Jominy End Quench

ENGR45 – Materials Science Laboratory

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Abstract

The Jominy End Quench test is useful in determining the hardenability of a material. A sample, such as 4140 Steel which is used in this experiment, is transformed entirely into a single solid phase through heating to a high temperature. It is then quenched by exposing one of its ends to a cooling source, such as water. The region of the sample that is put in contact with this cooling source drops in temperature more rapidly which limits growth in the material's grains. Other regions of the sample cool more slowly which allows for the grains in these areas to grow to greater sizes. The result of this is a single substance containing many different solid phases, each contributing differently to the hardness of the sample. Hardness readings are then taken along the length of the sample to establish the effects of changing temperature after heat treatment on the material's characteristics and behavior. In this experiment the Jominy End Quench test was performed on a 4140 Steel sample to investigate the effects of heat treatment followed by different rates of cooling.

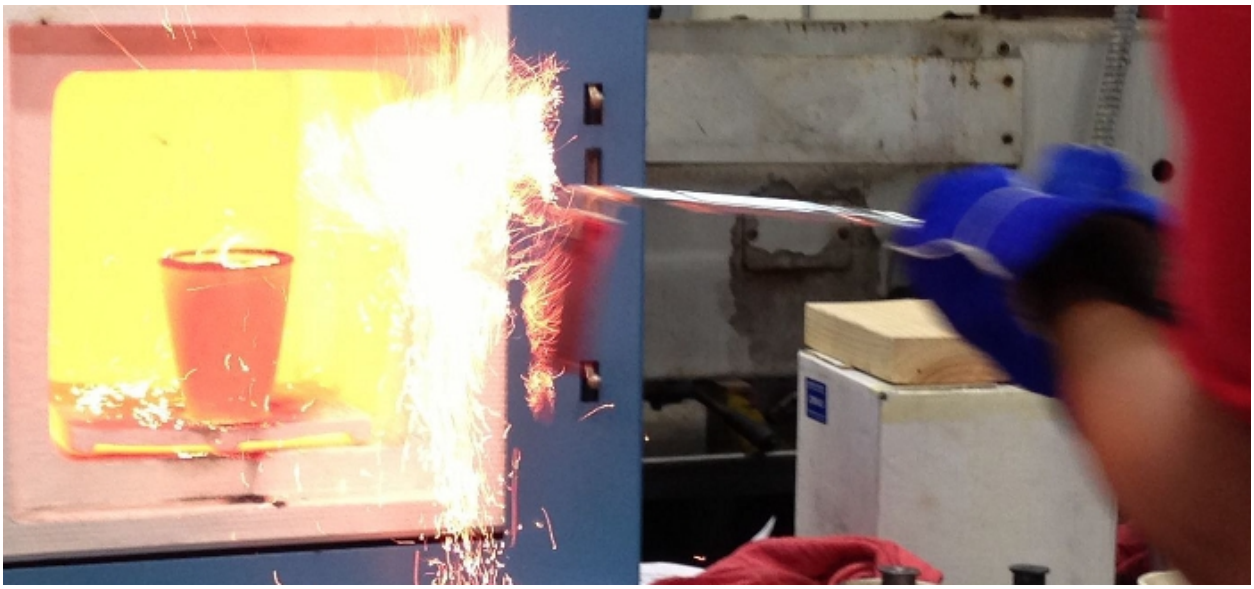
Procedure

Because the Jominy End Quench test requires heating a specimen to very high temperatures, a great deal of caution was exercised to ensure that the procedure was completed safely and without incident. The careful removal of the sample from the oven using metal tongs and heat insulating gloves was practiced many times before the experiment was started to ensure that the transfer was performed both quickly and safely. It is important that the sample be transferred to the quenching source as fast as possible to minimize energy transfers with the environment: if left to cool for too long in the coolness of the air then the quenching process is considered to have started at all locations along the surface of the sample instead of just a single end. Quenching along only the one end is required for the proper testing of the material, with the target duration of time for transfer from the oven to the quench bucket being less than five seconds. The temperature variability that is experienced during the quenching process produces a sample containing the requisite unique solid phases along its length and surface, each of which contributes differently to the hardness of the material.

The sample of 4140 Steel was placed within a crucible containing carbon powder. The carbon

powder submerged all but the top end of the sample and served to prevent the decarburization of the steel as higher temperatures were reached. The carbon powder is able to produce this effect because the high concentration of carbon on the surface of the material prevents carbon atoms inside the material from diffusing outward, which would change the material and its properties. The crucible containing the sample was placed inside an oven which was then heated to 982°C over the course of 40 minutes (see **Figure 1** located at the end of the report for the rate of applied heat experienced by the sample).

Upon removal from the oven the sample was glowing orange and red and radiating a tremendous amount of heat energy (shown below in **Picture 1**). It was quickly placed within the quench bucket where water was sprayed upward toward its bottom end to begin the quenching process. The sample was left to cool in this configuration for about ten minutes before it was submerged in water so that hardness tests could be performed. It is interesting to note that, even after a few minutes of the bottom end of the jominy being quenched, the top end continued glow reddish orange.



Picture 1. Removal of heated sample from oven at 980°C .

Hardness testing was performed on the cooled sample with measurements taken along the long side of the sample, beginning at the quenched end. The following intervals of distance were used: 1/16", 1/8", 3/16", 1/4", 3/8", 1/2", 3/4", 1", 5/4", 3/2", 7/4", and 2". This spacing reduced the total number of measurements required, but also allowed for a complete representation of the varying hardness to be obtained for the treated material.

Results

A significant mistake was made at the beginning of the experiment which invalidates all experimental data: the jominy loaded into the oven was 3130 Steel instead of the required 4140 Steel. This was not discovered until hardness testing was performed because the material required the Rockwell B scale instead of the expected Rockwell C scale. Measuring the hardness of the heat treated 3130 Steel sample showed absolutely no variability along its length, suggesting that for this particular type of steel 980°C is not a high enough temperature to change it into a single solid phase (see **Figure 2**). The obtained experimental data must be discarded because it does not represent hardenability data for either type of steel.

Conclusion

The procedure must be repeated using the correct steel sample. However, this attempt served as a means to become better familiar with the equipment used and safety precautions required when performing a Jominy End Quench test procedure. It is expected that future tests will be executed more confidently and without the complications that were encountered here.

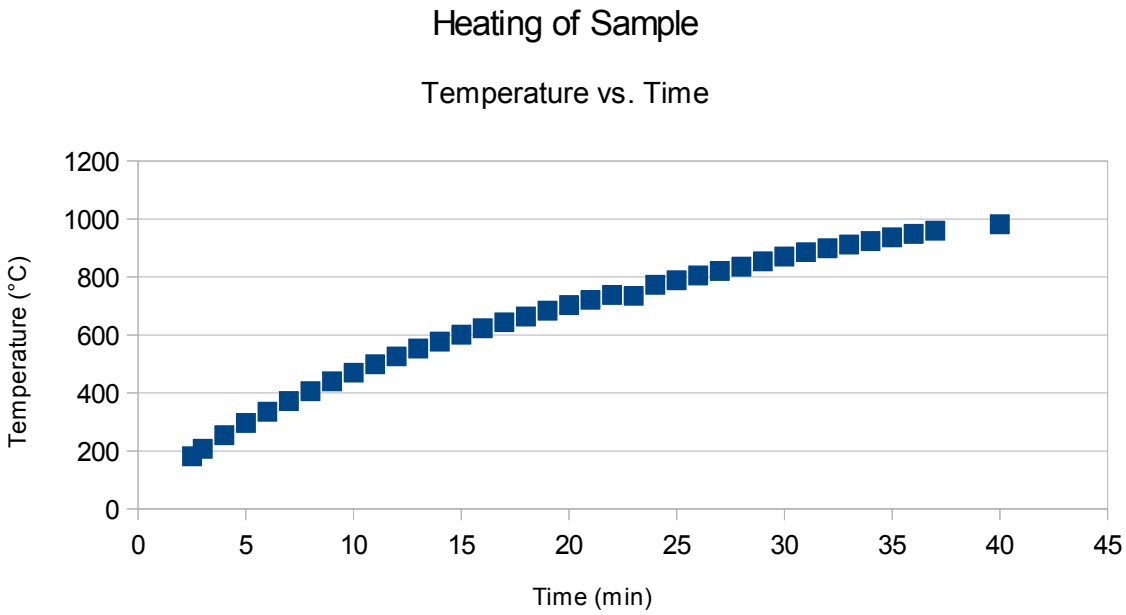


Figure 1. Rate of heating of sample within oven.

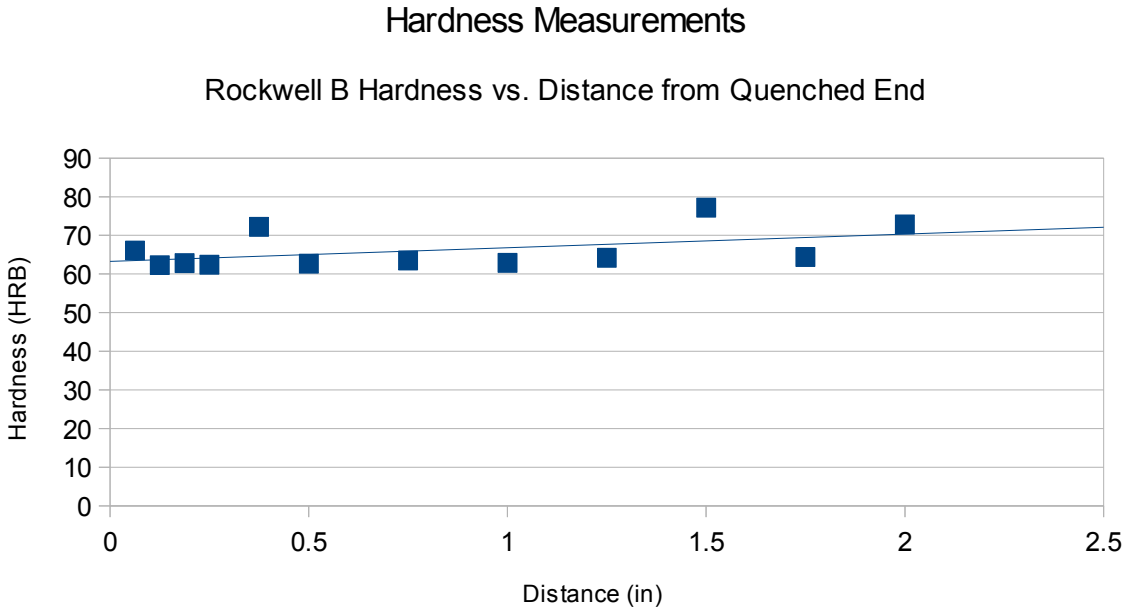


Figure 2. Hardness measurements for incorrect sample.