Tensile test

Outline

Tensile test purpose
Universal testing machines and test specimens
Stress-strain diagram
Mild steel:
  — proportional stage,
  — elastic limit,
  — yielding plateau, strain hardening,
  — unloading and reloading,
  — ultimate strength,
  — necking stage, fracture
Hard steel: conventional proportional limit, conventional yield limit
Other structural materials
Schematizations of tensile test diagram
**Tensile test purpose**

The primary use of the testing machine is to create the stress-strain diagram. Tensile test determines the strength of the material subjected to a simple stretching operation. Typically, standard dimension test samples are pulled slowly (static loading) and at uniform rate in a testing machine while the *strain* (the elongation of the sample) is defined as:

Engineering Strain = $\varepsilon = \frac{\text{change in length}}{\text{original length}} = \frac{\delta}{L_0}$

and the *stress* (the applied force divided by the original cross-sectional area) is defined as:

Engineering Stress = $\sigma = \frac{\text{applied force}}{\text{original area}} = \frac{P}{A_0}$

The aim of the test is to assess some mechanical characteristics of testing material: its elasticity, ductility, resilience and toughness.

There are two kinds of typical diagrams:

- with distinct yielding limit
- without distinct yielding limit
The diagram with distinct yielding limit. In red marked engineering stresses, in blue – true stresses.
The diagram without distinct yielding limit. Some conventions should be used instead.
Universal testing machines

There are many types of testing machines. The most common are universal testing machines, which test materials in tension, compression or bending.

There are two classes of testing machines, electromechanical and hydraulic.

The electromechanical machine uses an electric motor, gear reduction system and one, two or four screws to move the crosshead up or down. A range of crosshead speeds can be achieved by changing the speed of the motor through the software control. A microprocessor based closed-loop servo system can be implemented to accurately control the speed of the crosshead.

The main components of the universal testing machine are:

— actuator,
— attachment kit and
— measuring and safety devices
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**Universal testing machine UTS-100K**

- frame
- engine
- gear
- screws
- crosshead
- grips (gripping jaws)
- extensometer
- specimen
- hardware and software control
Universal testing machine UTS 100K

Self-locking jaws, tested sample and extensometer
Tensile specimens

cylindrical proportional with the knobs (heads) smooth or threaded

flat (paddle or strip)
Stress-strain diagram for mild steel

Stress-strain diagram
Linear proportionality and elasticity limit

Loading, unloading, reloading: Hooke’s law
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**Yielding plateau**

Elastic and plastic deformations of the specimen
Plasticity: sliding and twinning, dislocations movement

Sliding lines (Lüders’ lines like spider’s mesh), twinning of crystals and dislocations movement
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**Ultimate tensile strength, necking onset and fracture**

Difference between engineering (blue line) and true stress (red line)
Three stages of the necking
Types of break and fracture

In the cross-section of broken specimen there are three distinct zones:

— fibrous zone
— radial zone and
— sheared edge

The fracture type can be brittle, fissile or ductile (due to shear)
Comparison of break

- Steel neck down break
- Aluminum 45 degree break
- Cast iron straight break
The state of stress – analysis

**Tensile state of stress**

Transformation:

\[
\begin{pmatrix}
\cos \alpha, \sin \alpha \\
\-\sin \alpha, \cos \alpha
\end{pmatrix} = \begin{pmatrix}
0.707, 0.707 \\
-0.707, 0.707
\end{pmatrix}
\]
Schematizations

For practical use the stress-strain diagram is used in some schematic form, depending on main phenomenon of the structural material.

The main possibilities are:

— Hooke’s material
— Levy-Mises’ material
— Prandtl’s material
— others (with strain or isotropic or anisotropic hardening)

\[\text{schematizations of the tensile diagram}\]

\[\text{Hooke} \quad \text{Levy-Mises} \quad \text{Prandtl} \quad \text{others}\]
Interpretation of the state of stress

- Elastic Deformation
- Proportional Limit
- Upper Yield Point
- Lower Yield Point
- Ultimate Point (Tensile Strength)
- Necking
- Failure (Breaking Stress)
Material characteristics
Tensile diagram – different materials

- Hard steel
- Cr-Ni steel
- Mild steel
- Cast iron
- Copper
Definitions

**Elastic Limit (proportional limit):** the highest magnitude of stress for which the stress and strain are proportional to each other.

**Elastic modulus (Young's modulus):** the ratio of stress to strain below the elastic limit.

**Elongation:** the strain at fracture expressed as a percentage; this is a measure of the ductility of the material.

**Modulus of resilience:** the amount of energy (or work) stored per unit volume at the elastic limit.

**Modulus of toughness:** the amount of energy stored per unit volume at fracture of the material; this is a measure of the ductility of the material.

**Percent Area Reduction:** reduction in area at fracture in necking region with respect to original cross-section area; this is a measure of the ductility of the material.

**Strain (engineering):** the unit deformation of the material under load. Strain is not normally measured. Deformation is typically measured using extensometers with strain subsequently computed by dividing the measured deformation by the original.
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**Strain hardening:** portion of the stress-strain curve between the elastic limit and the ultimate stress.

**Stress (engineering):** load (force) per unit area; the normal (axial) stress is determined by dividing the load by the original cross-sectional area of the specimen.

**Stress-strain curve:** an x-y plot of stress vs. strain through the entire range of loading of the specimen until specimen failure.

**Ultimate stress:** the maximum observed stress that the specimen will withstand.

**Yield stress:** the stress at which the material begins to “yield”; for mild steel there is a noticeable increase in deformation with little increase in load. For steel and most metals, a 0.2% offset is used to define the yield stress. A strain value of 0.002 is selected and a line parallel to the elastic portion of the stress-strain curve is constructed. The intersection of this line with the stress-strain curve defines the value of the yield stress.