Experiment 6 : Rockwell Hardness Measurement of Metals

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1 Objective

The aim of this experiment is

- To determine the Rockwell hardness numbers of metals
- Compare these values with the values available in any metals handbook

2 Experimental Methods

The instruments used in the experiment are:

- Rockwell hardness testing machine : The machine consists of an anvil with adjustable height to station the block of material to be tested. It has a support to mount the indenter corresponding the scale of hardness. It has an automatic loading system and a digital screen to display the output. The output would be the Rockwell hardness of the material in the scale we had chosen.
- Indenters : In this experiment, we use two indenters. For B scale, we use a round ball indenter with a diameter of 1/16 inches. For C scale, we use a diamond indenter with an angle of 120°.
- Specimen : We are testing the hardness of Aluminum, Brass, Copper and High-speed steel. The surfaces of the specimen should be perfectly flat and polished. The thickness of the specimen should be at least 10 times the expected depth of indentation.

Hardness is a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion.
There are three ways of measuring hardness : Scratch hardness, indentation hardness and Rebound or dynamic hardness
The Rockwell scale is a hardness scale based on the indentation hardness. The Rockwell test measures the depth of penetration of an indenter under a preload compared to the penetration made by a larger load. There are different scales, each denoted by a single letter, that use other loads or indenters. It is a swift process, free of human error, and the result has a microscopic resolution of the measurement. The test causes only a small indent and does not damage the specimen.

The hardness of the material is inversely proportional to the depth of the indentation.

We start the experiment by mounting the appropriate indenter for the scale we will use. We position the specimen and adjust the height such that the distance between the top surface of the specimen and the less than 8 mm. Make sure that the surface the perpendicular to the indenter. Select the HRB/HRC scale with the help of touch screen display buttons on the machine and start the test. The machine first applies a minor load, then a major load and displays the Rockwell hardness of the material based on the depth of the indentation.

HRB scale uses a ball indenter of a diameter of 1/16 inches and applies a major load 100 kgf. HRC scale uses a diamond indenter with faces at 120°and applies a major load of 150 kgf.

We take 3 readings for each material. The indentations should be apart by a distance of at least 3 times the diameter of the indentation. We average out these readings to get a good estimation.

3 Results

Aluminium
Scale : HRB
Reading 1 = 45.87 HRB
Reading 2 = 50.95 HRB
Reading 3 = 51.07 HRB

$$Average = \frac{45.87 + 50.95 + 51.07}{3} = 49.30$$

So, hardness of the Aluminium specimen is 49.30 HRB. Theoretical hardness of Aluminium 6061 is 60 HRB.

$$Percentage\,error = \frac{60 - 49.3}{60} * 100 = 17.83\%$$

Brass
Scale : HRB
Reading 1 = 67.67 HRB
Reading 2 = 63.85 HRB
Reading 3 = 65.51 HRB

$$Average = \frac{67.67 + 63.85 + 65.51}{3} = 65.68$$

So, hardness of the Brass specimen is 65.68 HRB. Theoretical hardness of Brass-IS 319 is 67 HRB.

$$Percentage\,error = \frac{67 - 65.68}{67} * 100 = 1.97\%$$

Copper
Scale : HRB
Reading 1 = 29.53 HRB
Reading 2 = 26.42 HRB
Reading 3 = 28.97 HRB

$$Average = \frac{29.53 + 26.42 + 28.97}{3} = 28.31$$

So, hardness of the Copper specimen is 28.31 HRB. Theoretical hardness of Electro grade Copper is 51 HRB.

$$Percentage\,error = \frac{51 - 28.31}{51} * 100 = 44.49\%$$

High Speed Steel
Scale : HRC
Reading 1 = 66.99 HRC
Reading 2 = 67.98 HRC
Reading 3 = 67.67 HRC

$$Average = \frac{66.99 + 67.98 + 67.67}{3} = 67.55$$

So, hardness of the High-speed Steel specimen is 67.55 HRC. Theoretical hardness of High-speed Steel is 65 HRC.

$$Percentage\,error = \frac{65 - 67.55}{65} * 100 = -3.92\%$$

4 Observations

Final Result:
Hardness of Aluminium specimen = 49.30 HRB
Error in Aluminium hardness = 17.83%
Hardness of Brass specimen = 65.68 HRB
Error in Brass hardness = 1.97%
Hardness of Copper specimen = 28.31 HRB
Error in Copper hardness = 44.49%
Hardness of High-speed Steel specimen = 68.55 HRC
Error in High-speed Steel hardness = 3.92%
We can observe that :

$$Hardness_{High-speedsteel} > Hardness_{Brass} > Hardness_{Aluminium} > Hardness_{Copper}$$

High-speed steel as it is very hard compared to the other three specimen. The maximum suggested operating range for HRB scale is 100. From the conversion scale, we can know that 100 HRB = 22 HRC. Hence, we use HRC scale for measuring the hardness of high-speed steel.

Looking at the images of the indents, we can observe that the indent on the copper specimen is deeper than the others. Also, the indent on Brass is smaller in comparison to that on Aluminium and Copper. This behaviour directly supports the comparative relation of hardness that we get from the experimental values.

Hardness test causes the material near the indentation to harden due to strain hardening. Repeated tests in the vicinity could give a larger than expected values of hardness along with a smaller indent. Hence, we maintain enough distance between two indents, that is, more than three times the diameter of the indent.

The specimen might not be perfectly uniform throughout, hence we take multiple hardness readings at different locations and take the mean value as the recorded hardness of the specimen.

Roughness of the specimen could affect the hardness, so we use a well polished specimen.

5 References

1. Lab Manual
2. Wikipedia