Hardness

A material is *hard* if it is difficult to deform with an indenter. A hardness test indents a material with enough force to leave a permanent plastically deformed mark. There are several types of hardness tests. Each standardizes the indenter, most often a steel ball or a diamond indenter, and standardizes the load and the interpretation of the resulting plastic deformation.

Hardness tests are valuable as essentially non-destructive tensile tests. They are not truly non-destructive in that they leave a permanent mark on the sample. However, this mark is often small enough that it does not impair the desired performance of the part.
Importantly, the hardness number can be correlated with yield strength or ultimate tensile strength. Thus, materials engineers often use the terms *strengthening* and *hardening* interchangeably. This correlation must be calibrated for each type of material
– steels, aluminum alloys, and so on.

Hardness measurement is used extensively in conjunction with heat treatment. A heattreatable alloy is fabricated in a soft state, then subsequently heat treated to have a higher yield stress in the finished configuration. Our concern is based on the following question: was the heat treatment successful? We do not wish to destructively tensile test our finished part; rather, we specify that the hardness of the finished part must be within a particular range of hardness numbers.

True Hardness
True hardness has the units of stress. It is defined as the applied force divided by the cross-sectional area of the indent. Although a correction factor must be determined for materials that work harden appreciably, the starting relationship is:

$$H \approx 3\ \sigma y$$

where H is the true hardness and σy is the yield stress.

Brinell Hardness
This is a common commercial hardness measurement. It also has the units of stress, although the units are seldom explicitly written. The default units are kgf (kilograms of force) and mm^2. This hardness value is not a true stress, as the area used for computation is the surface area of the indentation rather than the cross-sectional area.

The *Brinell hardness test* uses a steel ball, most commonly 10 mm in diameter. After indentation, the diameter of the impression is measured with an optical comparator. An advantage of Brinell hardness is that it is a single scale suitable for both soft and materials. A disadvantage of the Brinell hardness test is that this is a large indenter and leaves a large mark on the sample.

Note: The unit of kgf used may not be familiar. One kgf is the weight of 1 kg of mass
when subjected to the standard gravity of the earth – that is, 1 kgf = 9.807 N.

Rockwell Hardness
This is one of the most widely used hardness tests. Its advantage is that a dimensionless hardness number is defined in terms of the depth of penetration. This permits hardness testing machines to indicate an immediate readout of the hardness number without post-analysis. A disadvantage of the *Rockwell hardness test* is that it consists of several short, overlapping scales. Common are the Rockwell C scale, using a diamond cone indenter for hardened steels; and the Rockwell B scale, using a 1/16 inch steel ball indenter for softer metals.