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Mechanical Testing

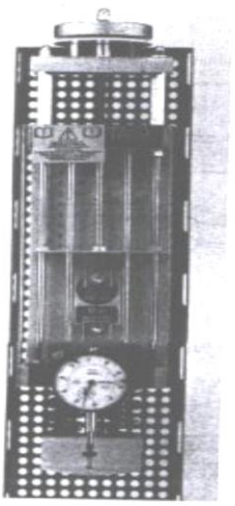
Tensile Test اختبار الشد

The main principle of the tensile test is representing the resistance of a material to a tensile load applied axially to a specimen. There are a several tensile testing machine, as in figure 1 (a) shows a popular bench-mounted tensile testing machine, whilst figure 1(b) shows a more developed machine suitable for industrial and research laboratories, while in figure 1(c) shows the schematic drawing of a tensile testing apparatus. These machines are capable of performing compression, shear and bending tests as well as tensile tests.

يتمثل المبدأ الرئيسي لاختبار الشد في تمثيل مقاومة المادة لحمل الشد المسلط محوريًا على العينة. هناك العديد من آلات اختبار الشد ، كما في الشكل 1 (أ) يوضح آلة اختبار الشد المشهورة المثبتة على المنضدة ، بينما يوضح الشكل 1 (ب) آلة أكثر تطوراً مناسبة للمختبرات الصناعية والبحثية ، بينما في الشكل 1 (ج) يُظهر الرسم التخطيطي لجهاز اختبار الشد. هذه الآلات قادرة على إجراء اختبارات الضغط والقص والانحناء وكذلك اختبارات الشد.

It is very important to the tensile test to be considered is the **standard dimensions** and **profiles (shapes)** are adhered to.

من الضروري الاخذ بنظر الاعتبار الابعاد القياسية وشكل العينة القياسي عند اجراء اختبار الشد.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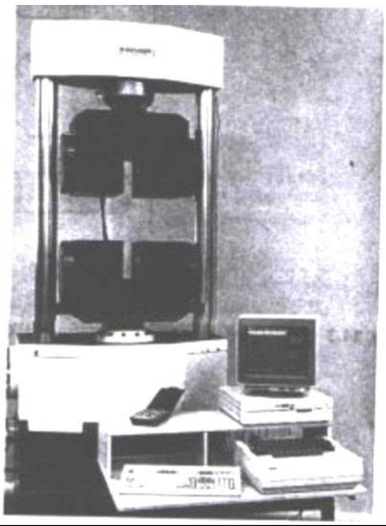
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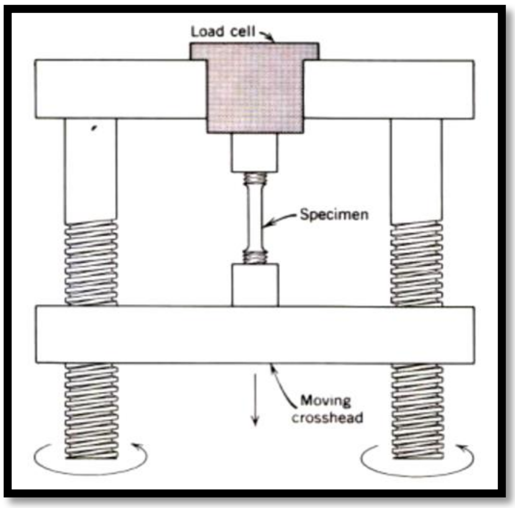

(c)

Figure 1. Tensile testing machines.

The typical progress (development) of tensile test can be seen in figure 2.

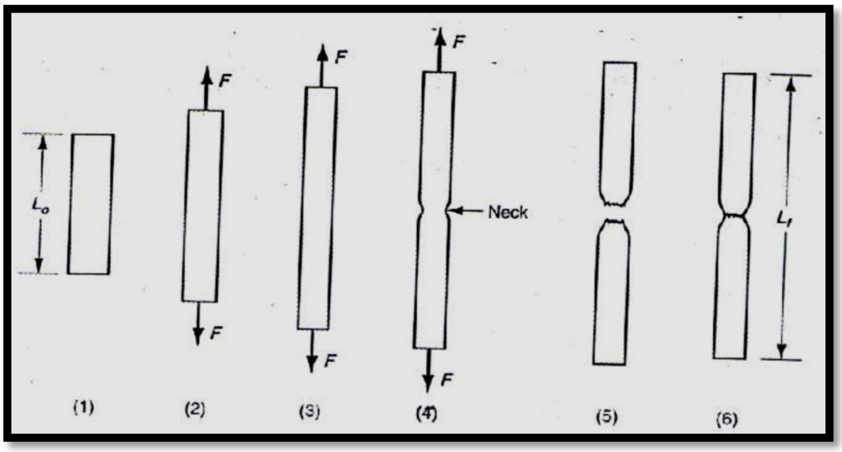

Figure 2. Typical progress (development) of a tensile test: (1) beginning of test, no load; (2) uniform elongation and reduction of cross-sectional area; (3) continued elongation, maximum load reached; (4) necking begins, load begins to decrease; and (5) fracture. If pieces are put back together as in (6), final length can be measured.

Let's now look at figure 3. In this figure, the gauge length (**L_0**) is the length over which the elongation of the specimen is measured. The minimum parallel length (**Lc**) is the minimum length over which the specimen must maintain a constant cross-sectional area before the test load is applied. The lengths L_0, Lc, Li, and the cross-sectional area (**A**) are all specified in BS 18.

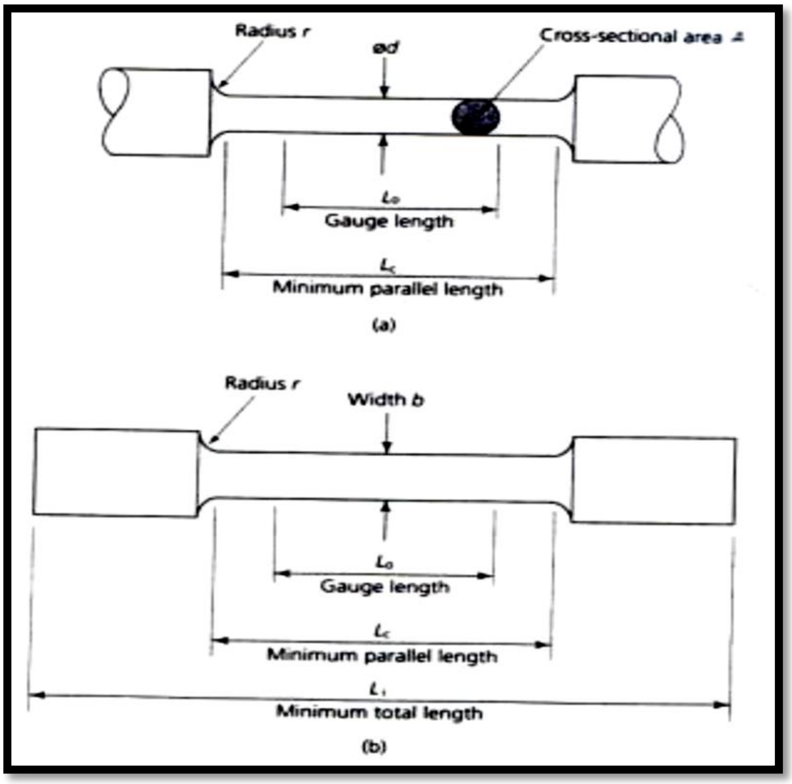

Figure 3. Properties of tensile test specimens: (a) cylindrical; (b) flat

The **elongation** obtained for a given force depends upon the **length** and **area** of the cross-section of the specimen or component, since:

$$\text{elongation} = \frac{\text{appliedforce} \times L}{E \times A}$$

where **L** = length.
A = cross-sectional area.
E = elastic modulus (modulus of elasticity).

Therefore, if the ratio [**L/A]** is kept constant (as it is in a proportional test piece), and **E** remains constant for a given material, then comparisons can be made between elongation and applied force for specimens of different sizes.

Tensile Test Results

Let's now look at the sort of results we would get from a typical tensile test on a piece of **annealed low-carbon steel**. The load applied to the specimen and the corresponding extension can be plotted in the form of a graph, as shown in figure 4.

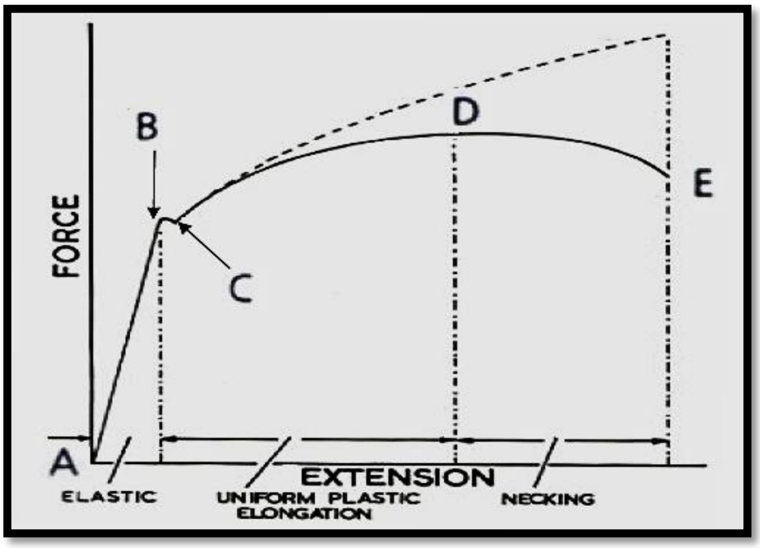

Figure 4. Load-extension curve for a low-carbon steel.

1. From **A** to **B** the extension is proportional to the applied load. Also, if the load is removed the specimen returns to its original length. Under these relatively lightly loaded conditions the material is showing **elastic properties**.
2. From **B** to **C** it can be seen from the graph that the metal **suddenly extends with no increase in load**. If the load is removed at this point the metal will not spring back to its original length and it is said to have taken a permanent set. Therefore, **B** is called "**limit of proportionality** ", and if the force is increased beyond this point a stage is reached where a sudden extension takes place with no increase in force. This is known as the " **yield point**" C.
3. The **yield stress** is the stress at the yield point; that is, the load at **B** divided by the original cross-section area of the specimen. Usually, a designer works at **50** per cent of this figure to allow for a 'factor of safety'.

4. From **C** to **D** extension is no longer proportional to the load, and if the load is removed little, no spring back will occur. Under these relatively greater loads the material is showing **plastic properties**.

5. The point **D** is referred to as the '**ultimate tensile strength**' when referred extension graphs or the '**ultimate tensile stress**' (**UTS**) when referred to stress-strain graphs. The ultimate tensile stress is calculated by dividing the load at **D** by the original cross-sectional area of the specimen. Although a useful figure for comparing the relative strengths of materials, it has little practical value since engineering equipment is not usually operated so near to the breaking point.

6. From **D** to **E** the specimen appears to be extending under reduced load conditions. In fact, the specimen is thinning out (**necking**) so that the 'load per unit area' or stress is actually increasing. The specimen finally work hardens to such an extent that it breaks at **E**.

7. In practice, values of load and extension are of limited use since they apply to one particular size of specimen and it is more usual to plot the **stress-strain curve**.

8. **Stress** and **strain** are calculated as follows:

$$stress(\sigma) = \frac{load}{areaofcross - section}$$

$$steain(\varepsilon) = \frac{extension}{originallength}$$

The Tensile Test Experimental Results on Some Materials

The explanation of tensile test data requires skill accepted from experience, since many factors can affect the test results, for instance, the **temperature** at which the test is carried out, since the tensile modulus and tensile strength decrease as the temperature rises for most metals and plastics, while the ductility increases as the temperature rises. The test results are also influenced by the **rate at which the specimen is strained**.

Figure **5** shows a typical stress-strain curve for a **grey cast iron**. From such a curve we can deduce (conclude) the following information.

1. The material is **brittle** since there is little plastic deformation before it fractures.

2. A gain the material is fairly (completely) rigid since the slope of the initial elastic range is steep (sharp).

3. It is difficult to determine the point at which the limit of proportionality occurs, but it is approximately 200 MPa.

4. The ultimate tensile stress (**UTS**) is the same as the **breaking stress** for this sample. This indicates (shows) negligible reduction (necking) in cross-section and minimal ductility and malleability. It occurs at approximately 250 MPa.

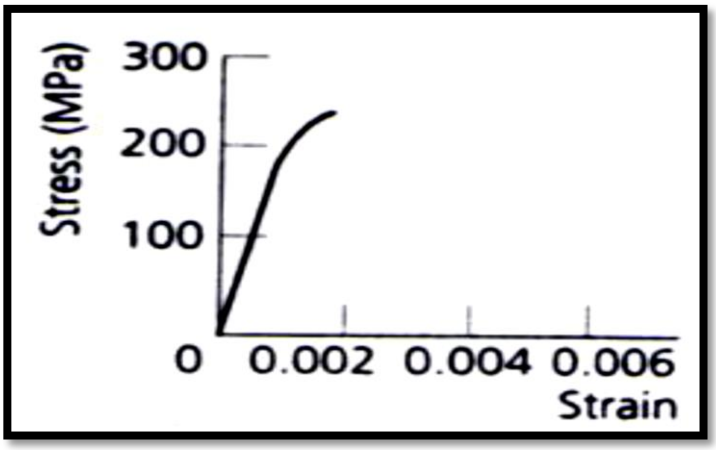

Figure 5. Typical stress-strain curve of grey cast iron (Brittle Material).

The **yield point**, however, is possibly of greater importance to the engineer than the tensile strength itself, so it becomes necessary to specify a stress which corresponds to a definite amount of permanent extension as a substitute for the yield point. This is commonly called the "**Proof Stress**", and is derived as shown in figure below.

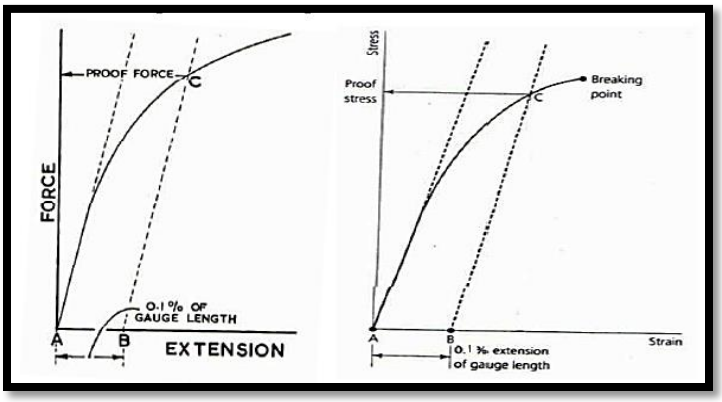

Figure6. Method used to obtain the 0.1 % proof stress.

A line **BC** is drawn parallel to the line of proportionality, from a predetermined point **B**. The stress corresponding to **C** will be the **proof stress** in the case explained it will be known as the "**0.1 % Proof stress**", since **AB** has been made equal to **0.1%** of the gauge length. The material will fulfil the specification therefore if, after the proof force is applied for **15** seconds and removed, a permanent set of not more than **0.1 %** of the gauge length has been produced. Proof lengths are commonly **0.1%** and **0.2%** of the gauge length, depending upon the type of alloy. The time limit of **15** seconds is specified in order to allow sufficient time for extension to be complete under the proffer force.

Figure **7** shows a typical stress-strain curve for a **wrought light alloy**. From this curve we can deduce (conclude) the following information:

1. The material has a **high level of ductility** since it shows a long plastic range.

2. The material is much less rigid than either low-carbon steel or cast iron since the slope of the initial plastic range is much less steep (sharp) when plotted to the same scale.

3. The limit of proportionality is almost impossible to determine, so the proof stress will be specified instead. For this sample a **0.2** per cent proof stress is approximately **500** MPa (the line AB).

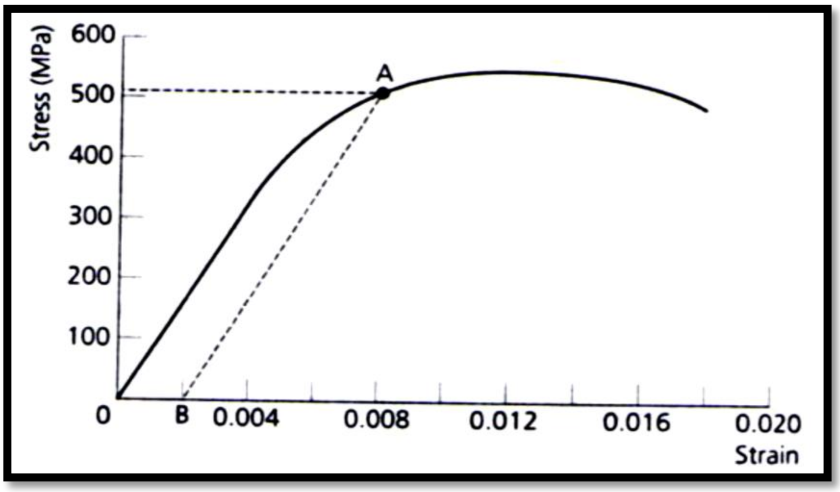

Figure 7. Typical stress-strain curve of a light alloy (Ductile Material).

It is important to determine the properties of **polymeric materials** which are may range from highly plastic to the highly elastic. As in figure 8, the stress-strain curves for polymeric materials have been classified in to five main groups by **Carswell** and **Nason**.

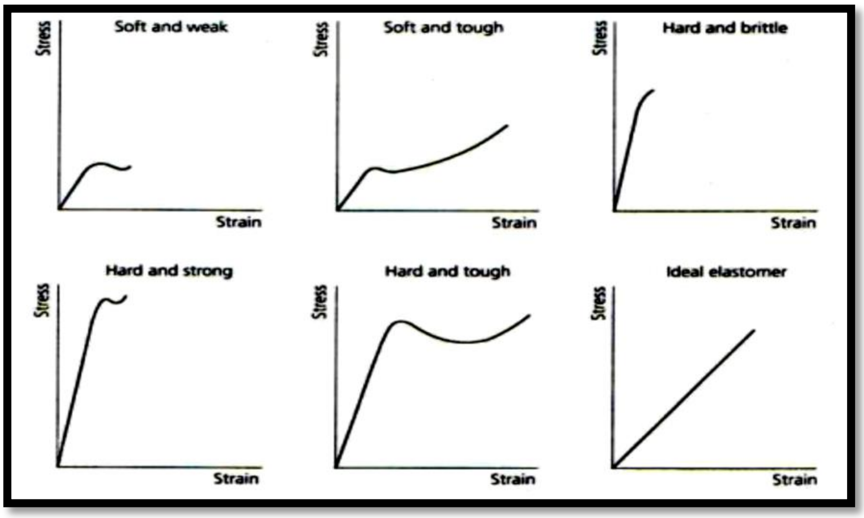

Figure 8. Typical stress-strain curves for polymers.

A tensile test can also yield other important facts about a material under test. For example, it can enable the elastic modulus (**E**) for the material to be calculated.

The physicist **Robert Hooke** found that within its elastic range the strain produced in a material is proportional to the stress applied. It was left to Thomas Young to quantify this law in terms of a mathematical constant for any given material.

strain α stress

therefore

stress / strain = constant (E)

This constant term (**E**) is variously known as **'Young's modulus'**, the **'modulus of elasticity**' or the **'tensile modulus**'. Thus:

$$E = \frac{\text{tensile or compressive stress}}{\text{strain}}$$

$$= \frac{\text{(force)/(original cross-sectional area)}}{\text{(change in length)/(original length)}}$$

Example.1

Calculate the modulus of elasticity (**E**) for a material which produces the following data when undergoing test: Applied load = **35.7 kN**, Cross-sectional area = **25mm^2**, Gauge length = **28 mm**, Extension = **0.2 mm**.

Solution

E = stress / strain

stress (σ)= 35.7 KN / 25 mm^2 = 1.428 MPa

strain(ε)= 0.2mm / 28mm = 0.007

Therefore

E = (35.7 ×28) / (25×0.2) = 199.92 kN/mm^2

= 200 GPa (approximately)

This would be a typical value for a low-carbon steel.

It was stated earlier that malleability and ductility are special cases of the types of plasticity.

1. **Malleability:** This refers to the extension (elongation) at which a material can undergo deformation in compression before failure occurs.
2. **Ductility:** This refers to the extension (elongation) at which a material can undergo deformation in tension before failure occurs.

All ductile materials are malleable, but not all malleable materials are ductile since they may lack the strength to withstand (resist) tensile loading.

Therefore, **ductility** is usually expressed, for practical purposes, as the percentage; **Elongation** in gauge length of a standard test piece at the point of fracture when subjected to a tensile test to destruction.

$$\text{Elongation \%} = \frac{\text{increase in length}}{\text{original length}} \times 100$$

The increase in length is determined by fitting the pieces of the fractured specimen together carefully and measuring the length at failure.

[Increase in Length = Length at Failure - Original Length]

Figure **9** shows a specimen for a **soft, ductile material** before and after testing. It can be seen that the specimen does not reduce in cross-sectional area uniformly, but that server local necking occurs prior to fracture. Since most of the plastic deformation and, therefore, most of the elongation occurs in the necked region, doubling (expanding) the gauge length dose (amount) not double (expand) the elongation when calculated as a percentage of gauge length. Therefore, it is important to use a standard gauge length if comparability between results is to be achieved.

Elongation is calculated as follows:

$$\text{Elongation \%} = \frac{L_u - L_o}{L_o} \times 100$$

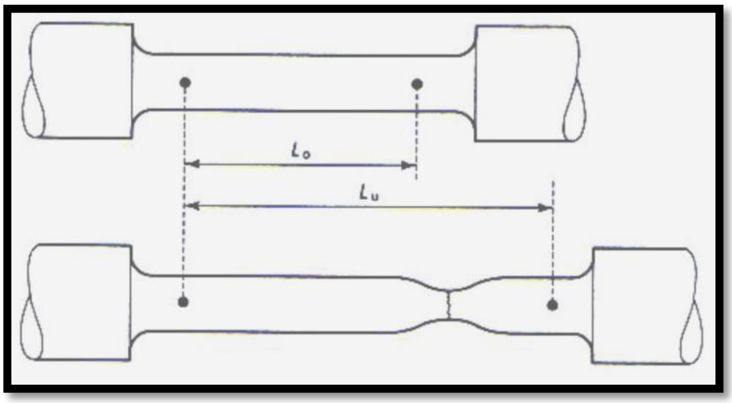

Figure 9. Elongation.

Example.2

Calculate the percentage elongation of a 70/30 brass alloy, if the original gauge length (L_0) is **56** mm and the length at fracture (Lu) is **95.2** mm.

Solution

$$\text{Elongation \%} = \frac{L_u - L_o}{L_o} \times 100$$

$$= \frac{95.2 - 56}{56} \times 100 = 70\ \%$$