MSE170 U. Washington

Fundamentals of Materials Science

EFFECTS OF HEAT TREATMENT ON STEEL, ALUMINUM AND BRASS ALLOYS -MICROSTRUCTURE AND PROPERTIES

PRE-LAB PREPARATION (REQUIRED!):

1. Using the ASM metal handbooks or other resources find and print/copy the following or as close as you can get (for example 4140 for 4340, if 4340 not available). Included in this lab are several pages from ASM handbooks that may be helpful.

   a. The chemical composition ranges for Steel 4340, 1018 (A36), Aluminum alloy 2024 and 70-30 (260) brass
   b. Microstructures of 4340 and 1018 (A36) steel in the normalized, quenched and tempered conditions
   c. Microstructure of aluminum alloy 2024 in the slow cooled & solutionized and the solutionized & aged conditions
   d. Phase diagrams for the alloys systems of interest.
   e. Time-Temperature-Transformation diagrams for each alloy, if possible. If not try to find heat treatment information for each alloy, e.g. hardness vs. time, etc.

2. In terms of heat treatment and the development of microstructure, what are two major limitations of the iron-iron carbide phase diagram?

3. Consider the Iron-Carbon Phase Diagram shown in your textbook. For steel alloys 1018 and 4340 which have been slowly cooled from the austenite region (1100°C) to room temperature, calculate the relative amounts and compositions of the phases present at room temperature. Draw the microstructure, which would result in each case.

4. What is the minimum temperature (for each alloy) to heat Steel 4340, 1018 (A36), Al 2024 and 70-30 (260) brass in order to form a single phase material?

5. Please answer the following questions using the TTT diagrams and phase diagrams of alloys: Steel 4340, 1018 (A36), Al 2024 and 70-30 (260) brass

   a. Predict what phases will form from the following heat treatments. Assume linear cooling rates:
      i. 4340 and 1018 (A36) cooled from 900°C to below 500°C in 1 second and room temp in less than 5 seconds
      ii. 4340 and 1018 (A36) cooled from 900°C to below 500°C in 20 seconds and room temp in 200 seconds

iii. Al 2024 and Brass 70-30 (260) cooled from 550°C to room temp in less than 1 second
iv. Al 2024 and brass 70-30 (260) cooled from 550°C to room temp in 200 seconds

b. Why does martensite not appear on the Fe-C phase diagram?

6. What does the "T#" signify after Al2024-TO, Al2024-T3, Al2024-T6?

I. Purpose:

- Understand the effect of cooling rates and reheating on microstructure and properties of steel, aluminum and brass alloys.
- To observe the heat treatment process for a 4340 and a 1018 (A36) steel sample and effect on properties.
- To observe the heat treatment process for a 2024 aluminum sample and effect on properties.
- To observe the effect of heat treatment on 260 Brass sample and effect on properties.
- Relate microstructure to mechanical properties

II. Heat Treatment

Each lab group will receive four alloys to test. We will be using 4340 and 1018 steel, 2024 aluminum and 70-30 (260) brass. The steel samples will be austenitized at 900°C for 30 minutes. The aluminum and brass samples will be heated to 550°C for 30 minutes. The samples will then be cooled in two manners. The first will be a slow air-cooling, which should result in a sample experiencing approximately equilibrium cooling. The second piece will be quenched in water resulting in a sample with non-equilibrium cooling. A subset of these samples will then be reheated to a temperature that will allow limited diffusion for 30 minutes.

III. Experimental Procedure

1. Wrap a piece of wire approximately 6 inches long around all samples. This will be used to place and remove samples from furnaces.

2. Heat the steel samples up to 900°C in furnace A. Heat the Aluminum and Brass samples to 550°C in furnace B. Allow samples to equilibrate for approximately 30 minutes.

3. Cool the samples:
   a. Take the first two samples of EACH alloy and quench them in water. They must be removed from furnace and placed in the water very quickly, approximately 1-2 seconds, so everything has to be ready.
   b. Remove second set of samples of each alloy and place in to bucket of vermiculite (an insulating material to slow cooling rate).

4. Take 1 sample from each alloy and cooling rate and place in Furnace C for steel and Furnace D for Aluminum and Brass samples. Steels will be reheated to 300°C and aluminum and brass to 200°C for 30 minutes.

Sample	1018 Steel (A36)	4340 Steel	2024 Aluminum	70-30 (260) Brass
1	Heat to 900°C Quench in H_2O	Heat to 900°C Quench in H_2O	Heat to 550°C Quench in H_2O	Heat to 550°C Quench in H_2O
2	Heat to 900°C Quench in H_2O Reheat to 300°C	Heat to 900°C Quench in H_2O Reheat to 300°C	Heat to 550°C Quench in H_2O Reheat to 200°C	Heat to 550°C Quench in H_2O Reheat to 200°C
3	Heat to 900°C Cool slowly	Heat to 900°C Cool Slowly	Heat to 550°C Cool Slowly	Heat to 550°C Cool Slowly
4	Heat to 900°C Cool slowly Reheat to 300°C	Heat to 900°C Cool slowly Reheat to 300°C	Heat to 550°C Cool Slowly Reheat to 200°C	Heat to 550°C Cool Slowly Reheat to 200°C

5. Once the samples are cool they may have to be ground to remove the oxide layer (Steels!!). Do this using the belt sanders with water cooling.

6. Take hardness measurements using Rockwell C and/or Rockwell B scales. Take at least 3 measurements on each sample and average the values. Be careful not to place hardness indentations too close together as it may affect the results.

7. Look at the microstructures of ALL samples at each of the four heat treatments. Polished and etched samples of each type will be provided by the TA's. These samples were polished to a 1 micron finish and then chemically etched to reveal the grain boundaries. View each of the samples, comment on the microstructures in your lab report and include microstructures at all heat treatments in your report. Compare the properties (hardness) of ALL alloys at after all heat treatments and explain in term of the phase transformations, resulting microstructure and easy of dislocation motion.

IV. Analysis

1. What is the difference between 4340 steel and 1018 (A36) steel?
2. Which steel sample was harder, the air-cooled or water quenched? Why was it harder?
3. Which steel alloy was harder? Why was it harder?
4. How did the different cooling rate affect the microstructure of each steel? Do these microstructures agree with what would be predicted from the TTT diagrams?
5. What did reheating do to the steels' (4340 and 1018 (A36)) microstructures and properties? Why?

6. Compare the TTT diagram for 1018 (A36) with that of 4340. What are the major differences? Why does the decomposition of austenite take longer in 4340 than 1018 (A36)?
7. What would be the effect of quenching in oil instead of water?
8. What was the effect of reheating the samples on microstructure and properties?
9. What would happen to the microstructure and hardness if the samples were reheated to 600^{o}C for 30 minutes and then quenched?
10. For aluminum alloys, what do T0, T3 and T6 refer to? Did you treat Al 2024 to any of those conditions?
11. Compare the hardness values you measured for each alloy in each condition with values from the literature. If there are any significant deviations from expected values, provide likely causes for this and how the deviations could be corrected.

V. Formal Lab Report

The formal lab report should address all the questions above but should not consist only of these questions. Please follow the procedures outlined on the homepage and in the lab. Look under lab handouts and report formats *(How to write a lab report)* for point distribution and requirements.

VI. References:

1. William D. Callister, Jr., **Materials Science and Engineering an Introduction, 6th Edition.** *John Wiley and Sons*, New York. (2000), Chap. 10-11.
2. E.C. Subbarao, et al., **Experiments in Materials Science.** *McGraw-Hill*, New York, (1972).
3. George L. Kehl, **The Principles of Metallographic Laboratory Practice, 3rd Ed.** *McGraw-Hill*, New York (1949), pp. 232-240.
4. L. Van Vlack, **Elements of Material Science and Engineering, 6th Ed.** *Addison Wesley*, Reading, MA (1986), pp. 257-262, 292-304.
5. R.E. Smallman, **Modern Physical Metallurgy, 4th Ed.** *Butterworths*, London, (1985), pp. 335-379.
6. ASM Metals Handbooks

APPENDIX

Possibly useful diagrams and microstructures from **Metals <u>Handbook 8th Edition, Vol. 7: Atlas of Time-Temperature Diagrams for Nonferrous Alloys / edited by George F. Vander Voort</u>**. *ASM International*, ©1991 and **<u>Atlas of Time-Temperature Diagrams for Irons and Steels / edited by George F. Vander Voort.</u>** *ASM International*, ©1991.