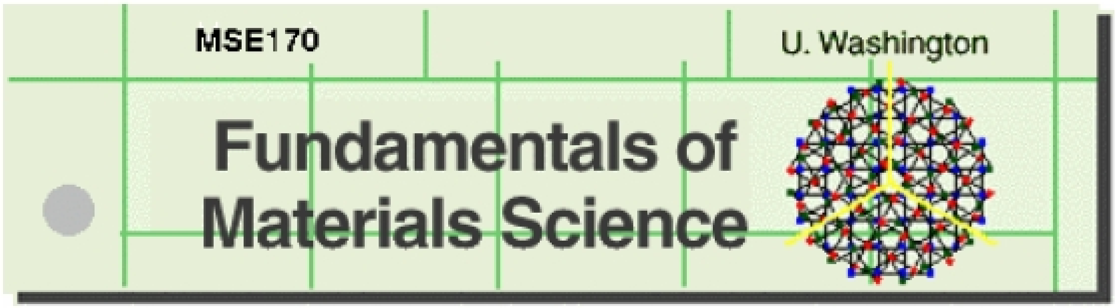

LAB V

Heat Treatment of Steel 4340, and Aluminum 2024 Alloys
Effects on Microstructure and Properties

Pre-Lab Questions

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, and Aluminum 2024
   b. Microstructures of Steel 4340 in the normalized, quenched and tempered conditions
   c. Microstructure of Aluminum 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 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 to heat Steel 4340, and Aluminum 2024 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, and Al 2024

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

ii. Steel 4340 cooled from 900°C to below 500°C in 20 seconds and room temp in 200 seconds
iii. Aluminum 2024 cooled from 550°C to room temp in less than 1 second
iv. Aluminum 2024 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, and aluminum alloys.
- To observe the heat treatment process for a 4340 steel sample and its effect on properties.
- To observe the heat treatment process for a 2024 aluminum sample and its effect on properties.
- Relate microstructure to mechanical properties

II. Heat Treatment

Each lab group will receive two alloys to test. We will be using Steel 4340 and steel, Aluminum 2024. The steel samples will be austenitized at 900°C for 30 minutes. The aluminum and samples will be heated to 550°C for 30 minutes. The samples will then be cooled in two different ways. The first cooling treatment will be a slow air-cool, which should result in a sample experiencing approximately equilibrium cooling. The second cooling treatment will be a 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. Heat the steel samples up to 900°C in furnace A. Heat the aluminum samples to 550°C in furnace B. Allow samples to equilibrate for approximately 30 minutes.
2. 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).
3. Take 1 sample from each alloy and cooling rate and place in Furnace C for steel and Furnace D for aluminum samples. Steels will be reheated to 300°C and aluminum to 200°C for 30 minutes.
4. Once the samples are cool they may have to be ground to remove the oxide layer (particularly in the steels). Do this using sand paper.

5. Measure the hardness of the samples 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.
6. 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. Look at the microstructures provided on the course website to help you explain these phenomena

Sample	4340 Steel	2024 Aluminum
1	Heat to 900°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 550°C Quench in H_2O Reheat to 200°C
3	Heat to 900°C Cool Slowly	Heat to 550°C Cool Slowly
4	Heat to 900°C Cool slowly Reheat to 300°C	Heat to 550°C Cool Slowly Reheat to 200°C

IV. Analysis

Use your data, phase diagrams, TTT diagrams, and the microstructure pictures on the course website to help you answer the following questions

1. Which steel sample was harder, the air-cooled or water quenched? Why was it harder?

2. How did the different cooling rate affect the microstructure of the steel? Do these microstructures agree with what would be predicted from the TTT diagrams?

3. What did reheating do to the steel's microstructures and properties? Why?

4. What did reheating do to the aluminum's microstructure and properties? Why?

5. What is the difference between the way Steel 4340 and Aluminum 2024 responded to the heat treatments? Which heat treatment resulted in the hardest sample? Which treatment resulted in the softest sample? Are the trends for the two materials the same? In terms of chemical composition and microstructure explain why.

6. For aluminum alloys, what do T0, T3 and T6 refer to? Did you treat Al 2024 to any of those conditions?

7. 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. 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 can be found in:

George F. Vander Voort ed. **Metals Handbook 8th Edition, Vol. 7: Atlas of Time-Temperature Diagrams for Nonferrous** *ASM International*, 1991

George F. Vander Voort ed. **Atlas of Time-Temperature Diagrams for Irons and Steels edited** *ASM International*, 1991.