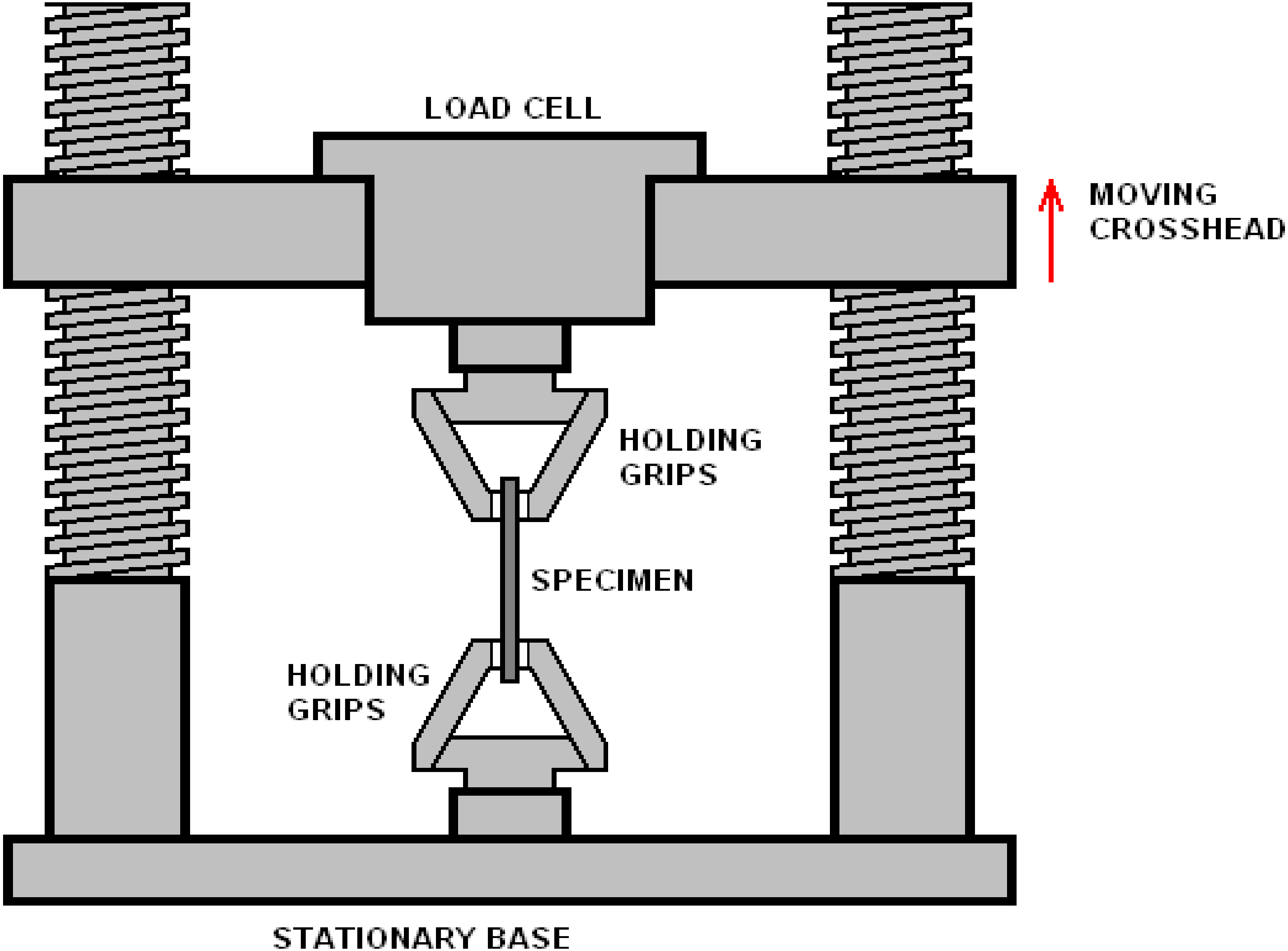
2-6 The Tensile Test:Use Of The Stress-Strain Diagram

The tensile test is popular since the properties obtained could be applied to design different components .The tensile test measures the resistance of a material to a static or slowly applied force.A test setup is shown in figure (2-8),in which the specimen is placed in the testing machine and a force F, called the load ,is applied .A universal testing machine on which tensile and compressive tests can be performed is used .A strain gage is used to measure the amount that the specimen stretches between the gage marks when the force is applied.Thus, what is measured is the change in length of the specimen (Δl) over a particular original length (l_0) . Information concerning the strength,young s'modulus ,and ductility of a material can be obtained from such a tensile test.Typically, a tensile test is conducted on metals, alloys,and plastics.Tensile teste can be used for ceramics, however ,these are not popular because the sample may fracture while it is being aligned.


LOAD CELL
MOVING CROSSHEAD
HOLDING GRIPS
SPECIMEN
HOLDING GRIPS
STATIONARY BASE

2-7 Toughness المتانة

It is also known as work of fracture. It is a measure of the ability of a material to absorb energy up to fracture .It is usually measured by the energy absorbed in a notch impact test[fig.(2-9)] ,but the area under the tensile stress-strain up to the point of fracture is also a measure .Ductile materials are tougher than brittle ones,fig.(2-10).

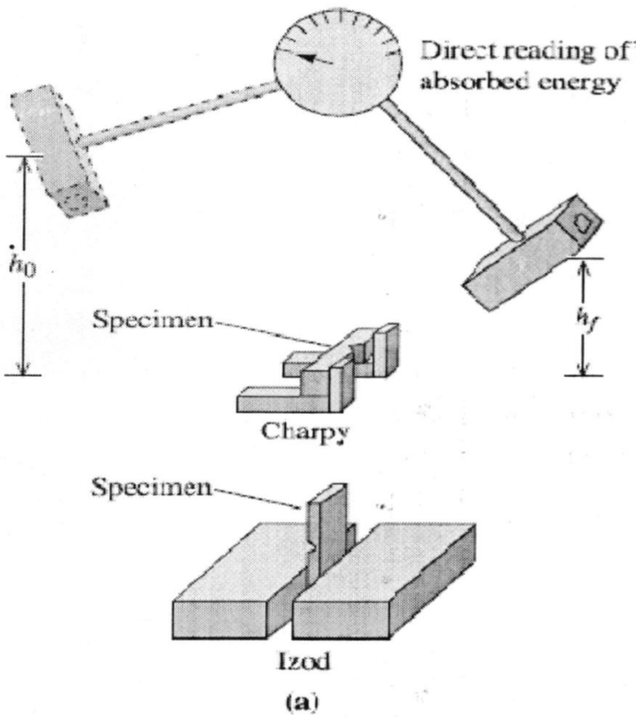


Figure 2-9 The impact test

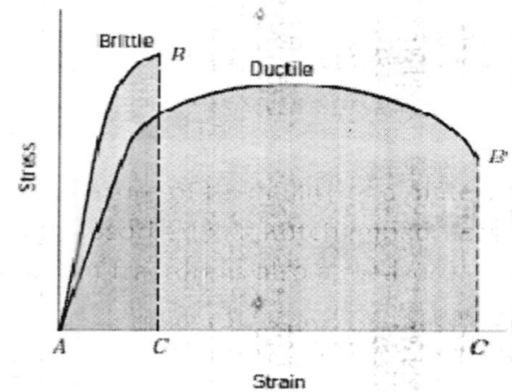


FIGURE 2-10 Schematic representations of tensile stress–strain behavior for brittle and ductile materials loaded to fracture.

هي قدرة المادة على مقاومة الاحمال الديناميكية، اي مقدرتها على مقاومة الصدمات وامتصاص الطاقة الميكانيكية، ويقصد بالمادة المتينة هي المادة التي تتحمل اجهاد كبير في الشكل بدون كسر، وتقاس المتانة بمقدار الطاقة التي تمتصها المادة، وتقاس عدديا بالمساحة تحت منحني الاجهاد – الانفعال.

Impact Test

- An impact test is used to observe the mechanics that a material will exhibit when it experiences a shock loading that causes the specimen to immediately deform, fracture or rupture completely.

- **Purpose of impact testing:**

To determine the ability of the material to absorb energy during a collision. This energy may be used to determine the toughness, impact strength, fracture resistance, impact resistance or fracture resistance of the material depending on the test that was performed and the characteristic that is to be determined. These values are important for the selection of materials that will be used in applications that require the material to undergo very rapid loading processes such as in vehicular collisions.

- **Types of impact tests:**

For a single impact test the three most popular types of test are the Charpy V-notch test, the Izod test and the Tensile Impact test. These three tests all essentially determine the same characteristics of the material but differ in the orientation of the test sample which causes the sample to be stressed in different directions and involve a known weight released from a known height colliding with the specimen in its test fixture. All of these tests are useful in determining the impact mechanics of the test specimen.

- **Types of materials for impact testing:**

Nearly all materials may benefit from impact testing, but the most common types used are metals, plastics, woods, composites, ceramics, and polymers. Generally these materials take the form of sheets of varying thicknesses or short rods depending on the test. However, most materials will experience either ductile or brittle failure depending of the type of test, the rate of loading and the temperature of the sample. Brittle failure of a material requires a small amount of energy to begin the crack or to cause the crack to grow until the sample fails. On the other hand, ductile failure of a material requires a much higher load to initiate and propagate the crack until failure.

2-8 The Bend Test For Brittle Materials

In many brittle materials ,the normal tensile test cannot easily be formed because just placing a brittle material in the grips of the tensile testing machine ,causes cracking . These materials may be tested using the bend test [fig(2-11)], By applying the load at three points and causing bending. The flexural strength or modulus of rupture, describes the material s′ strength:

$$\text{Flexural strength} = \frac{3FL}{2Wh^2} = \sigma_{bend}$$

The results of the bend test are similar to the stress-strain curves, however, the stress is plotted versus deflection rather than versus strain[fig(2-12)]. The modulus of elasticity in bending, or the flexural modulus (E_{bend}) , is calculated in the elastic region of figure (2-12).

$$\text{Flexural modulus} = E_{bend} = \frac{L^3 \cdot F}{4Wh^3\delta}$$

δ –is the deflection of the beam when a force F is applied

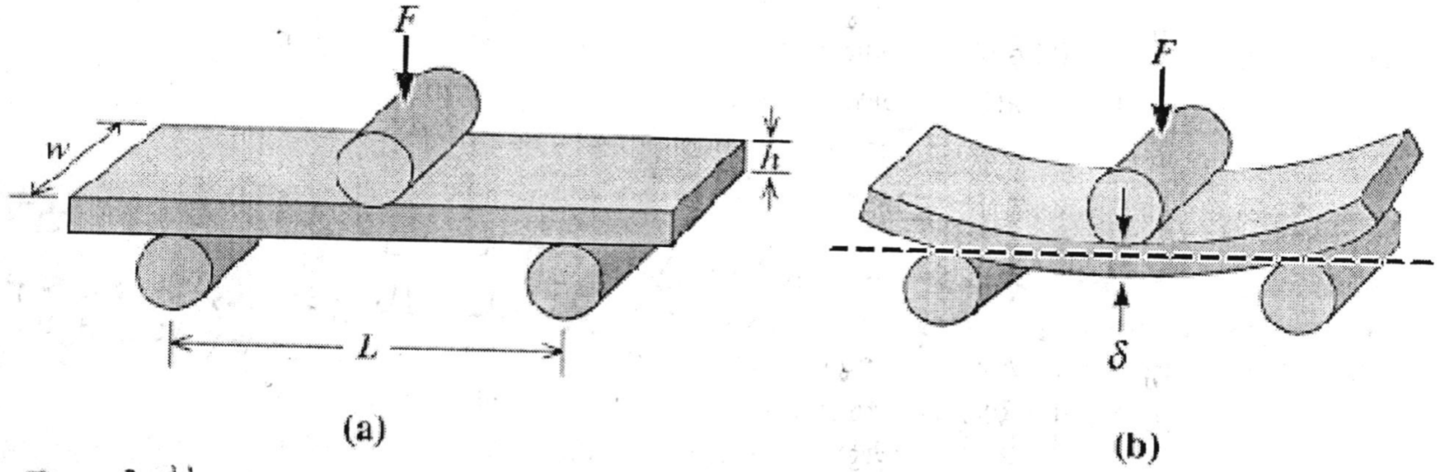


Figure 2-11 (a) The three-point bend test often used for measuring the strength of brittle materials, and (b) the deflection δ obtained by bending.

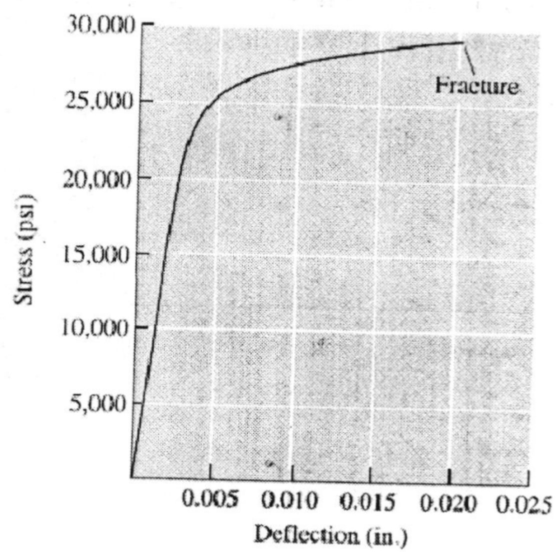
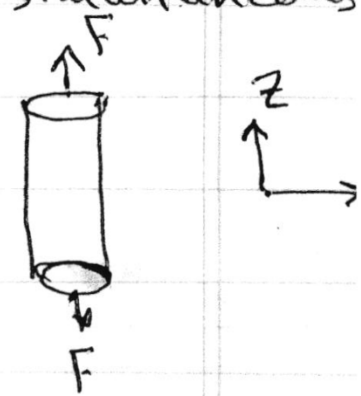


Figure 2-12
Stress-deflection curve for MgO obtained from a bend test.

2-9 poisson's ratio (μ)

it relates the longitudinal elastic deformati produced by asimple tensile or compressive stres to the lateral deformation that occurs simultaneous



$$\mu = -\frac{\epsilon_{lateral}}{\epsilon_{longitudinal}}$$

- μ is always positive since ϵ_x and ϵ_z will always be of opposite sign.
- For many metals in the elastic region, the poisson ratio is typically about 0.3.

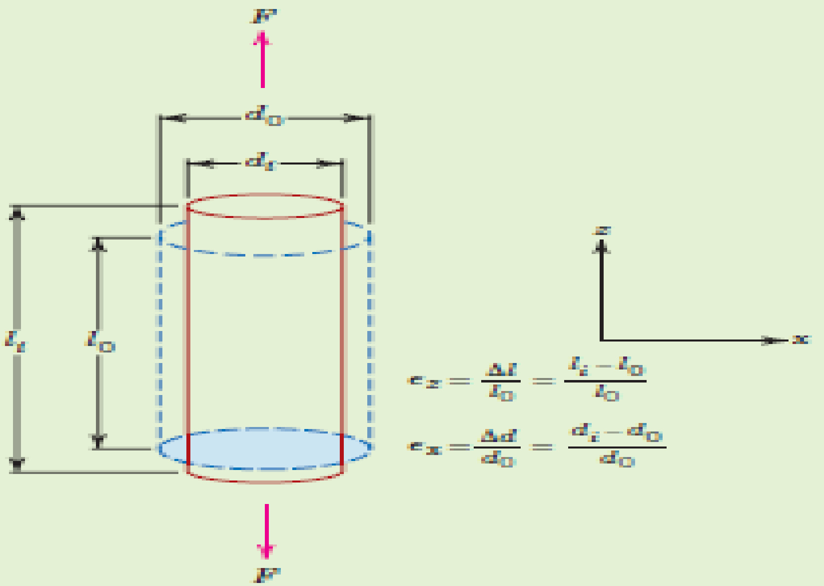
EXAMPLE PROBLEM 6.2

Computation of Load to Produce Specified Diameter Change

A tensile stress is to be applied along the long axis of a cylindrical brass rod that has a diameter of 10 mm (0.4 in.). Determine the magnitude of the load required to produce a 2.5×10^{-3} mm (10^{-4} in.) change in diameter if the deformation is entirely elastic.

Solution

This deformation situation is represented in the accompanying drawing.



When the force F is applied, the specimen will elongate in the z direction and at the same time experience a reduction in diameter, Δd, of 2.5×10^{-3} mm in the x direction. For the strain in the x direction,

$$\epsilon_x = \frac{\Delta d}{d_0} = \frac{-2.5 \times 10^{-3} \text{ mm}}{10 \text{ mm}} = -2.5 \times 10^{-4}$$

which is negative, since the diameter is reduced.

It next becomes necessary to calculate the strain in the z direction using Equation 6.8. The value for Poisson's ratio for brass is 0.34 (Table 6.1), and thus

$$\epsilon_z = -\frac{\epsilon_x}{\nu} = -\frac{(-2.5 \times 10^{-4})}{0.34} = 7.35 \times 10^{-4}$$

The applied stress may now be computed using Equation 6.5 and the modulus of elasticity, given in Table 6.1 as 97 GPa (14×10^6 psi), as

$$\sigma = \epsilon_z E = (7.35 \times 10^{-4})(97 \times 10^3 \text{ MPa}) = 71.3 \text{ MPa}$$

Finally, from Equation 6.1, the applied force may be determined as

$$F = \sigma A_0 = \sigma \left(\frac{d_0}{2}\right)^2 \pi$$

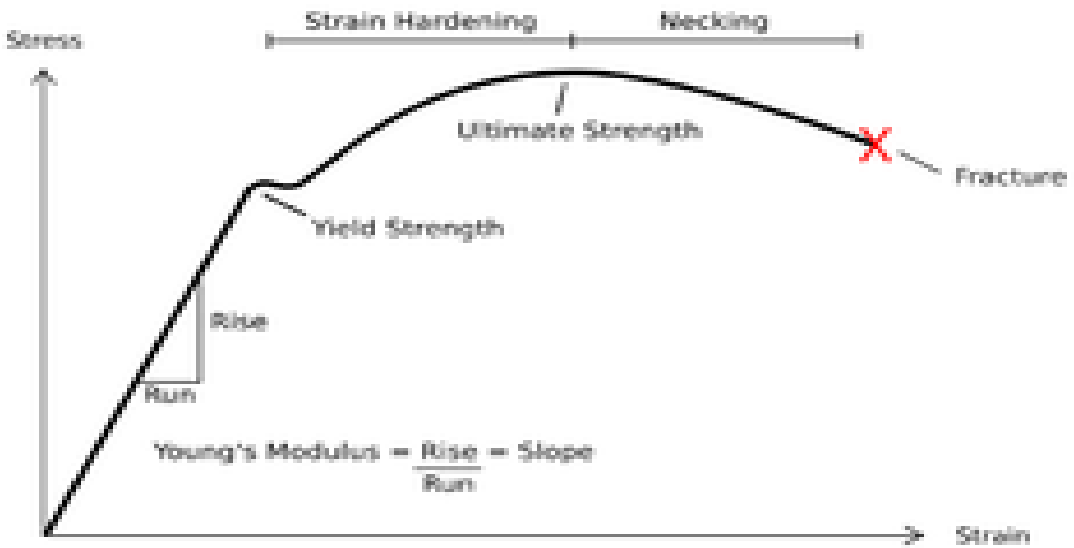
$$= (71.3 \times 10^6 \text{ N/m}^2)\left(\frac{10 \times 10^{-3} \text{ m}}{2}\right)^2 \pi = 5600 \text{ N} (1293 \text{ lb}_f)$$

2-10 The modulus of resilience

is defined as the maximum energy that can be absorbed per unit volume without creating a permanent distortion. It can be calculated by integrating the stress-strain curve from zero to the elastic limit. In uniaxial tension, under the assumptions of linear elasticity:

$$U_r = \sigma_y / 2E = \sigma_y * \varepsilon_y / 2$$

where U_r is the modulus of resilience, σ_y is the yield strength, ε_y is the yield strain, and E is the Young's modulus. This analysis is not valid for non-linear elastic materials like rubber, for which the approach of area under the curve till elastic limit must be used.



- The area under the linear portion of a stress-strain curve is the resilience of the material
- **U_r [=] N·m·m^{-3}**
- **U_r [=] J·m^{-3}**

2-11 HARDNESS

Another mechanical property that may be important to consider is hardness, which is a measure of a material's resistance to localized plastic deformation (e.g., a small dent or a scratch).

Hardness tests are performed more frequently than any other mechanical test for several reasons:

1. **They are simple and inexpensive—ordinarily no special specimen need be prepared, and the testing apparatus is relatively inexpensive.**

2. The test is nondestructive—the specimen is neither fractured nor excessively deformed; a small indentation is the only deformation.

3. Other mechanical properties often may be estimated from hardness data, such as tensile strength.

*Brinell Hardness Test

-The Brinell hardness has the units of stress(Kg/mm^2).

-A Brinell hardness number can be obtained in just a few minutes with no preparation of the specimen and without breaking the component.

-Both tensile strength and hardness are indication of a metal s' resistance to plastic deformation .Brinell hardness provides a close approximation of the tensile strength.For most steels,the HB and tensile strength are related according to

TS (psi) =500 x HB

*Rockwell Hardness Test

-It uses a small-diameter steel ball for soft materials and a diamond cone for harder materials

-The depth of penetration of indentor is automatically measured by the testing machine and converted to a Rockwell hardness number(HR)

The Rockwell tests

The Rockwell tests constitute the most common method used to measure hardness because they are so simple to perform and require no special skills.

Several different scales may be utilized from possible combinations of various indenters and different loads, which permit the testing of virtually all metal alloys (as well as some polymers).

Indenters include spherical and hardened steel balls for soft materials and a conical diamond indenter, which is used for the hardest materials. With this system, 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.HR has no units and can not be related to strength of metals and alloys.

Two other hardness-testing techniques are Knoop and Vickers (sometimes also called diamond pyramid).

For each test a very small diamond indenter having pyramidal geometry is forced into the surface of the specimen.

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.

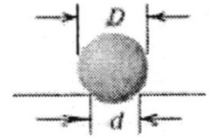
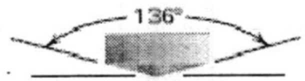
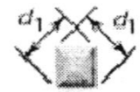
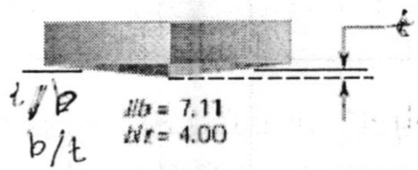
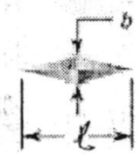
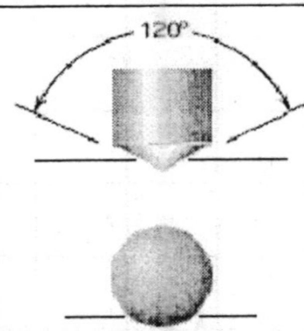
The Knoop and Vickers hardness numbers are designated by HK and HV, respectively.

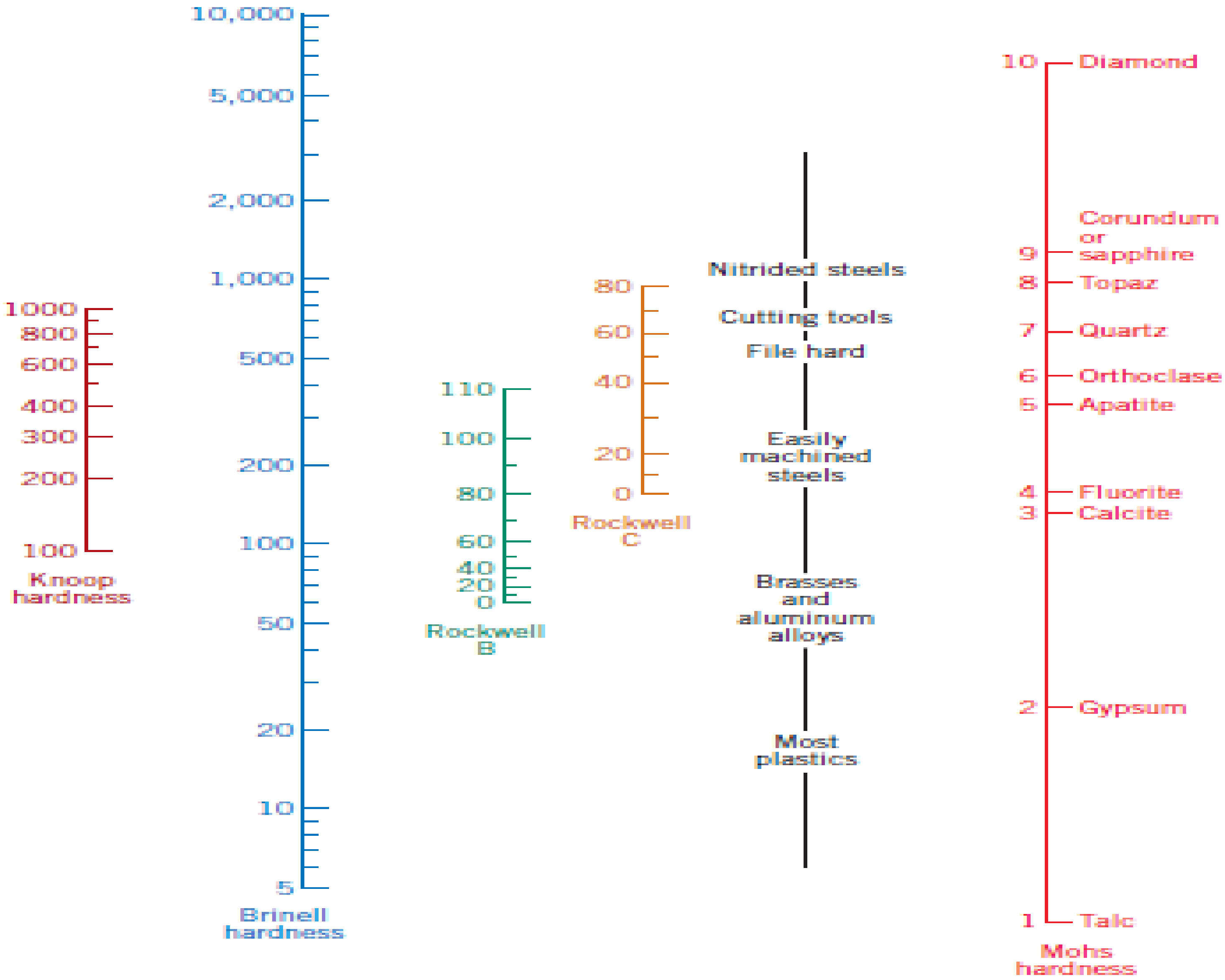
Knoop and Vickers are referred to as micro indentation-testing methods on the basis of indenter size. Both are well suited for measuring the hardness of small, selected specimen regions

furthermore, Knoop is used for testing brittle materials such as ceramics.

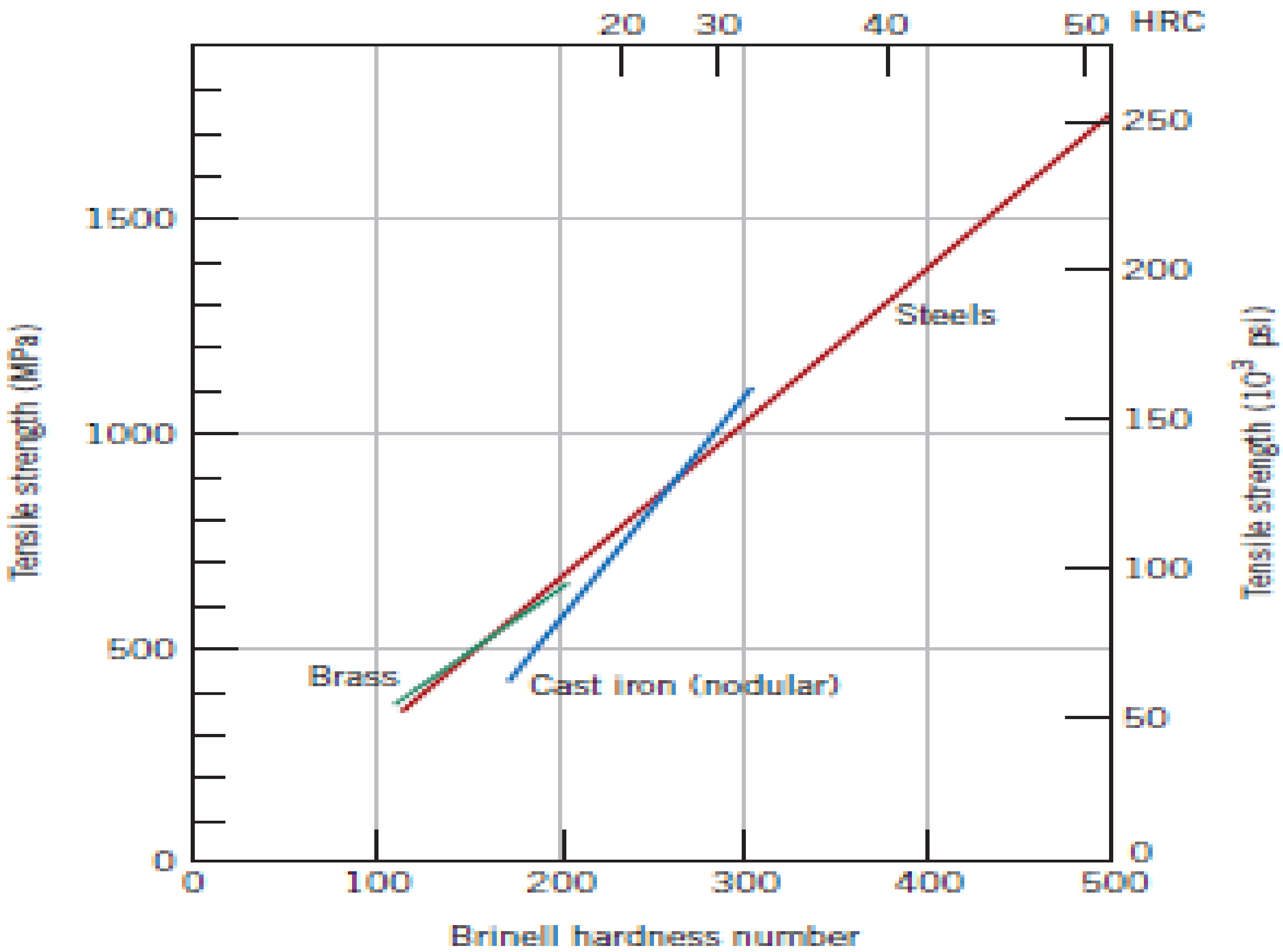
of the indent. Hardness is measured by different hardness techniques: Brinell, Vickers, Rokwell, and Knoop tests.

Table 2.1 Hardness Testing Techniques

Test	Indenter	Shape of Indentation: Side View	Shape of Indentation: Top View	Load	Formula for Hardness Number[a]
Brinell	10-mm sphere of steel or tungsten carbide			P	$HB = \frac{2P}{\pi D[D - \sqrt{D^2 - d^2}]}$
Vickers microhardness	Diamond pyramid			P	$HV = 1.854P/d_1^2$
Knoop microhardness	Diamond pyramid			P	$HK = 14.2P/l^2$
Rockwell and Superficial Rockwell	Diamond cone; $\frac{1}{16}, \frac{1}{8}, \frac{1}{4}, \frac{1}{2}$ in. diameter steel spheres			60 kg, 100 kg, 150 kg: Rockwell; 15 kg, 30 kg, 45 kg: Superficial Rockwell	



Comparison of several hardness scales.



Relationships between hardness and tensile strength for steel, brass, and cast iron.

2-12 Effect of Temperature on some Mechanical properties of Materials

The mechanical properties of materials depend on the temperature, for example, yield streng: tensile strength, and modulus of elasticity decrease at higher temperatures, where as ductility commonly increases.

A materials fabricator may wish to deform a material at a high temperature (known as hot working) to take advantage of the higher ductility and lower required stress. A high temperature is something that is approaching the melting temperature. When temperature are reduced, many, but not all, metals and alloys become brittle.

Ceramic and glassy materials are generally consid brittle at room temperatures. As the temperatur increases, glasses can flow better and become more ductile. As a result, glass processing (e.g., bottle manufacturing) is performed at high temperatures.