TENSILE TEST

Introduction

Metallic materials tensile test is used as the standard TS 138 EN 10002-1 standard. These test methods cover the tension testing of metallic materials in any form at room temperature, specifically, the methods of determination of yield strength, yield point elongation, tensile strength, elongation, and reduction of area.
The major parameters that describe the stress-strain curve obtained during the tension test are the tensile strength (UTS), yield strength or yield point (σ_y), elastic modulus (E), percent elongation ($\Delta L\%$) and the reduction in area (RA%). Toughness, Resilience, Poisson's ratio(v) can also be found by the use of this testing technique.

Specimen Preparation

In this test, a specimen is prepared suitable for gripping into the jaws of the testing machine type that will be used. The specimen used is approximately uniform over a gage length (the length within which elongation measurements are done).
Tensile specimens are machined from the material to be tested in the desired orientation and according to the standards. The cross section of the specimen is usually round, square or rectangular. For metals, a piece of sufficient thickness can be obtained so that it can be easily machined, a round specimen is commonly used.
For sheet and plate stock, a flat specimen is usually employed. The change in the gage length of the sample as pulling proceeds is measured from either the change in actuator position (stroke or overall change in length) or a sensor attached to the sample (called an extensometer).
A tensile load is applied to the specimen until it fractures. During the test, the load required to make a certain elongation on the material is recorded. A load-elongation curve is plotted by an x-y recorder, so that the tensile behavior of the material can be obtained. An engineering stress-strain curve can be constructed from this load-elongation curve by making the required calculations. Then the mechanical parameters that we search for can be found by studying on this curve.

Engineering Stress is obtained by dividing the load by the original area of the cross section of the specimen.

Stress: $\sigma = P/Ao$ (Load/Initial cross-sectional area)

Strain: $e = \Delta l/lo$ (Elongation/Initial gage length)

Engineering stress and strain are independent of the geometry of the specimen.

Elastic Region: The part of the stress-strain curve up to the yielding point. Elastic deformation is recoverable. In the elastic region, stress and strain are related to each other linearly.

Hooke's Law: $\sigma = Ee$

The linearity constant E is called the elastic modulus which is specific for each type of material.

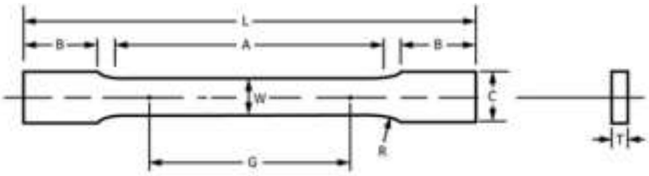
Plastic Region: The part of the stress-strain diagram after the yielding point. At the yielding point, the plastic deformation starts. Plastic deformation is permanent. At the maximum point of the stress-strain diagram (σ_{UTS}), necking starts.

Tensile Strength is the maximum stress that the material can support.

$\sigma_{UTS} = P_{max/Ao}$

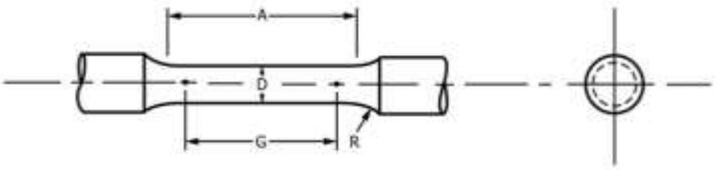
Because the tensile strength is easy to determine and is a quite reproducible property, it is useful for the purposes of specifications and for quality control of a product. Extensive empirical correlations between tensile strength and properties such as hardness and fatigue strength are often quite useful. For brittle materials, the tensile strength is a valid criterion for design.

Yield Strength is the stress level at which plastic deformation starts. The beginning of first plastic deformation is called yielding. It is an important parameter in design.



Dimensions	Standard Specimens		Subsize Specimen
	Plate-Type, 40 mm [1.500 in.] Wide	Sheet-Type, 12.5 mm [0.500 in.] Wide	6 mm [0.250 in.] Wide
	mm [in.]	mm [in.]	mm [in.]
G—Gauge length	200.0 ± 0.2 [8.00 ± 0.01]	50.0 ± 0.1 [2.000 ± 0.005]	25.0 ± 0.1 [1.000 ± 0.003]
W—Width	40.0 ± 2.0 [1.500 ± 0.125, -0.250]	12.5 ± 0.2 [0.500 ± 0.010]	6.0 ± 0.1 [0.250 ± 0.005]
T—Thickness		thickness of material	
R—Radius of fillet, min	25 [1]	12.5 [0.500]	6 [0.250]
L—Overall length, min	450 [18]	200 [8]	100 [4]
A—Length of reduced parallel section, min	225 [9]	57 [2.25]	32 [1.25]
B—Length of grip section, min	75 [3]	50 [2]	30 [1.25]
C—Width of grip section, approximate	50 [2]	20 [0.750]	10 [0.375]

Fig 1. Rectangular Tensile Test Specimens



Dimensions, mm [in.] For Test Specimens with Gauge Length Four times the Diameter [E8]	Standard Specimen	Small-Size Specimens Proportional to Standard			
	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
G—Gauge length	50.0 ± 0.1 [2.000 ± 0.005]	36.0 ± 0.1 [1.400 ± 0.005]	24.0 ± 0.1 [1.000 ± 0.005]	16.0 ± 0.1 [0.640 ± 0.005]	10.0 ±0.1 [0.450 ± 0.005]
D—Diameter	12.5 ± 0.2 [0.500 ± 0.010]	9.0 ±0.1 [0.350 ± 0.007]	6.0 ± 0.1 [0.250 ± 0.005]	4.0 ± 0.1 [0.160 ± 0.003]	2.5 ± 0.1 [0.113 ± 0.002]
R—Radius of fillet, min	10 [0.375]	8 [0.25]	6 [0.188]	4 [0.156]	2 [0.094]
A—Length of reduced parallel section, min	56 [2.25]	45 [1.75]	30 [1.25]	20 [0.75]	16 [0.625]

Fig 2. Round Tensile Test Specimens

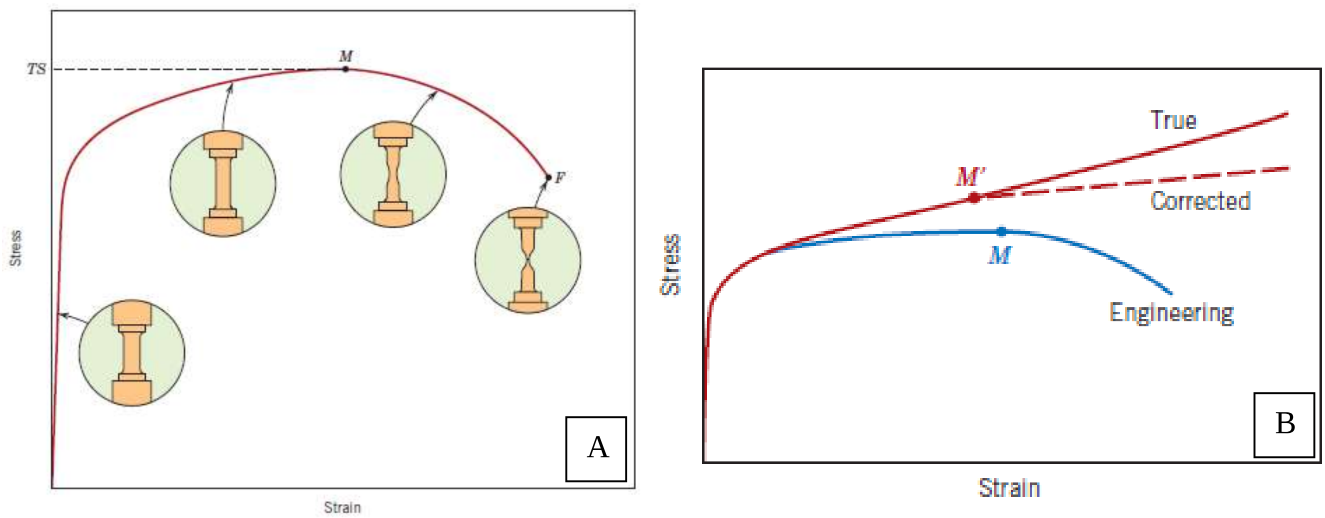


Fig 3. a)Typical engineering stress-strain curve b) A comparison of typical tensile engineering stress–strain and true stress–strain behaviors.

Ductility is the degree of plastic deformation that a material can withstand before fracture. A material that experiences very little or no plastic deformation upon fracture is termed brittle.
In general, measurements of ductility are of interest in three ways:

1. To indicate the extent to which a metal can be deformed without fracture in metalworking operations such as rolling and extrusion.
2. To indicate to the designer, in a general way, the ability of the metal to flow plastically before fracture.
3. To serve as an indicator of changes in impurity level or processing conditions. Ductility measurements may be specified to assess material quality even though no direct relationship exists between the ductility measurement and performance in service.

Resilience is the capacity of a material to absorb energy when it is deformed elastically.
Toughness is a measure of energy required to cause fracture.
Poisson's Ratio is the lateral contraction per unit breadth divided by the longitudinal extension per unit length.

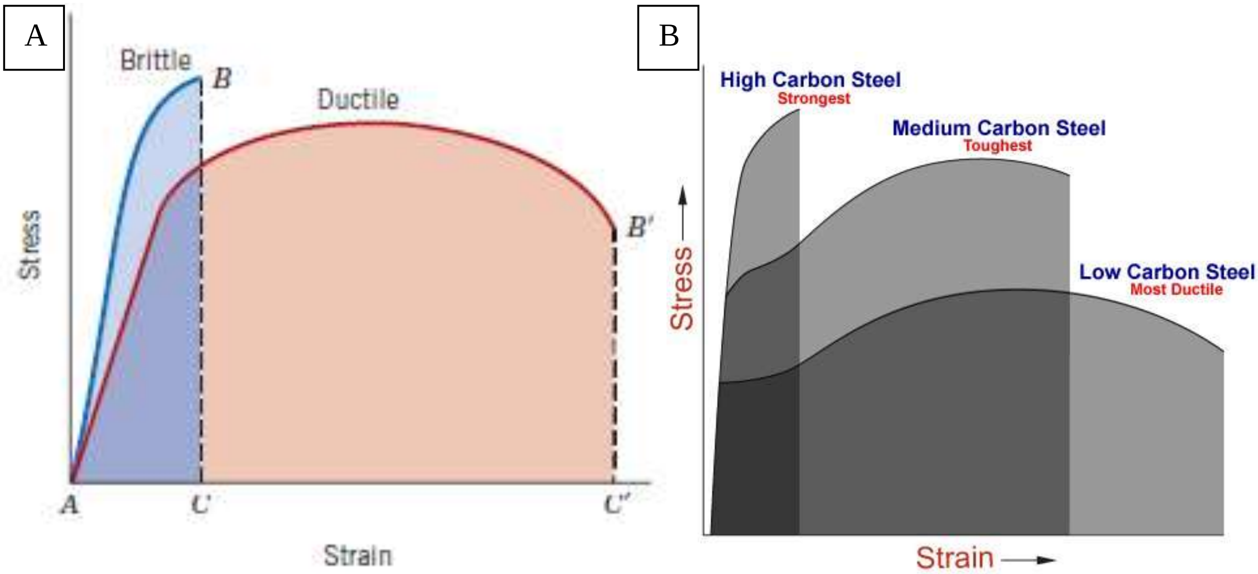


Fig 4. a) Schematic representations of tensile stress–strain behavior for brittle and ductile materials loaded to fracture b) Diagram of the stress-strain curves of low, medium and high carbon steel.

Fig 6. a) Ductile b) brittle fracture surface

Strain Hardening: The strain hardening exponent (also called strain hardening index), noted as n, is a materials constant which is used in calculations for stress–strain behavior in work hardening. In the formula,
$\sigma = K\,\varepsilon^n$
σ represents the applied stress on the material,
ε is the strain,
K is the strength coefficient.

The value of the strain hardening exponent lies between 0 and 1. A value of 0 means that a material is a perfectly plastic solid, while a value of 1 represents a 100% elastic solid. Most metals have an n value between 0.10 and 0.50.

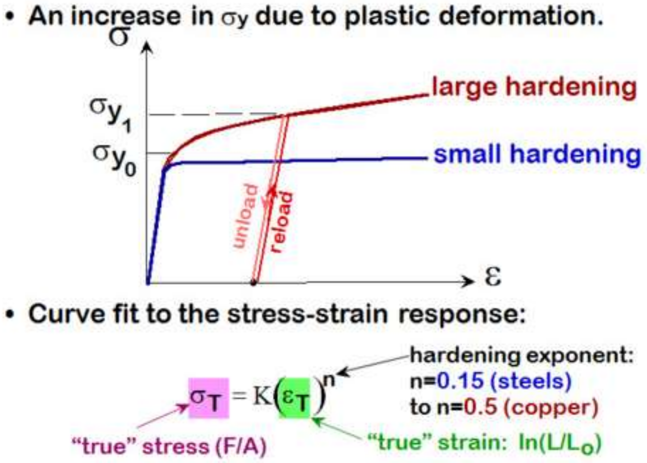


Fig 7. Strain Hardening

References

- *ASM Handbook,* Vol. 8, *Mechanical Testing and Evaluation,* ASM Int., Materials Park, OH, 2000.
- TS 138 Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature
- ASTM E8/E8M Standard Test Methods for Tension Testing of Metallic Materials
- Meyers, M. A. and K. K. Chawla, *Mechanical Behavior of Materials,* Prentice Hall PTR, Par., NJ, 1999.
- Courtney, T. H., *Mechanical Behavior of Materials,* 2nd ed., McGraw-Hill Higher Edu., Burr Ridge, IL, 2000.
- Materials Science and Engineering, Eight Edition, William D. Callister and David G. Rethwisch
- METU tension test sheet
- Web

Tasks

Length (mm)	Load (N)
0	0
1,08	9243
2,03	15837
3,05	21348,6
4,01	25045,8
5,09	27729
6	29770,8
7,01	31481,4
8,06	32868
9,01	33971,4
10,05	34861,2
11	35537,4
12,02	35999,4
13,08	36220,2
14,02	36220,2
15,07	35992,8
16,02	35544
17	34985,4
18,03	34296
19,02	33406,2
20,01	30846,6
20,82	25349,4

1- The cylindrical specimen has a cross-sectional diameter of 12.5 mm and gauge length of 50mm. Plot the engineering stress-strain diagram by using given data.

2- Show the elastic and plastic regions on the stress-strain diagram

3- Find the followings:

- **a.** Yield point
- **b.** Ultimate strength
- **c.** Elongation at break
- **d.** Modulus of elasticity
- **e.** Toughness
- **f.** Resilience

4- What is the differences between engineering stress-strain and true stress-strain behaviors? Explain briefly.