

Stress-strain curves for metals, ceramics and polymers

Objective

We are interested about studying and comparing stress-strain curves of metals, ceramics and polymers. Primarily, differences are due to their different chemical bonding properties (Homework 1).

Metals | Ceramics | Polymers

Metals are typically hard, opaque, shiny, and have good electrical and thermal conductivity. Generally, they are malleable (can be pressed permanently out of shape without breaking or cracking), fusible (able to be fused or melted) and ductile (able to be drawn out into a thin wire). This class of solids is also said to be mainly formed of metallic bonds. Where it is findable a “sea” of delocalized electrons that contributes for the characteristics discussed above.

On the other hand, ceramics have a high melting point, high hardness, poor conductivity, high moduli of elasticity (E), chemical resistance and low ductility are the norm.

Polymers, both natural and synthetic, are created via polymerization of many small molecules, known as monomers. The first ones include biomolecules (such as DNA or proteins) and the last ones some well-known compounds: polystyrene, nylon, teflon, kevlar... Their consequently large molecular mass relative to small molecule compounds produces unique physical properties, including toughness, viscoelasticity, and a tendency to form glasses and semi crystalline structures rather than crystals.

Stress-strain Curve

Each material has a specific stress-strain curve, mainly accordingly to their stiffness and yielding point. Even different tensile tests conducted on the same material yield different results, depending upon the temperature of the specimen and the speed of the loading. Although, general diagrams can be drawn for these 3 groups of materials, as shown below.

Metals

Curve can be divide in 4 regions (Fig. 1). O3: linear portion of the curve (*proportional region*), where its slope corresponds to the Young's modulus. As greater is this value, stiffer is the material. Additionally, it would be possible to determine the Poisson ratio by measuring the strain in a transversal direction of the longitudinal applied stress: $\nu = -\frac{\epsilon_{trans}}{\epsilon_{long}}$. 32:

final region of elasticity. Number 2 marks the *elasticity limit*, from this point on, any additional stress applied to the material will result in an irreversible modification of its shape. 21: material starts deforming itself in a plastic way. As soon as stress 1 is reached the *ultimate strength* is achieved and the *necking region* appears in the neighborhood. 14: necking region. Materials' cross section starts becoming thinner and, eventually, *rupture point* 4 is achieved and the specimen fractures. IMPORTANT: this description is about an apparent/engineering stress shown in the figure 1. Where it's assumed that the cross-sectional area remains constant. Although, this is not true! As soon as plastic deformations become relevant, cross-section area becomes increasingly thinner. So, the ratio of the tensile force to the true cross-sectional area at the narrowest region of the neck is bigger than considering an apparent stress.

Ceramics

Ceramics usually are brittle. Observing the diagram (Fig. 2), we verify this is significantly simpler than the previous. The main reason is that there is a very narrow plastic region. That's why the *fracture limit* (point 2) is the same as the *ultimate strength*.

Polymers

Polymers class englobes a vast number of materials w/ significantly different behaviors under stress. So, 4 main subclasses were represented. Flexible plastics behave similarly to metals, although w/ a greater plasticity. Elastomers are the ones that strains more w/ a lower stress. And finally, analogous to ceramics, are the stiff fibers and rigid plastics. With a very short elastic region but highly capable of supporting huge stresses.

Fig. 1 – Metals (Al alloy) stress-strain curve.

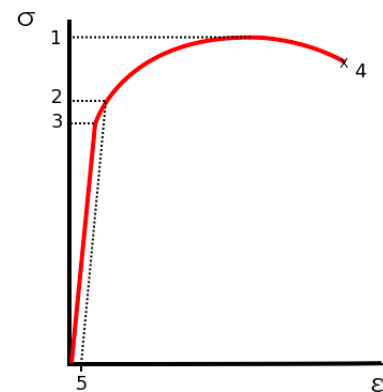


Fig. 2 - Stress-strain curve for ceramics.

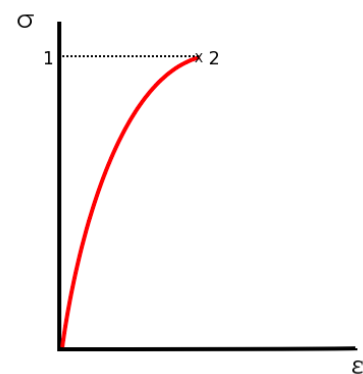


Fig. 3 – Stress-strain curve for polymers.

