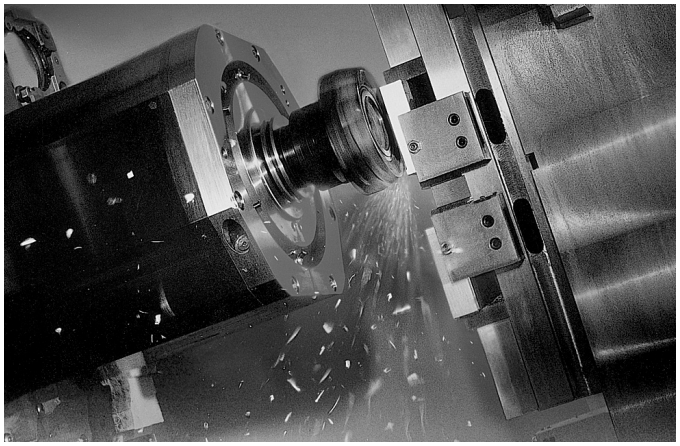


Chapter 25

Heat Treatment of Metals

LEARNING OBJECTIVES

After studying this chapter, students will be able to:

- Explain why some metals are heat-treated.
- List some of the metals that can be heat-treated.
- Describe some types of heat-treating techniques and how they are performed.
- Case harden low-carbon steel.
- Harden and temper some carbon steels.
- Compare hardness testing techniques.
- Point out the safety precautions that must be observed when heat-treating metals.

INSTRUCTIONAL MATERIALS

Text: pages 467–488
Test Your Knowledge Questions, page 487
Workbook: pages 135–138
Instructor's Resource: pages 323–330
Guide for Lesson Planning
Research and Development Ideas
Reproducible Masters:
25-1 Critical Range Diagram for Plain Carbon Steel
25-2 Test Your Knowledge Questions
Color Transparencies (Binder/CD only)

GUIDE FOR LESSON PLANNING

Prepare a number of center punches in various stages of heat treatment. The punch in the annealed stage should show a blunted point because it is not hard enough. The fractured pieces of a glass hard punch will illustrate what happens when steel is hardened but not tempered. A properly heat-treated punch will show no signs of wear.

Have the class read and study the chapter, paying particular attention to the illustrations. Review the assignment and discuss the following:

- Everyday items they believe must be heat treated to fulfill their function.
- What heat treatment involves.
- Metals that can be heat treated.
- Types of heat treatment.
- Purpose of stress-relieving.
- The annealing process.
- The process of normalizing steel.
- The hardening process and why additional heat treatment is usually required.
- Surface hardening and the various techniques used.
- Why case hardening is used and how it is done.
- Why tempering or drawing is done.
- Heat treatment of metals other than steel.

- Heat-treatment equipment.
- Quenching media and its uses.
- How carbon steel is hardened and tempered.
- How low-carbon steel is case hardened.
- Hardness testing and why it is performed.
- The equipment used for hardness testing and how each type is used.
- Heat-treating safety.

Emphasize the safety precautions that must be observed when performing heat-treating operations.

Demonstrate the following:

- Annealing.
- Hardening and tempering.
- Case hardening techniques.
- Furnace operation.
- The use of the various testing devices.

When demonstrating heat-treating techniques, be sure there is adequate ventilation and all safety precautions are observed by the instructor and students/trainees.

Plan work allowing the class to develop basic heat-treating skills.

Review the demonstrations and provide students with the opportunity to ask questions.

Technical Terms

Review the terms introduced in the chapter. New terms can be assigned as a quiz, homework, or extra credit. The following list is also given at the beginning of the chapter.

annealing
Brinell hardness tester
case hardening
hardness number
normalizing
Rockwell hardness tester
scleroscope
stress-relieving
tempering
Webster hardness tester

Review Questions

Assign *Test Your Knowledge* questions. Copy and distribute Reproducible Master 25-2 or have students use the questions on page 487 and write their answers on a separate sheet of paper.

Workbook Assignment

Assign Chapter 25 of the ***Machining Fundamentals Workbook.***

Research and Development

Discuss the following topics in class or have students complete projects on their own.

1. Prepare a glossary of heat treating terms. Duplicate and distribute copies to the class.
2. When heat-treating aluminum alloys, the terms *solution heat treatment* and *precipitation hardening* are used. What do they mean?
3. The Metcalf Experiment is one method used to show the grain structure of heat-treated steel and the effects caused by overheating. How is it performed? Perform the experiment and mount the pieces that show the results on a panel for observation.
4. Demonstrate the proper way to harden and temper a piece of tool steel.
5. Demonstrate the proper way to case harden low-carbon steel by carburizing. Use Kasenit as the carbon source.
6. Secure samples of work that have been heat-treated by various techniques.
7. The Moh Scale was the first hardness testing technique. Research the Moh Scale and explain how it was used.
8. Secure handbooks from the various steel manufacturers and/or distributors for inclusion in the shop's technical library.
9. Arrange a field trip to a local industry that has a heat-treating area. Ask to have the various hardness testers demonstrated.
10. Secure literature on various hardness testers for inclusion in shop's technical library.

TEST YOUR KNOWLEDGE ANSWERS, Page 487

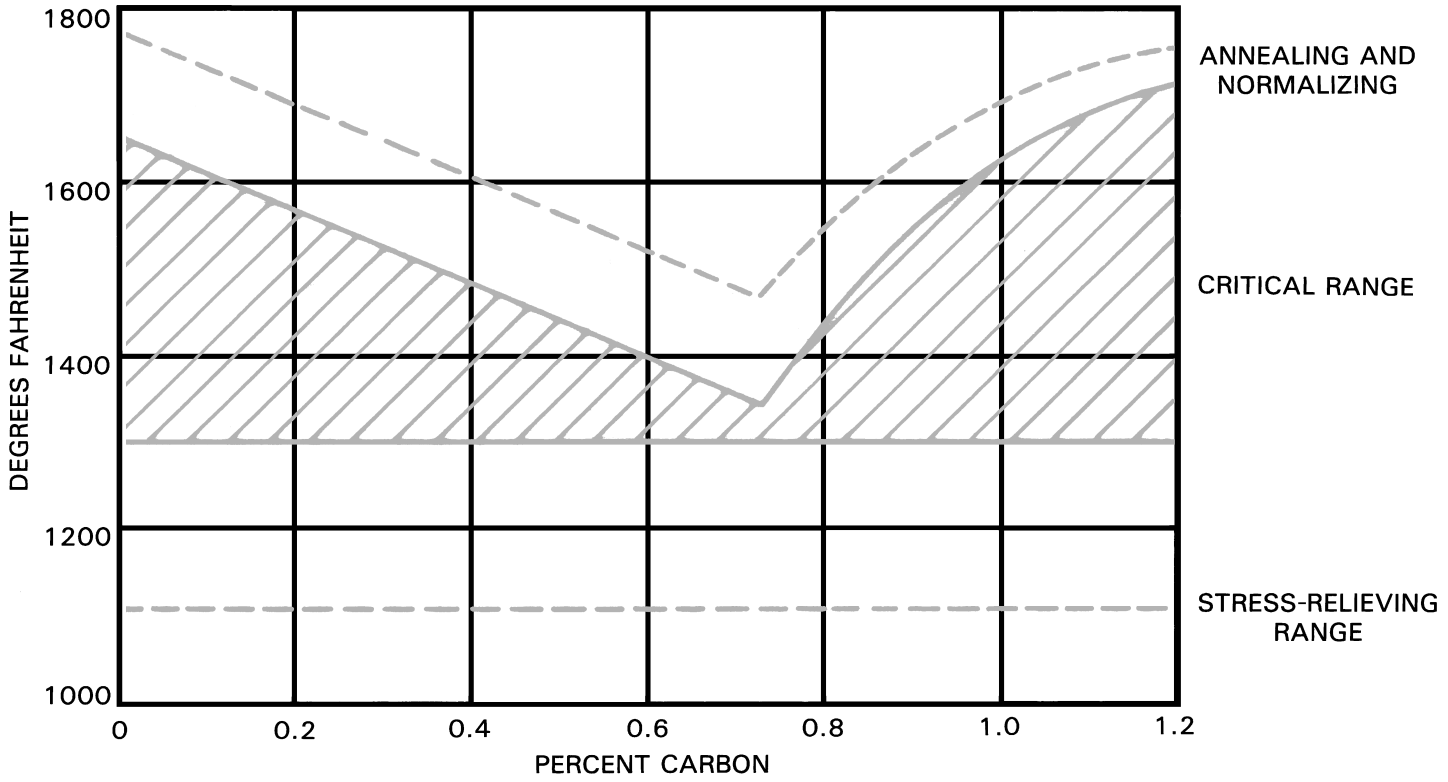
1. d. All of the above.
2. It is the controlled heating and cooling of a metal to obtain certain desirable changes in its physical properties.
3. Students may give an example such as: 60 point carbon steel would contain 60/100 (0.60) of 1% carbon. Evaluate individually.
4. Student answers will vary but may include four of the following: magnesium, many aluminum alloys, copper, titanium, beryllium copper.
5. oil, brine, air, nitrogen
6. c. Done to reduce stress that has developed in parts that have been welded, machined, or cold worked during processing.

7. a. Involves heating metal to slightly above its upper critical temperature and then permitting it to cool slowly in insulating material. Hardness of the metal is reduced.
8. b. Used to refine grain structure of steel and to improve its machinability.
9. e. Only the outer surface of low-carbon steel is hardened while the inner portion remains relatively soft and tough.
10. d. Used when only a medium-hard surface is required on high-carbon or alloy steels.
11. f. Accomplished by heating metal to its critical range and cooling rapidly.
12. c. Tough.
13. It is quieter, does not have to be ventilated, temperature can be more accurately controlled, and it is safer to operate.
14. pyrometer
15. Test used to accurately measure the degree of the hardness/softness of a metal compared to known standards.
16. The Brinell Hardness System, Rockwell Hardness System, and the Shore Scleroscope Hardness Tester.
17. Evaluate individually. Refer to Section 25.5.
18. Evaluate individually. Refer to Section 25.9.

WORKBOOK ANSWERS, PAGES 135–138

1. Improved resistance to shock, toughness development, and increased wear resistance and hardness.
2. 50
3. Removes internal stresses that have developed in parts that have been cold worked, machined, or welded. Also known as stress-relieving.
4. The part is placed in a metal box and the entire unit is heated, then allowed to cool slowly in the sealed furnace. It is used to prevent the work from scaling or decarbonizing.
5. Annealing reduces the hardness of a metal, making it easier to machine or work.
6. Normalizing is a process employed to refine the grain structure of some steels thereby improving machinability.
7. Surface hardening is used when only a medium hard surface is required on high-carbon or alloy steels.
8. Hardening is accomplished by heating metal to its critical range and cooling rapidly. It is normally employed to obtain optimum physical qualities in steel.
9. The temperature at which steel will harden. It ranges from 1400°F–2400°F (760°C–1316°C), depending on the alloy and carbon content.
10. b. Flame
11. Carburizing, liquid salt or cyanide, nitriding or gas method.
12. Case hardening puts a hard shell on the surface of low-carbon steel while the inner portion of the metal remains soft.
13. carburizing
14. Tempering or drawing is used to reduce a metal's brittleness or hardness. It involves heating the steel to below the metal's critical range. It is held at the temperature until penetration is complete and then it is quenched.
15. d. All of the above.
16. titanium
17. d. All of the above.
18. sealed and a vacuum drawn to remove atmospheric gases that might contaminate the metal being heat-treated
19. With the use of a color chart, the temperature can be judged by the color of the metal as it heats.
20. Evaluate individually. Students may give one of two methods listed in Section 25.7.
21. Hardness testing
22. They use the technique that measures the distance a steel ball or special-shaped diamond penetrates into the metal under a specific load.
23. The scleroscope uses a technique that drops a small diamond hammer onto the test piece and the height of the rebound of the hammer is used to determine the hardness of the metal.
24. a. Webster hardness tester
25. Evaluate individually. Refer to Section 25.9.

Critical Range Diagram for Plain Carbon Steel



Heat Treatment of Metals

Name: _____Date: _____ Score: _____

1. Heat-treating is done to: 1. _____
   a. Obtain certain desirable changes in the metal's physical characteristics.
   b. Increase the hardness of the metal.
   c. Soften (anneal) the metal.
   d. All of the above.
   e. None of the above.
2. What does heat-treating involve? _____

_____

_____

_____

_____

_____

_____

3. Carbon steels are classified by the percentage of carbon they contain, expressed in "points" or hundredths of 1%. If this statement is true, briefly explain what it means. _____

_____

_____

_____

_____

_____

4. Other than steel, list four other metals that are capable of being heat-treated. _____

_____

_____

_____

5. In addition to water, _____, _____, blasts of cold _____, or liquid _____ may be used as a quenching medium. 5. _____

_____

_____

_____

Name: _____

- Each word in the left column matches one of the sentences. Write the letter next to the appropriate number to match the words and statements.

_____ 6. Stress-relieving.

_____ 7. Annealing.

_____ 8. Normalizing.

_____ 9. Case hardening.

_____ 10. Surface hardening.

_____ 11. Hardening.

a. Involves heating metal to slightly above its upper critical temperature and then permitting it to cool slowly in insulating material. Hardness of the metal is reduced.
b. Used to refine grain structure of steel and to improve its machinability.
c. Done to reduce stress that has developed in parts that have been welded, machined, or cold worked during processing.
d. Used when only a medium-hard surface is required on high-carbon or alloy steels.
e. Only the outer surface of low-carbon steel is hardened while the inner portion remains relatively soft and tough.
f. Accomplished by heating metal to its critical range and cooling rapidly.

12. Tempering a piece of hardened steel makes it: 12. _____
    a. Brittle.
    b. Soft.
    c. Tough.
    d. All of the above.
    e. None of the above.

13. What advantages does an electric heat-treating furnace have over a gas fired heat-treating furnace?

_____

_____

_____

14. The _____ is used to measure and monitor the high temperatures needed in heat-treating. 14. _____

15. What is hardness testing? _____

_____

_____

_____

16. List three types of commonly used hardness testers._____

_____

_____

_____

Name: _____

17. What safety precautions must be observed when lighting a gas-fired heat-treating furnace?

_____

_____

_____

_____

_____

18. List five safety precautions that must be observed when heat-treating metal.

_____

_____

_____

_____

_____