

**American University of Beirut**

Faculty of Engineering & Architecture

Mechanical Engineering

**Brinell Hardness of Metallic Material**

**(Lab03)**

MECH 341 – Engineering Materials Lab

Section 3 (4:00 pm)

Due Date: 27/10/2010

Professor: Mr. Charbel Seif

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**I. Objective:**

The main objective of this experiment is to determine the mechanical properties of 5 materials which are: Low carbon steel, high carbon steel, Cast iron, Heat treated carbon steel & brass specimens.

During the following experiment we should:

1. Measure indentation diameter and determine the Brinell hardness of the mentioned materials.
2. Find the tensile strength of each specimen.
3. Determine the effect of carbon content on the hardness of a material.
4. Find the effect of heat treatment on hardness.
5. Determine the effect of present microstructures on the hardness.
6. Try to find a relation between the results of the previous 2 experiments and this experiment.

**II. Introduction:**

In our introduction we will start by the definition of Hardness.

Definition: *Hardness* is “the measure of material’s resistance to deformation by surface indentation or by abrasion” (Materials Science glossary, Callister 2007).

The hardness test is applied by forcing an indenter into the surface of a sample and then measuring its indentation. Hardness was previously measured using a qualitative analysis method which was performed by testing the ability of a material to scratch another. The scale ranges from 1 to 10; where 1 is for extremely soft materials and 10 for hard material (diamond). This scale is known as the Mohr’s scale (Figure 7).

Over the past century, a quantitative hardness indexing system was invented and the most known tests are the following:

a. Rockwell Hardness Test.

b. Knoop & Vickers Hardness Test.

c. Brinell Hardness Test.

***Below is a comparison between those 3 tests.***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | **Rockwell** | **Knoop & Vickers** | **Brinell** |
| i. | ASTM ref. | ASTM Standard E 18 | ASTM Standard E 92 | ASTM Standard E 10 |
| ii. | Indenter Geometry | Spherical and hardened steel balls or conical diamond (Brale) | Small diamond having pyramidal geometry | Spherical tungsten carbide or steel |
| iii. | Shape of geometry | Diamond Cone 120o angle  Spherical Diameter: | Vickers: 136o square based diamond pyramid  Knoop: *l/b* = 7.11  *b/t* =4.00 | Diameter: 2.5, 5 & 10 mm |
| iv. | Designated Symbol | HR | Knoop: HK  Vickers: HV | HB |
| v. | Formula for hardness Number | No formula available  (unit less) |  |  |
| vi. | Shape of indenters  (Figure 9) | Figure  Row 4 | Figure  Vickers: Row 2  Knoop: Row | Figure  Row 1 |
| vii. | Scale level | Macro indentation | Micro indentation | Macro indentation |
| viii. | Force applied | Rockwell:  60, 100, 150 kg  Superficial Rockwell  15, 30, 45 kg | Range 1-1,000 grams | 3,000 kg |
| ix. | Scale range | Range [0-130] HR  Most accurate  20 – 100 HR  (A,B,C,D,E,F,G,H,K) | Knoop Range  [100-1,000] HK | Range [5-10,000] HB |
| x. | Variable under study | Depth of indenter in specimen | Length of indenter in specimen | Diameter of indenter in specimen |

In our experiment we used the Brinell Hardness Test since it is the easier to implement and because measuring the diameter is more accurate than measuring the depth of the hole with equipment that we have at hand.

Here is a comparison between Brinell hardness testing and tensile testing used in the previous labs.

|  |  |
| --- | --- |
| Brinell Hardness Testing | Tensile Testing |
| Non – Destructive, can be reused | Destructive, can not be reused |
| Wild range of test forces and ball sizes to suit every application | **Maximum load supplied by the Housefield UTM machine on specimens is about 100 KN** |
| Needs 30 seconds at most | Depending on load strain rate applied. |
| No need to prepare specimen to specific dimensions | **Requires accurate dimensions for the dog bone specimen** |
| Only Relates hardness to Tensile strength  TS (MPa) = 3.45 x HB | Determines most of mechanical properties of the specimen. |
| Main drawback: needs to optically measure the indent size, thus experimental errors may take place. | **Main advantage: provides computerized measurements** |

* Micro Structure

Pure iron, called ferrite or α iron, at room temperature has a BCC crystal structure. It transforms into γ-austenite at 912oC and persists till 1394oC to revert back into BCC until it melts at 1538oC.

The iron-carbon carbide phase diagram (Figure 5) represents the different micro crystal structures as the temperature and carbon weight percentage varies.

For ferrous steels (weight %C < 1%) as the temperature decreases bellow 727oC, γ-austenite transforms into pearlite, carbon diffusion takes places across the grain boundaries to form an alternating layers of ferrite (α iron) and cementite (Fe3C) of a ratio 8 to 1. Moreover, depending on the cooling rate austenite is transformed into fine pearlite, coarse pearlite or bainite.

However, if rapid cooling takes place (less than 10 seconds), and the temperature drops from 727 oC to less than 300 oC(Figure 4), no diffusion would take place and martensite crystals would form having BCT (body central tetragonal, length = width ≠ height) (Figure 3), no diffusion takes place, and carbon are held inside the crystals.

**III. Problem Approach:**

**IV. Measured Values:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Section and Experiment Number** | | **Dent Diameter (d) in mm** | | | | |
| **Cast Iron** | **Low Carbon Steel** | **High Carbon Steel** | **Heat-Treated High Carbon Steel** | **Brass** |
| **Section 3 Experiment1** | 1 | 4.4 | 4.35 | 4.25 | 2.65 | 5.5 |
| 2 | 4.5 | 4.35 | 4.1 | 2.6 | 5.45 |
| **Average** | **4.45** | **4.35** | **4.175** | **2.625** | **5.475** |

**V. Brinell Hardness & tensile strength:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Brinell Hardness Number** | | | | |
| Cast Iron | Low carbon steel | High carbon steel | Heat treated high carbon steel | Brass |
|  | 60.9 | 63.9 | 69.5 | 181.5 | 39.0 |
| TS (MPa) = 3.45 x HB | 210.105 | 220.455 | 239.775 | 626.175 | 134.55 |

Brinell hardness to carbon content and the specific microstructure of cast iron is also unidentified (coarse/fine pearlite, bainite, spherodites, cementite, and ferrite.)

**VI. Comparison:**

**VII. Conclusion**

As a conclusion, hardness tests are the most popular mechanical tests because they are nondestructive and they allow us to determine some important mechanical properties besides hardness (tensile strength, yield strength, carbon content). Moreover, Brinell hardness is the easiest to perform among other tests since it is on the macro scale and it doesn’t require much calculations or specimen preparation.

**VIII. Appendix**

***Graphs & Figures***

|  |  |  |
| --- | --- | --- |
| **Figure_3_2ab** | | Figure 1: Body Centered Cubic (BCC) crystal structure |
|  | | Figure 2: Faced Centered Cubic (BCC) crystal structure |
|  | | Figure 3: Body Centered Tetragonal (BCT) crystal structure |
|  | | Figure 4: Heat Treated Martensite, Temperature vs. Time |
| **f24_09_pg290** | | Figure 5: Iron-Iron Carbide phase diagram |
| **f19_06_pg160** | | Figure 6: Tensile strength vs. Brinell hardness number |
| **f18_06_pg159** | | Figure 7: Comparison between several hardness scales |
| **t05_06_pg156** | | Figure 9: Hardness-testing geometric indenter’s shape and size. |
|  | | Figure 10: Hardness, tensile strength and yield stress for steels as function of carbon content. |
|  | | |
|  | Figure 11:  Brinell Test  Where:   * F: Applied Force   = 1000 kg force.   * D: Indenter (Ball) Diameter   = 10 mm.   * d: Indentation Diameter. * TS: Tensile strength (MPa). | |

**IX. References**

Internet:

* http://en.wikipedia.org/wiki/Carbon\_steel
* <http://en.wikipedia.org/wiki/Cast_iron>
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