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University of Portland
EGR 221 - Materials Science
Exam 5 (CLOSED BOOK, CLOSED NOTES, **NO CALCULATOR**)
December 3, 2015. Dr. K. Lulay

On my honor, I acknowledge that the work I submit for this examination is completely my own. Sign: SOLUTION Print name: ____________________

1) (5pts) Briefly, describe the process that could be used to make tempered martensite in 2024 aluminum alloy (aluminum with about 4% copper).

Martensite is BCT iron created by "traping" carbon in FCC austenite. It can NOT be formed in 2024 aluminum

2) (5 pts) Briefly, describe the similarities and/or differences between natural aging and artificial aging in an alloy such 2024 aluminum.

Aging: formation of 2nd phase precipitates to increase strength and hardness. Natural aging: aging at room temp. Artificial aging: aging above room temp.

3) (5 pts) Briefly describe the three steps of solution heat treating of an aluminum alloy such as 2024.

1) Solution heat treat - heat to form single solid solution.
2) Quickly quench to room temp (or colder). Supersaturated, single phase.
3) Age: allow 2nd phase precipitates to form

STEP 1 & 2 μstruct.

after step 3

4) (14 points) Answer true (T) or false (F)

(T) F Martensite is the hardest and least ductile microstructure in plain carbon steel.

T (F) Pearlite is the softest and most ductile microstructure in plain carbon steel. (spheroidite is)

(T) F Martensite is a metastable phase.

T (F) Cementite (Fe_3C) is a metastable phase. (its equilibrium (stable) phase)

T (F) Martensite can **not** be directly transformed into austenite by heating. Only pearlite, bainite or spheroidite can be directly transformed into austenite by heating.

T F Over-aging in precipitation heat treated alloys is a result of prolonged exposure to elevated temperatures and results in a weaker alloy.

T F Martensitic transformation occurs without long-range diffusion.

5) (15 pts) Select the best answer:

I) The eutectoid composition of plain carbon steel is 0.76wt%C. If 0.4wt%C plain carbon steel is slowly cooled from austenite, which one of the following best describes the likely microstructure:

a) mostly martensite; b) about 50% martensite & 50% pearlite; c) about 50% primary-α and 50% pearlite; d) mostly pearlite; e) mostly bainite

II) By weight, what is the composition of cementite (Fe_3C)?

a) 0wt%C b) 6.7wt%C c) 25wt%C d) cannot be determined without a phase diagram

III) Which one of the following microstructures is **not** composed of α-ferrite and cementite?

a) pearlite b) bainite c) spheroidite d) martensite

IV) The curve shown below shows results from Jominy end-quench testing of two different steels ("a" and "b"). From this data, which single answer is the best:

a) Both of these two steels can be hardened to about 60 Rc; therefore, they both have similar hardenability.

b) Both of these two steels can be hardened to about 60 Rc; however, "b" is harder than "a" at distances beyond the quenched end. Therefore, "b" is more hardenable than "a."

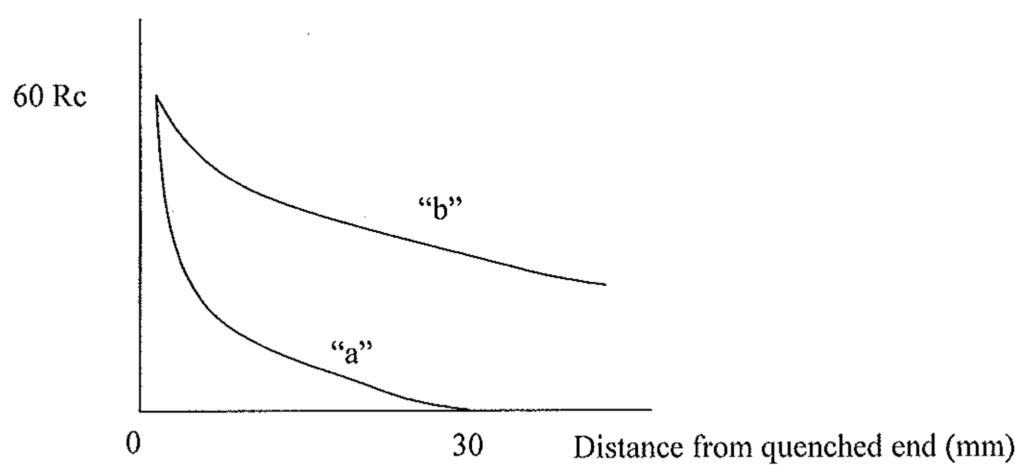
c) Since the data at "zero distance" is not shown and the data beyond 30 mm for "a" is not shown, no conclusion can be reached regarding hardenability.

V) The curve shown below shows results from Jominy end-quench testing of two different steels ("a" and "b"). From this data, which single answer is the best:

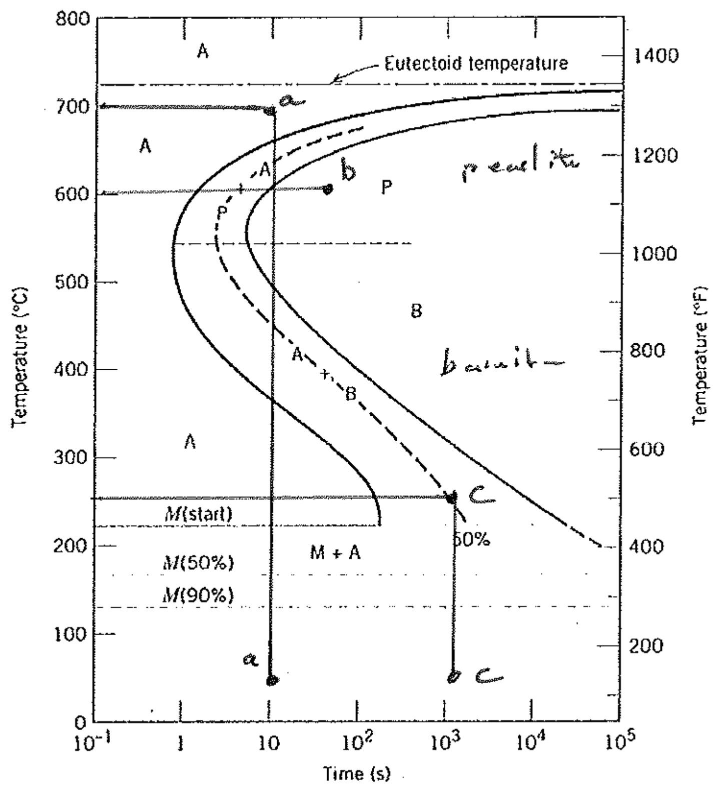
a) Both of these two steels can be hardened to about 60 Rc; therefore, they both have similar carbon content.

b) Both of these two steels can be hardened to about 60 Rc; therefore, they both have similar alloying elements besides carbon.

c) Both of these two steels can be hardened to about 60 Rc; but no conclusion can be reached regarding carbon content or other alloy elements.



6) (16 pts) A plain carbon steel with eutectoid composition has been fully austenitized. What is the final microstructure of the specimens for the following the time-temperature treatments? Choices include: *pearlite, bainite, martensite, austenite, spheroidite,* and *tempered martensite* – or combinations of these. **FOR FULL CREDIT, CLEARLY** mark on the attached TTT diagram to support your answers. Label the marks with "6a" "6b" etc. corresponding the problem number. **USE A STRAIGHT EDGE (ID cards work fine)** and **READ** the diagrams **CAREFULLY!** Provide an explanation if you wish. "Quickly" should be interpreted as near-instantaneously.



a) Austenitize, quickly cool to 700°C, hold for 10 seconds, then quickly cool to room temperature.

100% Martensite

b) Austenitize, quickly cool to 600°C, hold for 50 seconds, then slowly cool to room temperature by air quenching.

NOTE: once it is pearlite or bainite, cooling rate thereafter does not have an effect

100% Pearlite

c) Austenitize, quickly cool to 260°C, hold for 1000 seconds, then quickly cool to room temperature.

50% B, 50% M

d) Using the TTT diagram provided here, can you describe how bainite could be formed by a continuous cooling process?

NO – TTT ≠ CCT

(CCT for plain carbon would show you cannot make bainite by continuous cooling)

5 pts extra credit: "marquenching" is a somewhat complex cooling process that maybe performed to create martensite. Why would "marquenching" be used rather than directly quenching from austenite to room temperature? An example of marquenching: *austenitize then quickly cool to around 240°C and hold for about 90 seconds, then quickly cool to room temperature.*

Prevent quench cracking