EXPERIMENT 7

Subject: Heat treatment application; austenitizing and quenching

Objective: The main goal of this subject is to investigate the conventional heat treatment procedures such as austenitizing/quenching, and the investigation of microstructure.

Theory: Iron is one of the oldest well-known metals, and carbon is the cheapest and most effective alloying element for hardening iron. Iron-Carbon alloys are known as “carbon steels”. Carbon is added to iron in quantities ranging from 0.04 to 2 wt% to make low, medium, and high carbon steels. It can be seen in the following figure as iron-carbon equilibrium diagram.

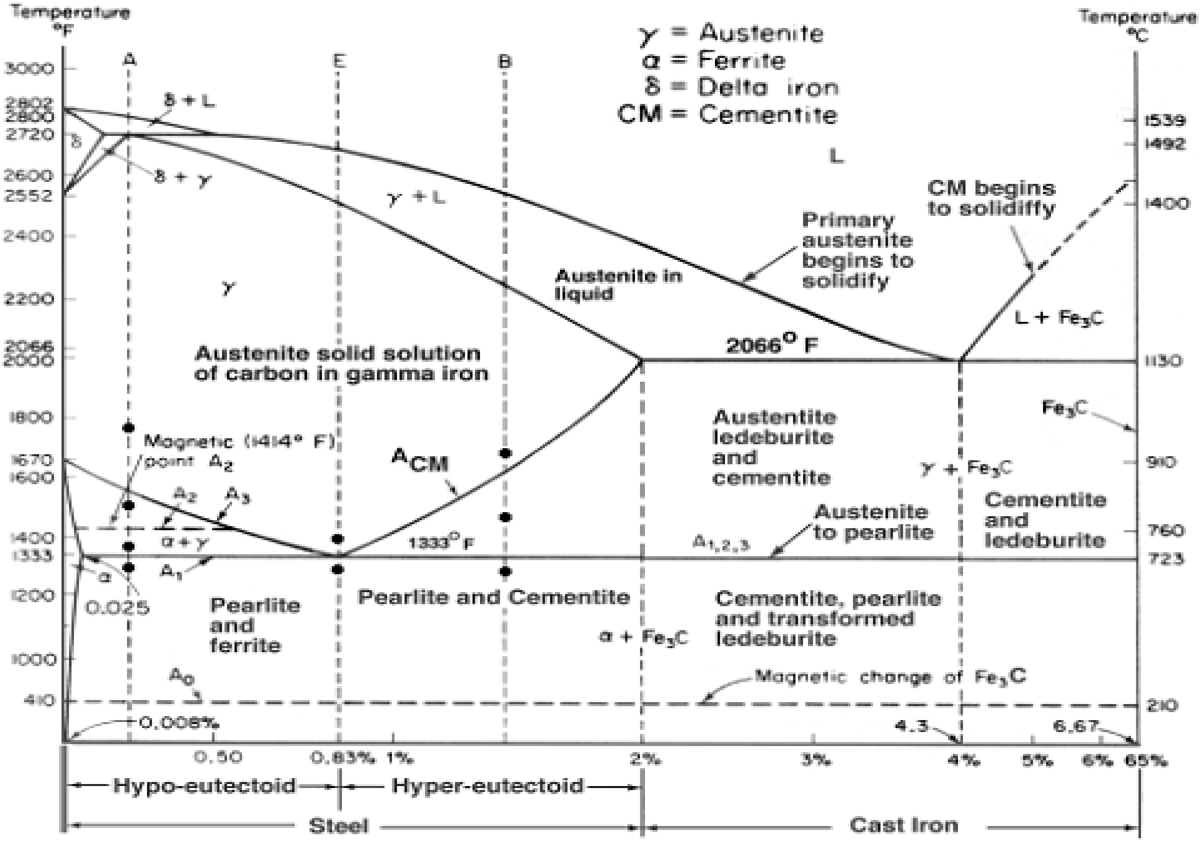

Figure 1: Iron-Carbon Phase Equilibrium diagram. (Source: Material Science and Metallurgy, 4th edition, Pollack, Prentice-Hall 1988)

The microstructure and resulting mechanical properties of these steels are amenable to modification via heat treatment, and a wide range of mechanical properties can be obtained by proper variations of heating and cooling cycles.

The heat treatment process for steel and steel alloys is composed of three steps:

a) Heating to a temperature at which austenite is formed (austenitizing)

b) Rapid cooling (quenching)

c) Reheating to stabilize structure (tempering)

Austenite is a solid solution of carbon in iron in a face centered cubic (FCC) crystalline structure that is stable at elevated temperature. The temperature at which austenite formation occurs depends primarily on carbon content of the steel. This temperature can be determined from the phase equilibrium diagram for the particular steel composition. The material must be held at the austenitizing temperature for a period to ensure completeness of the phase transformation and homogeneous structure. The amount of time required is dependent on the size and shape of the work piece as well as its composition.

After the time required for austenite formation, the material is rapidly cooled by quenching. Most often, quenching is accomplished by immersing the material in oil or water although air quenching is also used. Under conditions of rapid cooling, austenite transforms into an unstable (nonequilibrium) phase known as martensite. This phase is a supersaturated solution of carbon in iron in a body centered tetragonal structure. Martensite is very hard, relatively brittle phase, which provides the ability of strengthening steel to very high levels. Quenching usually results in a structure composed of martensite plus ferrite (solid solution of carbon in iron in body centered cubic structure) and iron carbide (cementite). The proportions present after quenching depend on carbon content and cooling rate. Higher carbon content and rapid cooling tend to produce larger proportions of martensite. Martensite is hard and brittle. In order to reduce brittleness, increase ductility, and relieve internal stresses from rapid cooling step, the material is subjected to a second heating operation known as tempering. The temperature for the tempering step must be below the austenite transformation temperature and is usually between 200^0C and 450^0C. The resultant properties of the steel after tempering depend on the time allowed for tempering as well as the temperature. In this laboratory, we will demonstrate the essential steps involved in the heat treatment of medium carbon steels.

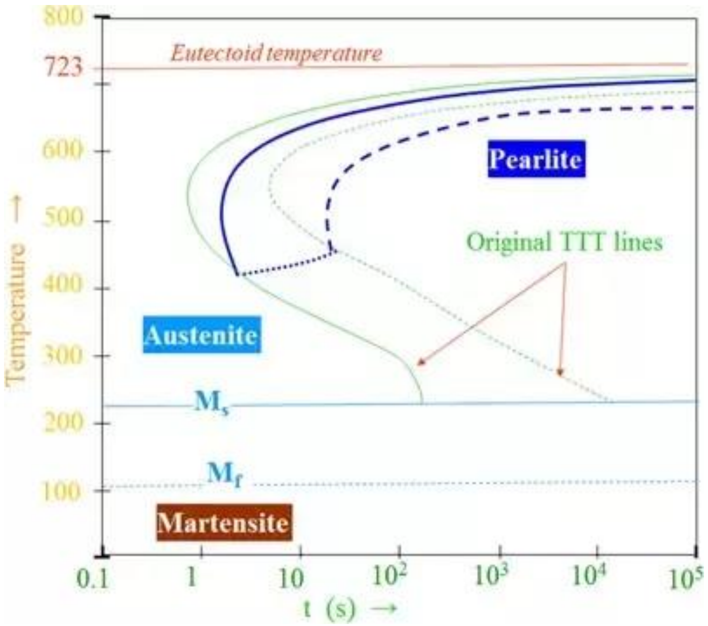

Figure 2: CCT diagram

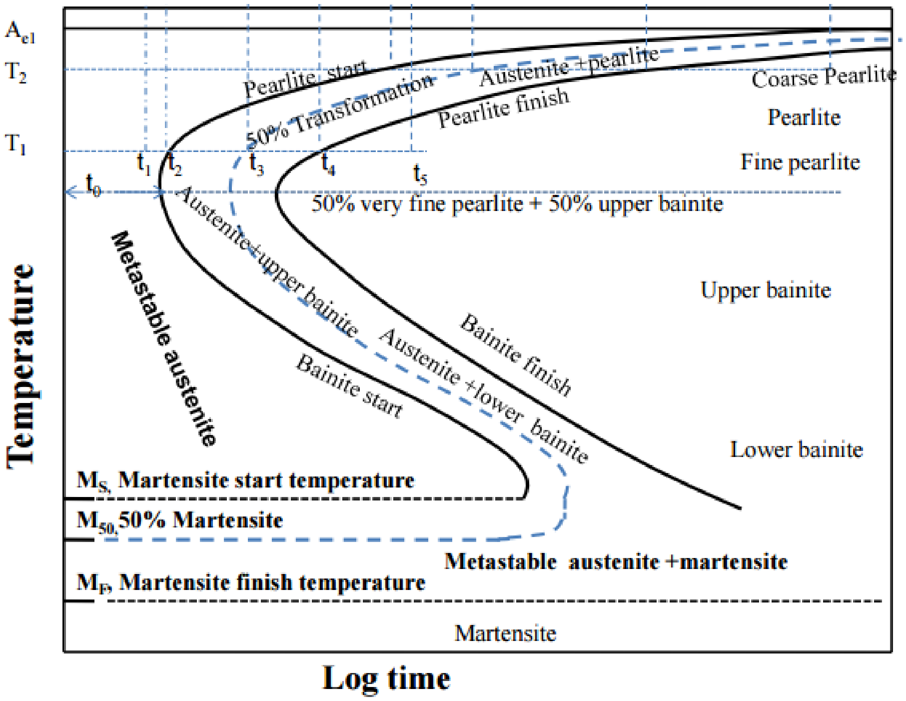

Figure 3: TTT Diagram (ASM 2012, F.C.Campbell, Phase Diagrams Understanding The Basics)

LAB Procedures

1. Prepare SAE 1040 and/or SAE 4140 steel specimens (4 each) for hardening process.
2. Give the name all specimens as (a), (b), (c) and (d).
3. Set the furnace temperature as 900^0C.
4. Austenitize: Put specimens (b), (c) and (d) in furnace at 900^0C in the austenite range and hold for 1 hour until equilibrium temperature and corresponding solid solution structure have been reached.
5. Quench Hardening: Rapidly remove the specimen (b) from furnace, plunge it into a large reservoir of water at ambient temperature, and stir vigorously.
6. Air Cooling (Normalizing): Remove the specimen (c) from furnace, the specimen is cooled in air.
7. Slow Cooling: Keep the specimen (d) inside the furnace, specimen is cooled slowly.
8. Draw the TTT diagram of specimens.
9. Grind and polish all specimen (a), (b), (c) and (d) then measure hardness by micro hardness tester.
10. Take microstructural picture of specimens.
11. Compare the pictures and hardness data.
12. Write a lab report.