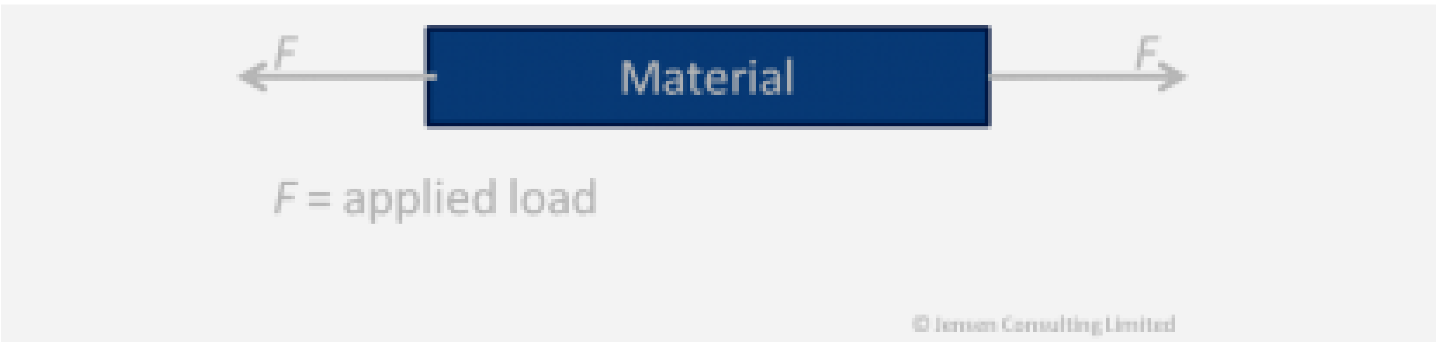
Mechanical Material Properties

Tensile Strength

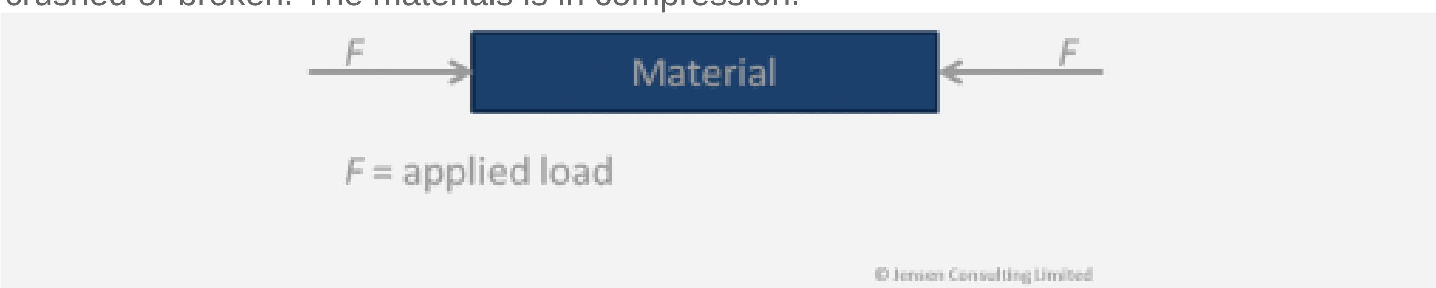
This is the ability of a material to withstand tensile (stretching) loads without rupture occurring. The material is in tension.



Explanation Tensile Strength

Compressive strength

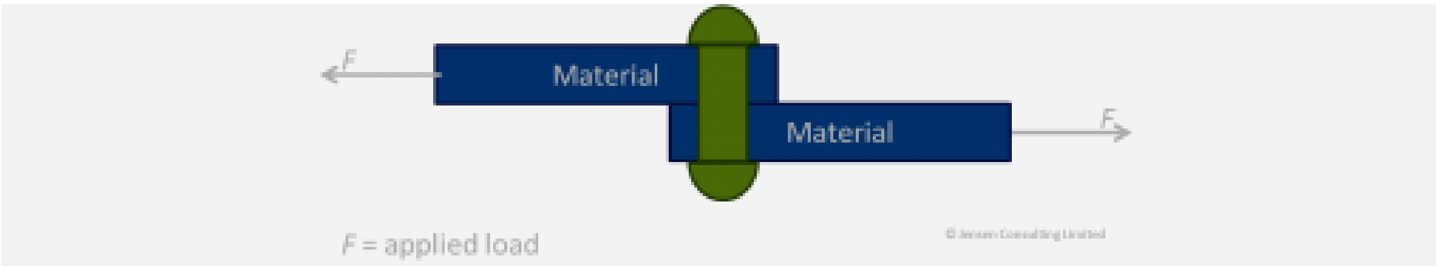
This is the ability of a material to withstand compressive (squeezing) loads without being crushed or broken. The materials is in compression.



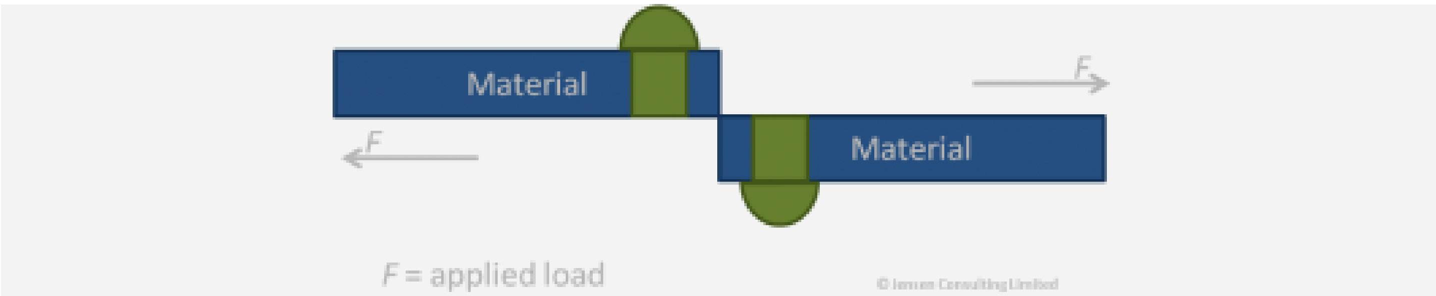
Explanation Compressive Strength

Shear Strength

This is the ability of a material to withstand offset or transverse loads without rupture occurring. The rivet connecting the two bars shown is in *shear* whilst the bars themselves are in *tension*. Note that the rivet would still be in *shear* if the bars were in *compression.*



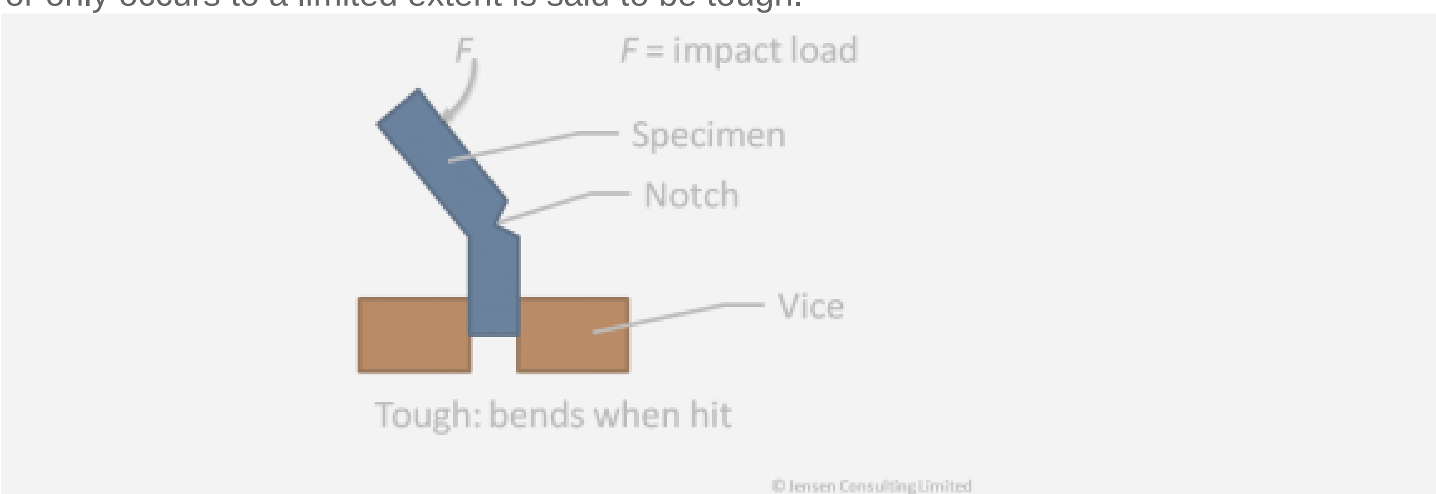
Rivet connecting the two bars in resisting shear



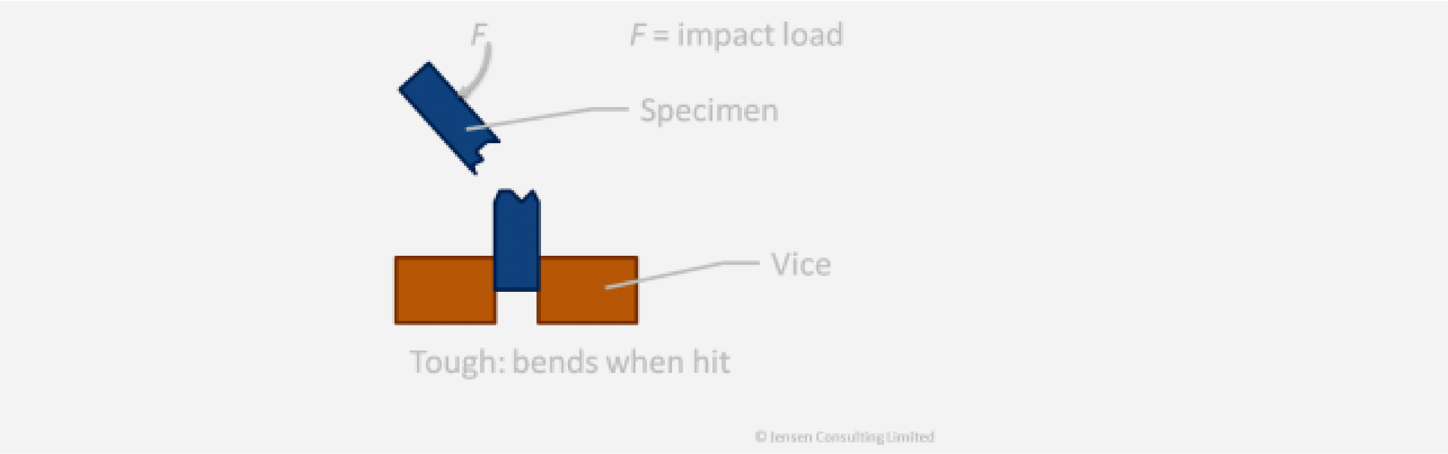
Rivet connecting the two bars has failed in shear

Toughness: impact resistance

This is the ability of a material to resist shatter. If a material shatters it is brittle (e.g. glass). If it fails to shatter when subject to an impact load it is tough (e.g. rubber). Toughness should not be confused with strength. Any material in which the spread of surface cracks does not occur or only occurs to a limited extent is said to be tough.



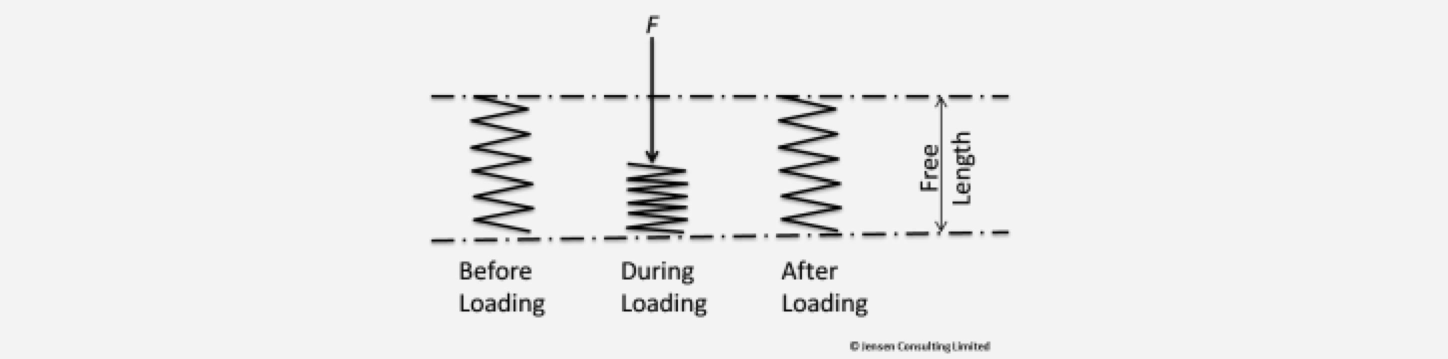
Explanation Tough Material



Explanation Brittle Material

Elasticity

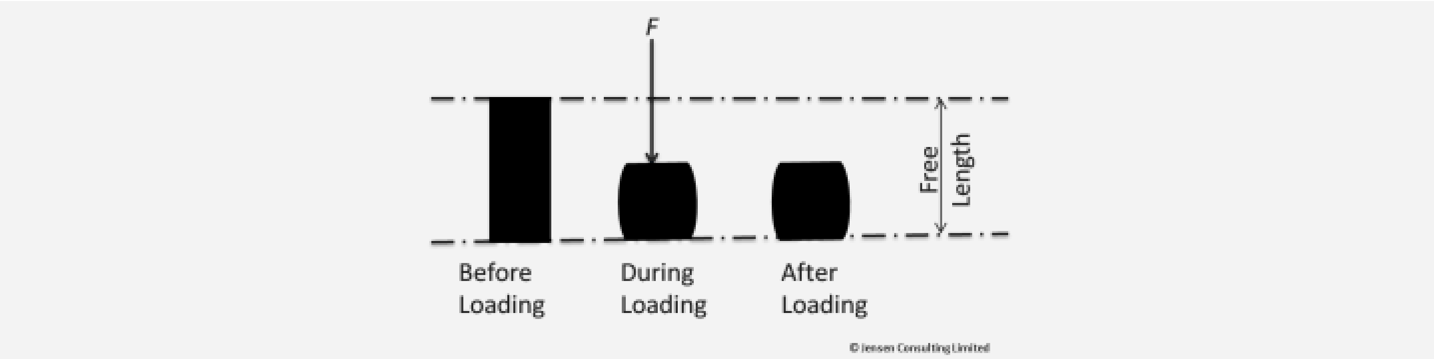
This is the ability of a material to deform under load and return to its original size and shape when the load is removed. Such a material would be required to make the spring as shown.



Explanation Elasticity

Plasticity

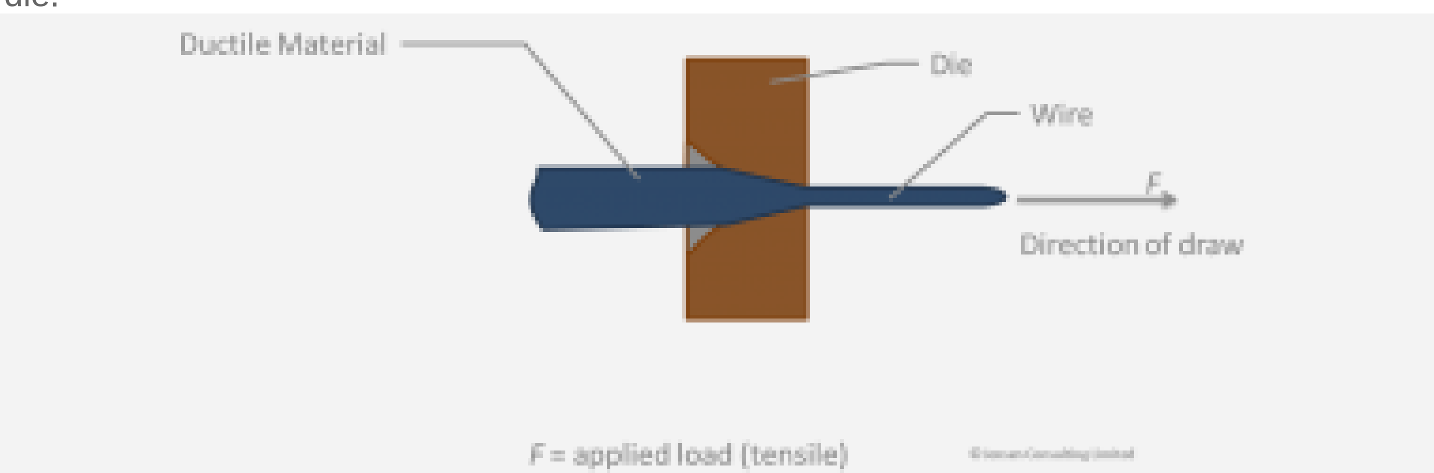
This property is the exact opposite of elasticity. It is the state of a material which has been loaded beyond its elastic state. Under a load beyond that required to cause elastic deformation (the elastic limit) a material possessing the property of plasticity deforms permanently. It takes a *permanent set* and will not recover when the load is removed.



Explanation Plasticity

Ductility

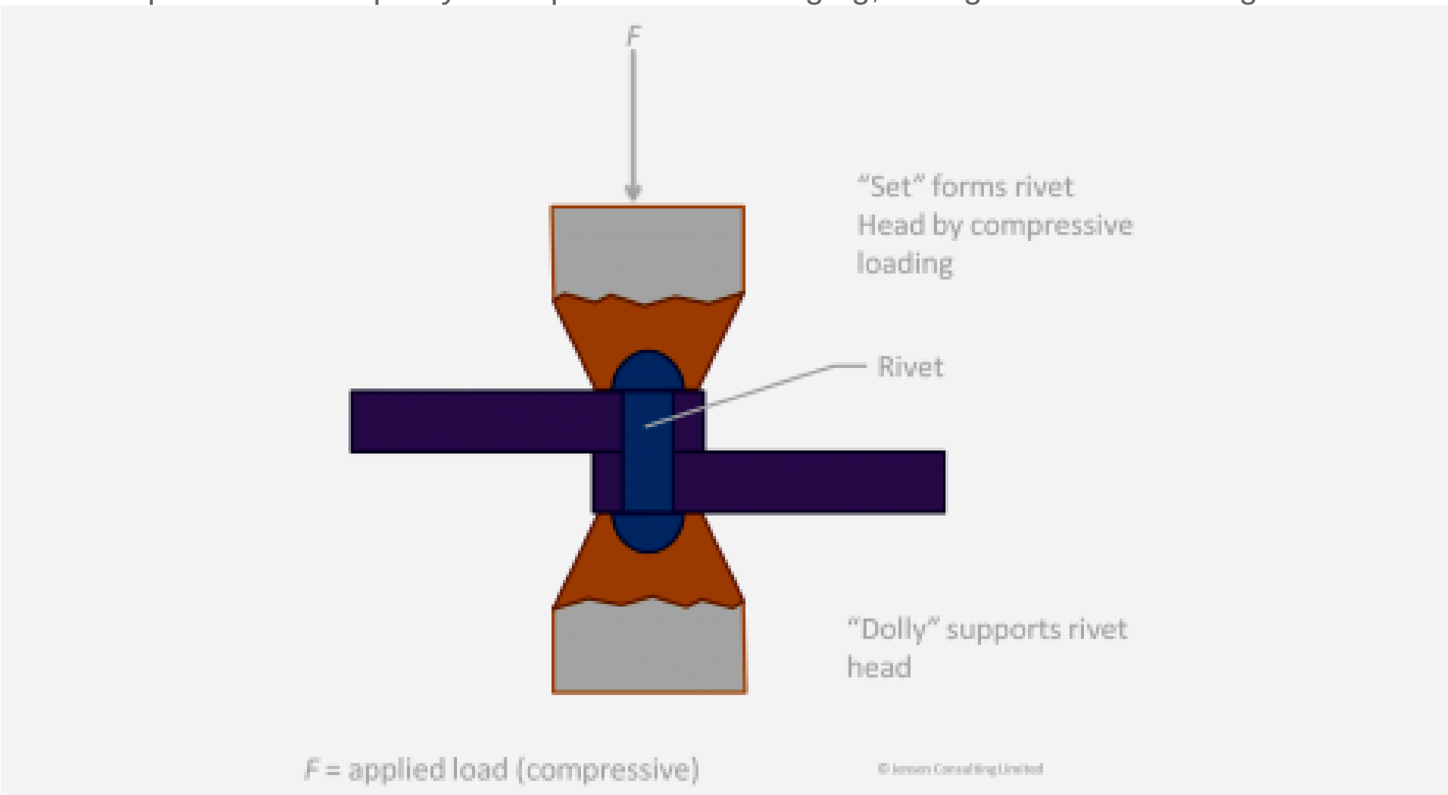
This is the term used when plastic deformation occurs as the result of applying a tensile load. A *ductile* material combines the properties of a plasticity and tenacity (tensile strength) so that it can be stretched or drawn to shape and will retain that shape when the deforming force is removed. For example, in wire drawing the wire is reduced in diameter by drawing it through a die.



Explanation Ductility

Malleability

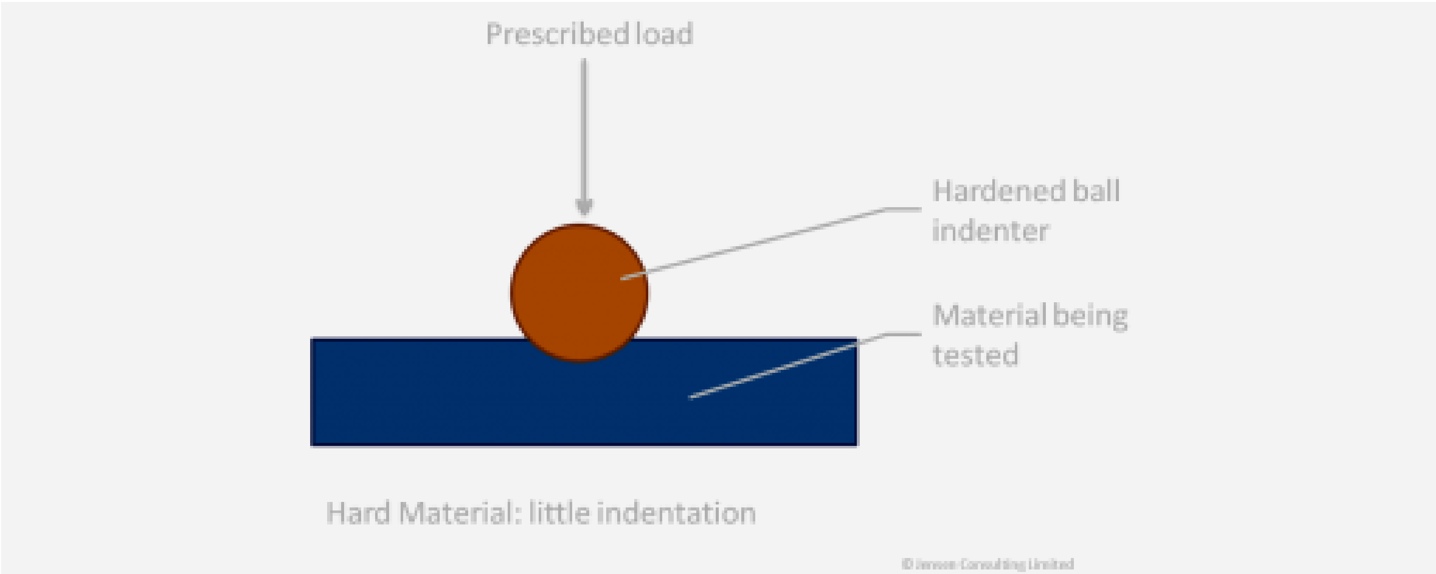
This is a term used when plastic deformation occurs as the result of applying a *compressive load*. A malleable material combines the properties of plasticity and compressibility, so that it can be squeezed to shape by such processes as forging, rolling and rivet heading.



Explanation Malleability

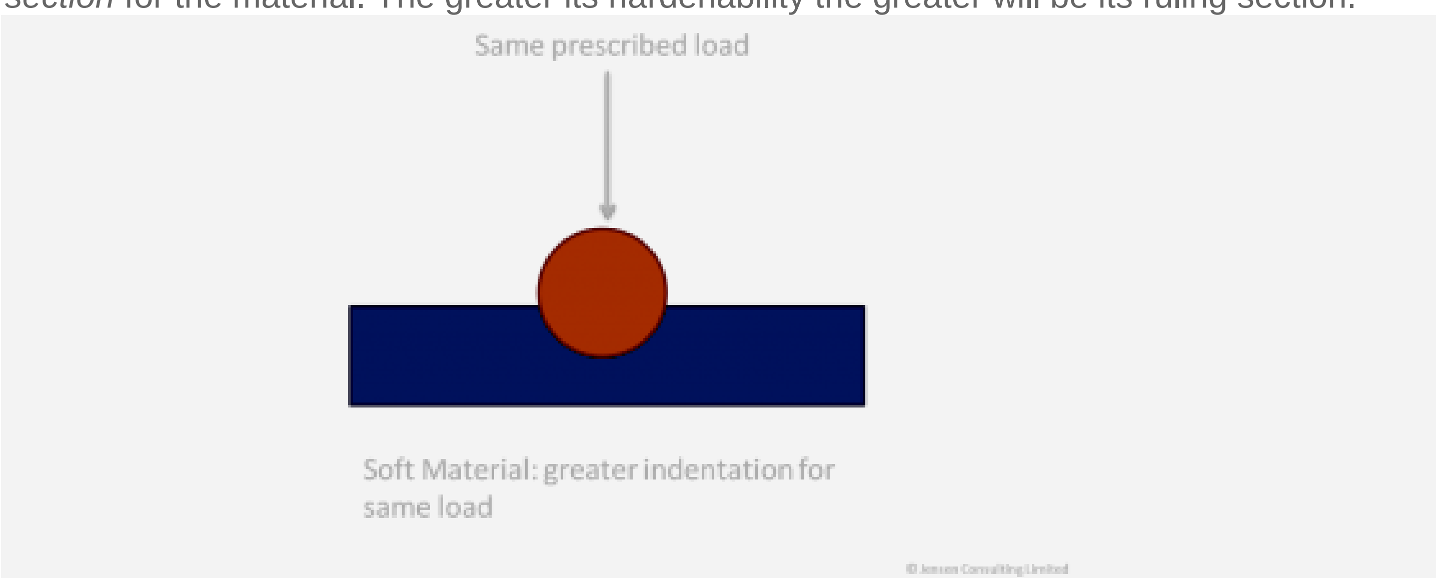
Hardness

This is the ability of a material to withstand scratching (abrasion) or indentation by another hadrd body. It is an indication of the wear resistance of a material.



Explanation Hard material

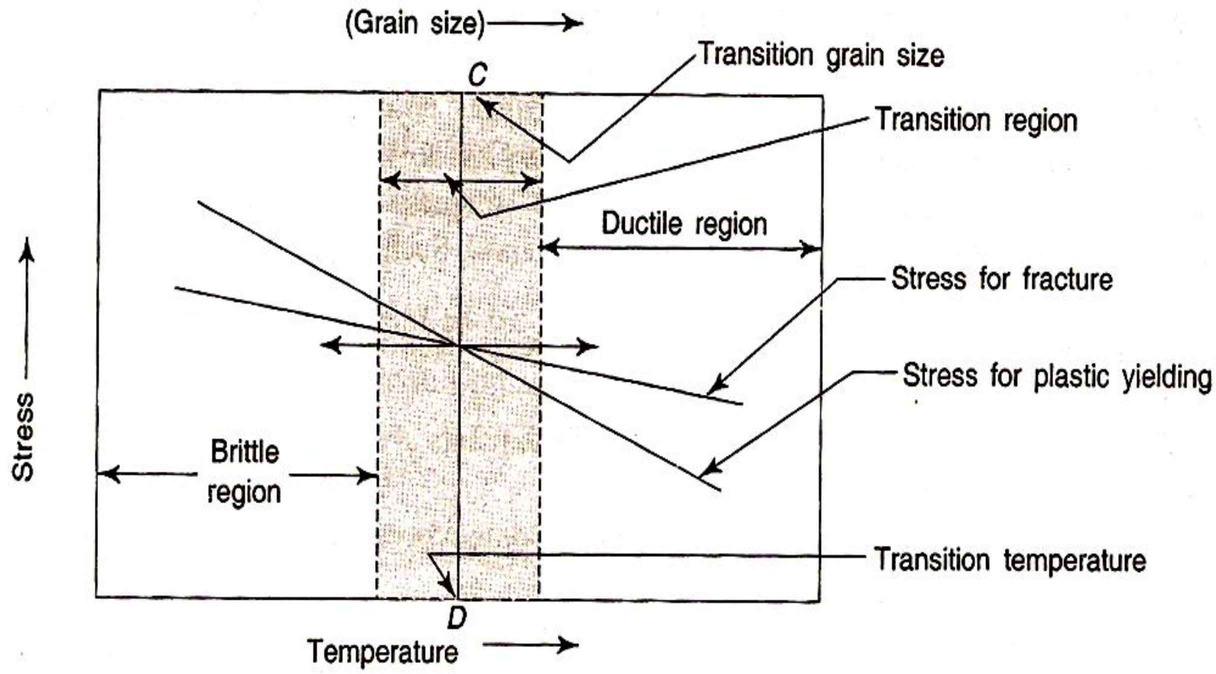
Processes which increase the hardness of materials also increase their tensile strength. At the same time the toughness of the material is reduced as it becomes more brittle. *Hardenability* must not be confused with hardness. Hardenability is the ability of a metal to respond to the heat treatment process of quench hardening. To harden it, the hot metal must be chilled at a rate in excess of its *critical cooling rate.* Since any material that cools more quickly at the surface than tat the centre there is a limit to the size of bar which can cool quickly enough at its centre to achieve uniform hardness throughout. This is the *ruling section* for the material. The greater its hardenability the greater will be its ruling section.



Explanation Soft Material

The Ductile – Brittle Transition

The increase in yield stress associated with low temperature or high strain rates can results in a material changing its mode of fracture from ductile to brittle and this is very important when selecting materials for engineering purposes.



- The plot of brittle fracture stress ($\sigma\delta$) and the yield stress (σy) as a function of temperature or strain rate can explain the ductile to brittle tranisition.
- The curve for brittle fracture stress rises slightly because surface energy increases as temperature decreases.
- The yield stress curve shows the strong temperature dependence.
- The brittle fracture stress and the yield stress curves are intersect with each other then a vertical line is drawn at the point of intersection.
- This is called the ductile brittle transition temperature.

Factors Affecting Mechanical Properties

The mechanical properties of materials are affected by various factors

1. Grain size
2. Heat treatment
3. Atmospherics exposure
4. Low and high temperature

Effect of Grain size

- The metals are composed of crystals (or) grains. If the grain size of a metal is small, it is called a fine grained metal, on the other hand, when the grain size is comparatively large, then it is called a coarse grained metal.
- A fine grained metal has a greater tensile and fatigue strength. It can be easily work hardened.
- A coarse grain causes surface roughness.
- Coarse grain metal is difficult to polish.
- Course grained metal is less tough and has a greater tendency to cause distortion than the fine grained metal.
- Coarse grained metal has a better workability, hardenability and forgeability.
- At Room Temperature the grain boundary is more for fine grained metals. Therefore it has higher strength and hardness than the coarse grained metal.
- At higher temperature coarse grained materials have better creep resistance than the fine grained ones.

The strength of the metal is inversely proportional to the square root of the grain size

Effect of Heat Treatment

- Mechanical properties like ductility hardness, tensile strength, toughness and shock resistance can be improved by heat treatment.

Heat treatment is generally done for the following purposes:

- To refine the grain and improve mechinability.
- To relieve the internal stresses induced in the metals during cold and hot working of the metals.
- To improve resistance to corrosion.
- To modify the structure, either coarse grained or fine grained.
- To improve chemical, magnetic, electrical and thermal properties.

To improve mechanical properties like ductility, hardness, tensile strength, shock resistance etc.

Effect of Atmospheric Exposure

- Most of the metals get oxidized when exposed to the atmospheric. Due to oxidation, of metal surface, a film is formed. The presence of moisture, sulphur dioxide, hydrogen sulphide and other corrosive conditions decrease the electrical resistivity of metals.

The atmospheric effect on the metal depends on the following:

- Characteristics properties of the metal
- Value of the protective film on its surface
- Presence of certain reducing agents
- Local cells formed due to development of cracks and discontinuity on the protective film surface.

Effect of low temperature

- Decrease in temperature there is an increase in the tensile strength and yield strength of all metals.
- Alloys of nickel, copper and aluminium retain most of their ductility and toughness at low temperature.
- For mild steel, the elongation and reduction in cross – sectional area is satisfactory upto - 180°c but after that it goes down to a large extent.
- Near absolute zero temperature many metals exhibit the phenomenon of super conductivity
- Below - 100°c non-ferrous metals show better properties than ferro metals.

Low temperature causes low thermal vibrations and lattice parameters are stabilized.

Effect of high temperature

- Field stress and ultimate tensile strength decrease with rise in temperature
- Stiffness and fracture stress of many metals also decrease with increasing temperature
- At high temperatures, the toughness of steel is reduced.
- At high temperature, creep takes place and the material fails even at a very small stress.
- Due to rise in temperature, there is a corresponding rise in thermal vibration of atoms causing changes in structural properties.