ME 354, MECHANICS OF MATERIALS LABORATORY

01 Januarly 2000 / mgj

MECHANICAL PROPERTIES AND PERFORMANCE OF MATERIALS: HARDNESS TESTING*

PURPOSE

The purpose of this exercise is to obtain a number of experimental results important for the characterization of the mechanical properties and performance of materials. The hardness test is a mechanical test for material properties which are used in engineering design, analysis of structures, and materials development.

EQUIPMENT

- Fractured "halves" of reduced gage section tensile specimen of 6061-T6 aluminum.
- Fractured "halves" of reduced gage section tensile specimen of 1018 (hot rolled).
- Flat coupons of 6061 T6 aluminum.
- Flat coupons of 1018 (hot rolled).
- Rockwell hardness tester with 1/16 inch ball indenter tip and 100 kg of mass weights.
- Tensile test machines with compression platen, 10-mm diameter Brinell indenter ball fixture and controller
- Reticular eye piece microscope

PROCEDURE

Brinell Hardness Test

per ASTM E10 "Standard Test Method for Brinell Hardness of Metallic Materials"

- Place the flat coupon of one of the materials on the compression platen of the test machine, ensuring that the specimen is centered and resting flat on the platen.
- In displacement control, with force protect ON and set to 5 kg, adjust the actuator position of the test machine such that the Brinell indenter ball just contacts the surface of the flat coupon with a NEGATIVE force.
- Turn off force protect, switch to force control, use waveform to ramp the force to -500 kg.
- Maintain the maximum compressive force for not more than 15 s.
- Ramp the force back to ~-10 kg.
- Switch to displacement control and adjust the actuator position of the test machine such that the Brinell indenter ball is no longer in contact with the surface of the flat coupon.
- Remove the flat coupon from the compression platen.
- Use the Micro Mike to measure the diameter of the indentation of the surface
- Repeat these steps for the other material.

Rockwell Hardness Test

per ASTM E18 "Standard Test Method for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials"

- Place the cylindrical gripped end of one half of a fractured tensile specimen of one of the materials in the V-notched platen of the Rockwell hardness tester.
- With the load handle pulled forward, raise the specimen and load fixture until the indenter contacts the specimen
- Continue raising the specimen until the small dial hand is pointing at the small black dot (this applies a 10 kg preload).
- Rotate the Rockwell dial until the large dial hand is pointing at "0".
- Depress the loading bar, allowing the machine to apply the maximum load of 100 kg.
- Wait until the large dial hand stops moving, holding the load for not more than 25 s.
- Pull the load handle forward again
- Read the number on the B-scale indicated by the large dial hand
- Repeat this hardness test for the flat sections of the gripped end of one half of the tensile specimen and the flat coupon of the same material using the flat platen

- Repeat these steps for the other material.

ANALYSIS

The analysis is conducted from recorded data.

The Brinell hardness number is obtained by dividing the applied force (in kilograms) by the curved surface of the indentation which is a segment of sphere such that:

$$BHN = HB = \frac{2P}{\pi D\left[D - \sqrt{\left(D^2 - d^2\right)}\right]} \tag{1}$$

where P is the applied load in kg, D is the diameter of the ball (nominally 10 mm) and is the diameter of the indention. See Figure 1 for a schematic illustration of the Brinell hardness test.

The Rockwell hardness number (HRX or RX) is determined from the differences of the indentation depths at the preload and the maximum load. The Rockwell number is read directly from the dial of the indenter, but the number must be reported along with the Rockwell scale which automatically identifies the type of indenter type and the maximum load (otherwise the number is meaningless). See Figure 2 for a schematic of the Rockwell hardness test.

Use ASTM E 140-88 "Standard Hardness Conversion Tables for Metals (Relationship Between Brinell Hardness, Vickers Hardness, Rockwell Hardness, Rockwell Superficial Hardness, and Knoop Hardness)" to convert the BHN to RB and vice versa. Are the measured and converted values similar? Why or why not? Compare the size of "artifacts" left by both indenters. What conclusions might you draw about the possible effects of indents on the mechanical properties of indented components?

Compare the hardness values obtained from flat coupons / flat sections of the component and those obtained on the curved surfaces of the component (i.e., the tensile specimens). Are the values similar? If not, which value shows a "softer" material? Would you expect this? What type of recommendation might you have about indenting components and curved surfaces, in general.

The deformations caused by a hardness indenter are of similar magnitude to those occurring at the ultimate tensile strength of a tension test. However, an important difference is that the material cannot freely flow outward, so that a complex triaxial stress state exists under the indenter. Nevertheless, empirical correlations can be established between hardness and tensile properties, primarily the engineering ultimate tensile strength, S_{uts}.

Use appropriate empirical relations (e.g., see Mechanical Behaviour of Materials by Dowling or ASM Metals Reference Book with various editors) estimate ultimate tensile strengths for the two materials from the hardness numbers. Compare these estimated strengths to those measured from tensile tests (those of this class or from the literature).

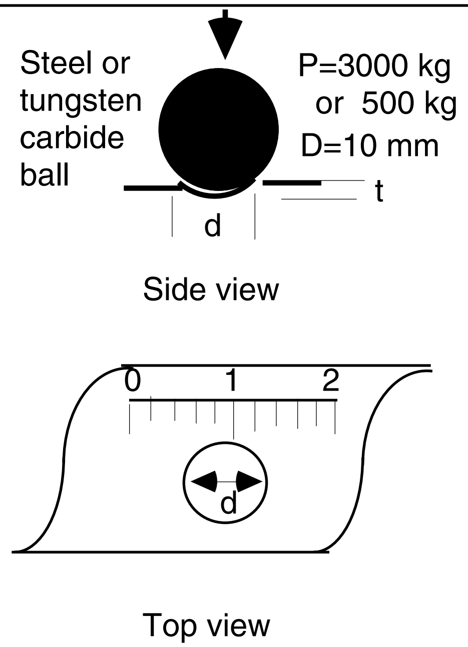
* REFERENCES

Annual Book or ASTM Standards, American Society for Testing and Materials, Vol. 3.01

E10 Standard Test Method for Brinell Hardness of Metallic Materials

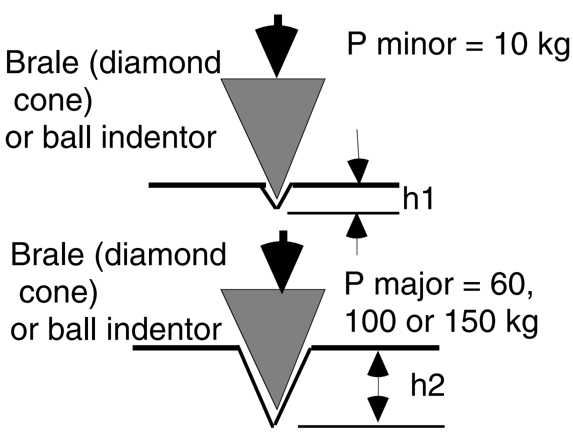
E18 Standard Test Method for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 140 Standard Hardness Conversion Tables for Metals (Relationship Between Brinell Hardness, Vickers Hardness, Rockwell Hardness, Rockwell Superficial Hardness, and Knoop Hardness)



$$BHN = HB = \frac{P}{\pi D t} = \frac{2P}{\pi D\left[D - \sqrt{\left(D^2 - d^2\right)}\right]}$$

Figure 1 - Schematic Diagram of Brinell Hardness Test



Rockwell Scale (X =)	Indentor	Pmajor (kg)
A	Brale (diamond)	60
B	1/16" ball	100
C	Brale (diamond)	150
D	Brale (diamond)	100
E	1/8" ball	100
F	1/8" ball	60
M	1/4" ball	100
R	1/2" ball	60

$$HRX = R_X = M - \frac{\left(h_2 - h_1\right)}{0.002}$$

$M = 100$ for A, C, and D scales

$M = 130$ for B, E, M, R, etc. scales

Figure 2 - Schematic Diagram of Rockwell Hardness Test

LABORATORY REPORT

1. Include the following information in the laboratory report.

	6061-T6 aluminum	1018 (HR) or A36 steel
BHN (kg/mm^2)......[measured]		
BHN (kg/mm^2). [literature]		
% difference......................................		
S_{uts} (MPa) [estimated from BHN]...		
S_{uts} (MPa) [measured or literature].		
% difference......................................		
RB ....[measured, flat coupon]..........		
RB ....[literature]		
% difference......................................		
S_{uts} (MPa) [estimated from RB].......		
S_{uts} (MPa) [measured or literature]		
% difference......................................		
RB ....[measured, tensile specimen cylindrical grip]		
RB ....[literature].................................		
% difference......................................		
S_{uts} (MPa) [estimated from RB].......		
S_{uts} (MPa) [measured or literature]		
% difference......................................		
RB ....[measured, tensile specimen flat grip]		
RB ....[literature].................................		
% difference......................................		
S_{uts} (MPa) [estimated from RB].......		
S_{uts} (MPa) [measured or literature].		
% difference......................................		

2. Include the following information in the laboratory report.
   a. Compare results of the hardness tests for each metal to 'book' values from a source such as the ASM Metals Handbook. Comment on any differences.
   b. Compare the size of the artifact (i.e., indentation) from each type of test. Discuss the possible effect of such "artifacts" on material response if hardness tests are used for quality control of components.
   c. Comment on the empirical relations which allow estimates of ultimate tensile strength of each material. Discuss the merits of using hardness versus tensile tests for determining/estimating mechanical properties of materials for engineering design.

3. Include the following information in the appendix of the laboratory report. THIS MAY NOT BE ALL THAT IS NECESSARY (i.e., don't limit yourself to this list.)
   a. Original data sheets and/or printouts
   b. All supporting calculations. Include sample calculations if using a spread sheet program. DO NOT INCLUDE ALL TABULATED RAW OR CALCULATED DATA.

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DATA SHEET

01 January 2000 / mgj

NAME____**DATE**_____________

LABORATORY PARTNER NAMES____

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EQUIPMENT IDENTIFICATION____

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Aluminium

Flat Coupon	
Brinell	
Maximum Load (kg), P	
Brinell Ball Dia (mm), D	
Indentation Dia (mm), d	
Rockwell	
Load (kg)	
Indenter Size/Type	
Rockwell Scale	
Rockwell Number	
Tensile Specimen	
Cylindrical Grip	
Rockwell	
Load (kg)	
Indenter Size/Type	
Rockwell Scale	
Rockwell Number	
Flat Grip	
Rockwell	
Load (kg)	
Indenter Size/Type	
Rockwell Scale	
Rockwell Number	

Steel

Flat Coupon	
Brinell	
Maximum Load (kg), P	
Brinell Ball Dia (mm), D	
Indentation Dia (mm), d	
Rockwell	
Load (kg)	
Indenter Size/Type	
Rockwell Scale	
Rockwell Number	
Tensile Specimen	
Cylindrical Grip	
Rockwell	
Load (kg)	
Indenter Size/Type	
Rockwell Scale	
Rockwell Number	
Flat Grip	
Rockwell	
Load (kg)	
Indenter Size/Type	
Rockwell Scale	
Rockwell Number	