Mechanical Properties: Brinell Hardness Test

OBJECTIVES

-To determine the hardness for different materials using a Brinell Hardness Tester

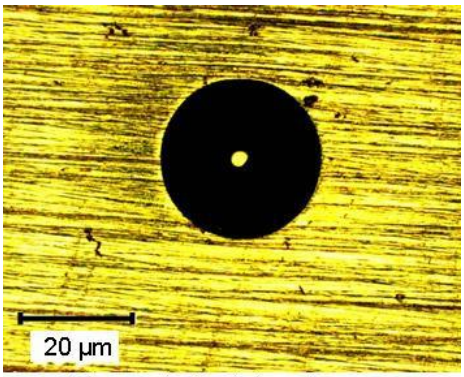
-To understand the relationship between a material's hardness, indentation size, and the Brinell number (no units) associated with the material.

THEORY

Hardness is a measure of the resistance of a metal to plastic deformation. The hardness of the metal is measured by forcing an indenter into its surface. The indenter material which is usually a ball or cone, is made of a material much harder, usually diamond or carbon steel, than the material being tested. For most standard hardness tests, a known load is applied slowly by pressing the indenter orthogonally into the metal surface being tested. After the indentation has been made, the indenter is withdrawn from the surface. An empirical hardness number is then determined, which is based on the cross-sectional area and depth of the impression.

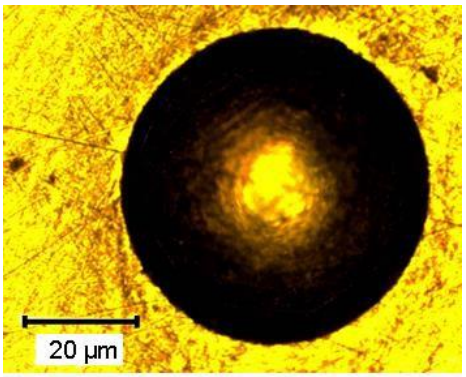
The hardness of a metal depends on the ease with which it plastically deforms. Thus a relationship between hardness and strength for a particular metal can be determined empirically. The hardness test is much simpler than the tensile test and can be nondestructive (i.e., the small indentation, shown in figure 1 and 2, of the indenter may not be detrimental to the use of an object). For these reasons, the hardness test is used extensively in industry for quality control.

"Materials Science and Engineering: An Integrated Approach" by Callister; Chapter 7, Section 16 (Page 213) has more information regarding material hardness.



Micrograph of an indentation on a steel specimen by a diamond indenter

Fig. 1



Micrograph of an indentation on brass specimen by a ball indenter

Fig. 2

The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a defined load (for this experiment 10,000 N). The full load is normally applied for at least 10 to 15 seconds in the case of steel and for at

least 30 seconds in the case of other metals. The diameter of the indentation left in the test material is then measured (either with a caliper or with a low powered microscope). The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation using the following formula:

$$\text{Brinell Hardness (HB)} = \frac{0.102\,F}{A}$$

where, F = Applied test force in Newton
and, A = Surface area of the impression given by:

$$A = 0.5 * \pi * D * \left(D - \sqrt{D^2 - d^2}\right)$$

where, D = diameter of the hardened steel ball = 10 mm
and, d = diameter of the impression produced by the hardened steel ball on the sample.
d is measured as shown in Fig. 3

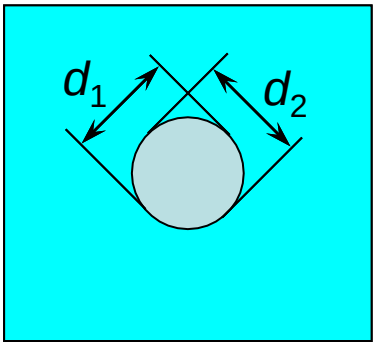


Fig. 3 : Measuring diameter of the impression

TEST PROCEDURE

1. Insert the test sample between the test ball and the pressure plate (See Fig. 4)

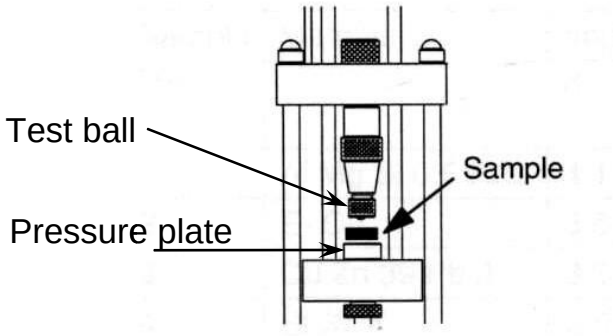


Fig. 4. Sample positioning

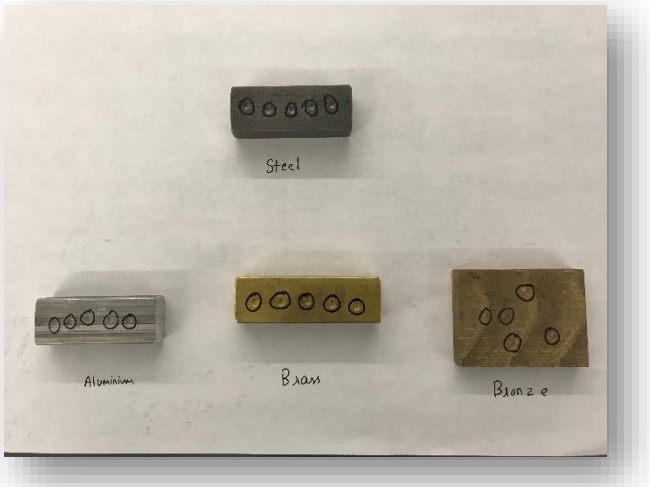
2. Carefully lower the test ball onto the sample by rotating the hand wheel.
3. Smoothly apply the test force of 10,000 N (corresponding to 10 kN on the force display). **DO NOT** apply the force too quickly. From 0 to 10kN, it should take at least 20 seconds.
4. Hold the test force for at least 30 seconds and then release the load (by turning the hand wheel in the opposite direction).
5. Remove the sample and carefully measure the diameter of the impression.
6. Repeat the test 5 **times for EACH sample**.
7. Calculate the hardness for EACH indentation (since you are running the test 5 times for each specimen, 5 Brinell hardness numbers for each of the 4 tests (for each specimen) should be reported.)
8. For each sample, compare the values for Brinell hardness you obtained with values reported in literature.
9. Examine each tested specimen's indentation under a microscope/magnifying glass to create a subjective opinion of the material's hardness.

10. Report your data and the uncertainty in the following tabular format for **EACH sample**:

Test	Impression diameter			Brinell Hardness (HB)	Remarks
	d_1	d_2	*d(average)*		
1					
2					
3					
4					
5					
Average Brinell hardness					
Brinell Hardness reported in literature					

** Include the uncertainty in the table. Report results as xx±xx

Errors and discrepancies can arise during the experiment from many sources, the most likely being from human error. For example, if the cam handle is turned to quickly or not in a smooth constant motion, the resulting hardness could be inaccurate. If the hardness test is performed too close (within 3 indentation diameters) to a previous indentation, the results may differ. Also a specimen may not be entirely homogeneous and may sometimes have different hardness in different areas due to deformations or corrosion.



REPORTING REQUIREMENTS

1. Report the average Brinell hardness and corresponding standard deviation for each metal. Show calculation in the appendix, include equations and sample calculation. (20 points)

2. Compare the Brinell hardness number that you obtained with hardness numbers reported for the materials in literature. (5 points)

3. What is the relationship of the Brinell number to the size of the indentation and the hardness of the material? (i.e., If metal A has a higher Brinell number than metal B, then what can be assumed about the indentation size and hardness of metal A with respect to metal B assuming they are on the same scale.) (5 points)

4. What is the relationship of the Brinell number to the following (directly proportional or inversely proportional) and explain your reasoning. (10 points)
    a. Material's tensile strength?
    b. Material's modulus of elasticity?
    c. Material's ductility?

5. Determine the metals' tensile strength based on the Brinell hardness numbers measured. (5 points)

6. **Calculate uncertainty and determine the number of significant figures for all reported values**, report results as xx±xx. Show calculation in the appendix, include equations and sample calculation. (20 points)

Technical Laboratory Report Format

The following sections must be included in the Technical Laboratory Report.
(Report limit is 5 pages not including Appendices or Title Page)

1. TITLE PAGE

This is the cover page and should present the report in a professional manner. The following should be included:

a. Title of Report
b. Authors (Team #, Team Leader(s) for this report, other Team Members)
c. Date

2. TABLE OF CONTENTS

This page should include all sections of the report, figures, tables, and appendices and their corresponding page numbers.

3. ABSTRACT

This is a brief summary (6-10 sentences) of what was done, what was found, and why it is important.

4. INTRODUCTION

This section provides motivation and a general summary of the experiment. Any definitions, theory, and background literature are included in this section.

5. EXPERIMENTAL PROCEDURE

This section describes step-by-step the procedures used to conduct the experiment(s). If an ASTM standard test method was used, only the standard test number needs to be cited along with any deviations from this standard method.

6. RESULTS

This section includes summary data in tables and figures used in the analysis (next section) and text to describe these tables and figures. Each table and figure must have a number and be cited in the text. This section does not include raw data.

7. DISCUSSION

In this section, results presented in the previous section are analyzed and discussed in response to the reporting requirements. Additional figures may also be added. Any problems encountered in the experiment should also be highlighted as well as the effects of these problems on the results and analysis and methods by which to avoid these problems in the future.

8. CONCLUSIONS AND RECOMMENDATIONS

This section contains summary conclusions based on the analysis, positive aspects of the experiment in terms of learning, and recommendations for improving and/or expanding the experiment.

9. **APPENDICES.** This section (if necessary) contains specific calculations and raw data.