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INSTITUTE OF APPLIED TECHNOLOGY

Engineering Materials

Module 6: Hardness Test

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IAT Curriculum Unit

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Module 6: Hardness Test

Module Objectives

After the completion of this module, the student will be able to:

- Explain the hardness property and where is it needed .
- Identify the different types of hardness tests.
- Describe the Brinell hardness test.
- Describe the Rockwell hardness test.
- Describe the Vickers hardness test.
- Explain hardness quotations used by Brinell.
- Carry out a Brinell hardness test for aluminum, brass, copper and steel.
- Calculate the Brinell hardness for each of the tested materials.

Module Contents

Introduction

If we scratch or file copper, brass, steel and aluminum using an engineer's file we can compare how easy or difficult it is to remove metal from each of these materials. The most difficult material to remove metal from will be the hardest

1.Hardness definition:

Hardness is the ability of a material to resist scratching, wear, tear and indentation.

There are many engine parts that need the hardness property to resist wear. An example is shown in Fig. 6.1.

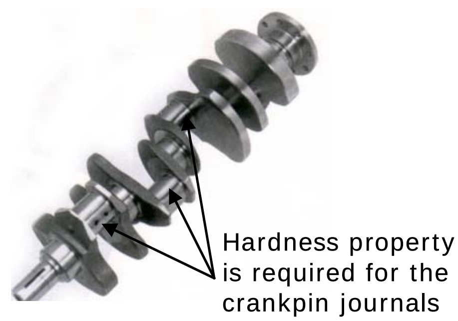


Fig.6.1:crank shafts need hardness property to resist wear

2.Types of hardness tests:

The most frequently used types hardness tests are:

1. Brinell Hardness test.
2. Rockwell Hardness test.
3. Vickers Hardness Test.

3.Brinell hardness test:

The Brinell scale characterizes the indentation hardness of materials through the diameter of penetration of an indenter, loaded on a material test-piece as illustrated in Fig.6.2. A wide range of materials can be tested using the Brinell test simply by varying the test load and indenter ball size.

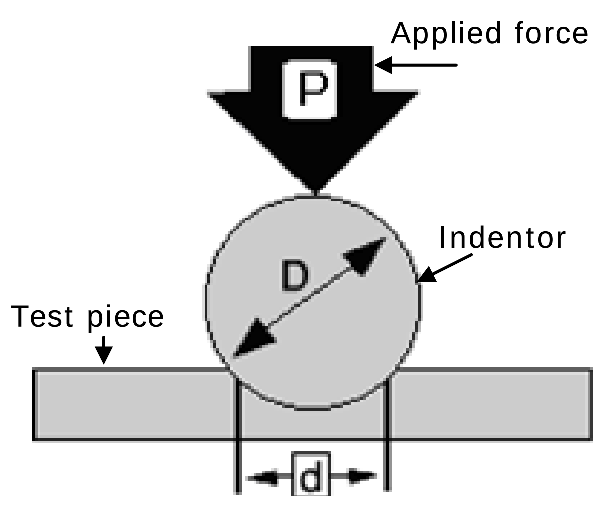


Fig. 6.2: Brinell hardness test

The Brinell hardness tester is shown in Fig.6.3. The typical test uses a 10 mm diameter **steel ball** as an indenter with a 3000 Kgf (29 KN) force. For softer materials, a smaller force is used and for harder materials, a **tungsten carbide ball** is substituted for the steel ball.

After the test is completed the indentation diameter is measured and hardness is calculated using the following formula:

$$BH = \frac{2 * P}{\pi * D * (D - \sqrt{D^2 - d^2})}$$

Fig. 6.3: Brinell hardness tester

Where:

P = applied force (Kilogram force)

D = diameter of indenter (mm)

d = diameter of indentation (mm)

3.1.Brinell hardness quotation:

When quoting a Brinell hardness number (**BHN** or, more commonly, **HB**), the conditions of the test used to obtain the number must be specified.

The quoted result should always contain full details of the test variables, thus:

120 HBS 10/3000/15: Indicates that a hardness number of 120 BHN was calculated using a 10 mm diameter hardened steel indenter (HBS [S for steel]) and a force of 3,000 kgf for 15 seconds.

1800 HBW 10/3000/30: Indicates that a hardness number of 1800 BHN was calculated using a 10 mm diameter tungsten carbide indenter (HBW [W for wolfram, the original name of tungsten]) and a force of 3,000 kgf for 30 seconds.

4. The Rockwell hardness test.

The Rockwell scale characterizes the **indentation hardness** of materials through the depth of penetration of an indenter, loaded on a material sample. The indenter may either be a steel ball of some specified diameter or a spherical diamond-tipped cone. The Rockwell hardness tester is shown in Fig.6.4.

Fig. 6.4 : Rockwell hardness tester

4.1 Describe the Rockwell hardness test?

1. A minor load of 10 kg is first applied, which causes a small initial penetration to seat the indenter and remove the effects of any surface irregularities.
2. The dial is set to zero.
3. The major load is applied.
4. Upon the removal of the major load, the depth reading is taken while the minor load is still on as illustrated in Fig.6.5.

5-The machine displays the hardness readings directly on a dial.

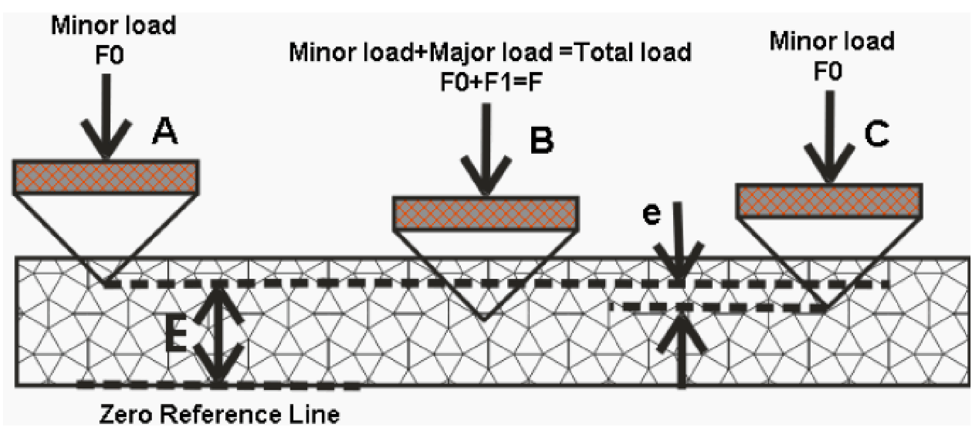


Fig. 6.5: Rockwell hardness test

4.2 Advantages of the Rockwell test machine:

- The ability to display hardness values directly as shown in Fig.6.6.
- The machine is relatively simple.
- Inexpensive set-up that enables its installation in college laboratories.

Fig. 6.6: Digital Rockwell hardness tester

5. Vickers's Hardness Test

The Vickers hardness tester shown in Fig. 6.7 uses a diamond indenter, with the shape of square-based pyramid for all materials as shown in Fig. 6.8.

Fig. 6.7: Vickers hardness tester.

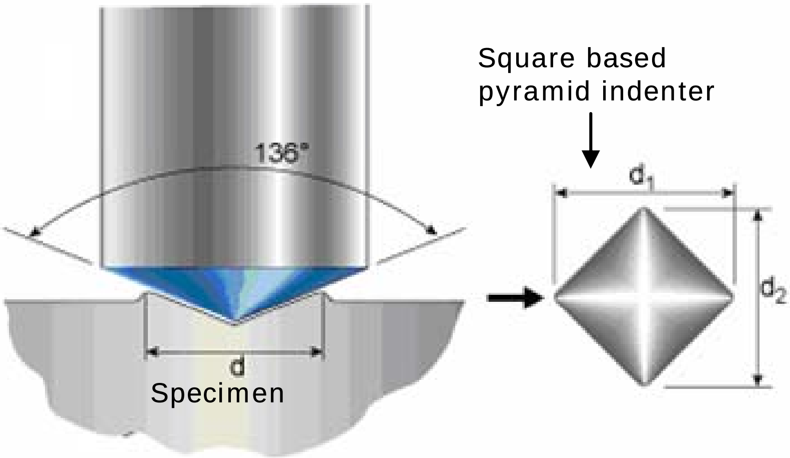


Fig. 6.8: The square shaped pyramid indenter used in Vickers hardness test

6. The Brinell hardness test procedure on the universal testing machine:

1. Put the Brinell attachment in the test machine.(The diameter of the indenter is 12 mm)

2. Place the test piece on the anvil as shown in Fig. 6.9. (the indentation should not be made close to the edge of a specimen to avoid unnecessary concentration of stresses)

Fig.6.9: Place the test piece on the anvil.

3. Close the plastic door.

4. Switch on the instrument panel and make sure that the middle button is set to "**MAN**" as shown in Fig. 6.10.

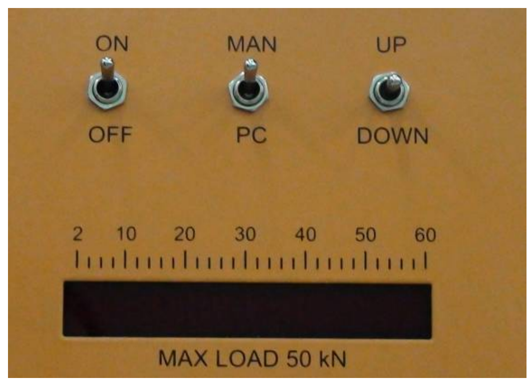
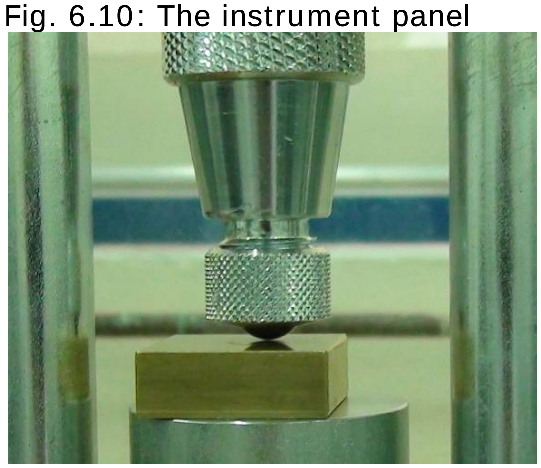


Fig. 6.10: The instrument panel

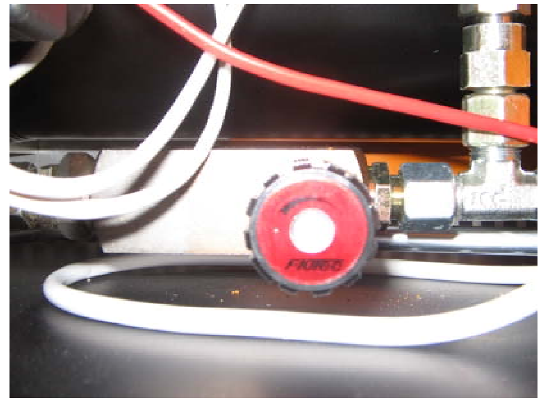
5. Push the (up/down) switch to the "**Up**" position and move the attachment closer to the test piece as shown in Fig.6.11.

N.B: leave a small gap between the attachment and the workpiece.



6.11: Moving the Brinell attachment close to the workpiece.

6. Adjust the speed of the hydraulic cylinder valve to 1/8 of a turn counter clock wise from the closed position to decrease the speed of the main cylinder. See Fig. 6.12.



6.12: Speed adjustment valve

7. Start the test by pushing the (up/down) switch to the "**Up**" position and hold it there till the end of the test. The indenter will reach the test piece and start the indentation. Once the indentation force reaches a maximum of 50 KN (factory calibrated), use the stop watch to calculate 15 seconds, and then stop the test as shown in Fig.6.13.

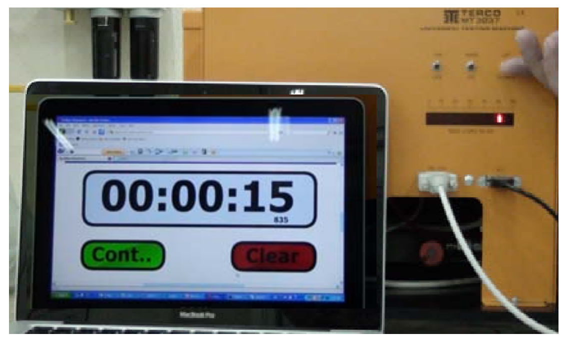
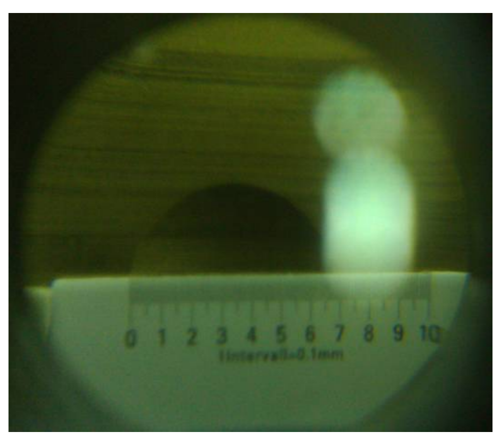


Fig.6.13: Performing the Brinell hardness test.

8. Push the (up/down) switch to the "**Down**" position enough to release the test piece.

9. Use the magnifier to check the diameter of the indentation as illustrates in Fig.6.14.



6.14: Using the magnifier to check the indentation diameter.

10. The hardness unit is **kgf / mm²** and calculated by the equation:

$$BH = \frac{2 * P}{\pi * D * (D - \sqrt{D^2 - d^2})}$$

Where:

P = load in kilogram force.

D = Diameter of indenter (Steel ball diameter=12 mm)

d = diameter of indentation (mm).

7.Hardness test results

7.1.The test results for an aluminum specimen

Aluminum Specimen	
Diameter of indenter (mm).	D=…………………..mm
Diameter of indentation (mm).	d=………………………mm
Force (Load) N.	F=………kN = ……...x1000=…………………………N
Force (Load) kgf	P = 0.102 x F (load in Newton) P = 0.102 x …………………………….. = …………..……………………………... Kgf
Brinell hardness (kgf/mm^2)	$BH = \frac{2 * P}{\pi * D * (D - \sqrt{D^2 - d^2})}$ …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………

7.2.The test results for a copper specimen

Copper Specimen	
Diameter of indenter (mm).	D=……………………..mm
Diameter of indentation (mm).	d=……………………..mm
Force (Load) N.	F=………kN = ….…..x1000=………………………..N
Force (Load) kgf	P = 0.102 x F (load in Newton) P = 0.102 x …………………………….. = ………..……………………………... Kgf
Brinell hardness (kgf/mm²)	$BH = \frac{2 * P}{\pi * D * (D - \sqrt{D^2 - d^2})}$ …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………

7.3.The test results for a brass specimen

Brass Specimen	
Diameter of indenter (mm).	D=……………………mm
Diameter of indentation (mm).	d=……………………..mm
Force (Load) N.	F=……...kN = ………x1000=………………………..N
Force (Load) kgf	P = 0.102 x F (load in Newton) P = 0.102 x …………………………….. = ………..…………………………….... Kgf
Brinell hardness (kgf/mm^2)	$BH = \frac{2*P}{\pi * D*(D-\sqrt{D^2 - d^2})}$ …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ………………………………………………………………………………………

7.4.The test results for a steel specimen

Steel Specimen	
Diameter of indenter (mm).	D=……………………..mm
Diameter of indentation (mm).	d=……………………..mm
Force (Load) N.	F=………kN = ….…..x1000=…………………………N
Force (Load) kgf	P = 0.102 x F (load in Newton) P = 0.102 x …………………………….. = ……………………………………….. Kgf
Brinell hardness (kgf/mm^2)	$BH = \frac{2*P}{\pi * D * (D - \sqrt{D^2 - d^2})}$ …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………

Activity:

Use the results of the four tested specimens to fill in the following table:

Hardness order	Metal name	Indentation diameter (mm)	Brinell hardness number
1st (hardest)			
2nd			
3rd			
4th (least hardest)			

What is the relation between the hardness of a material and the diameter of indentation?

For further reading, you can use the following links

http://www.ndt-ed.org/EducationResources/CommunityCollege/Materials/Mechanical/Hardness.htm

8. Supplementary recourses

1. Mechanical and Non-destructive testing video.
2. http://www.ajdesigner.com/phphardness/brinell_hardness_number.php

9. References

1. MT3037 Universal Testing machine manual.MT3037-312 July 2007.
2. Engineering materials 1. “An introduction to Properties, Applications, and Design”.
3. Different internet sites.

Student’s notes