Lab 2 – Hardness testing

(prepared By Mutlu Ozer
as a supplemental Lab manual)

Objectives

1. To understand what hardness is, and how it can be used to indicate some properties of materials.
2. To conduct typical engineering hardness tests and be able to recognize commonly used hardness scales and numbers.
3. To be able to understand the correlation between hardness numbers and the properties of materials.
4. To learn the advantages and limitations of the common hardness test methods.

Concepts

Hardness testing, which describes the resistance to deformation, is a fast and simple method to characterize the mechanical properties of materials. By using an indentor with a fixed load, the size of the indentation is proportional to the material's hardness. An indentation requires permanent deformation from dislocation slip; therefore any obstacle to slip will serve to increase hardness.

Background

It is a common practice to test most materials before they are accepted for processing, and before they are put into service to determine whether or not they meet the specifications required. One of these tests is for hardness. The Rockwell and Brinell machines are those most commonly used for this purpose.

<u>Rockwell Hardness Test</u>
The penetrators for the Rockwell hardness tester range from 1/2-inch diameter steel balls to very small diamond (brale) tips (points). The smaller points are used for harder materials that have a greater resistance to indentation. There are various force scales used for various materials.

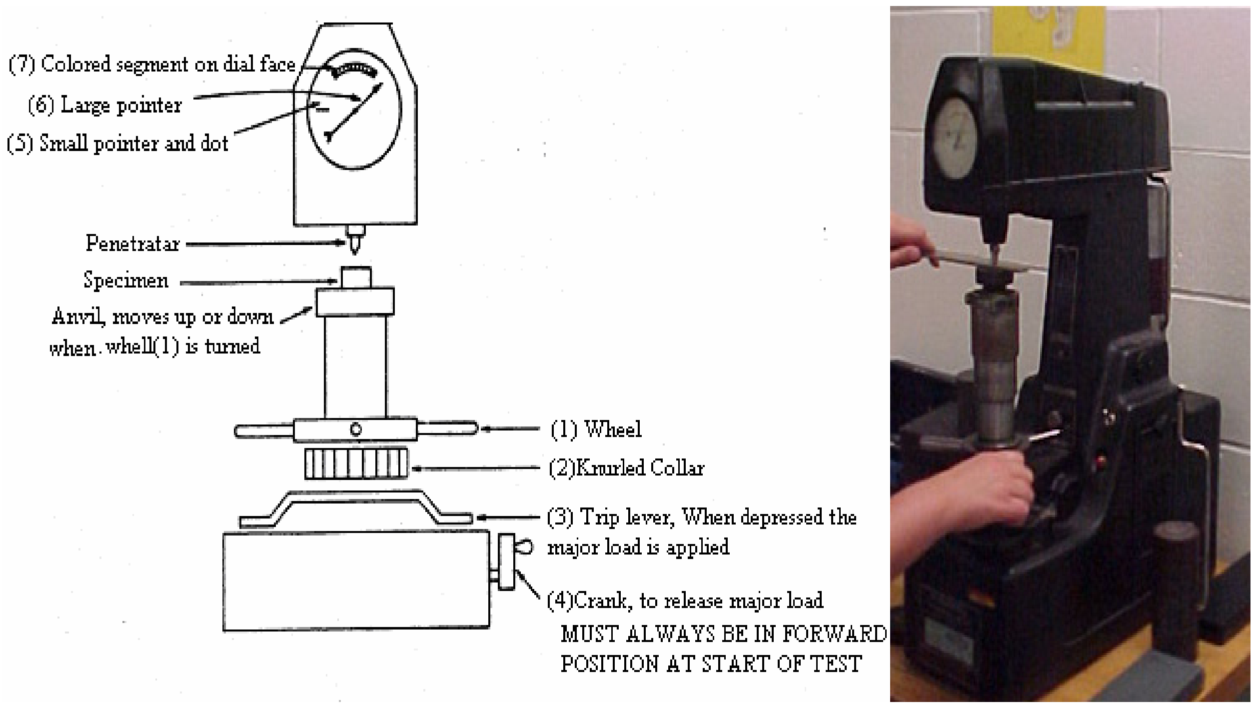

Figure 1.1. Rockwell Hardness Tester

The Rockwell B and Rockwell C scales will be used for this experiment. The Rockwell B scale is suitable for soft engineering metals, and the Rockwell C scale is appropriate for hard engineering metals. Each scale requires a specified tip and load. The B scale uses a 1/16- inch diameter hard steel ball and a 100-kg load. The C scale uses a conical diamond point and a 150-kg load. If one examines the table in Appendix B, one will find that there is a range of tensile strengths for which there are no Rockwell B numbers and likewise a range where there are no Rockwell C numbers. In these ranges, the specific Rockwell tests are not valid. To perform the Rockwell tests, the penetrator is pressed against the specimen with an initial 10-kg preload to properly seat the penetrator. The remaining load is applied gradually after the dial on the hardness tester has been zeroed. After the penetrator has stopped moving into the specimen, the final position of the dial pointer indicates the Rockwell hardness number that is related to the depth of penetration

Brinell Hardness Test

Brinell hardness is determined by forcing a hard steel or carbide sphere of a specified diameter under a specified load into the surface of a material and measuring the diameter of the indentation left after the test. The Brinell hardness number, or simply the Brinell number, is obtained by dividing the load used, in kilograms, by the actual surface area of the indentation, in square millimeters. The result is a pressure measurement, but the units are rarely stated.

The Brinell hardness test uses a desktop machine to press a 10mm diameter, hardened steel ball into the surface of the test specimen. The machine applies a load of 500 kilograms for soft metals such as copper, brass and thin stock. A 1500-kilogram load is used for aluminum castings, and a 3000-kilogram load is used for materials such as iron and steel. The load is usually applied for 10 to 15 seconds. After the impression is made, a measurement of the diameter of the resulting round impression is taken. It is measured to plus or minus .05mm using a low-magnification portable microscope. The hardness is calculated by dividing the load by the area of the curved surface of the indention, (the area of a hemispherical surface is arrived at by multiplying the square of the diameter by 3.14 and then dividing by 2). To make it easier, a calibrated chart is provided, so with the diameter of the indentation the corresponding hardness number can be referenced. A well structured Brinell hardness number reveals the test conditions, and looks like this, "75 HB 10/500/30" which means that a Brinell hardness of 75 was obtained using a 10mm diameter hardened steel with a 500-kilogram load applied for a period of 30 seconds. On tests of extremely hard metals a tungsten carbide ball is substituted for the steel ball. Among the other hardness tests, the Brinell ball makes the deepest and widest indentation, so the test averages the hardness over a wider amount of material, which will more accurately account for multiple grain structures, and any irregularities in the uniformity of the alloy.

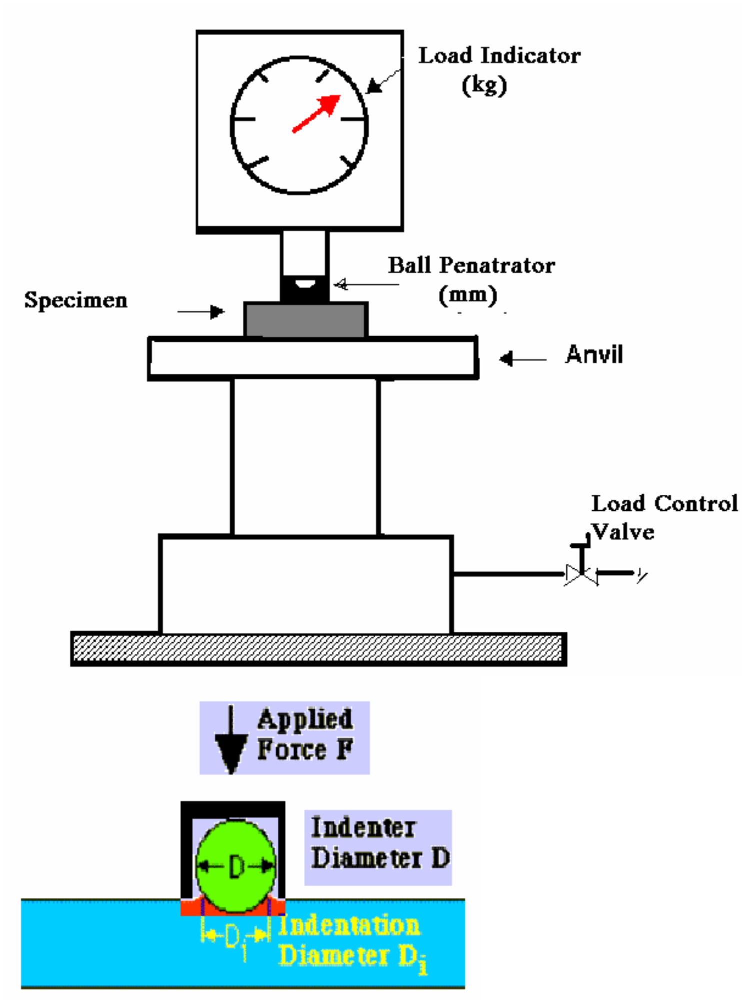

Figure 1.2. Brinell hardness Testing Machine

The Brinell hardness test was one of the most widely used hardness tests during World War II For measuring armour plate hardness. The test is usually conducted by pressing a tungsten carbide sphere 10mm in diameter into the test surface for 10 seconds with a load of 3,000kg, then measuring the diameter of the resulting depression. The BHN is calculated according to the
Following formula:

BHN = $\mathbf{2P/\{\pi D\ [D-\ (D^2\text{-}d^2)^{\ 0.5}]\}}$

Where:

BHN = The Brinell hardness number
F = The imposed load in kg
D = The diameter of the spherical indenter in mm
D_i = Diameter of the resulting indenter impression in mm

Small errors in this measurement will lead to small variations in BHN values. As a result, BHN is usually quoted as a range of values (e.g. 210 to 245, or 210-245) rather than as a single value.
The BHN of face-hardened armour uses a back slash ? \? to separate the value of the face-hardened surface from the value of the rear face. For example, a BHN of 555\353-382 indicates the surface has a hardness of 555 and the rear face has a hardness of 353 to 382.

ASTM E-10 is a standard test for determining the Brinell hardness of metallic materials. The load applied in this test is usually 3,000, 1,500, or 500 kgf, so that the diameter of the indentation is in the range 2.5 to 6.0 mm. The load is applied steadily without a jerk. The full test load is applied for 10 to 15 seconds. Two diameters of impression at right angles are measured, and the mean diameter is used as a basis for calculating the Brinell hardness number (BHN), which is done using the conversion table given in the standard.

Experimental Procedure

Operation of Rockwell Testing Machine
(1) Select the correct combination of weights (at the rear of the machine) and penetrators (diamond brale, 1/16-inch ball, etc.) for the hardness scale you wish to use. The numbers given in black represent the scales that use brale and the numbers given in red represent the scales that use ball penetrators.
(2) Make certain that the crank (4) is in forward position (nearest to you).
(3) Place sample on the anvil.
(4) Slowly turn the wheel spokes (1) clockwise. This raises the anvil and sample toward the penetrator tip. After contact is gently made, continue raising sample until small pointer (5) is about in line with small black dot and large pointer (6) is within colored sector (7). The minor load has now been applied to the sample.
(5) After step 4, large pointer (6) on the dial is nearly vertical. Now, turn the knurled collar (2) until "SET" line on the dial scale is in line with large pointer (6).
(6) Depress trip lever (3). This triggers the mechanism that applies the major load. Crank (4) will automatically move away from you.
(7) After the crank (4) has come to rest (against a "stop" and away from you), gently pull the crank toward you as far as it will go. If this is done abruptly, a false reading will be obtained because of jarring.
(8) Now record the scale reading of large pointer (6). The black scale is read for the diamond penetrator (Example: Rockwell C), and the red scale is for ball penetrators (Example: Rockwell B).
(9) Remove the minor load, which remains on the specimen, by lowering the anvil (Turn the wheel (1) counterclockwise). Move the sample to position for next test and repeat the steps above.

Operation of Brinell Testing Machine:
(1) Turn button on

(2) Set the required load on the dial.
Note: For steel and other hard materials the load is 3,000 kg. for 30 seconds. For non-ferrous materials a 500 kg. Load is used for 60 seconds. Thin specimens should not be tested by this method.
(3) Place the specimen on the anvil and apply a preload by bringing the specimen surface to contact with the ball penetrator.
(4) Pull the load knob and apply the appropriate timing at that load level.
(5) Release the load by pushing the load knob back into the initial position.
(6) Remove the specimen and measure the diameter of the indentation. The Brinell Microscope reads in millimeters. Take several readings and average them.
(7) Look up BHN from chart or calculate from the formula.

Report Requirements and Questions:

(1) Develop tables of Rockwell and Brinell hardness numbers and predicted tensile strengths for the specimens.
(3) Summarize, in words, the results of the testing. Comment on the accuracy of using the Brinell hardness test to predict tensile strength of the steel and brass specimen.
(4) Comment on appropriateness of various hardness tests for the different specimens.
(5) Why do the instructions specify the period during which the pressure is to remain on the Brinell ball?
(6) Is the Brinell indentation truly spherical? Explain.
(7) In a Brinell test why is a polished specimen surface more important for harder materials?
(8) Will side bulging resulting from a Brinell impression taken too close to the edge of a specimen result in a hardness number greater or less than the value obtained by a correct procedure?
(9) Why is a minimum thickness of at least ten times the depth of the impression required in the Brinell test? How should the value obtained be influenced by specimens, which are too thin assuming they are tested on a heavy anvil, which is:
(a) Harder than the specimen?
(b) Softer than the specimen?
(10) Is a hardness test normally employed because the property of hardness is desired? Explain.
(11) Can a satisfactory comparison of two dissimilar materials be obtained from hardness numbers?

The following is a sample hardness data table as presented in this laboratory manual. Use the same format in your report.

<u>Students' Names:</u>

Material	Rockwell Hardness Scale, Major Load, Type of Penetrator	Rockwell Hardness Number	Rockwell Hardness Number (Digital)	Brinell Load, Indentation Diameter	Brinell Hardness Number	Tensile Strength (Ksi), (Mpa)
Specimen 1 (steel)						
Specimen 2 (Copper)						
Specimen 3 (Aluminum)						
Specimen 4 (Brass)						