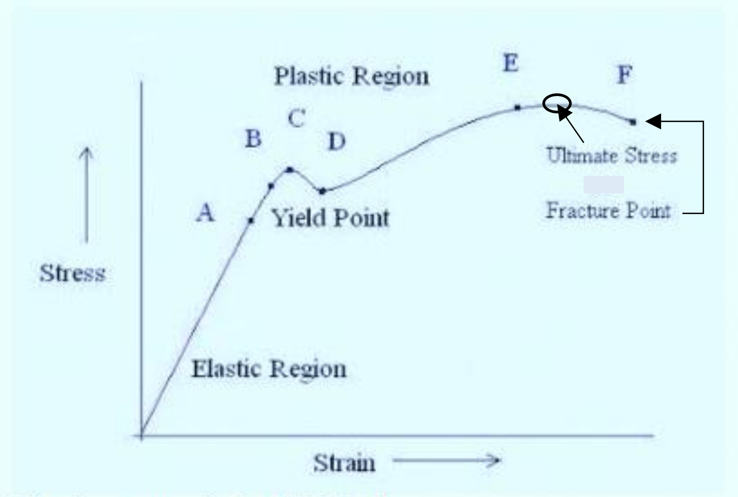
Describing stress-strain graph of a typical ductile metal (like steel)

This shows a stress strain graph for Mild Steel.



The given curve is for Mild Steel.

Like many metals, there is an elastic region to begin with (O to B). Any stress here results in elastic deformation, once the stress or force is removed the original strain or length/shape is resumed.

- Point A is the limit of proportionality. This is the point at which the strain $(\frac{extension}{original\ length})$ is no longer proportional to the stress $(\frac{Force}{Area})$. The material will still behave elastically after this point but for not much longer. We tend to say Young's modulus no longer applies beyond this limit.

- Point B is the limit of elasticity, beyond this the material no longer deforms elastically and any further load/stress added will result in plastic (permanent) deformation. If the stress/load is removed then the material will not return to its original shape.

- Point C is the yield point (upper yield point). It is the threshold at which the grains/fibres in the metal structure start to flow as they rearrange themselves. The stress value appears to decreases (although this is not true). Necking occurs and so the cross sectional area decreases at one point causing a significant increase in extension disproportionally in one region however the stress being plotted is still assuming that the cross sectional area is unchanged. This makes the graph show a region where stress appears to decrease (an illusion/ abstraction to reality).

- D is the lower yield point, plastic flow is exhibited here as the atoms rearranging has stopped and now the atoms are becoming more spread out, stress continues to increase resulting in increasing strain (not proportional).

  The strange behaviour between the yield points C & D are due to necking as the wire increases in length significantly in one localised area (the straightness and cross sectional area is reduced). I.e. There is a rearranging on the atomic scale that causes significant elongation. Beyond D necking may continue but at a slower rate.

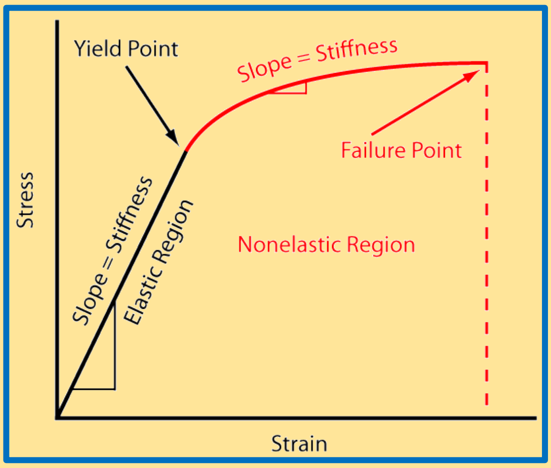
  Necking is a mode of tensile deformation where a relatively large amount of strain is disproportionately localised to a small region of the material. Necking may occur again in a different region of the material later on.

- There is an extensive plastic region (Points D to F). This allows for the material to be drawn into wires (ductile) and also makes it malleable (beaten into sheets and easily shaped).

- Point F is the fracture point, usually rupture occurs at the necked region with the smallest cross sectional area since this supports the least amount of stress (low load bearing strength).

- Before point F, is the highest point on the graph. This is the ultimate tensile strength (UTS). This is the maximum stress the material undergoes before failure.

Another stress-strain graph (ductile material)

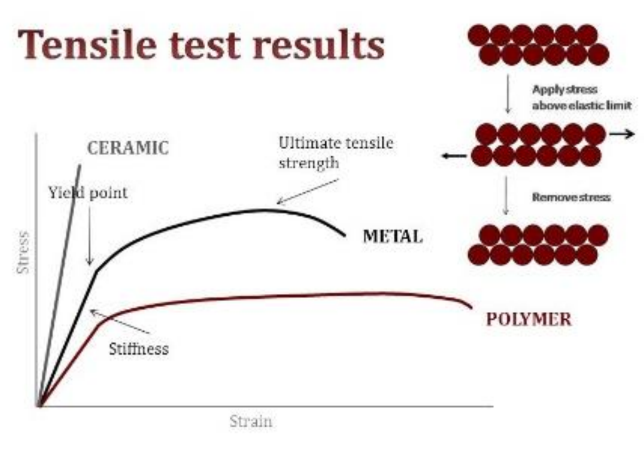


This is another example of a ductile material. There is a large plastic region after the yield point/ limit of elasticity. During plastic deformation, little increase in stress results I a large amount of strain compared to elastic behaviour.

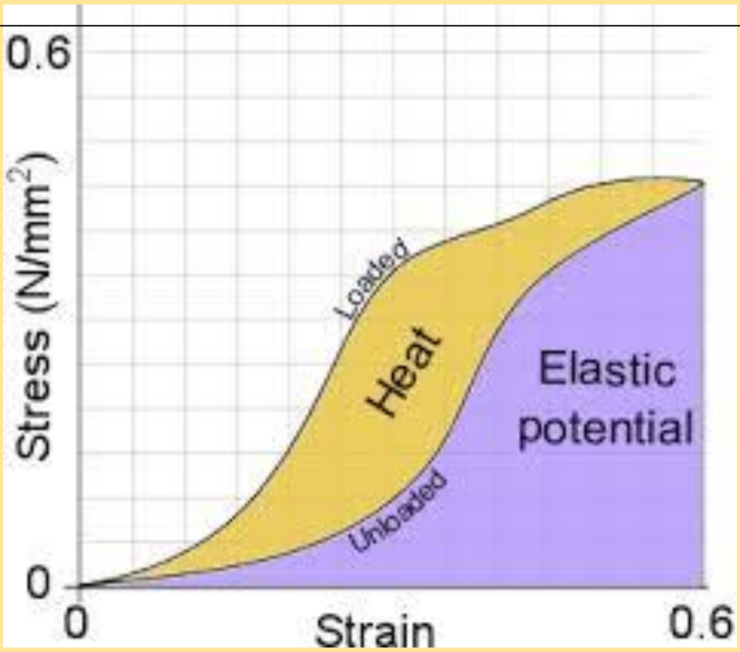
This material is also tough as it absorbs a large amount of energy during plastic deformation before rupture.

We can only tell if it is strong with the quantitative height. If this graph is tall/high stress then the material went under a large amount of stress before failure and so would be strong.

Common material	Property
Biscuit	Hard, brittle
Boiled sweets	Hard, strong, brittle
Bone	Strong, Brittle
Cast iron	Hard, strong, brittle
Ceramics	Hard, strong, brittle
Glass	Hard, strong, brittle
Fudge	Plastic, ductile, malleable
Lead	Ductile, plastic, tough, malleable
Copper	Ductile, plastic, tough, malleable
Chewing gum	Plastic and ductile when wet
Poly(ethene) and many other polymeric materials	Ductile, weak, plastic
Thermo-setting polymers	Hard, rigid, brittle
Thermo-softening polymers	Plastic, tough, flexible
LD poly(ethene)	Ductile, Plastic, Weak
HD poly(ethene)	Hard, strong, brittle
Elastomers like rubber bands	Flexible Small tension forces cause large amount of strain/extension. Due to straightening of long chained polymer molecules. They store the energy as elastically potential energy which is used to resume original shape one deforming force is removed.



Rubber band, area of hysteresis represents heat energy lost during loading



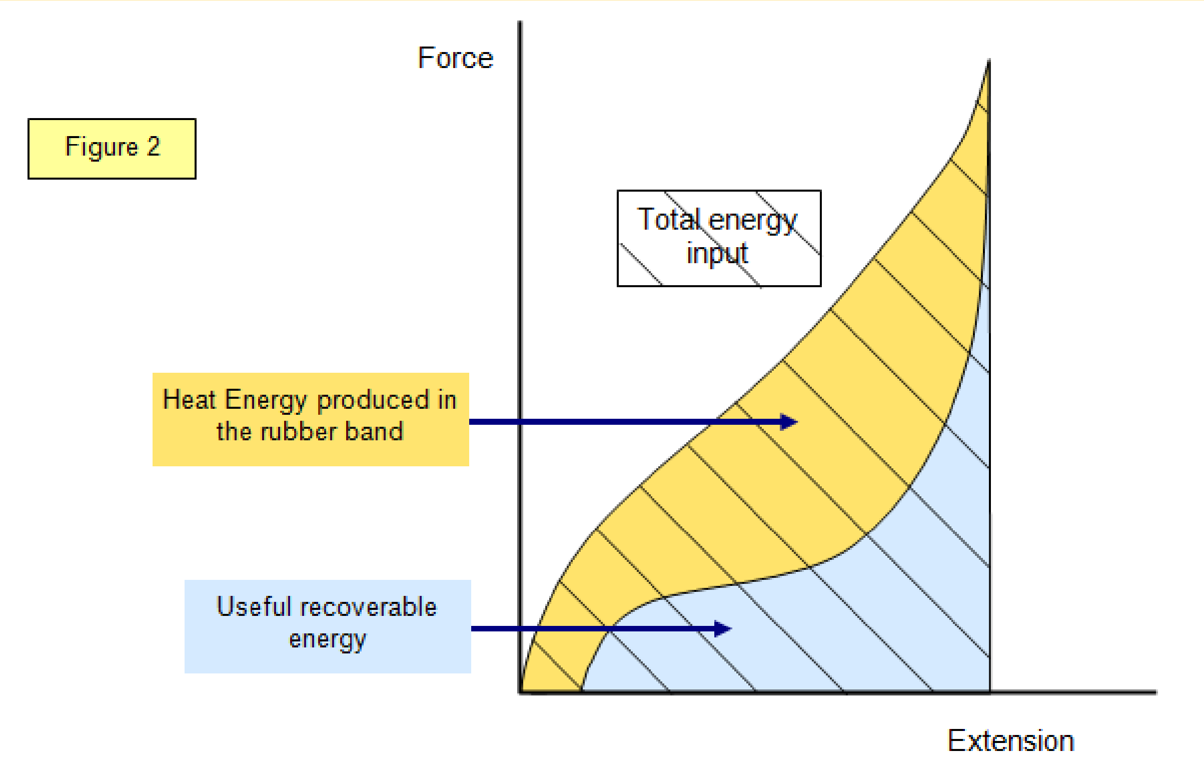
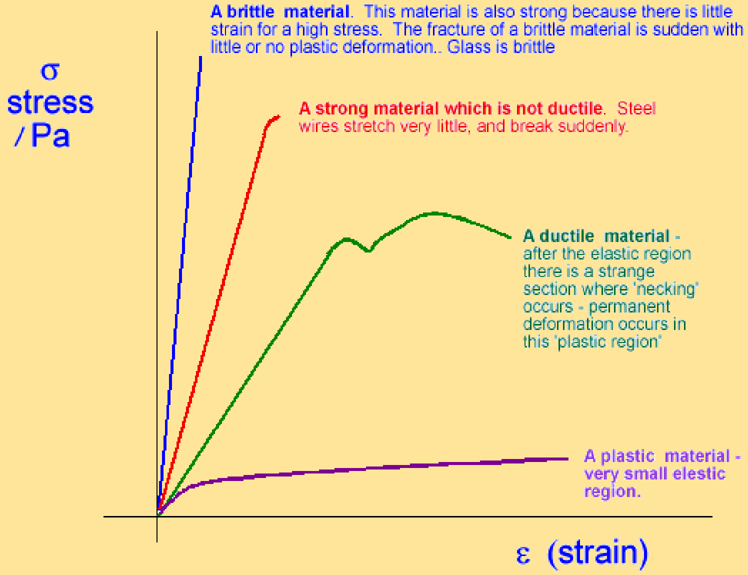


Figure 2



A brittle material. This material is also strong because there is little strain for a high stress. The fracture of a brittle material is sudden with little or no plastic deformation.. Glass is brittle

A strong material which is not ductile. Steel wires stretch very little, and break suddenly.

A ductile material - after the elastic region there is a strange section where 'necking' occurs - permanent deformation occurs in this 'plastic region'

A plastic material - very small elestic region.