UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session of 2003/2004

September/October 2003

EBB 521/3 - Industrial Heat Treatment

Time : 3 hours

Please ensure that this paper consists of TEN printed pages before you proceed with the examination.

This paper contains EIGHT questions.

Answer any SIX questions. If a candidate answer more than six questions, only the first six answered will be examined and awarded marks.

Answer to any question must start on a new page.

All questions must be answered in English.

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1. [a] The kinetics of the austenite-to-pearlite transformation obey the Avrami relationship. Using the fraction transformed-time data given below, determine the total time required for 95% of the austenite to transform to pearlite :

Fraction Transformed	Time (s)
0.2	12.6
0.8	28.2

(30 marks)

[b] In terms of heat treatment and the development of microstructure, explain the two major limitations of the iron – iron carbide phase diagram?

(20 marks)

[c] Briefly describe the microstructural difference between spheroidite and tempered martensite and explain why tempered martensite is much harder and stronger.

(20 marks)

[d] Briefly describe the simplest heat treatment procedure that would be used in converting a 0.76 wt% C steel from one microstructure to the other, as follows :

(i) Martensite to pearlite
(ii) Pearlite to tempered martensite
(iii) Tempered martensite to spheroidite

(30 marks)

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2. On the Fe-C phase diagram bellow (figure1) locates and explains the following heat treatment processes :

    1. Full annealing
    2. Stress relief annealing
    3. Process Annealing
    4. Normalizing
    5. Hardening

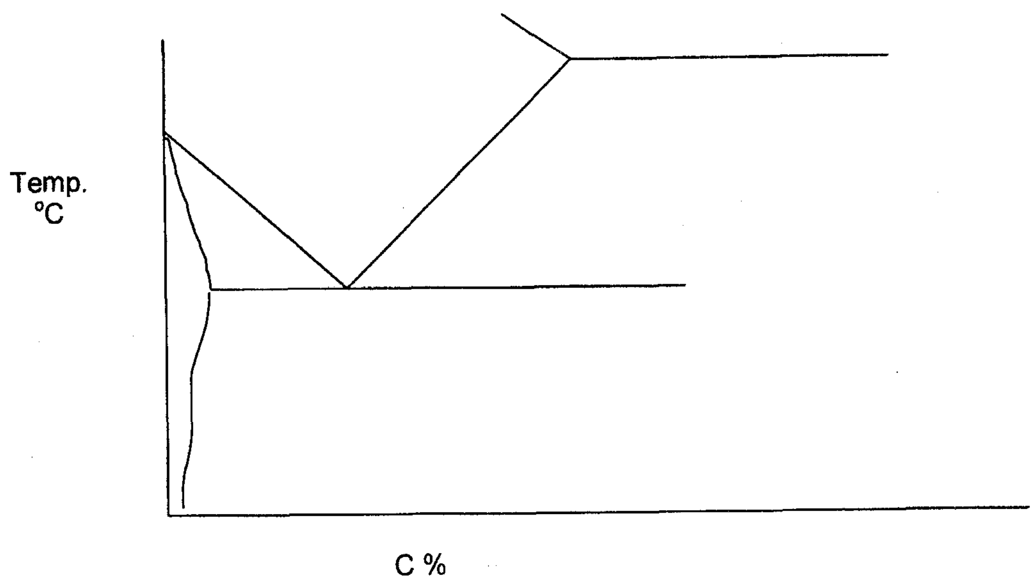

Figure 1

(100 marks)

3. [a] From the curves shown in Figure 2 and using Equation [$r = 1/t_{0.5}$], determine the rate of recrystallization for a metal at the several temperatures.

(35 marks)

[b] Make a plot of ln(rate) versus the reciprocal of temperature (in K^{-1}), and determine the activation energy for this recrystallization process.

(35 marks)

[c] By extrapolation, estimate the length of time required for 50% recrystallization at room temperature, 20°C (293 K).

(30 marks)

4. Using the isothermal transformation diagram for an iron-carbon alloy of eutectoid composition (Figure 3), specify the nature of the final microstructure (in terms of micro constituents present and approximate percentages of each) of a small specimen that has been subjected to the following time-temperature treatments. In each case assume that specimen begins at 760°C (1400F) and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

(a) Cool rapidly to 700°C (1290°F), hold for 104 s, then quench to room temperature.

(b) Reheat the specimen in part (a) to 700°C (1290°F) for 20h.

(c) Rapidly cool to 600°C (1110°F), hold for 4 s, rapidly cool to 450°C (840°F), hold for 10 s, then quench to room temperature.

(d) Cool rapidly to 400°C (750°F), hold for 2 s, then quench to room temperature.

(e) Cool rapidly to 400°C (750°F), hold for 20 s, then quench to room temperature.

(f) Cool rapidly to 400°C (750°F), hold for 200 s, then quench to room temperature.

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(g) Rapidly cool to 575°C (1065°F), hold for 20 s, rapidly cool to 350°C (660°F), hold for 100 s, then quench to room temperature.

(h) Rapidly cool to 250°C (480°F), hold for 100 s, then quench to room temperature in water. Reheat to 315°C (600°F) for 1 h and slowly cool to room temperature.

(100 marks)

5. On the isothermal transformation diagram for a eutectoid (0.76 wt% C) iron-caroon n alloy shown below, sketch and label curves or lines for heat treatments to yield specimens having the following Brinell harnesses. Using Figure 3, Figure4 and Figure 5

(a) 200 HB

(b) 275 HB

(c) 400 HB

(100 marks)

6. A cylindrical piece of steel 38 mm (1.5 in.) in diameter is to be quenched in moderately agitated oil. Surface and center hardnesses must be at least 50 and 40 HRC, respectively. Which of the following alloys will satisfy these requirements: 1040, 5140, 4340, 4140, and 8640? Justify your choices. Use figure 6 and 7.

(100 marks)

7. [a] Austempering is a heat-treating process developed from the I-T diagram to obtain a structure which is 100 percent bainite. Describe and illustrate the austempering schematically showing the difference between austempernig and the conventional quench and temper method.

(50 marks)

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[b] There is a combined effect of temperature gradient on surface and the center causing possible fracture. Describe the methods (tempera ting and mar tempering) to minimize the distortion and cracking.

(50 marks)

8. Construct radial hardness profiles for the following using figure 6 and figure7 :

(a) A 50-mm (2-in.) diameter cylindrical specimen of an 8640 steel alloy that has been quenched in moderately agitated oil.

(35 marks)

(b) A 75-mm (3-in) diameter cylindrical specimen of a 5140 steel alloy that has been quenched in moderately agitated oil.

(35 marks)

(c) A 90-mm (3in.) diameter cylindrical specimen of an 8630 steel alloy that has been quenched in moderately agitated water.

(30 marks)

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Useful Diagrams

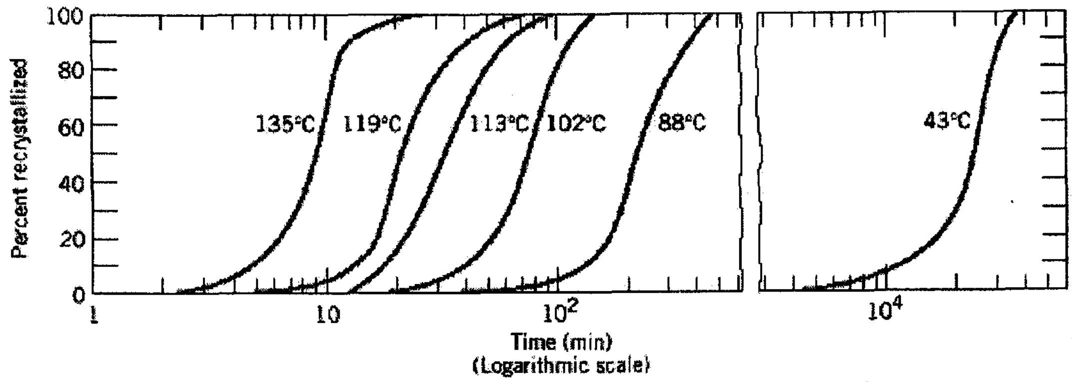

Figure 2. Percent recrystallization as a function of time and at constant temperature for a metal

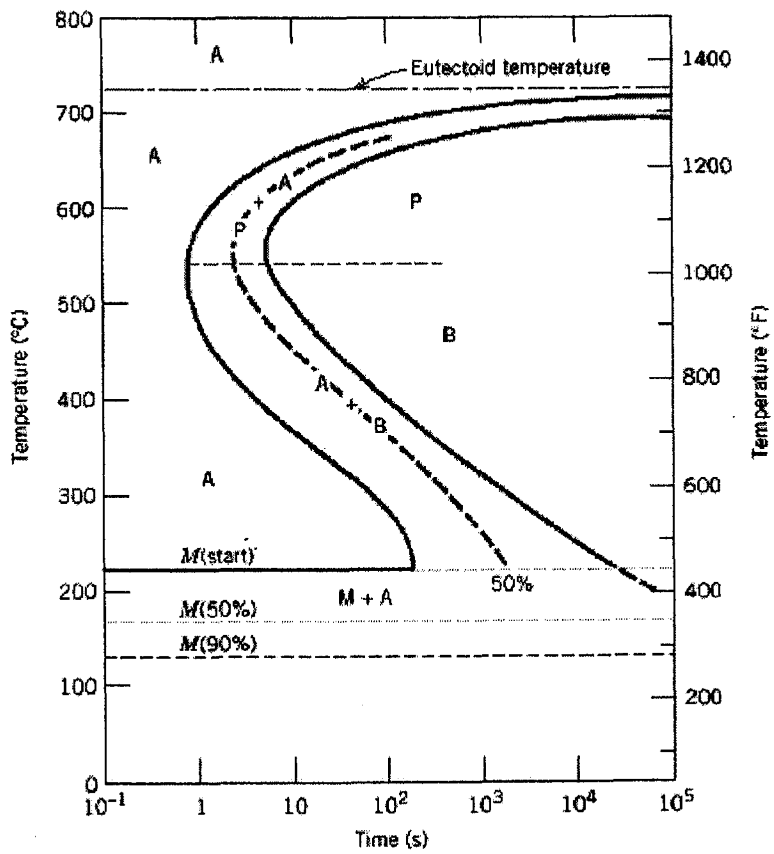

Figure 3. The complete isothermal transformation diagram for an iron-carbon alloy of eutectoid composition : A, austenite; B, bainite: M, martensite; P, pearlite.

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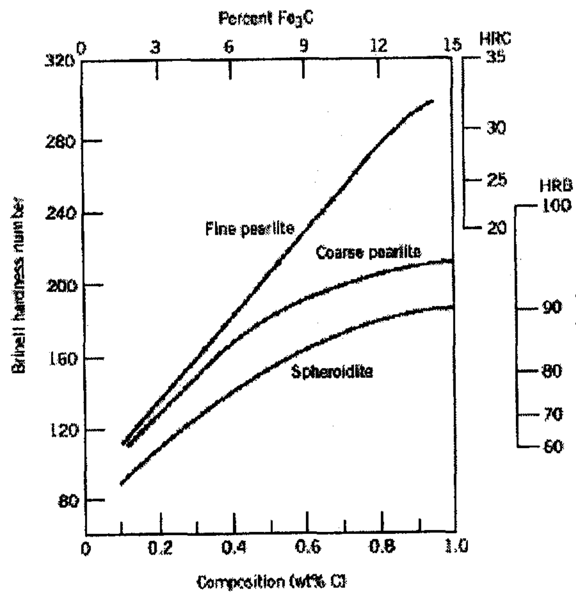

Figure 4. Brinell and Rockwell hardness as a function of carbon concentration for plain carbon steels having fine and coarse pearlite as well as spheroidite microstructures.

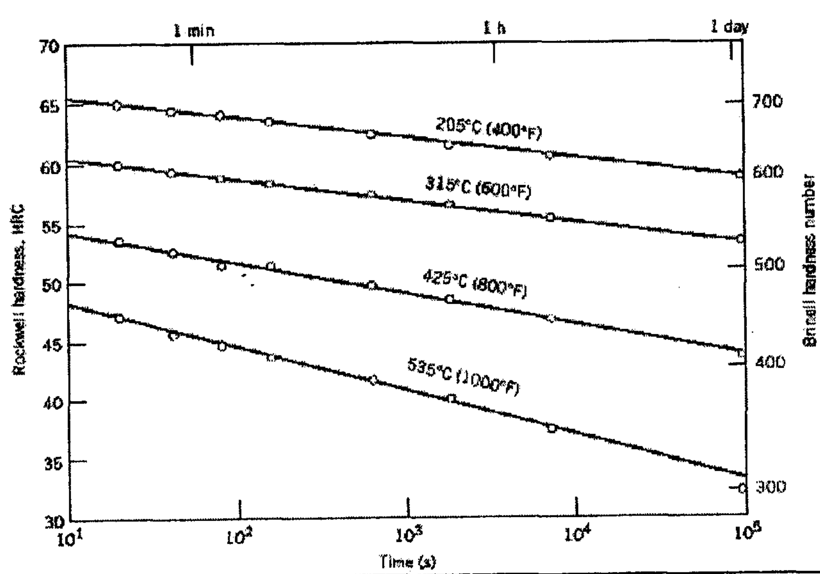

Figure 5. Hardness versus tempering time for a water-quenched eutectoid plain carbon (1080) steel.

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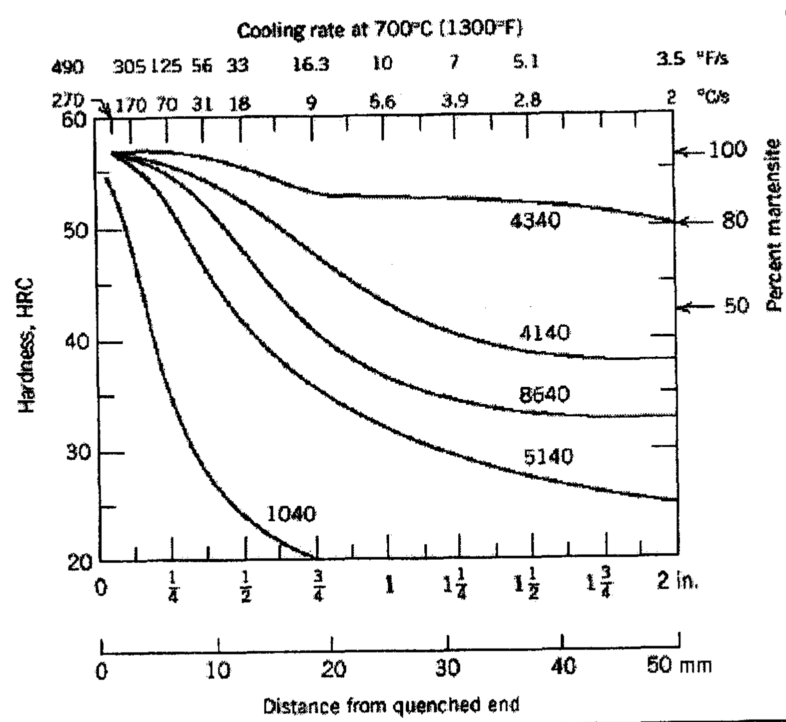

Figure 6. Hardenability curves for five different steel alloys, each containing 0.4 wt% C. Approximate alloy compositions (wt%) are as follows: 4340-1.85 Ni, 0.80 Cr, and 0.25 Mo; 4140-1.0 Cr and 0.50 Cr, and 0.20 Mo:8640-0.55Ni, 0.50 Cr, and 0.20 Mo; 5140-0.85 Cr; 1040 is an unalloyed steel.

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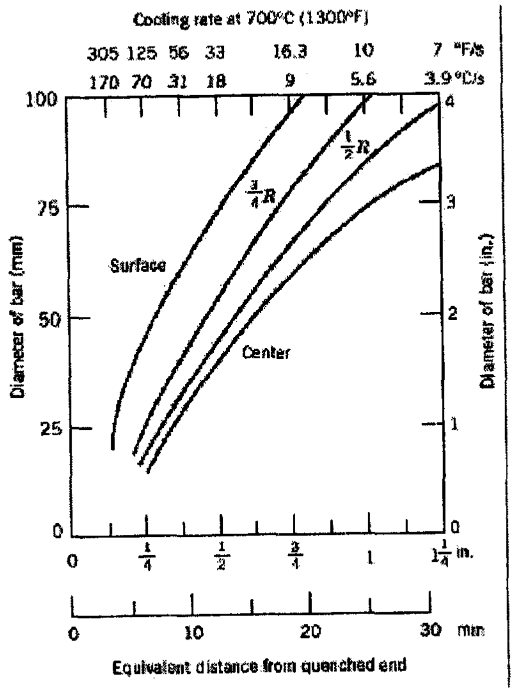

Figure 7. Cooling rate as a function of diameter at surface, three-quarters radius (3/4R), midradius (1/2R), and center positions for cylindrical bars quenched in oil. Equivalent Jominy positions are included along the bottom axis.

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