Institute

American Society of Mechanical Engineers

ArcelorMittal

ASM International®

ATTCO, Inc.

Barnes International, Inc.

Bazell Technologies

Besly Cutting Tools, Inc.

Brodhead Garrett, a member of the School Specialty Family

Bryant Grinder Corporation

Buck Chuck Company

California Community Colleges

Cinetic Landis Ltd.

Clausing Industrial, Inc.

Climax Portable Machine Tools, Inc.

CMPC Surface Finishes, Inc.

Cogsdill Tool Products, Inc.

Command Tooling Systems/EWS

Confederation College

Criterion Machine Works

Dake Corporation

Desmond-Stephan Manufacturing Company

DoALL Company

Enco Manufacturing Company

Engis Corporation

ERIX TOOL AB

Fadal Engineering

Fine Tools

Fox Valley Technical College

Giddings & Lewis Machine Tools, LLC

Haas Automation, Inc.

Hardinge Inc.

Harig Mfg. Corp.

HE&M Saw

Illinois Tool Works, Inc.

IMI Machine Tools Pvt. Ltd.

Ingersoll Cutting Tool

Kalamazoo Machine Tool

Kennametal, Inc.

K&M Industrial Machinery Co.

Lane Community College

Louis Levin & Son, Inc.

Lovejoy Tool Company, Inc.

MAG Giddings & Lewis, Inc.
MAG Industrial Automation Systems LLC
Magna-Lock USA, Inc.
Mahr Federal Inc.
Maximum Advantage–Carolinas
Mazak Corp.
Metal Web News
Micro-Mark
Mitsubishi Laser
Mitutoyo America Corp.
Monarch Lathes
Monarch Machine Tool Company
North American Tool Corporation
Okamoto Corporation
Okuma America Corporation
Olson Saw Company
Pacific Machinery & Tool Steel Co.
Peerless Chain Company
Rank Scherr-Tumico, Inc.
Regal Cutting Tools
Reishauer Corp.
Reko Automation & Machine Tool
Renishaw, Inc.
Renishaw Plc
SCHUNK Inc.
Sii Megadiamond, Inc.
Sipco Machine Company
Southwestern Industries, Inc.
Supfina Machine Company, Inc.
TE-CO INC.
The duMONT Company, LLC
The L.S. Starrett Co.
TRUARC Company LLC
Ultramatic Equipment Co.
United Grinding Walter-EWAG
Vannattabros.com
Vermont Gage
Walker Magnetics
Weldon Tool–A Dauphin Precision Tool Brand
Wilson® Instruments
Wilton Corporation

About the Authors

Kelly S. Curran grew up in Michigan's Upper Peninsula where he started working in machine shops at a very young age. He holds an Associate of Applied Science degree from Ferris State College with an emphasis in machine tool technology. He also holds an Associates of Applied Science degree from the Northern Michigan University with an emphasis in Business.

Mr. Curran has considerable machine shop experience as well as industrial teaching experience and is the author and co-author of several publications in the machine tool manufacturing field. Mr. Curran has spent many years developing self-paced machine tool curriculum for the State of Wisconsin and Fox Valley Technical College.

Richard R. Kibbe (Late) served his apprenticeship in the shipbuilding industry and graduated as a journeyman marine machinist. He holds an associate in arts degree in applied arts from Yuba Community College with an emphasis in machine tool technology. He also holds bachelor's and master's degrees from the California State University with an emphasis in machine tool manufacturing technology.

Mr. Kibbe has considerable machine shop experience as well as community college and industrial teaching experience and is the author and co-author of several publications in the machine tool manufacturing field.

Roland O. Meyer spent the first 20 years of his career in the metal-working industry as a tool and die maker and machinist in machine design and manufacturing. He completed his apprenticeship as a tool and die maker at Siemens in Germany and then worked in die shops in Toronto and Windsor, Canada, before moving to Chicago, where he worked as a gage maker at Ford Motor Company. He was in charge of the U.S. Army machine shops in Korea and Italy for five years. When he returned to the United States, he worked in a manufacturing company designing and building experimental machines used in the timber and plywood industry.

He next entered academia and became the lead instructor at Lane Community College's manufacturing technology program in Eugene, Oregon, where he taught for 25 years. As CNC became the new method in machining, he developed a CNC curriculum and program. When CAM became available, he also developed a state-of-the-art CAM program with the assistance of a local software company.

John E. Neely (Late) grew up in the Pacific Northwest and entered the Army to serve in World War II. He became a master machinist, a mechanical engineer, a hydraulic engineer, and eventually an instructor at Lane Community College in Eugene, Oregon.

During his time as an instructor, he collaborated with others to develop highly successful course materials based on the individualized instruction approach. He and his collaborators wrote and published several textbooks based on those materials. Those books continue to be in use nationally and internationally.

Jon Stenerson served an apprenticeship in Tool Making with Mercury Marine. He has a BBA from the University of Wisconsin-Oshkosh and a Masters Degree from the University of Wisconsin-Stout. He held certifications for Certified Quality Engineer, Certified Quality Auditor, and Certified Lead Auditor.

Jon is the author and co-author of several books in the machining and automation field. Jon spent many years teaching and developing self-paced machine tool and automation curriculum for Fox Valley Technical College.

Warren T. White (Late) apprenticed as an optical instrument maker with Land-Air, Inc. After military service with the Army Air Defense Board, he obtained a graduate degree in psychology at Clark University. His interest in both learning theory and machine tools led to employment at Foothill College in the engineering department.

He initiated the machine tool technology program at De Anza College after an extensive survey of Silicon Valley manufacturing firms. He was the director of a California state-funded program to develop an individualized machinist curriculum in conjunction with several California community colleges and Lane Community College in Oregon. He also initiated the California community colleges' Multimediamobile, which operated between several California community colleges to develop individualized instructional media in several technical disciplines. He later taught industrial engineering classes at San Jose State University. He is certified by the Society of Manufacturing Engineers as a manufacturing engineer.

This page intentionally left blank

SECTION A

Introduction: Machining Careers and Competitive Manufacturing

Machining processes will always remain among the most important of the manufacturing processes. The fundamental cutting processes in machining such as milling and turning are still the most prominent. What has changed is the way in which these processes are applied, the cutting tool materials, the materials used for products, and the methods of material removal. These new methods include the use of lasers, electrical energy, electrochemical processes, and high-pressure water jets.

Computers have enhanced automated manufacturing; machining is no exception. Computer numerical control (CNC) machine tools have been available for many years. Modern machine tools of all types are equipped with their own computer numerical controls and almost every machining process can now be efficiently automated with an exceptional degree of accuracy, reliability, and repeatability. In fact, machining processes have become so sophisticated and reliable that robots are often used to load and unload parts. This application of computer-driven automated equipment is creating employment opportunities for skilled machinists and machine operators.

The computer has found its way into almost every other phase of manufacturing as well. One important area is computer-aided design/computer-aided manufacturing (CAD) (Figure A-1). Design is now done on computer terminals, and CNC programs are generated directly in CAD software utilizing the part electronic blueprint and specifications.

In order to be competitive, industry will continue to automate. There will be increased use of manufacturing cells of machines, increased use of robotics for loading and unloading parts to/from CNC machines. The automation will continue to improve the working conditions in manufacturing, reduce the manual labor required, and increase the need for skilled and knowledgeable workers.

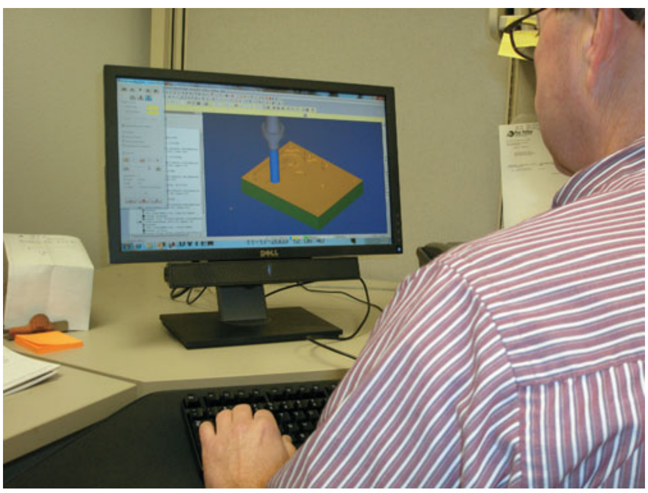


Figure A-1 A CNC programmer utilizing a CAD/CAM system to program a CNC machine *(Courtesy of Fox Valley Technical College).*

CAREER OPPORTUNITIES IN MACHINING AND RELATED AREAS

The increased use of computer technology and processes in industry has had a significant effect on the types and numbers of jobs available in manufacturing. Many exciting career opportunities are available in manufacturing and in machining in particular.

Manufacturing creates wealth. Manufacturing is crucial to economic success. There is a large demand for skilled manufacturing people. Wages and benefits for skilled manufacturing people are excellent. Wages and benefits for manufacturing are usually higher than other types of jobs. Working conditions have also dramatically changed. Most modern manufacturing facilities are clean, bright, and well-organized. Modern computer-controlled equipment has dramatically changed the role of the machinist from manual dexterity and manual skills to more knowledge-based skills.

Helpers and Limited Machinists

A person's first job in manufacturing might be as a helper or limited machinist. Many manufacturing industries use limited machinists or machinists' helpers. They learn the trade from the floor up. They might be sweeping the floor or cutting stock to rough lengths for further machining. They are given additional responsibilities as they prove themselves. Helpers and limited machinists may advance to other positions in the plant after gaining experience.

Machine Operator/Production Machinist

The machine operator's responsibilities are to operate computer-driven (CNC) machine tools such as turning or machining centers. The operator observes machine functions and tool performance, changes and inspects parts, and has limited duties in setting up and making minor changes to programs. Figure A-2 shows a machinist programming a part on a CNC turning center.

Machine operators should be familiar with basic machining processes, tooling selection and application, speeds and feeds, basic blueprint reading, basic math calculations, basic machine setup, and basic use of measurement tools. Machine operators are generally taught to use one or more CNC machine controls. Machine operators may receive training from a technical college, industrial training programs, or they may learn on the job. Additional education improves the chances of getting a good job and career advancement in the future.

Apprentice Machinist

The apprentice machinist learns the trade by entering a formal training program sponsored by private industrial, trade union, or government entity. The period of training

Figure A-2 Machinist programming a part on a CNC turning center *(Courtesy of Fox Valley Technical College).*

is typically four years and is a combination of on-the-job experiences and formal classroom education. Serving an apprenticeship represents one of the best methods of learning a skilled trade. Upon successful completion of the apprenticeship a journeyman's card is issued to the machinist.

Some companies have developed their own training programs for machinists. This is not a conventional apprenticeship and may not be as highly valued by other companies as a traditional apprenticeship.

Journeyman Machinist

The journeyman machinist will have the capability to set up and operate all the common conventional machine shop equipment as well as being competent with most CNC equipment. A person becomes a journeyman by serving an apprenticeship. A machinist apprenticeship is generally four years long. States have apprenticeship divisions that facilitate apprenticeships. An apprenticeship is a contract between the apprentice, the company, and the state. The contract is called an indenture. The indenture agreement specifies how long the apprenticeship will be, what the pay will be, what classes need to be taken, and the responsibilities of the apprentice, employer and the state. The role of the state apprenticeship division is to make sure that the apprentice learns a broad variety of knowledge and skills during the apprenticeship so they are very versatile and have a wide breadth of knowledge. The apprenticeship agreement will specify a number of hours to complete the apprenticeship. A four-year apprenticeship would be approximately 8320 hours. The pay for the apprentice generally increases about every six months until the apprentice finishes and gets full pay. The agreement will also specify the hours of required education. The apprentice then must attend the required classes during the apprenticeship. This would generally be one day a week during a normal school year. Classes are generally offered at a technical or community college. Employers might give a beginning apprentice credit for prior experience or classes already taken. This boosts their pay and shortens the length of time required to complete the apprenticeship. When an apprentice finishes, he or she is awarded a journeyman's card by the state. The card is proof that he or she has completed an apprenticeship. A journeyman's card is held in high regard by potential employers if the machinist wants to change employers. A machinist may also be involved with building special purpose fixtures for automating processes or for weld-type fixtures. Apprenticeship classes normally involve some welding. Welding is often used to weld components together to make fixtures. Larger shops may employ welders. In many shops machinists may do some welding to make weldments.

Tool and Die Maker

The tool and die maker will usually be an experienced general machinist with superior talents developed through an apprenticeship and more years of experience. The tool and die apprenticeship is usually five years and requires more classes than a machinist apprenticeship. Tool and die makers may receive training through industrial apprenticeships and/or college and trade school programs. They may also be selected for industrial training in companies large enough to have an in-house tool and die shop. Although tool and die makers are often chosen only after several years of on-the-job experience, it is possible to start out in tool and die work through an apprenticeship program. Tool and die makers often receive premium pay for their work and are involved with many high-precision machining applications, tool design, material selection, metallurgy, and general manufacturing processes. Tool and die makers may be involved with making tooling and fixtures for automated processes and production.

Quality Control Technician

Quality control technicians are involved with quality control and inspection. They utilize common measurement equipment as well as computerized coordinate measurement machines (CMMs) to inspect parts to make sure they meet the specifications (see Figure A-3). When parts are complex and or costly, the quality control technician often checks the first part coming out of a machine to be sure they meet requirements before more parts are run. Quality control technicians often have the responsibility for measurement tool calibration systems as well. They make sure that measurement equipment is accurate throughout the plant. Many quality control technicians began as machinists and moved into a quality control position. The quality control technician may receive training through college and trade school programs or on the job.

Supervisor

Many shop supervisors began their careers as machinists. A machinist who proves his or her capability might be chosen to be a supervisor. A supervisor is responsible for a group of people and a part of the production process.

Figure A-3 Quality control technician using a CMM to inspect a part *(Courtesy of Fox Valley Technical College).*

They may further their education by taking supervisory management classes at a local technical college, community college, or university.

CNC Programmer

Many shops centralize the programming of CNC machines. Instead of having machinists write their own programs, they have specialized people doing the CNC programming with special software. A machinist is very well prepared to be a CNC programmer. A machinist has knowledge of tooling, machining operations, feeds and speeds, and materials. To become a CNC programmer, a machinist would attend a class on the software or be trained by another employee on the software that the company uses for programming. Another advantage of centralized programming is that part programs can be developed and used for multiple machines.

Manufacturing Engineer

The manufacturing engineer, industrial technologist, and industrial engineer are often involved with the application of manufacturing technology. These individuals may be involved with the design of manufacturing tooling, setting up manufacturing systems, applying computers to manufacturing requirements, new product development, and improving efficiency.

Estimator/Bidder

Most machine shops do not make complete products. They produce parts for larger companies that do produce products. Shops that produce parts for other companies are often called job shops. Job shops must bid on work. An estimator/bidder looks at potential parts that need to be made and develops an estimate of how much it will cost to make. They consider costs such as: material, tooling, machine, special processes, labor, shipping, and so on. They then develop a quote that is sent to the company that is requesting quotes on the parts. If the quote is accepted, the shop will get an order for the parts. The estimator/bidder must be skilled at developing the quotes. The quote price must be high enough to make a profit, but low enough to beat bids from other shops.

Shop Owner

Most machine shops were started by machinists. Many shop owners were machinists who learned the trade, gained experience, and then bought one or more CNC machines and started their own company. Many manufacturing companies started this way and grew very rapidly to become large, successful businesses.

SPECIAL OCCUPATIONS

Automotive Machinist

The automotive machinist will work in an engine rebuilding shop where engines are overhauled. This person's responsibilities will be somewhat like those of the general machinist, with specialization in engine work, including boring, milling, and some types of grinding applications. Training for this job may be obtained on the job or through college or trade school programs.

Maintenance Machinist

The maintenance machinist has broad responsibilities. The person may be involved in plant equipment maintenance, machine tool rebuilding, or general mechanical repairs, including welding and electrical repairs. The maintenance machinist is often involved with general machining as well as with general industrial mechanical work. The maintenance machinist normally just uses simple manual machines to make or repair parts for machines.

MACHINING AND YOU

There are many exciting occupations available in manufacturing. These occupations provide a good working environment with wonderful wages and benefits as well as opportunities for advancement. Industry really needs people with good attitude and good work ethic. There is a real demand for, and shortage of, good attitude and good work ethic. Anyone with a good attitude and good work ethic will go far. Industry is more than willing to invest in training and advancement for those individuals. Professional behavior will also serve you well. Appropriate clothing and language help promote a professional personal image. Dealing well with people is also an important attribute. A working knowledge of the machining processes and the related subjects described in this book will provide an excellent basis on which to build a successful career in manufacturing.

FURTHER INFORMATION ABOUT OCCUPATIONS IN MANUFACTURING

If you have further interest in machine shop career opportunities, discuss the potential with an employment counselor at your school or a program instructor. Study the job advertisements in local newspapers to see what types of jobs are available. Talk to an employment agency about jobs that are in demand and the skills required to get them. Contact local manufacturing companies that employ machinists and ask for an opportunity to talk to someone about employment opportunities and tours of their facility. You may well find an employer who is willing to take you on as an intern while you go to school.

MANUFACTURING COMPETITIVENESS

Manufacturing is very competitive. A large percentage of manufacturing is done in job shops. They must bid on jobs to get work. The lowest bid with the ability to meet the specifications will generally get the bid and work. One of the techniques that manufacturers have been adopting to increase their efficiency is *lean manufacturing*.

Lean manufacturing is a technique that views the investment of a company's resources for any reason other than the creation of value for the customer to be wasted. The goal is to reduce or eliminate costs that do not create value for the customer. Customer value could be defined as any process that the customer would be willing to pay for. Many of the concepts and techniques of lean manufacturing have been around for a very long time. They only began to be called lean in the 1990s.

Lean manufacturing is concerned with producing the product with fewer resources. Many of the concepts are based on principles from the Toyota Production System (TPS). The Toyota Production System was based on reducing waste. TPS identified seven principal wastes.

The original seven wastes are:

Overproduction

Overproduction is defined as making a product before it is actually required. Overproduction is very costly because it prevents the efficient flow of materials and adversely affects productivity and quality. Overproduction often hides the real problems and opportunities for improvement in manufacturing. The goal is to make only what can be sold or shipped immediately. This is often called just-in-time.

Wait Time

If a product is not moving or being worked on, waste is occurring. In a typical company more than 99% of a product's time in the plant might be spent waiting to be processed. This is often because distances between work centers are too far, production runs are too long, and material flow is often very inefficient. Waiting can be reduced by having each process feed directly into the next process.

Unnecessary transportation

Transporting products between processes is a cost that does not add any value to the product. Excessive transportation and product handling can cause damage. When people have to excessively transport parts in a plant it takes time from their real role of adding value to the product. This is another cost that adds no value.

Excess Inventory

Excess inventory or work in progress (WIP) is a direct result of overproduction and waiting. Excess inventory hides problems on the plant floor. Excess inventory wastes floor space, increases lead times, and dramatically increases costs.

Unnecessary Motion

Unnecessary motion by people or equipment is a waste. This waste is related to ergonomics and is seen in all unnecessary movement of people performing an operation or task.

Over Processing

Over processing often involves the use of expensive, high-cost equipment where simpler tools would do the job. The use of high-cost technology often results in higher quantity runs to try and recover the high cost of the equipment. Toyota is famous for using low-cost automation and well maintained, older machines. If a machine is needed to produce X number of parts, Toyota would typically by a low-cost machine to produce that many parts. If production demands increase, they would buy another low-cost machine to meet the increased demand. American manufacturers would typically buy a more expensive machine that could produce many more than the required parts. There is less risk involved with the Toyota method. Where possible, companies should invest in smaller and more flexible equipment.

Defective Product

Quality defects that cause scrap or rework are a huge cost to manufacturers. When scrap is produced many additional costs occur. These additional costs include quarantining the defective product, reinspecting it, and rescheduling the line to reproduce the scrapped product. This results in the loss of capacity as the time and resources used to reproduce the product cannot be used to create additional product. The total cost of defects is often a very significant percentage of the total cost of manufacturing.

An eighth waste has been recently been added: underutilization of employees**.** Enterprises often hire employees to physically produce products but do not utilize their brain. Manufacturers must utilize their employees' creativity to eliminate the seven wastes and increase productivity.

Many of the principles of lean manufacturing come from the Japanese manufacturing industry.

LEAN MANUFACTURING TOOLS FOR IMPROVEMENT

Many view lean manufacturing as a set of tools that assist in the identification and elimination of waste. When waste is eliminated, quality improves, and production time and cost are reduced. Some of the tools that are utilized in lean manufacturing include: Five S, Value Stream Mapping, Kanban (pull systems), and Poka-Yoke (error-proofing).

The Five S Improvement Tool

The term *Five S* comes from the Japanese. The five Japanese words used to describe the method all begin with the letter s.

Sorting (Seiri) All unnecessary parts, tools, and instructions should be eliminated. Thoroughly examine all tools, materials, instructions, and so on in the work area and overall plant. Only essential items should be kept. Essential tools should be easily accessible in the work station. Everything that is nonessential should be stored or discarded.

Stabilizing or Straightening Out (Seiton) This technique stresses that there should be a place for everything and everything should be in its place. There should be a place for each item in a station and it should be clearly labeled. Parts, tools, supplies, and equipment should be located close to where they are needed. Everything should be arranged to promote efficient work flow.

Cleaning or Shining (Seiso) Clean the workspace and equipment, and then ensure it is always keep it clean and organized. At the end of each shift, clean the work area and be sure everything is restored to its place. Spills, leaks, and other messes also then become a visual signal for equipment or process steps that need attention. Maintaining cleanliness must be an integral part of the daily work.

Standardizing (Seiketsu) All work practices should be consistent and be standardized. Work stations for a particular operation should all be exactly the same. All employees with the same role should be able to work in any station. The same tools should be in the same location in every station.

Sustaining the Practice (Shitsuke) The new standards that have been implemented as a result of the previous tools must be reviewed, maintained, and improved. After the first four S's have been established, they must continue to be the new way to operate. This new way must be sustained. The plant must not be allowed to slide back to the old ways of operating. Everyone must also commit to continuously trying to find improvements.

Value Stream Mapping

Value stream mapping is a lean manufacturing tool that can be used to analyze and design the flow of materials and information required to bring a product to a customer. It originated at Toyota.

Implementation Steps

1. Identify the product to be studied.
2. Draw a state value stream map based on the shop floor that reflects the current steps, waits, and information flows required to deliver the product. This can be done by drawing it on paper or with special value stream mapping software.
3. Assess the efficiency of the current value stream map in terms of improving flow by eliminating waste.
4. Develop the redesigned value stream map.
5. Implement the redesign.

Value stream mapping is also used in manufacturing, supply chain, service, healthcare, product development, and many other areas.

Shigeo Shingo was a Japanese industrial engineer who is considered one of the world's leading experts on manufacturing and the Toyota Production System. Shigeo Shingo suggested that the value-adding steps be drawn horizontally across the center of the value stream map and the non–value-adding steps be drawn vertically at right angles to the value stream.

This makes it easy to distinguish the value stream from the wasted steps. Shingo calls the value stream the process and the non–value streams the operations. Shingo viewed each vertical line as the story of a person or workstation. He viewed the horizontal line as the story of the product being created. As you can see, this is a very visual and easy to understand tool to study and improve a process.

Kanban

Kanban is not an inventory control system. It is a scheduling system that helps determine what to produce, when to produce it, and how many to produce.

In the 1940s, Toyota studied supermarkets to try and apply store and shelf-stocking techniques to the factory floor. It was Toyota's thought that in a supermarket, customers get what they need at the needed time, and in the needed quantity. Toyota saw that a supermarket only stocks what it thinks will sell, and customers only buy as many as they need because they are not worried about getting additional products in the future. Toyota saw a process as being a customer of the processes that preceded it. The customer (worker) goes to the store to get the parts they need, and the store restocks with additional product like a store would.

Kanban uses the rate of demand to control the rate of production. Demand is passed from the end customer through the chain of customer (worker) processes. Toyota first applied this technique in 1953 in their main machine shop.

Imagine that one of the components needed to make the product is a ¼-20 bolt and it arrives in a box. There are 100 of the bolts in a box. The worker might have two boxes of bolts available. When the first box is empty, the assembler installing the bolts would take the card that was attached to the box and send it to the bolt making department. The assembler would then begin to use the bolts from the second box of bolts. The card would serve as an order for another box of 100 bolts. The box of bolts would be made and sent to the assembler.

A new box of bolts would not be produced until a card is received. In this way the demand drives the rate of production.

Kanban is called a pull-type production system. The number of bolts that are produced depends on the actual demand. In this example, the demand is the number of cards received by the bolt manufacturing area from the customer (assembler).

Poka-Yoke Poka-Yoke is a Japanese word that means mistake-proofing or fail-safing. A Poka-Yoke is any mechanism in a lean manufacturing process that helps an equipment operator avoid mistakes. For example, the addition of a pin in a fixture to prevent the part from being mislocated would be a Poka-Yoke. Poka-Yoke attempts to eliminate product defects by preventing, correcting, or warning the operator an error is about to occur. Shigeo Shingo first used the term Poka-Yoke as part of the Toyota Production System.

With a Poka-Yoke technique the operator is alerted when a mistake is about to be made, or the Poka-Yoke device actually prevents the mistake from being made.

Summary of Lean Manufacturing

Toyota's belief is that *lean* is not the tools, but the actual reduction of three types of waste: non-value-adding work, overburden, and unevenness of production. The tools are used to expose problems and improve processes.

Lean manufacturing attempts to get the correct things to the correct place at the correct time in the correct quantity to achieve an efficient work flow. Lean manufacturing also attempts to minimize waste and make processes flexible and able to react to change. For lean manufacturing techniques to be effective, it must be understood and be actively supported by the employees who build the product and add the value.

SELF-TEST

1. Develop a personal career plan. What job would you like to start your career in? What would you like to be doing in five years? Fifteen years?
2. List five things you can do to achieve your 15-year goal.
3. Companies are looking for people with good attitude and work ethic. List at least five things that describe the attributes of good attitude. List at least five things that describe the attributes of work ethic.
4. How is lean manufacturing supposed to make a company more efficient and more profitable?
5. What was the basis of improvement in the Toyota Production System?
6. The Toyota Production System originally listed seven wastes. An eighth was added. What is it and what does it mean for you in your career?
7. What is the basis of the Five S tool?
8. How can Value Stream Mapping improve a process?
9. What is Kanban?
10. What is Poka-Yoke?

Units in This Section

The units in this section deal with the important areas of safety in the machine shop, mechanical hardware, and reading shop drawings. These fundamental technical foundation areas are necessary for anyone involved in any phase of manufacturing technology.

UNIT ONE

Shop Safety

OBJECTIVES

After completing this unit, you should be able to:

- Identify common shop hazards.
- Identify and use common shop safety equipment.
- Explain the classes of fires that are applicable to a machine shop.
- Given a fire extinguisher, explain what types of fires it can be used on.
- Demonstrate safe working practices in the shop.
- Explain Lockout/Tagout.

SAFETY FIRST

We generally do not think about safety until it is too late. Safety is not often thought about as you proceed through your daily tasks. Often you expose yourself to needless risk because you have experienced no harmful effects in the past. Unsafe habits become almost automatic. You may drive your automobile without wearing a seat belt. You know this to be unsafe, but you have done it before and so far no harm has resulted. None of us really likes to think about the possible consequences of an unsafe act. However, safety can and does have an important effect on anyone who makes his or her living in a potentially dangerous environment such as a machine shop. An accident can reduce or end your career as a machinist. Accidents are always unexpected! You may spend several years learning the trade and more years gaining experience. Years spent in training and gaining experience can be wasted in an instant if you should have an accident, not to mention a possible permanent physical handicap for you and hardship on your family. Safety is an attitude that should extend far beyond the machine shop and into every facet of your life. You must constantly think about safety in everything you do. Safe habits must be developed and utilized. Safety glasses are just one example. You must develop the habit to wear them at all times in the shop to the point that you feel naked without them.

PERSONAL SAFETY

Grinding Dust, Hazardous Fumes, and Chemicals

Grinding dust is produced by abrasive wheels and consists of extremely fine metal particles and abrasive wheel particles. These should not be inhaled. In the machine shop, most grinding machines have a vacuum dust collector (Figure A-4). Grinding may be done with coolants that aid in dust control. A machinist may be involved in portable grinding operations. You should wear an approved respirator if you are exposed to grinding dust. Change the respirator filter at regular intervals. Grinding dust can present a great danger to health.

Some metals, such as zinc, give off toxic fumes when heated above their boiling point. When inhaled, some of these fumes cause only temporary sickness, but other fumes can be severe or even fatal. The fumes of mercury and lead are especially dangerous, as their effect is cumulative in the body and can cause irreversible damage. Cadmium and beryllium compounds are also very poisonous. Therefore, when welding, burning, or heat-treating metals, adequate ventilation is an absolute necessity. This is also true when parts are being carburized with compounds containing potassium cyanide. These cyanogen compounds are deadly poisons, and every precaution should be taken when using them. Kasenit, a trade name for a nontoxic carburizing compound, is often found in school shops and in machine shops.

There may also be chemical hazards in the machine shop; lubricating oils, cutting oils, various coolants, solvents, and some types of degreasing agents may be used. Any of these chemical agents can cause both short- and long-term health problems. Cutting oils may smoke when heated and give off noxious fumes. Inhaling any type of smoke can have short- and long-term health risks. Coolants may cause contact dermatitis, a skin irritation problem, and prolonged exposure can cause other long-term health problems. You should seek chemical safety data regarding these products

Figure A-4 Dust collector installed on grinder.

and determine what heath problems both short- and long-term exposures can cause. In the past, exposure to hazardous chemicals was often neglected until serious health problems began to appear, sometimes many years after exposure. Today, in the industrial world, exposure to chemicals has become a keenly studied subject because it is not always known what the results of long-term exposures can mean to lifetime health issues. Chemical hazard awareness programs label chemicals to make employees aware of particular fire, health, and reactivity issues.

Material Safety Data Sheets (MSDS)

A material safety data sheet or MSDS contains information describing the properties of particular chemicals, materials, and other substances. Technical data are provided defining the chemical and physical properties of materials, such as melting point, boiling point, flash point, and any toxic elements that are likely to be present during processing or handling. Other items that may be included on an MSDS are proper disposal techniques, first-aid issues from exposure to hazardous materials, and protective equipment required to safely handle the material. Material safety data sheets are available from many different sources including the Occupational Safety and Health Administration (OSHA) and manufacturers' published information. MSDS sheets should be readily available in the shop. Modern industrial operations often use many hazardous materials. Safety in using, handling, and disposing of these materials has become extremely important owing to concerns about environmental pollution and protecting the human workforce from both short- and long-term health concerns.

Eye Protection

Eye protection is a primary safety consideration around the machine shop. Machine tools produce metal chips, and there is always a possibility that these may be ejected from a machine at high velocity. Sometimes they can fly many feet. Furthermore, most cutting tools are made from hard materials. They can occasionally break or shatter from the stress applied to them during a cut. The result can be more flying metal particles.

Eye protection must be worn at all times in the machine shop. Several types of eye protection are available. Plain safety glasses are all that are required in most shops (see Figure A-5). These have shatterproof lenses that may be replaced if they become scratched. The lenses have a high resistance to impact.

Side shield safety glasses must be worn around any grinding operation. The side shield protects the side of the eye from flying particles. Side shield safety glasses may be of the solid or perforated type. The perforated side shield type fits closer to the eye.

Prescription glasses may be covered with safety goggles. The full face shield may also be used (Figure A-6). Prescription safety glasses are available. In industry, prescription safety glasses are sometimes provided free to employees.

Foot Protection

Generally, the machine shop presents a modest, but real hazard to the feet. However, there is always a possibility that you could drop something on your foot. A safety shoe with

Figure A-5 Safety glasses.