Donald P. Shiley School of Engineering
EGR 221 Materials Science
Assignment 11, Fall 2015

1) A) Based on the color alone, which could be considered "bright red" – how hot would you estimate the samurai sword was just prior to the final quench? Was it likely austenite or not? Briefly justify your answer.

   B) In order to determine the microstructures that may form when a samurai sword is removed from glowing red charcoal fire into water, which curve would be more appropriate to use and why: time-temperature-transformation (TTT) curve (aka isothermal transformation diagram) or a continuous cooling transformation (CCT) curve? Briefly, why?

   C) In order to determine the microstructures that may form during a Jominy end-quench test, which curve would be more appropriate to use and why: time-temperature-transformation (TTT) curve or a continuous cooling transformation (CCT) curve? Briefly, why?

2) A) Plain carbon steels (steels that contain only iron and carbon as alloy elements) are designated by both SAE (Society of Automotive Engineers) and AISI (American Iron and Steel Institute) with a four-digit number system. The first two digits are used to specify the alloy elements and the last two digits are the amount of carbon present. For example AISI 1080 (aka SAE 1080) steel --- the first two digits, "10", tell us that it is a plain carbon steel. The last two digits "80" tell us that there is 0.80wt% carbon. The eutectoid composition of plain carbon steel is about 0.76wt%C, therefore, AISI 1080 is generally considered to be eutectoid (close enough to 0.76%). Can bainite be produced in AISI 1080 by continuous cooling? If the samurai sword was made from AISI 1080 steel, would it possibly contain bainite?

   B) What are the alloying elements in AISI/SAE 4340? What is the range of the allowable carbon content (hint, nominally there is 0.40wt%, but 0.40 is not a range)? What are its principal design features (what's it particularly good for)? Can bainite be produced in AISI 4340 by continuous cooling? If the samurai sword was made from AISI 4340 steel, would it possibly contain bainite?

3) A) Briefly define hardness and hardenability – and distinguish between them (how are they different?)

   B) How/why do certain alloying elements increase hardenability? In other words, why can a highly hardenable steel be more slowly quenched than a less hardenable steel and still result in martensite?

4) A) Using hardenability curves (such as Fig 13-21 in the textbook) that compare AISI 4340 and AISI 1050, what do you conclude about the role of carbon in regards to hardness and hardenability?

   B) Using hardenability curves, what do you conclude about the role of alloying elements such as chromium and molybdenum in regards to hardness and hardenability?

5) For AISI 1080 steel (or if you prefer, AISI 1076) what microstructures would likely result for each of the following (use the TTT (isothermal transformation) diagram attached, mark on it appropriately):

   a) Hold at 740°C sufficiently long to achieve austenitic structure, then cool rapidly to 700°C, hold for 10 seconds, then rapidly quench to room temperature.

   b) Hold at 740°C sufficiently long to achieve austenitic structure, then cool rapidly to 600°C, hold for 10 seconds, then rapidly quench to room temperature.

   c) Hold at 740°C sufficiently long to achieve austenitic structure, then cool rapidly to 500°C, hold for 10 seconds, then rapidly quench to room temperature.

   d) Hold at 740°C sufficiently long to achieve austenitic structure, then cool rapidly to 400°C, hold for 10 seconds, then rapidly quench to room temperature.

   e) Hold at 740°C sufficiently long to achieve austenitic structure, then cool rapidly to 300°C, hold for 10 seconds, then rapidly quench to room temperature.

   f) Hold at 740°C sufficiently long to achieve austenitic structure, then rapidly quench to room temperature.

6) What is marquenching (aka martempering) and why is it done? What may possibly happen if rather than marquenching, the hot (austenite) steel is rapidly quenched directly to room temperature? Which of the conditions in question 5 could be considered marquenching?

Now onto something besides steel….let's talk about aluminum alloys. Obviously, aluminum is very different stuff than steel, but also has similarities. It is about one-third the density and about one-third the elastic stiffness of steel (E_{alum} ~ 1/3 E_{steel}). Some aluminum alloys have strength that competes with many commonly used steels (but no aluminum alloys compete with high strength steels). The designation for aluminum alloys looks very similar to the AISI designation for steels – however, looks may be deceiving. With aluminum alloys, there are four digits but all of the digits are "codes", similar to the first two digits for steel (43xx, the 43 is a code – it does not represent the quantity "43" of anything). The first digit is a code indicating the primary alloy element. 6000 series aluminum alloys are magnesium and silicone. In 2000 series, copper is the primary alloying element. The next three digits are codes regarding specific alloy elements and their quantities.

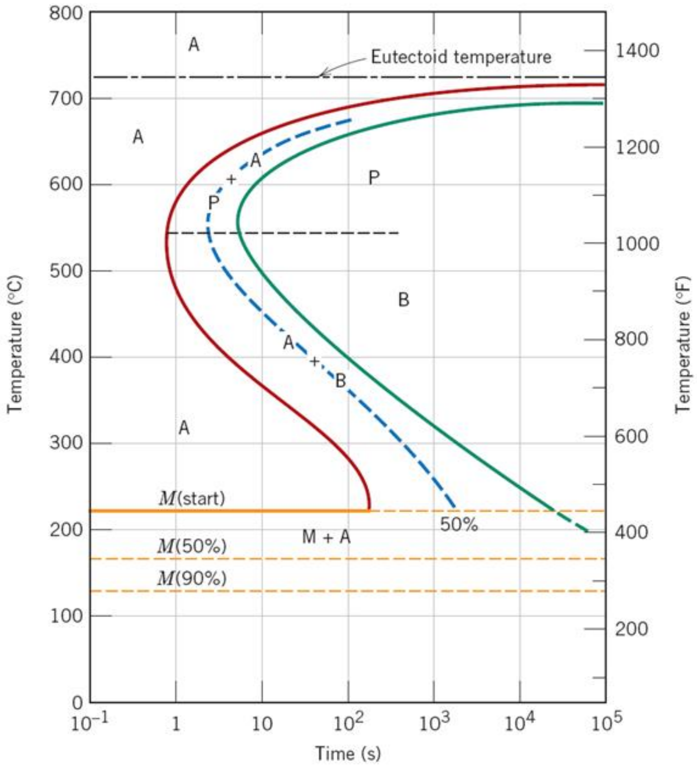
There are two general classes of aluminum alloys: heat treatable and non-heat treatable. Non-heat treatable alloys are alloys for which heat treating has no significant effect on properties. Heat treatable alloys are heat treated in various ways to create desired properties. They are more interesting to talk about right now…

7) How would you form martensite, pearlite, bainite, or spheroidite in an aluminum alloy? HINT: this is a trick question – please please don't fall for the trick!

8) A) 2024 is a heat treatable aluminum alloy. It contains approximately 4wt% copper. Briefly describe age hardening (aka precipitation hardening) and include a sketch of the microstructures resulting from the three steps (similar to figure 12-9 – okay, exactly similar).

   B) Why is the alloy quickly quenched from solution heat treat temperature? What would likely result if 2024 aluminum was not quenched in water but rather slow cooled in air immediately following solution heat treating

9) What is meant by overaging? Would it be possible for an airplane made from 2024 aluminum alloy to overage if it flew too close to the sun --- assuming by flying too close it actually got too warm? How warm would it have to get to overage? What could be the result if it did overage?


Eutectoid temperature
A
A
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B
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M(start)
50%
M + A
M(50%)
M(90%)
Temperature (°C)
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