1 Introduction

The objective of this experiment is to determine and compare the hardness of various metal samples using the Brinell, Vickers, and Rockwell methods. The study focuses on evaluating the influence of material treatment such as quenching and plastic deformation on hardness. Appropriate loads and indenters are applied for each method, and multiple indentations are conducted to ensure accuracy.

Results are analyzed using standardized conversion tables to establish correlations between hardness and tensile strength, as well as to assess the suitability of each testing method for different materials and applications.

2 Background/ Theory

The hardness of metals is measured via standardized tests, in which a small indenter of a defined shape is pressed into the material with a certain force. The hardness is then deduced from the dimensions of the indentation remaining after the test (Vickers and Brinell methods). In the Rockwell methods, one reads the hardness directly on the device on a dial gauge, which actually measures the depth of this indentation.

3 Method & Materials

A hardness apparatus is used for the test, in which one mounts the desired indenter, and one adjusts the desired force. A pre-load of 10 kgf is manually applied to the sample beforehand by turning a wheel, pushing the sample against the indenter with a force of 10 kgf. The rest of the measurement is performed automatically: via a mechanism, the main load is applied, held for a few seconds, and then removed.

5 total samples tested using multiple types of hardness tests — two C-45 steel blocks, one of them being quenched, a brass strip, and two steel tensile samples, one of them having undergone a tensile test. Firstly, the two C-45 steel cubes and the brass strip are subjected to the Vickers hardness test. Afterwards, all the samples get subjected to the two Rockwell tests. To determine which rockwell test would be appropriate, the Vickers rating is used. Finally, the brass sample is subjected to the Brinell test.

4 Results

4.1 Measurements

4.1.1 Vickers measurements

All of the samples were subjected to a load of 100 kgf and measured with a digital microscope which was able to digitally measure the dimensions of the indentation. The results of these measurements is displayed in table 1.

Table 1: Measurement results of Vickers hardness test

Material	d_1 (mm)	d_2 (mm)
$\text{Steel}_{\text{hardened}_1}$	0.488	0.498
$\text{Steel}_{\text{hardened}_2}$	0.5	0.515
$\text{Steel}_{\text{hardened}_3}$	0.499	0.5
$\text{Steel}_{\text{unhardened}_1}$	1.09	1.118
$\text{Steel}_{\text{unhardened}_2}$	1.067	1.085
$\text{Steel}_{\text{unhardened}_3}$	1.08	1.09
Brass_1	1.06	1.054
Brass_2	1.061	1.048
Brass_3	1.6	1.58

Afterwards, the necessary calculations are done to determine the Vickers hardness, and the results are placed in table 2.

Table 2: Hardness value results of the Vickers test

Material	d_{avr} (mm)	HV_{avr} $(-)$	ΔHV $(-)$	$HV_{standard\ notation}$ $(-)$
$\text{Steel}_{\text{hardened}}$	0.5	741.33	200	(741.33 ± 200)
$\text{Steel}_{\text{unhardened}}$	1.09	156.12	30	(156.12 ± 30)
Brass	1.06	166.33	30	(166.33 ± 30)

4.1.2 Rockwell measurements

By using the results of the Vickers hardness test, the kind of Rockwell test that needed to be used was determined. For the hardened steel, Rockwell C was used, whereas for the brass and the unhardened steel, Rockwell B was used.

The results of the respective tests are arranged in table 3.

Table 3: Rockwell hardness results for both of the steel blocks and brass strip

Measurement	$\text{Steel}_{\text{hardened}}$ (HRC)	$\text{Steel}_{\text{unhardened}}$ (HRB)	Brass (HRB)
1	67	80	86
2	62	82	86
3	63	81	87
4	61	83	87
5	83	84	88

After taking the average of these values and calculating the error, the final results are displayed in table 4.

Table 4: Final result of the Rockwell hardness tests

Material	HR_{avr} $(-)$	ΔHR $(-)$	$HR_{standard\ notation}$ $(-)$
$\text{Steel}_{\text{hardened}}$	63.2	2	(63.2 ± 2)
$\text{Steel}_{\text{unhardened}}$	82	1	(82 ± 1)
Brass	86.8	1	(86.8 ± 1)

4.1.3 Rockwell B measurements

For both tensile samples, the Rockwell B hardness test was used. The measurements are displayed in table 5.

Table 5: All measurement results of the tensile samples

Measurement	$\text{Sample}_{\text{original}}$ $(-)$	$\text{Sample}_{\text{drawn}}$ $(-)$
1	65	82
2	61	86
3	69	87
4	58	86
5	61	87

Afterwards, the same steps to calculate the error are done as before, the final results being displayed in table 6.

Table 6: Final results of the tensile sample tests

Material	HR_{avr} $(-)$	ΔHR $(-)$	$HR_{standard\ notation}$ $(-)$
$\text{Sample}_{\text{drawn}}$	85.6	2	(85.6 ± 2)
$\text{Sample}_{\text{original}}$	82	1	(82 ± 1)

4.1.4 Brinell for brass

Firstly to utilize the Brinell hardness test, the main load must be calculated. The force is determined to be 60 kgf. Afterwards, the results of the indentation measurements are noted down in table 7.

Table 7: Indentation results of the Brinell test

Measurement	$d_{indentation}$ (mm)
1	0.728
2	0.709
3	0.719
4	0.728
5	0.72

Finally, the final hardness value can be calculated. The results of this calculation are shown in table 8.

Table 8: Hardness measurement results of the Brinell test

d_{avr} (mm)	HB_{avr} $(-)$	ΔHB $(-)$	$HB_{standard\ notation}$ $(-)$
0.721	150	20	(150 ± 20)

4.2 Calculations