

Memorandum

Purpose

The hardness lab investigated the effects of quenching an alloy and its related effects on surface hardness. Specifically, the lab investigated the effect on hardness of quenching one end of a piece of metal heated to the austenite phase while allowing the other end to cool slowly.

In addition to testing the quenched steel sample, the hardness values of copper, steel, and aluminum plates was investigated.

Procedure

Jominey Bar Testing

The lab could be divided into two major steps, first heat-treating the alloy to be tested and second, testing the heat-treated alloy.

Heat-treating the alloy did not require very high tech or state of the art equipment. Using an oven, three pieces of cylindrical steel were heated. The pieces were samples of 1090 Steel, 8620 Steel and 4340 Steel. Once the samples reached the austenite temperature, they were removed from the oven and placed into the quencher. The quencher cooled one end of the metal with a stream of water and allowed the other end of the sample to cool naturally.

Once the sample returned to room temperature, a flat was ground on along the side of the cylinder. This flat was used to test for hardness.

Using two different machines, hardness values of the sample were calculated. Both machines operated on the same principle, the only difference being forty years of technology.

To test the sample using the 1940's Rockwell dial machine, the sample first was inserted into the machine. Magnets held the sample into place to prevent slippage and inaccuracies. The machine placed a small calibration load on the sample. Next, the user zeroed the dial to ensure accurate readings. Then the machine placed the full load on the sample and the dial read the hardness of the sample at the point tested. The sample was slid to the right 1/16 inch (by the use of a screw device to ensure precise movement), and the process is repeated. After the sample was tested 24 times at 1/16", the values started to level out. As a result, the test points were extended to 1/8" increments.

To test the sample using the 1980's Brinell digital machine, the sample was first inserted into the machine. Then the machine tested the sample and returned a value. The sample was slid to the right by 1/16" inch and the process is repeated. As in the Rockwell hardness testing, after the 24th sample point, the hardness values started to level out and the test points were extended to 1/8" increments.

Plate Hardness testing

A similar process was used to test the copper, aluminum, and steel plates for hardness. To test the sample using the Rockwell hardness machine, the plate was first placed underneath the testing mechanism. The arm was cranked until dashes appeared on the display, then very slowly cranked until the test began. The test started just after the fourth dash appeared and disappeared. The hardness of the sample appeared on the display. This process was repeated three times.

The Brinell hardness machine was not as automated. Instead of returning a hardness value, the machine simply dented the metal. After placing the sample underneath the testing mechanism, the flat arm was cranked until it slipped. Then the test button was pushed and the test began. After the green light came on and the machine stopped whirring, the denting process was finished. To calculate hardness, the diameter of each indentation was determined using a small microscope. Finally, the diameter and corresponding hardness was looked up on a chart. The procedure was repeated two more times to ensure an accurate hardness reading.

Results

Methods used to obtain results

Most of our raw data did not require any manipulation or processing. With both Jominey bar testing and the Brinell plate hardness testing, the raw data is the final processed data.

The Rockwell plate hardness test required using two charts. First, the dent diameter was converted to a Rockwell hardness value by using a chart. Second, the Rockwell hardness value was converted to Brinell hardness measurements by using a second chart.

Results of plate hardness testing

Table 1 summarizes the results of the plate hardness testing of the copper, aluminum, and steel plates.

Machine	Copper	Aluminum	Steel
Rockwell B (Converted to Brinell)	83.6	99.7	147
Rockwell B (Unconverted)	50.6	63.7	79.4
Brinell	98.8	109	154

Results of Jominey Bar testing

Please see Figure 1, Figure 2, and Figure 3 for the results of the Jominey bar testing. The first four points in each test are not useable because the Jominey bar were slightly warped due to the rapid quenching of the steel.

Interpretation of Results

Accuracy of Results

The newer Brinell hardness machine was much more accurate than the older Rockwell machine. The graph of the hardness using the digital machine is much smoother and gives more predicable results. In addition to accuracy issues due to age of the equipment, the Rockwell hardness machine did not move the steel sample precisely 1/16" each time. The screw adjustment was loose, and it moved the steel anywhere from 1/32" to 3/32" per turn. This caused some of the unpredictability of the graph. After the first test was ran, the screw adjustment was tightened and that helped accuracy.

The precision and accuracy of the plate hardness results is also limited. The Brinell hardness machine worked well and should have been accurate. Being a newer, digital machine, the results are not subject to human error. In addition, the values did not need to be converted, improving the accuracy. The Rockwell machine was the questionable machine. First, the machine only creates the indentations. It did not measure the hardness of the sample. Visual measurement of the indentations was needed in order to calculate the hardness of the material. While a ruler in the microscope provide some accuracy, it

was possible to make an incorrect measurement. In addition, there is some human bias when measuring (i.e. The first two measurements are .23 mm, the third should also be .23 mm). Finally, a chart was used to convert the Rockwell measurements to Brinell measurements. Since the chart read only to the nearest whole number, the values were extrapolated. This allowed for some error in the measurements.

Finally, an interesting observation is the Rockwell dial machine readings and Brinell digital machine readings do not agree with each other. In all three tests, the dial readings are somewhat higher than the digital readings. Other lab groups experienced the same discrepancy between the two machines.

Conclusion

Practical applications of the hardness lab

Steel often needs to be hardened. Axels, piston heads, and bolts are three examples of applications of hardened steel. However, hardened steel is also more brittle than untreated steel. Because hardened steel is brittle, and its brittleness depends on its hardness, it is important not to over harden steel.

The desired amount of hardness can be found on the Jominey bar by using the data table and graphs created from the measurements. Using the distance from the end of the bar, the rate of cooling that produced the desired hardness can be found and a manufacturing plant that cools steel at the calculated rate can be setup. The materials produced at the manufacturing plant will be created at the desired hardness and ductility.

Recommendations for improvement

The major issue encountered was the slippage in the screw adjustment of the dial hardness machine. This allowed the material to slide more or less than the desired 1/16" distance. Tightening up the lab equipment before the experiment was started would have improved the accuracy of the lab.