SCUPI

Sichuan University - Pittsburgh Institute

ME 1042

Mechanics/Materials
Lab

Heat Treatment of Materials

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Mechanical Engineering Department

<u>Goal</u>: To observe the heat treatment process for steels and the effect it has on mechanical properties.

<u>Equipment Needed</u>:
GB #45 Steel
Furnace
Rockwell Hardness Tester

1 Introduction and Basic Theory

Hardness is defined as the resistance of a material to permanent deformation such as indentation, wear, abrassion, scratch. Principally, the importance of hardness testing has to do with the relationship between hardness and other properties of material. For example, both the hardness test and the tensile test measure the resistance of a metal to plastic flow, and results of these tests may closely parallel each other. The hardness test is preferred because it is simple, easy, and relatively nondestructive. Factors influencing hardness include microstructure, grain size, strain hardening, etc. Generally as hardness increases so does yield strength and ultimate tensile strength (UTS), thus specifications often require the results of hardness tests rather than tensile tests.

Current practice divides hardness testing into two categories: macrohardness and microhardness. Macrohardness refers to testing with applied loads on the indenter of more than 1 kg and covers, for example, the testing of tools, dies, and sheet material in the heavier gages. In microhardness testing, applied loads are 1 kg and below, and material being tested is very thin (down to 0.0125 mm, or 0.0005 in.). The most popular methods are Brinell, Vickers and Rockwell hardness tests for metals and alloys. Applications include extremely small parts, thin superficially hardened parts, plated surfaces, and individual constituents of materials.

1.1 *Heat Treatment*

A material can possess a variety of different mechanical properties such as strength, stiffness, plasticity, elasticity, and deflection. A material's mechanical properties are dependent on the material's microstructure, including the phases present, the number and arrangement of dislocations, and the grain size and shape. Thermal processing is used to change the crystal structure, defect structure (dislocations), and/or grain structure of a material. Annealing is a process used to weaken metals, such as steel, to make them easier to form into desired shapes. To anneal metal, it must be heated above a critical temperature, maintained at that temperature, and then allowed to cool. For steel, that critical temperature is the transformation temperature to austenite or austenite/cementite. If a metal is annealed for too long it is considered to be "over-aged," and in this state, it has very few dislocations and is very ductile. Heating the metal to a red-hot temperature causes the atoms to move faster and more freely. By slowly cooling from this high temperature, the atoms are able to adopt more ordered arrangements and create a more perfect crystal. The more perfect the crystal of the metal, the easier atoms can "slide" past one another, and thus, the more easily the metal can bend. The material also tends to have large grains after annealing and slow cooling, and this leads to a more malleable material. In contrast, to make a metal hard and brittle through thermal processing, it must be rapidly quenched from high temperature to room temperature. This quick cooling of the metal from red-hot temperatures freezes the atoms into a disordered phase with many defects. Due to the large number of defects, the atoms cannot move easily, and the metal is considered hard to bend and brittle.

2 Experimental Procedure

2.1 Week 1: Prepare Steel Samples

1. Heat three steel samples in the furnace to 840℃ and allow them to equilibrate for 10 minutes.
2. Quickly remove two of the samples and directly quench them in a water bath.
3. Remove the other one sample and allow it to cool slowly in a bucket of vermiculite.
4. Place one quenched sample back in the furnace at 400℃ for 30 minutes.
5. Remove the sample from the furnace and allow to cool in air.

2.2 Week 2: Hardness Measurement

1. Use polishing paper to remove any resulting oxide layer on samples.
2. Use the Rockwell hardness tester to do this under the Rockwell F scale. Take three measurements on four samples and be sure to not take measurements too close together.
    a. Measure the hardness of one steel sample that have not undergone heat treatment.
    b. Measure the hardness of other three steel sample that have undergone heat treatment.

3 For the Report

In this experiment you tested steel materials that have experienced specific heat treatment techniques. The report should be an extended memo. This will include a few paragraphs of introduction to state the purpose of the study (no theory is needed) and a description of the experiments, followed by results and discussion.

- Create a table to show the mechanical property change of the steel due to the heat treatment procedure. A sample table should look like this

Table 1 Data for steel hardness

Hardness \ Set	1	2	3	Average
Without heat treatment				
After normalizing				
After quenching				
After tempering				

- Use your observation, data, phase diagrams and TTT diagrams to help answer the following questions.

1. Which sample is harder, the vermiculite-cooled sample or water quenched sample? Why?
2. What did quenching do to the steel's microstructures and properties? Why?
3. Compare your resultant values to published values in literature. Discuss any deviations that may exist and provide likely causes for this.