2.2 HARDNESS TEST

1. HARDNESS

- ❖ The term ‘hardness’ is a structure-sensitive mechanical property of materials, primarily associated with the surface. If a material is uniform in composition and structure, the hardness measured on the surface layer will represent the hardness of the bulk of the material.
- ❖ The hardness is defined as the resistance of a material to permanent or plastic deformation of its surface, usually by indentation, under static or dynamic load.

2. CLASSIFICATION OF HARDNESS

- ❖ Depending on the manner in which the hardness test is conducted, hardness may be classified as follows
  - Indentation hardness
  - Rebound hardness
  - Scratch hardness
  - Wear or abrasion hardness
  - Cutting hardness

(a) Indentation hardness

- ❖ It is the resistance of a material to permanent indentation under static or dynamic load. The types indentation hardness test is given below,
  - ✓ Brinell
  - ✓ Meyer
  - ✓ Vickers (macro- and micro-hardness)
  - ✓ Rockwell (regular and superficial)
  - ✓ Knoop (micro hardness)
  - ✓ Nano hardness

(b) Rebound hardness

- ❖ It is the resistance offered by a material to strike and absorb energy for plastic deformation under impact loads, causing the hammer to rebound.
- ❖ Most common example is the ‘Shore scleroscope hardness test’ which measures the hardness in terms of the rebound height of the indenter. It is virtually an indentation test.

(c) Scratch hardness

- ❖ It is the resistance of a material to scratch by another material, for example Mohs scale of hardness which is discussed after.

(d) Wear or abrasion hardness

- ❖ It is the resistance of a material to abrasion and wear, when subjected to rotational or sliding motion, for example file hardness test.

(e) Cutting hardness

- ❖ It is the resistance of a material to various cutting or drilling operations. This hardness is a measure of machinability of materials.

3. MOHS SCALE

- ❖ Mohs scale of hardness is widely used in the field of mineralogy but rarely applied for the testing of metals and alloys; it is a qualitative ordinal scale characterizing scratch resistance of various minerals through the ability of harder material to scratch softer material.

Mohs scale	Material
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

4. INDENTER

- Indenter is the tool of material which causes deformation or indentation on the surface of the specimen to be tested which must be harder than the test piece.
- The deformation mark or impression on the surface of the test piece is called indentation.

Indenter Type	Test
Hard metal ball	Brinell hardness test
Right pyramid with a square base	Vickers hardness test
Diamond or ball type	Rockwell hardness test

5. SELECTION CRITERIA OF HARDNESS TESTER

Main elements to consider before choosing a hardness tester

(a) Test load

- This is determined by the hardness of the material. Metals such as steel or alloys, for example, require test loads of up to 3,000 kgf, while soft metals require only 500 kgf. The higher the load, the higher the accuracy. It is important to note that the impression should not exceed 1/10 of the thickness of the sample.

(b) Hardness range

- It determines the material of the indenter. Over 650 HB/30 hardness, you should favor a diamond indenter. Below this value, steel or hard metal indenters are suitable.

(c) Accuracy level

- It depends on the surface to be measured (cleanliness, flat surface, static or dynamic system, etc).

(d) Adaptability of the device

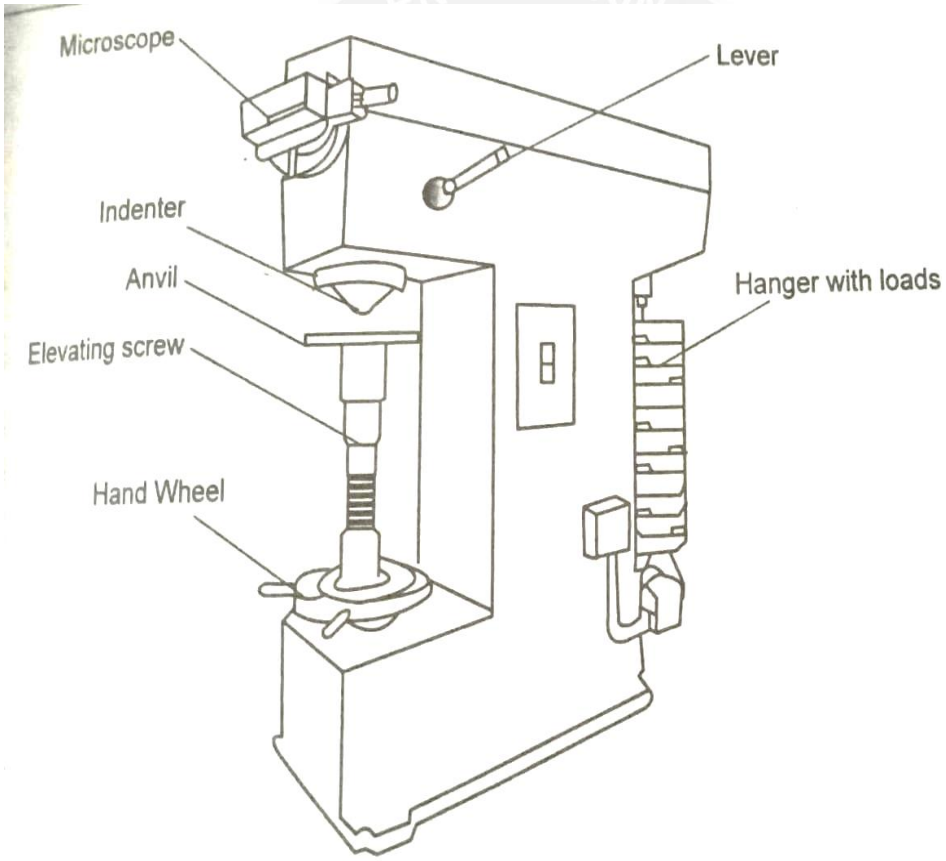
- ❖ It is importance varies according to the shape and size of the samples to be tested.

6. BENEFITS OF HARDNESS TEST

- ❖ Easy
- ❖ Inexpensive
- ❖ Quick
- ❖ Non-destructive
- ❖ May be applied to the samples of various dimensions and shapes
- ❖ May be performed in-situ

2.3 BRINELL HARDNESS TEST

- The Brinell Hardness Test method is the most commonly used hardness measurement technique in the industry. In the Brinell Hardness Testing, the hardness of a metal is determined by measuring the permanent indentation size produced by an indenter.
- Harder materials will generate shallow indentations while softer materials will produce deeper indentations. This test method was first proposed by Swedish engineer Johan August Brinell in 1900 and according to his name, the test is popular as Brinell Hardness Test.



1. PRINCIPLE

- An indenter (hard metal ball with diameter) is forced into the surface of a test piece and the diameter of indentation, 'd' left in the surface after removal of the surface, 'F' is measured under a definite static load applied for a standard period of time.

- ❖ The standard brinell hardness tester operates usually under hydraulic pressure that applies force.

2. MAJOR COMPONENTS

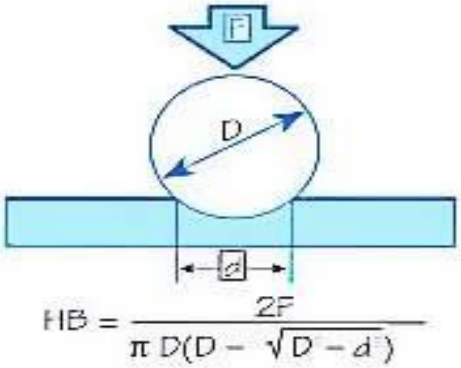
- Brinell Hardness Testing Machine
- Indenter Sphere, and
- Brinell microscope to measure the generated impression
- Anvil

3. INDENTERS

- ❖ The diameter of spherical steel ball indenters used in the standard Brinell hardness test are either 5 or 10 mm. The ball indenter normally used is make from heat treated hard high carbon steel, known as 'Hultgren ball'.

4. WORKING

- ❖ The Brinell Hardness test is performed in a Brinell hardness test unit.
- ❖ In this test method, a predetermined force (F) is applied to a tungsten carbide ball of fixed diameter (D) and held for a predetermined time period, and then removed.
- ❖ The spherical indenter creates an impression (permanent deformation) on the test metal piece.
- ❖ This indentation is measured across two or more diameters and then averaged to get the indentation diameter (d).
- ❖ Using this indentation size (d) Brinell Hardness Number (BHN) is found using a chart or calculated using the Brinell hardness test formula.



$$HB = \frac{2F}{\pi D(D - \sqrt{D - d})}$$

5. ADVANTAGES

- The hardness of rough samples can be measured which is difficult with other methods.
- Application of high test load (up to 3,000 Kg) is possible.
- Wide measuring range due to availability of a range of indenter sizes and loads
- A Brinell hardness tester can determine the hardness of all types of metals.
- Provides reliable results.

6. DISADVANTAGES

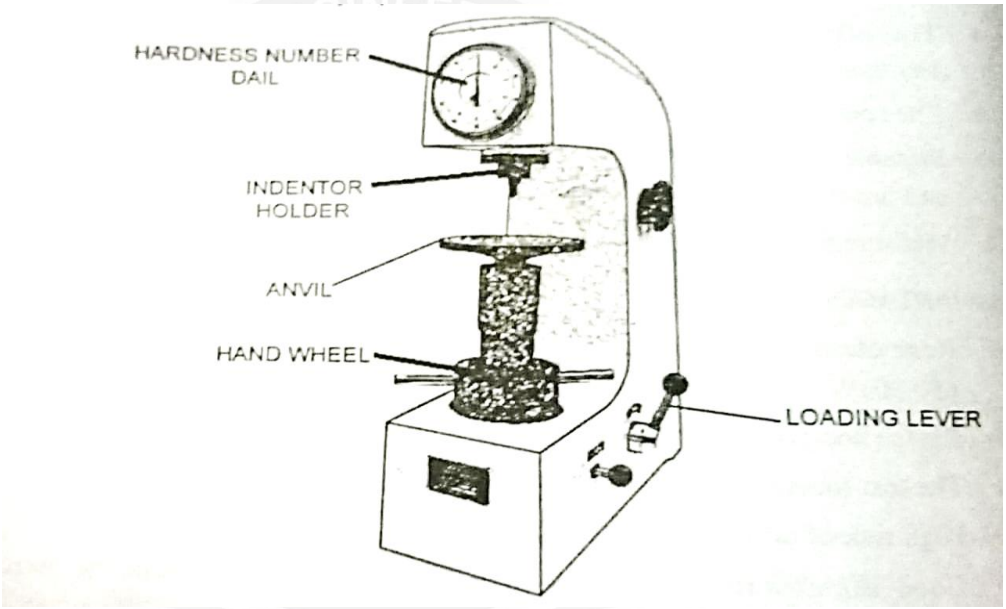
- There could be measuring errors due to using of optical instruments.
- Surface imperfections can interfere with the test result if the surface is not prepared thoroughly.
- The requirement of a flat surface makes this test redundant for cylindrical surfaces.

2.4 ROCKWELL HARDNESS TEST

- In the Rockwell test the depth of the indenter penetration into the specimen surface is measured. Each time a test is performed two loads are applied to the sample being tested.

1. PRINCIPLE

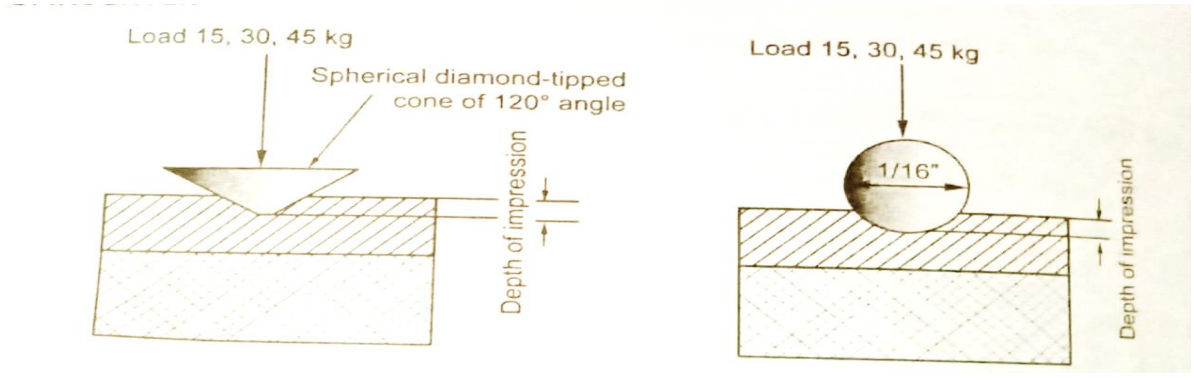
- Rockwell hardness test is to determine the hardness of a metal by 'differential depth' measurement test. This hardness testing method involved the measurement of the increment of an indenter forced into the metal by a primary and a secondary load.



2. COMPONENTS

- Rockwell hardness tester
- Indenter

3. INDENTER



- The indenter or ‘penetrator’ is either made of hardened steel with shape of a spherical ball or made of diamond with shape of a cone having a spherical tip called the ‘Brale’.
- The indenter may be either a diameter 1/6”, 1/8” or a spherical diamond cone of 120° angle.

4. WORKING

- The specimen to be tested is made flat by grinding and then roughly polished because any surface irregularities will be taken care of by the minor load.
- The application of the minor load becomes effective when the surface of the specimen kept on the anvil is brought in contact with the indenter by rotating the elevating wheel.
- First, the indenter is forced into the test material under a preliminary minor load and this depth is recorded.
- With the minor load still applied an additional load is introduced known as the major load which increases the depth of penetration on the sample.
- The major load is then removed, and the force on the sample is returned to the minor load.
- The increase in the depth of penetration that results from applying and removing the major load is used to calculate the Rockwell hardness value.

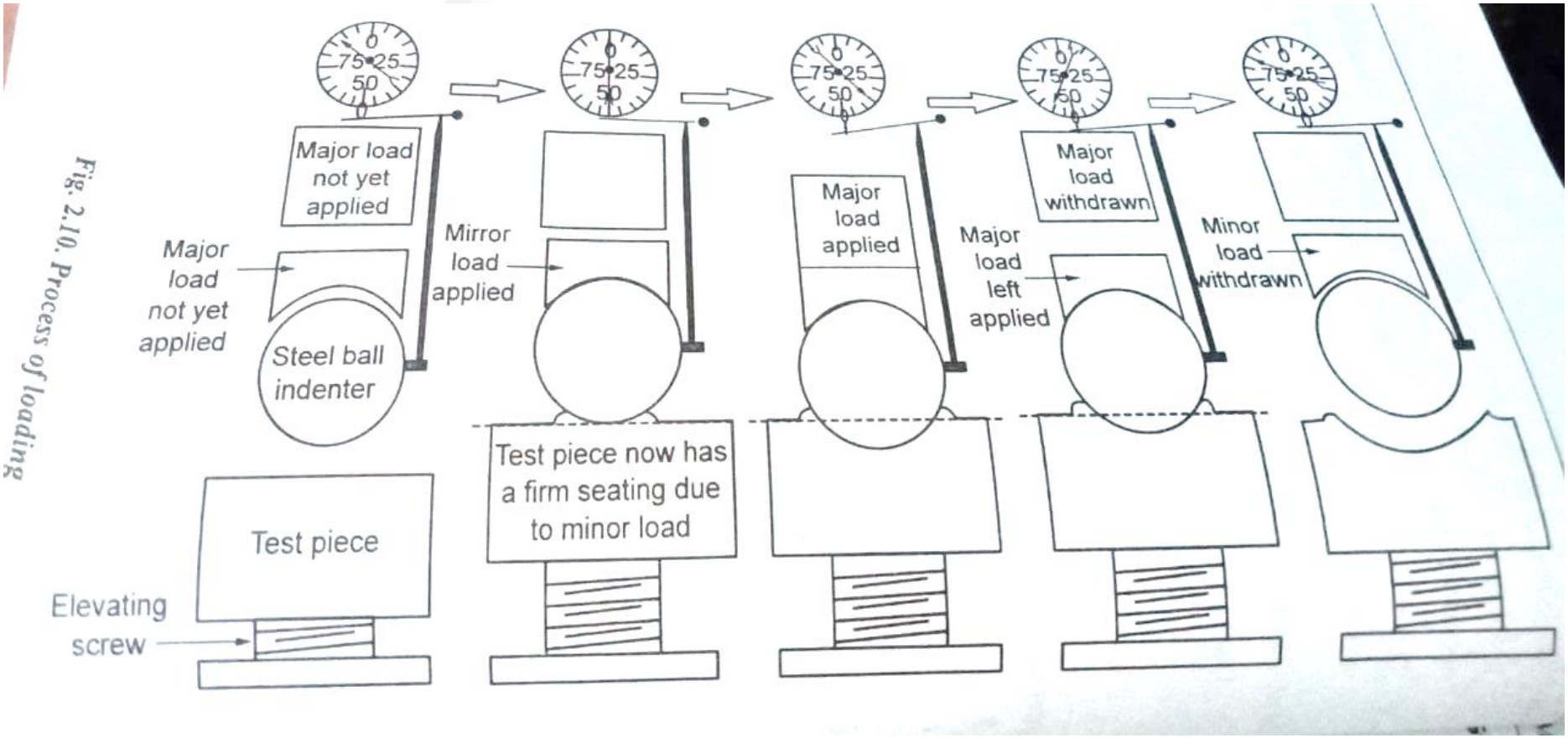


Fig. 2.10. Process of loading

5. APPLICATIONS

- It is widely applied in the industry of cemented carbides, Copper alloys, Thin steel and medium case hardened steel, Cast iron, aluminium etc due to the rapidity and simplicity.

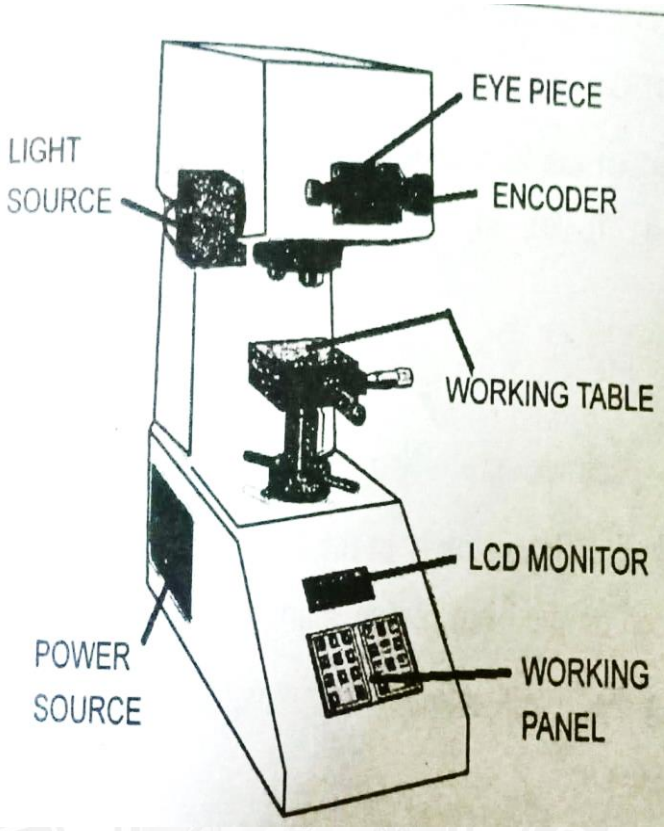
6. ADVANTAGES

- High accuracy is achieved.
- Relatively short time needed to train operator.
- It is generally used for testing of larger samples.
- It can be used for advanced tests.
- There was no special surface preparation.

7. DISADVANTAGES

- The main limitations are due to the fact that between maximum and minimum load there is only a 10:1 ratio.
- The quality of the indenter and the surface has a strong influence on the test results.
- Relatively low sensitivity on the difference in hardness.

2.5 VICKER HARDNESS TEST



- The Vickers hardness test, used to determine quantitatively the indentation hardness of material under the application of a constant static load, is a widely accepted method for research work because it is capable of measuring hardness from very soft materials to extremely hard materials without changing the load or indenter.

1. PRINCIPLE

- A diamond indenter in the form of a right pyramid with a square base and with a specified angle between opposite faces at the vertex is forced into the surface of a test piece followed by measurement of the diagonal length of the indentation left in the surface after removal of the test force F.

2. COMPONENTS

- Vickers hardness tester
- Intender

3. INTENDER

- It is made of diamond in the form of a square-based pyramid with an included angle of 136° between opposite faces.

4. WORKING

- Place the specimen carefully on the testing table.
- Turn the hand wheel slowly in the clockwise direction so that the specimen gets focused on the front screen sharply.
- Now bring the inventor to the "set" position and turn on the loading, dwell-unloading cycle.
- The indentation is now projected on the front focusing screen.
- Measure the diagonals along both the axis of the impression and record them.

5. ADVANTAGES

- There is only one type of indenter, which can be used for all Vickers methods.
- Non-destructive testing is possible, so the test specimen can be used for other purposes.
- Useful for finding stress values.

6. DISADVANTAGES

- The test location must be prepared, otherwise precise evaluation is difficult.
- Relatively long test time due to the measurement of the diagonal lengths.
- Sensitivity of the diamond indenter to damage.
- Very sensitive to effects of vibration, especially in the micro hardness range.