Metallography and Temperature Measurement

Experiment #1

Minster

ABSTRACT

Students performed two experiments in this lab. One was preparing a metallographic specimen, examining the specimen with a microscope with 100X, and analyzing the specimen with grain size, volume fraction of a phase or structure. Another was a measuring the temperature of furnaces and salt baths with a thermocouple every 10 seconds. The purpose of this lab is to learn how to perform metallographic of alloy specimens which including section, mount, polish and etch a carbon steel. Also students can learn how to measure temperature with a thermocouple and converting millivolts to temperature and vise versa.

INTRODUCTION

Two experiments were performed for this laboratory including metallographic techniques and thermocouple temperature measurement. For metallographic techniques, a metallographic specimen was prepared and then a light microscope was used to examine this specimen and microstructural quantities, namely average grain diameter and ASTM grain size, were calculated. For measuring temperature using a thermocouple, a thermocouple was created and an unknown pure metal was analyzed by creating a cooling curve with the data obtained from the thermocouple and a millivoltmeter. The purpose of this laboratory was to familiarize students with these techniques of metallography and thermocouples as they will be used often later on in the course.

PROCEDURE

Thermocouples and Temperature Measurement

For this part of the laboratory, a thermocouple was used as an electrical sensor for measuring temperature. To construct a thermocouple, a chromel and alumel wire was chosen and the end of the wire was stripped of the insulation. After that, the chromel and alumel wire ends were twisted as tightly as possible to have a tight measuring junction and the ends were welded together with a torch. The thermocouple was then hooked up to the millivoltmeter with the chromel wire being positive and the alumel wire being negative. The measuring junction of the thermocouple was then inserted into a crucible of molten metal heated by a Bunsen burner and the millivolt output was read on the millivoltmeter and recorded. In addition, the reference junction temperature was also recorded from a thermometer. Once the thermocouple was placed in the crucible, the Bunsen burner was turned off and the crucible of molten metal was allowed to cool. As it cooled, voltage readings were taken every 10 seconds until the metal solidified. The temperatures were then calculated for all of the voltage readings and a cooling curve was created using the time and temperature data. The melting point of the metal was determined using the plateau region of the curve.

Metallographic Specimen Preparation, Photomicroscopy and Grain Size Determination

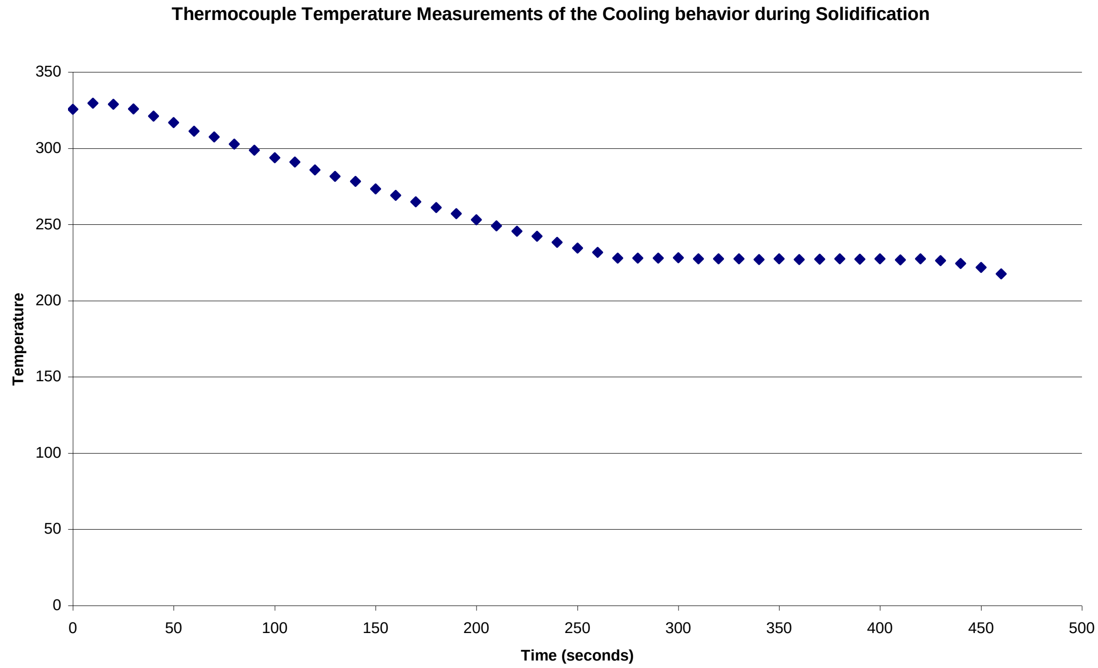
For this part of the laboratory, a small piece of normalized AISI/SAE 1018 steel was sectioned from a ½ inch diameter bar using an abrasive cut-off wheel. The cut surface was then ground flat using coarse (80 grit and 120 grit) belts of the grinder. The specimen was then dried off with a paper towel and mounted in an epoxy mounting polymer. After the plastic specimen was cured for about 10 minutes and removed from the mold, it was ground flat using the fine (120 grit) belt of the grinder and the edges were beveled. Next, the specimen was ground from 240 grit SiC paper through 600 grit paper and turned 90° between each grinding. The specimen was then polished with 1.0 μm Al_2O_3 to remove all scratches. Next, the specimen was etched with a 3% by volume solution of nitric acid in methanol (3% Nital) by immersion for about 5 seconds. After the specimen was etched, it was washed thoroughly with water and methanol and then dried with a heat gun. The etched specimen was then examined with a light microscope at 200x magnification and a photomicrograph was obtained. In addition, the average grain diameter was calculated along with the ASTM grain size.

RESULTS

A. Grain Size Determination

Picture 1. Photomicrograph of annealed AISI/SAE 1018 Steel. X200.

Each line is two inches. The square box is the scale marker, one inch by one inch. Both are used to determine



Graph 1. Thermocouple Temperature Measurements of the Cooling behavior during Solidification

Please see the attachment for original work and calculation.

Table 1 shows average grain diameter and ASTM grain size. Average grain diameter is 23.09 μm and ASTM grain size is 8 even though actual calculation is 7.81 because grain size should be the closest integer. Picture 1 shows the photomicrograph of annealed AISI/SAE 1018 Steel with 200 magnifications. There are also possibilities of counting errors, measurement errors, imperfect polishing, etching errors, etc.

Table 2 shows thermocouple temperature measurements of the cooling behavior of 1018 steel during solidification. The T(RJ) represents the room temperature when students performed the experiment and 1.041 mV is the value that converted from room temperature to voltage. Graph 1 is created with the data of table 2. According to graph1, the melting point of 1018 Steel is 227.2 Celsius degrees. The melting point was decided with the region shows steady temperature after plateau and before starting to decrease temperature. Research shows that the accepted melting point of 1018 steel is from 300 to 337 Celsius degrees (Gannon University Mechanical Engineering web site). Even though the result of the experiment does not fall in the region, the result is acceptable. Because students assumed that room temperature stayed same during measuring voltage, there are measuring or human errors, ignoring temperature changes of crucible of molten metal, and others.

DISCUSSION

Metallic and ceramic samples are first polished to produce a smooth surface and then are chemically etched. Thus, the grain boundaries will have some groove along the boundaries. When the samples are examined with an optical microscope, the incident light will not be as intensely reflected at the grain boundaries. Therefore, the grain boundaries will appear as dark lines in the eyepiece of the microscope. The shape of the grain boundaries is determined by the restrictions imposed by the growth of neighboring grains. Some grains appear larger than others in the photomicrograph. Because the grain boundary itself is a small region so the atomic packing in grain boundaries is not perfect because it does not have atomic match. Also students did not make specimens flat, did not polish well, or did not etch right. When those expectations failed, light reflected from the specimen surface is not evenly distributed and it will make some grain boundaries appear larger than others.

Supercooling appears below the equilibrium melting temperature of the metal, the greater the change in volume free energy. However, the change in free energy due to the surface energy does not change much with temperature. Thus, the critical nucleus size is determined mainly by free energy.

CONCLUSION

This lab was successful because students were able to learn how to make metallographic specimens, examine these specimens with a light microscope, and analyzing results including grain size, grain diameter. Moreover, students accomplished to measure thermocouples and to convert voltage to temperature. Students analyzed the results of thermocouple with determining melting point through generated graph that based on data.