

Hardness Testing of Materials

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Hardness Testing

Hardness Testing

➤ Hardness is the ability to withstand indentation or scratches.
















❖ **Hardness**, which is a measure of a material's resistance to localized plastic deformation (e.g., a small dent or a scratch).

➤ Qualitative Hardness Test

Mohs Hardness Scale

➤ ranged from 1 on the soft end for talc to 10 for diamond.

Mohs Hardness Scale

	Mineral Name	Scale Number	Common Object
↑ Increasing Hardness	 → Diamond	10	
	 → Corundum	9	←  Masonry Drill Bit (8.5)
	 → Topaz	8	
	 → Quartz	7	←  Steel Nail (6.5)
	 → Orthoclase	6	
	 → Apatite	5	←  Knife/Glass Plate (5.5)
	 → Fluorite	4	
	 → Calcite	3	←  Copper Penny (3.5)
	 → Gypsum	2	
	 → Talc	1	←  Fingernail (2.5)

Quantitative Hardness Test

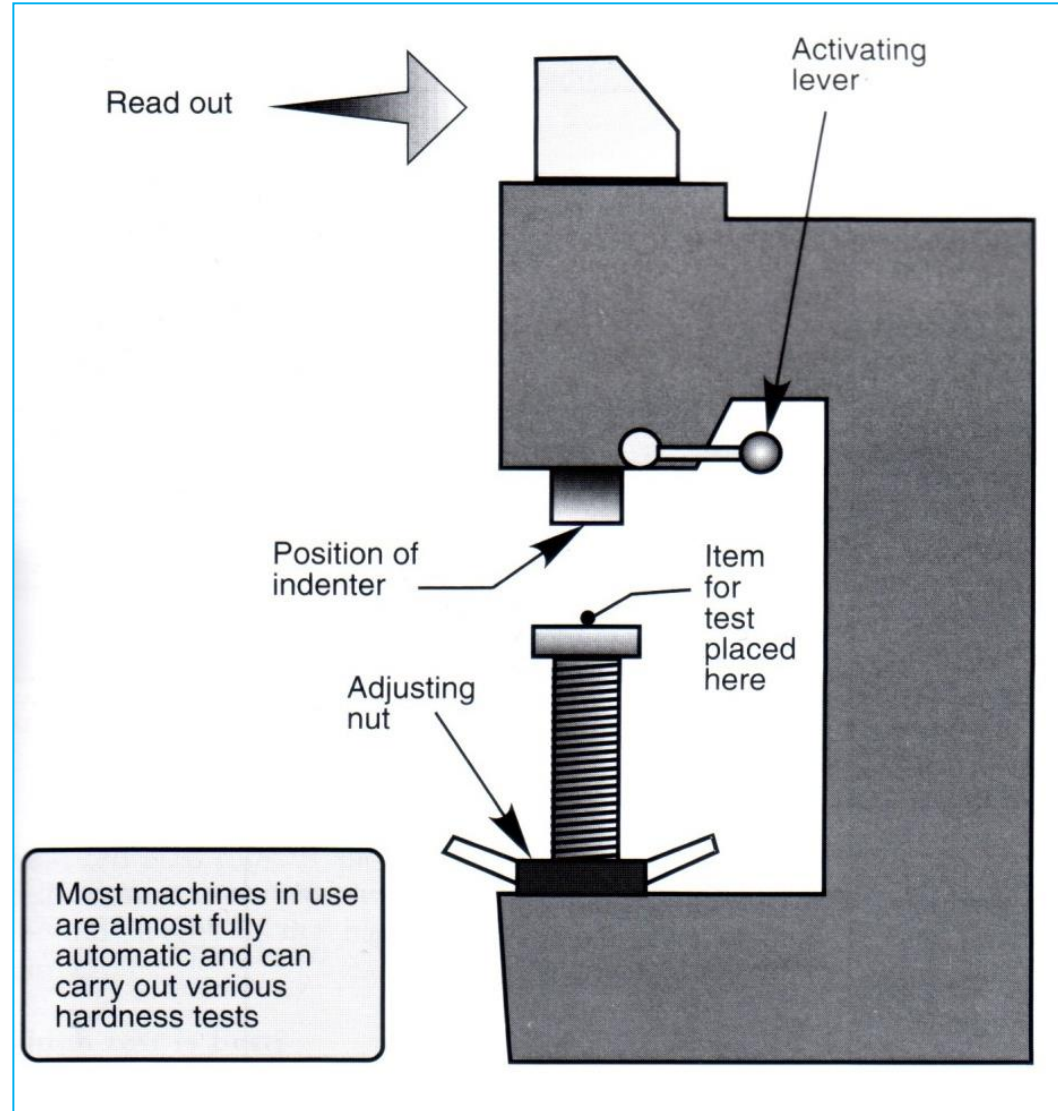
- ❑ A small indenter is forced into the surface of a material to be tested, under controlled conditions of load and rate of application.
- ❑ The depth or size of the resulting indentation is measured, which in turn is related to a hardness number.
- ❑ The softer the material, the larger and deeper the indentation, and the lower the hardness index number.

Benefits of Hardness Tests than any other Mechanical Test

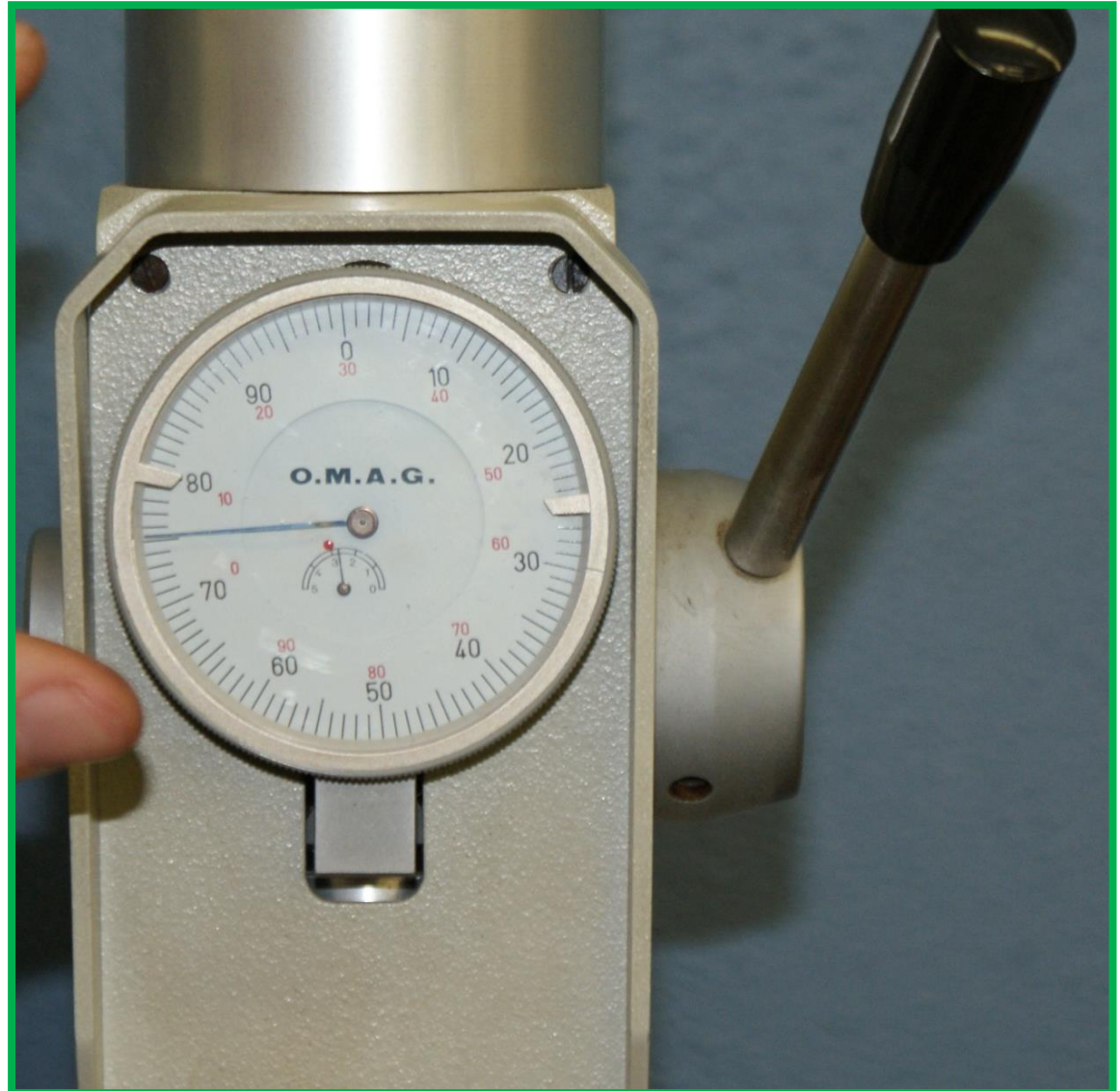
- They are simple and inexpensive — ordinarily no special specimen need be prepared, and the testing apparatus is relatively inexpensive.
- The test is nondestructive — the specimen is neither fractured nor excessively deformed; a small indentation is the only deformation.
- Other mechanical properties often may be estimated from hardness data, such as tensile strength.

Hardness Testing Machine

- The indenter is pressed into the metal
- Softer materials leave a deeper indentation



Hardness Testing Machine



Rockwell and Superficial Rockwell Hardness Tests



Indenters

- (1) Spherical and hardened steel balls having different diameters and
- (2) Conical diamond (Brale) indenter.



- A hardness number is determined by the difference in depth of penetration resulting from the application of an initial minor load followed by a larger major load.
- Utilization of a minor load enhances test accuracy.

On the basis of the magnitude of both major and minor loads, there are two types of tests

Rockwell and Superficial Rockwell

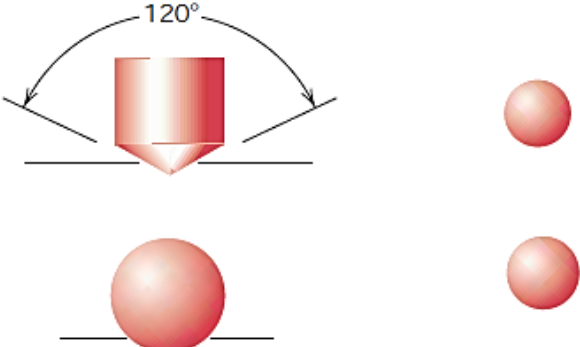

For Rockwell Tests,

- the minor load is 10 kg, whereas
- the major loads are 60, 100, and 150 kg.

For Superficial Rockwell Tests,

- the minor load is 3 kg, whereas
- the major loads are 15, 30, and 45 kg.

Hardness Testing Technique

<i>Test</i>	<i>Indenter</i>	<i>Shape of Indentation</i>		<i>Load</i>	<i>Formula for Hardness Number^a</i>
		<i>Side View</i>	<i>Top View</i>		
Rockwell and Superficial Rockwell	{ Diamond cone $\frac{1}{16}, \frac{1}{8}, \frac{1}{4}, \frac{1}{2}$ in. diameter steel spheres	 <p style="text-align: center;">120°</p>		60 kg 100 kg 150 kg 15 kg 30 kg 45 kg	} Rockwell } Superficial Rockwell

Rockwell Hardness Scales

<i>Scale Symbol</i>	<i>Indenter</i>	<i>Major Load (kg)</i>
A	Diamond	60
B	$\frac{1}{16}$ in. ball	100
C	Diamond	150
D	Diamond	100
E	$\frac{1}{8}$ in. ball	100
F	$\frac{1}{16}$ in. ball	60
G	$\frac{1}{16}$ in. ball	150
H	$\frac{1}{8}$ in. ball	60
K	$\frac{1}{8}$ in. ball	150

Superficial Rockwell Hardness Scales

<i>Scale Symbol</i>	<i>Indenter</i>	<i>Major Load (kg)</i>
15N	Diamond	15
30N	Diamond	30
45N	Diamond	45
15T	$\frac{1}{16}$ in. ball	15
30T	$\frac{1}{16}$ in. ball	30
45T	$\frac{1}{16}$ in. ball	45
15W	$\frac{1}{8}$ in. ball	15
30W	$\frac{1}{8}$ in. ball	30
45W	$\frac{1}{8}$ in. ball	45

- 80 HRB represents a Rockwell hardness of 80 on the B scale, and
- 30 HR30W indicates a superficial hardness of 30 on the 30W scale.

Inaccuracies in the result

- If the test specimen is too thin,
- If an indentation is made too near a specimen edge, or
- If two indentations are made too close to one another.
- Specimen thickness should be at least ten times the indentation depth,
- The allowance should be made for at least three indentation diameters between the center of one indentation and the specimen edge, or to the center of a second indentation.
- Furthermore, testing of specimens stacked one on top of another is not recommended.
- Also, accuracy is dependent on the indentation being made into a smooth flat surface.

Brinell Hardness Test

- Uses ball shaped indenter.
- Cannot be used for thin materials.
- Ball may deform on very hard materials.
- Surface area of indentation is measured.

Hardened steel
or tungsten
carbide ball



Diameter =
10 mm or
5 mm or
1 mm



Hardness Testing Techniques

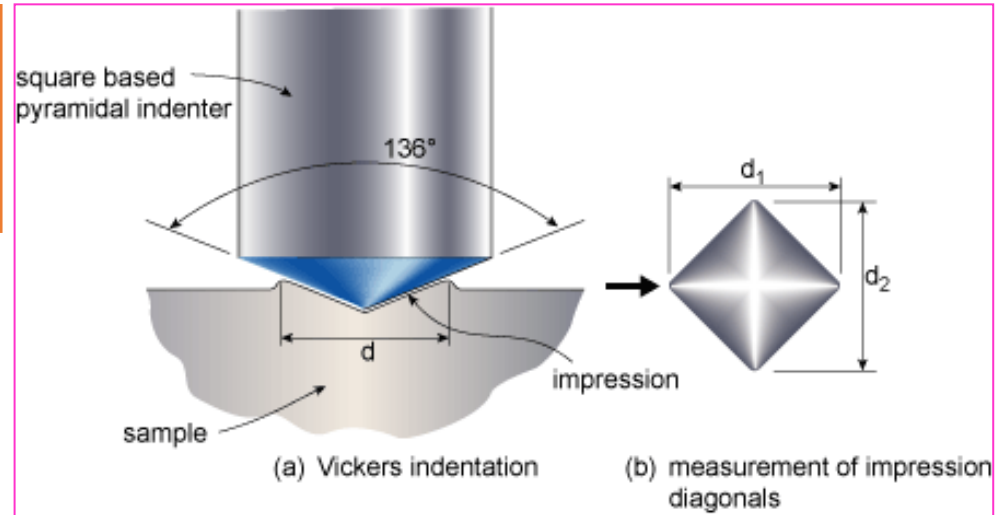
Test	Indenter	Shape of Indentation		Load	Formula for Hardness Number ^a
		Side View	Top View		
Brinell	10-mm sphere of steel or tungsten carbide			P	$HB = \frac{2P}{\pi D [D - \sqrt{D^2 - d^2}]}$

Brinell Hardness Test

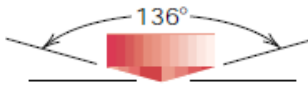
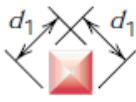
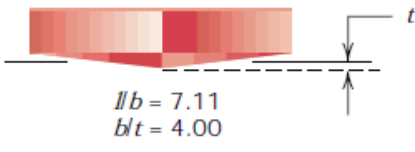
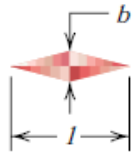
- Standard loads range between 500 and 3000 kg in 500-kg increments; during a test,
- The load is maintained constant for a specified time (between 10 and 30 s).
- Harder materials require greater applied loads.
- The Brinell hardness number, HB, is a function of both the magnitude of the load and the diameter of the resulting indentation
- This diameter is measured with a special low-power microscope, utilizing a scale that is etched on the eyepiece.
- The measured diameter is then converted to the appropriate HB number using a chart; only one scale is employed with this technique.
- Maximum specimen thickness as well as indentation position (relative to specimen edges) and minimum indentation spacing requirements are the same as for Rockwell tests.
- In addition, a well-defined indentation is required; this necessitates a smooth flat surface in which the indentation is made.

Knoop and Vicker's Hardness Test

- Uses square shaped pyramid indenter.
- Accurate results.
- Measures length of diagonal on indentation.
- Usually used on very hard materials



Hardness Testing Techniques

Test	Indenter	Shape of Indentation		Load	Formula for Hardness Number ^a
		Side View	Top View		
Vickers microhardness	Diamond pyramid			P	$HV = 1.854P/d_1^2$
Knoop microhardness	Diamond pyramid			P	$HK = 14.2P/l^2$

Knoop and Vicker's Hardness Test

- Applied loads are much smaller than for Rockwell and Brinell, ranging between 1 and 1000 g.
- The resulting impression is observed under a microscope and measured; this measurement is then converted into a hardness number
- Careful specimen surface preparation (grinding and polishing) may be necessary to ensure a well-defined indentation that may be accurately measured.
- The Knoop and Vickers hardness numbers are designated by HK and HV, respectively.
- Knoop and Vickers are referred to as micro-hardness testing methods on the basis of load and indenter size.
- Both are well suited for measuring the hardness of small, selected specimen regions furthermore, Knoop is used for testing brittle materials such as ceramics.