

# Hardness Testing of Materials

Elizabeth Merten  
Department of Materials Science & Engineering  
University of Washington  
Seattle, WA 98195

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## **Abstract:**

Hardness tests are often utilized in order to access the materials hardness and usability. Hardness is the measurement of a material's ability to resist plastic deformation, usually by bending, scratching or penetration. The hardness property value is defined by a specified measurement procedure depending on the equipment utilized. The three principal tests used in determining the hardness of a material utilize Brinell, Vickers or Rockwell equipment. Hardness tests achieve a hardness value (dimensionless number) through measuring the depth of the indentation by a specific shape indenter under an applied force at a specific time interval.

This module builds upon previous modules and experiments located on the MatED website. If hardness testing machines are not readily available, see the Hardness of Brass module for a potential substitution, located on the MatEd website.

## **Module Objectives:**

The demonstration or lab provides an introduction to the various characterization tools utilized in hardness testing of materials. It can provide the basis for understanding the differences in hardness of materials through experimentation and/or demonstration.

## **Student Learning Objectives:**

- Determine the differences in hardness of various materials
- Observe differences in measuring hardness
- Measure, record and report hardness values for materials
- Observe and compare differences from measured and literature values

**MatEd Core Competencies Covered:**

- 0.B Prepare Tests and Analyze Data
- 0.D Demonstrate General Technical Competence
- 1.C Demonstrate Laboratory Skills
- 8.A Demonstrate the Planning and Execution of Materials Experiments
- 8.B Apply Mechanical Testing Processes to Solid Materials
- 8.E Perform Appropriate Tests of Metallic Materials

**Key Words:** Hardness Testing, Brinell, Vickers, Rockwell, Mechanical Properties

**Type of Module:** PowerPoint presentation with lab or in-class demonstration depending on characterization tools available

**Time required:** 30-50 minutes with discussion

**Pre-requisite Knowledge:** Hardness Module 1

**Suggested prerequisite:** Hardness of Brass

**Target grade level:** Advanced High School, Introductory College/Technical School

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### **Equipment and Supplies Needed:**

- PowerPoint projection system
- Rockwell/Vickers/Brinell hardness tester(s)
- Steel (any type)
- Aluminum
- Copper-Brass/Bronze
- Microscope and/or magnifying lenses if available

### **Curriculum Overview and Notes for Instructor**

The hardness of a material is defined by the material's ability to resist plastic deformation such as indentation or scratching when a force is applied. Hardness is not a basic property of a material, but rather a composite, one with contributions from the yield strength, work hardening, true tensile strength, modulus, and other factors.

Hardness tests are widely used in order to assess the quality of materials as it is considered to be non-destructive. The tests are quick and the marks and or indentations incurred by testing are small and inconspicuous.

A hardness indenter is typically utilized in order to assess the hardness of a material. Though many types of indenting machines are available, there is no standard in comparing the values to one another. In order to emphasize the relationship between processing of materials and hardness, examples of similar materials must be tested and analyzed.

In carrying out this module it should be noted that the samples will display hardness values differing from one another depending on the treatment. An example of this would be looking at how the hardness of brass changes after it goes through a process called cold-rolling, which increases the hardness of the material. After cold-rolling the sample could be annealed near its melting temperature in order to alleviate internal stress thus decreasing the hardness value.

Also, all samples should have smooth flat surfaces in order to have accurate measurements. In utilizing the indenter, the sample must be placed carefully in place or the reported hardness value will be incorrect. If the sample is too thin the indenter can penetrate through the sample possibly damaging the machine. In order to avoid this, samples should be no less than  $\frac{1}{4}$  inch in thickness.

Sample preparation should be discussed to avoid hardness values that are false. There should be a slight emphasis on the importance of accuracy in measurements and how the operator plays a role in eliminating error in the data collection.

This exercise can be carried out as a demonstration, individually, or in groups. If used in a demonstration several samples should be tested and students should be encouraged to be involved by recording the data obtained in order to determine trends in the materials and to confirm predictions.

The overall set-up, fundamental concepts and data analysis are discussed in the PowerPoint presentation.

**Optional:**

**Lab report** - Have students report, presenting their results and discussing any variables involved in differences in measurements and literature in order to reiterate the key concepts involved in hardness evaluation for materials.

**Module Procedure**

1. Display each sample on a hard surface and discuss hardness and the varying factors that are involved.
2. Ask the students if they can predict which material will have a higher hardness value and ask how they define hardness. Discuss hardness in materials in order to expand on the concept.
3. Show the PowerPoint presentation and discuss each slide.
  - a. Slide 1-2: Introduction to Hardness (key concepts)
  - b. Slide 3: Diagrams of typical machines and indenters
  - c. Slide 4: Experimental Set-up
  - d. Slide 5: Example of Indentation and Schematic of various indenters
  - e. Slide 6: Discuss experimental analysis

4. Perform demo/lab

If a demonstration, show the students the technique that will be utilized and how the hardness will be measured. Choose a student to record the data while everyone is observing the technique performed on each sample.

If a lab, (individually or in groups) issue several different metal samples. The samples can be the same material processed differently or a variety of materials. Have the students perform hardness testing on the samples record the values. Each measurement should be taken three times on different locations on the sample. Have them rotate the samples among one another. (Values depend on machine and technique utilized for measurement of hardness)

5. Ask the students to identify the variables in measuring the hardness of the materials. Are all three measurements within an acceptable range?

If using the same materials processed differently, ask students why hardness measurements differ for each sample. Discuss how processing of materials can affect the mechanical properties such as hardness.

6. Conduct a class discussion on the exercise to determine what the students have learned. Were their predictions correct?

Repeat the PowerPoint in order to solidify/emphasis the concepts. Answer the experimental analysis questions. Ask students to identify variables that could cause the results to change.

**Additional optional activity**

In order to help emphasize the concept of how processing of materials effects hardness, the Materials Processing Module or Work Hardening Lab could be added to the current lesson plan.

**Supporting Materials and References**

Please see accompanying PowerPoint

## **Acknowledgments**

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## **Evaluation**

### **Student evaluation (discussion/quiz)**

1. Were the hardness results of the various materials tested what you expected them to be? If not, explain.
2. Why is there a difference in hardness values for the various metals when using different hardness testing techniques?
3. Are pure metals harder than alloys? Explain. Does this agree with the results obtained?
4. Why is it important to have a hardness test and should they all be done on the same machine? Explain.
5. How does sample preparation affect hardness values?
6. How could hardness testing be used in order to help select materials needed to construct a building?

### **Instructor evaluation**

1. What grade level and class was this module utilized for?
2. Were the students able to grasp the key concepts introduced in the module?
3. Was the level and rigor of the module acceptable for the grade level of the students? If no, how can it be improved?
4. Was the demonstration/lab work as outlined? Did it help the students in learning the material? Were there any problems encountered?

5. Was the background on hardness testing sufficient for your understanding and for the discussion with the students?

Any comments and/or suggestions on improving this module are encouraged.

### **Course evaluation questions**

1. Was the demonstration/lab clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions or concerns?
4. Was the instructor able to answer your questions thoroughly and to your satisfaction?
5. Was the importance of hardness testing made clear?
6. What was the most interesting thing that you learned about in regards to testing hardness of materials?