	UNIVERSITI TEKNIKAL MALAYSIA MELAKA	No. Dokumen: SB/MSTB/T2/ BMCB2423/4	No. Isu./Tarikh: 2/28-6-2008
MATERIALS SCIENCE Heat Treatment Of Steel		No. Semakan/Tarikh: 2/28-6-2008	Jum. Mukasurat 5

OBJECTIVES

1. To familiarize students with common heat treatments done on steels.
2. To familiarize students in using a *Time-Temperature-Transformation* diagram to design cooling treatments to achieve particular steel structures and properties.

LEARNING OUTCOMES

At the end of laboratory session, student should be able:

1. Identify the dependent and independent variables of the experiment.
2. Record and tabulate the raw data nicely so that the experimental data can be neatly presented.
3. Plot the histogram chart of Rockwell hardness C vs quenching media on specimen given.
4. Differentiate the influence of quenching media to the hardness of carbon steel after being heat treated.
5. Define the relationship between hardness, quenching media and cooling rate.
6. Provide good and strong conclusion based on the analysis constructed.
7. Make use of suitable references and write them correctly.

THEORY

Steels are among our most important engineering materials. Without them, the machinery and tools required to establish any industrial activity would be difficult to imagine. A very important property of steel is the ability to alter its hardness by simple heat treatments. Hardened steel is capable of cutting and shaping other softer materials such as other steels, nonferrous materials, plastics, wood, stone, etc.

Heat treatment of steels is a heat-treating process whereby the steels are exposed to an elevated temperature for a period of time and cooled of which transforms/changes the mechanical properties without changing the product shape. Common heat treatment processes used for machined steels are as such annealing, normalizing, hardening (quench and temper) and case hardening.

A hardening treatment critically depends on the rate at which the steel is cooled from high *austenitizing* temperatures. The *Time-Temperature-Transformation* curve was developed as a convenient way to describe the resultant structure and phase make up of the treated steel

as a function of both temperature and time. An equilibrium phase diagram only gives information on the phase or phases thermodynamically stable at a particular T, P, composition, etc. In many practical situations, however, true equilibrium conditions are not achieved, because a particular processing method does not allow sufficient time at an elevated temperature for a system to achieve equilibrium. Instead, the system is kinetically trapped in some metastable or non-equilibrium state.

The Fe-Fe₃C Phase Diagram

Figure 1 shows the equilibrium diagram for combinations of carbon in a solid solution of iron. The diagram shows iron and carbons combined to form Fe-Fe₃C at the 6.67%C end of the diagram. The left side of the diagram is pure iron combined with carbon, resulting in steel alloys. Three significant regions can be made relative to the steel portion of the diagram. They are the eutectoid E, the hypoeutectoid A, and the hypereutectoid B. The right side of the pure iron line is carbon in combination with various forms of iron called alpha iron (ferrite), gamma iron (austenite), and delta iron.

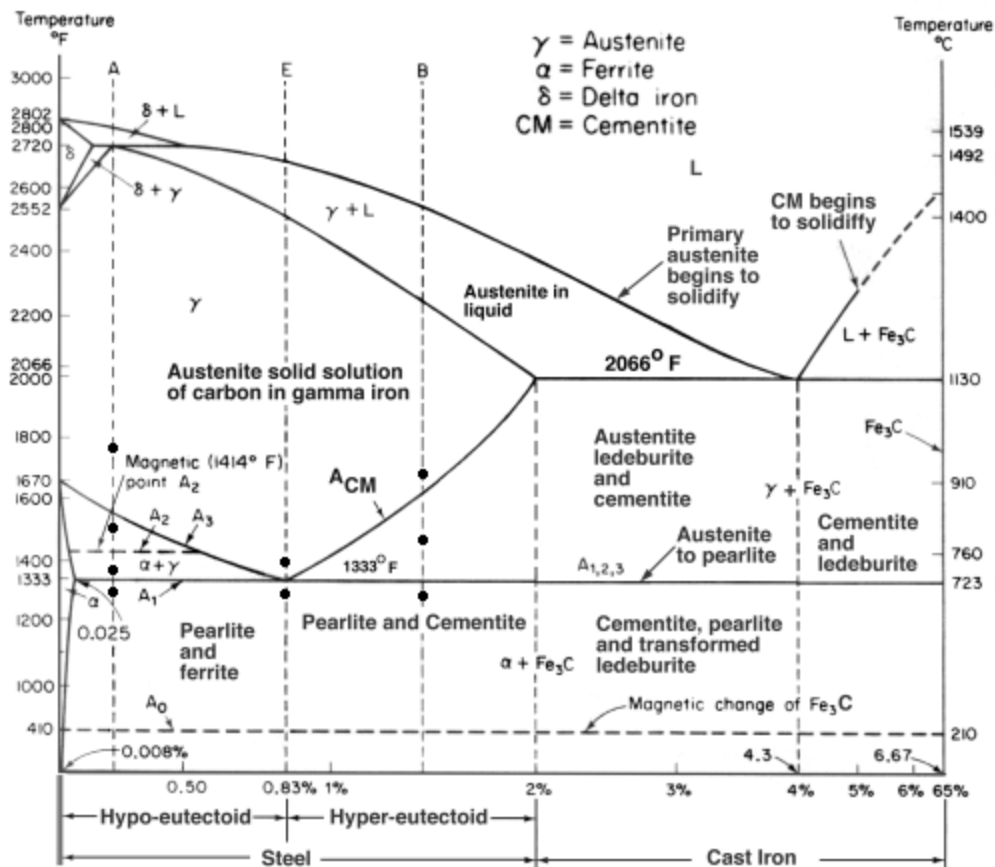


Figure 1 Fe-Fe₃C Phase Diagram, *Materials Science and Metallurgy*, 4th ed., Pollack, Prentice-Hall, 1988

Isothermal Transformation (IT) Diagrams for Steels

The isothermal transformation diagram characteristic of a 1080 plain-carbon steel is shown in Figure 2.

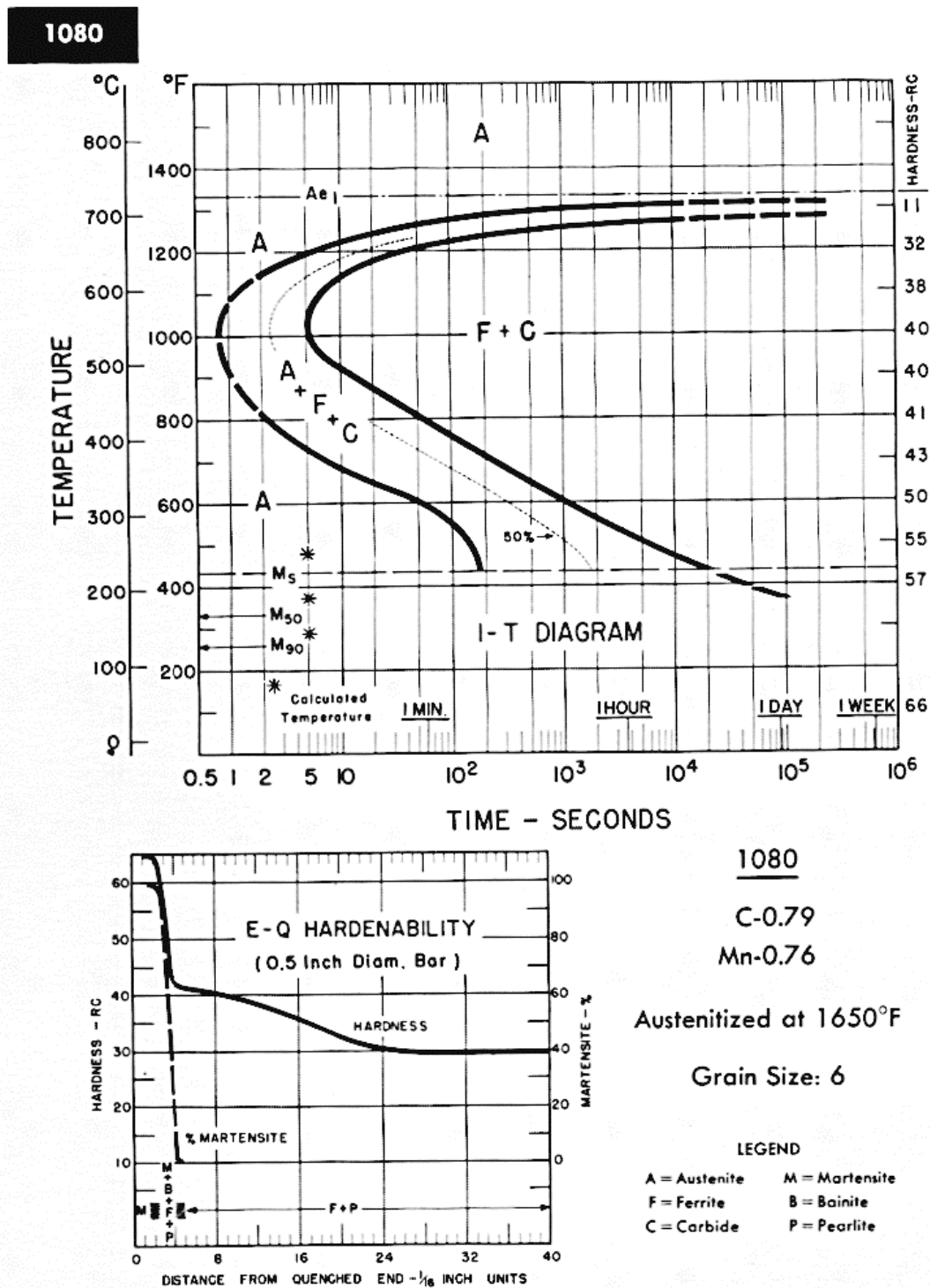


Figure 2 TTT diagram for 1080 steel. Nominal composition (wt.%) Fe-0.79C-0.76Mn. [Atlas of Isothermal Transformation and Cooling Transformation Diagrams, ASM (1977)]

EQUIPMENTS

Plain Carbon Steel, Gas Furnace and Tongs, Water and Quenching Oil.

PROCEDURES

I. Specimen preparation

Treat all the specimens of carbon steel according to the specified parameters. Refer to **Table 1**.

Table 1 Heat treatment process for each specimen

Specimen number	Austenitization temperature (°C)	Soaking time (min)	Quenching medium
A-1	900	30	Natural Air
A-2	900	30	Oil
A-3	900	30	Water

II. Austenization process

1. Place the specimen into the gas furnace.
2. Heat the specimen to the required temperature stated in **Table 1** and holds for specified soaking time.

III. Quenching process

3. Deeply immerse the specimen into the specified quenching medium in **Table 1** for rapid cooling processes.
4. Left the specimen A-1 to cool normally to the room temperature in sand bucket.

IV. Grinding process

5. Grind the surface if possible, otherwise smoothen the surface with sand paper and polish the part to be tested.
6. Make sure the surface is flat and smooth.
7. Clean the surface carefully to be tested removing any oil, grease or rust.

V. Rockwell Hardness Test

8. Place the specimen on the surface of the Rockwell hardness tester. The surface to be tested must be parallel to the opposite one.
9. Select a suitable indenter for the specimen. Make sure that the indenter to be used for the test is correctly assembled.
10. Choose a Rockwell hardness scale C (HRC scale) category for the specimen.
11. Position the specimen to be tested in such way as to avoid the sleeve coming out more than 50 mm. The distance between specimen and indenter must be at least 2 or 3 mm.
12. Apply a minor load 10 kgf to the specimen and set the gauge to be zero.
13. Press start button at 6 dx 6 sx located at the of the base of the device and keep it pressed until the beginning of the countdown for the predefined time of permanence of the load.
14. Apply the major load by tripping a lever. After 15 seconds the major load is removed. The specimen is allowed to recover for 15 seconds.
15. Wait for the indenter to return to its initial position.
16. Record the Rockwell hardness value which is appears on the display.
17. Measure the hardness values at least at 3 different points of each specimen. Use the average data for Experimental Results.

Name: _____ **Matrix Number:** _____

Section / Group: _____ **Date of Experiment:** _____

EXPERIMENTAL DATA

Record the hardness of all the specimens in Table format. Include also the average data in this section.

EXPERIMENTAL RESULTS

1. Plot graph of the overall heat treatment process (temperature vs. time) for all the specimens.
2. Plot Histogram chart to show the relationship between quenching medium and hardness achieved.

DISCUSSIONS

1. Discuss the heat treatment terms below:
 - a. Austenizing/Hardening.
 - b. Quenching.
 - c. Tempering.
 - d. Normalizing.
2. What do you think are the influences of cooling rates and the amount of martensite formed of heat treated steels?

QUESTIONS

1. What are applications and relative usage of medium carbon, heat treated plain carbon steel? Why there are often utilized in such area?
2. How are steels classified according to:
 - a. Carbon content?
 - b. Alloy content?
3. List possible errors during heat treatment processes in your laboratory practice?
4. Distinguish between proeutectoid ferrite and eutectoid ferrite.
5. Name two thermal properties of a liquid that will influence its quenching effectiveness?

CONCLUSION

Write down your conclusion based on the experiment objectives.

REFERENCES