Experiment #1

Brinell hardness test

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Section PI-X

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1. Objective

The objective of this experiment was to determine the Brinell hardness HB of steel and aluminum.

2. Introduction

The hardness of a material is a very important property in the domain of engineering since it governs to what extent the material deforms, scratches or indents. Knowing the hardness of materials allows engineers to pick the proper materials to use in the members of the structure of a large building or in the blade of a saw which needs to cut hard materials. The Brinell hardness test is a method to measure and quantify the hardness of a material. This test makes use of a 10 mm steel ball as an indenter which is then uniformly pressed with a known load into a flat and smooth surface of the tested material. It is assumed that steel will have a significantly higher Brinell hardness number than aluminum. There are many alternative hardness tests like the Vickers, Rockwell, Mohs, Shore and Knoop test.

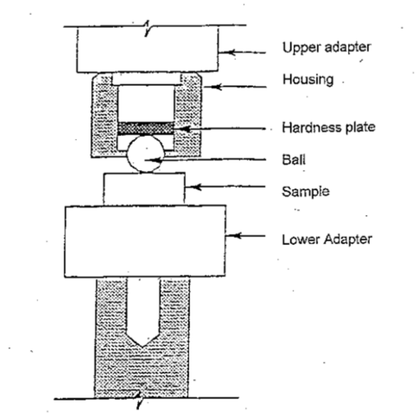

Figure 1: demonstration of Brinell harness test (lab Manuel reference)

3. Procedure

Place and center the sample of the material on the lower adapter of the machine Ensure slight contact between the loading ball and the sample material. Then progressively apply test load. The load to be applied for steel is 10×10^3 N and 5×10^3 N for aluminum. Maintain the load for 15 seconds. Remove the load and use microscope to analyze the indentation.
4. Results

Formulas

(1) $HB = \frac{P(kg)}{A(mm^2)}$

(2) $A = \pi Dt = \frac{\pi D(D - \sqrt{(D^2 - d^2)}}{2}$

(3) $d = \frac{dx + dy}{2}$

(4) $P(kg) = \frac{N}{g}$

Where
P=applied load
g=9.81m/s^2
A= area of indentation
T= depth of indentation
D=diameter of ball, 10 mm
Dx= horizontal diameter
Dy= vertical diameter

Sample calculations

Iron trial no 1

$$d = \frac{dx + dy}{2}$$

$$d = \frac{3.1 + 3.1}{2}$$

$$d = 3.1\ mm$$

$$p(kg) = \frac{N}{g}$$

$$p(kg) = \frac{10140\ N}{9.81 m/s^2}$$

$$p(kg) = 1033.64\ kg$$

$$\pi Dt = \frac{\pi D(D - \sqrt{(D^2 - d^2)}}{2}$$

$$t = \frac{(10 - \sqrt{(10^2 - 3.1^2)}}{2}$$

$$t = 0.246\ mm$$
$$A = \pi D t$$
$$A = \pi 10(0.246mm)$$
$$A = 7.728\ mm^2$$

$$HB = \frac{P(kg)}{A(mm^2)}$$
$$HB = \frac{1033.64\ kg}{7.728\ mm^2}$$

$$average\ brineel\ hardness = \frac{(133.75 + 138.76 + 142.72)}{3}$$
$$average\ brineel\ hardness = 138.41$$

<u>Data For Steel</u>

No. of trial.	Diameter of impression			Load, p		Depth of indentation t (mm)	Area of indentation $A(mm^2)$	Brinell hardness, HB (kg/mm^2)	Average Brinell Hardness HB (kg/ mm^2)
	dx	dy	d	in N	in Kg				
1	3.1	3.1	3.1	10140	1033.64	0.246	7.728	133.75	138.41
2	3.1	3.0	3.05	10182	1037.97	0.238	7.46	138.76	
3	3.0	3.0	3.0	10116	1031.19	0.230	7.225	142.72	

<u>Data For Aluminum</u>

No. of trial.	Diameter of impression			Load, p		Depth of indentation t (mm)	Area of indentation A(mm^2)	Brinell hardness, HB (kg/mm^2)	Average Brinell Hardness HB (kg/ mm^2)
	dx	dy	d	in N	in Kg				
1	2.5	2.5	2.5	5125	522.43	0.159	4.99	104.69	106.93
2	2.5	2.4	2.45	5041	513.86	0.152	4.78	107.50	
3	2.5	2.4	2.45	5092.5	519.11	0.152	4.78	108.60	

The average Brinell hardness number obtained for steel was 138.41 and for aluminum it was 106.93. In (2) to isolate for the indentation depth, both sides of the equation must be divided by πD to obtain t. The same exact same series of calculations is repeated for aluminum. As it can be determined from the results steel has a much higher Brinell hardness number than aluminum. The average obtained for steel is not too far off. There is a significant discrepancy between the experimental and literature value for the Brinell hardness value of aluminum.

5. Discussion

The values obtained for the both the steel and aluminum are 138.41 and 106.93 respectively. The literature value for the Brinell hardness of steel is 130 and for aluminum it is 75. There is a significant discrepancy between the literature value and the experimental one for aluminum. The experimental value of steel is similar to the literature value.

The Hardness test has many practical applications in the field of engineering. It permits material selection in the design of structures or systems. The hardness describes a materials strength and resistance to wear so if an engineer was looking to design a part that undergoes through heavy or repetitive mechanical forces, they would choose a material with a high hardness number. The hardness test also allows for quality controls of materials to ensure they meet designer specifications or industry code. Hardness testing can also be used to monitor heat treating. After a metal has been heat treated, hardness tests are commonly used to validate if the heat treatment was successful and uniform.

The Vicker’s hardness test uses square based diamond pyramid indenter, and the hardness number is equal to the load divided by the product of the lengths of the diagonals of the square impression. The Rockwell hardness testing is another test used on metals common in engineering. A diamond cone indenter or a small diameter steel ball is used depending on if the material is hard or soft. Every test, two different loads are applied, the minor and major load. When the minor load is applied the depth is record and then the major load is added to the minor load. Then the major load is removed. The increase in depth from applying and removing the major load is then used to calculate the Rockwell hardness value.

If the indentations are made to close to the edge of the sample of metal, the material will dent more easily since there is less material constraining where the force is applied. This will invalidate the hardness test since the metal will have a lower hardness number than it should.

If the indentations are made to close to each other the hardness test would also be invalid. The material will have a harder time indenting near another indent since the preliminary indent pushed more material around its edges and reinforced itself. The second indent will have to push more material down with the same force resulting in a smaller indentation. This would make the material seem harder than it actually is.

There are some possible sources of errors due to the equipment in this experiment since there could have been air bubbles in the compressor and the seals of the valves weren’t tight enough leading to a loss of pressure. These defects could have affected the applied load on the samples. The machines are also not ASTM approved so the values obtained would not be approved values. Another possible source of error could be due to the surface of the steel sample. The surface of the steel sample contained unwanted grooves which could have affected the hardness to a very small extent. If the force was applied in between a groove, there would be less material to displace making it easier to indent deeper. This would cause a smaller hardness number. If the force applied is on the peak of a groove, there would be more material to displace resulting in a smaller grove making the material appear harder. These defects weren’t found in the aluminum sample.

7. References

“Brinell Hardness Test.” *Nuclear Power*, 11 Aug. 2022, www.nuclear-power.com/nuclear-engineering/materials-science/material-properties/hardness/brinell-hardness-test/.

“Rockwell Hardness Test.” *Industrial Physics*, 31 Oct. 2023, industrialphysics.com/knowledgebase/articles/rockwell-hardness-test/#:~:text=The%20Rockwell%20Hardness%20Test%20uses,This%20depth%20is%20recorded.