Department of Water and Sewage Management and Waste Technology

Recycling

LABORATORY 5

Topic: STATIC TENSILE TEST, IMPACT TESTING OF ARTIFICIAL MATERIALS BY CHARPY HAMMER METHOD - STRENGTH TESTS

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1. Static tensile test - strength of plastics during breaking in a uniaxial stress state

It consists of uniaxial deformation of suitably prepared samples and measurement of the forces that arise. Such a test is one of the basic sources of information about the mechanical properties of plastics. The quantities measured in this test are deformation (elongation) and deforming force. Absolute elongation (delta l) is the difference between the final and initial length of the sample measuring section:

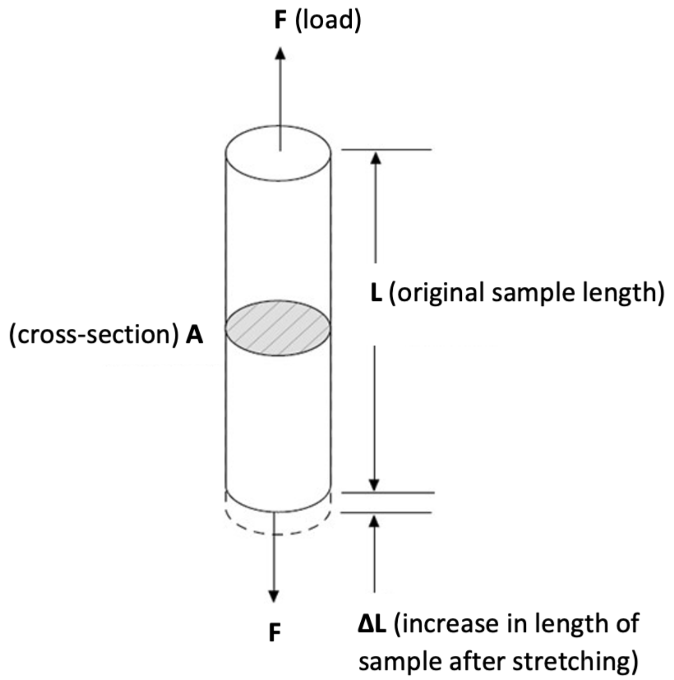

Figure 1. Schematic diagram of the distribution of forces and deformations in the sample [1]

Relative elongation is the ratio of the absolute strain to the initial length of the measuring section l_0:

$$\boldsymbol{\varepsilon} = \frac{\Delta \boldsymbol{l}}{\boldsymbol{l_0}}$$

Stress is most often defined as the ratio of the deforming force to the initial tensile cross-sectional area of the sample, measured before the load is applied.

$$\boldsymbol{\sigma} = \frac{\boldsymbol{F}}{\boldsymbol{A_0}}$$

where: F - deforming force; A_0 - initial cross-sectional area

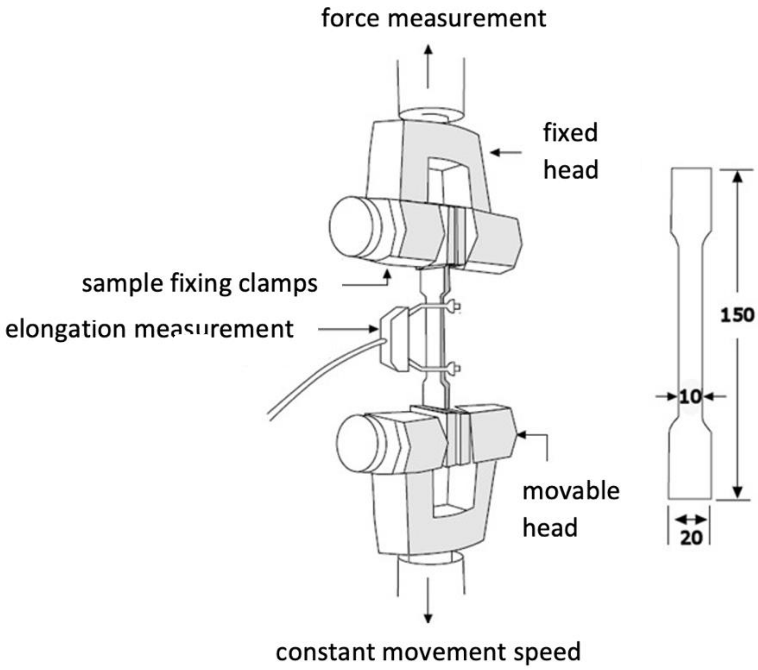

Figure 2. Schematic process of sample stretching [1]

The tensile strength is calculated using the formula:

$$\boldsymbol{R_m} = \frac{\boldsymbol{F}}{\boldsymbol{A_0}} \quad \left[\frac{N}{mm^2}, MPa\right]$$

where: F - maximum deforming force, A_0 - area of the initial cross-section of the measuring section

Tensile strength is therefore the maximum stress that a material can withstand during short-term static stretching.

Figure 3. LLOYD LR 10K testing machine with LLOYD TC540 thermal chamber

The quantities measured directly during the tensile test are: **elongation ε** and **deformation force F**. The absolute elongation Δl_x is defined as the difference between the final and initial length of the measuring section of the used sample.

$$\Delta \boldsymbol{l_x} = \boldsymbol{l_x} - \boldsymbol{l_0}\ [\boldsymbol{mm}]$$

where: l_0 – initial length of the measuring section [mm], l_x – final length of the measuring section [mm].

Relative elongation ε_x is the absolute deformation expressed as a percentage of the initial length of the measuring section.

$$\boldsymbol{\varepsilon_x} = \frac{\Delta \boldsymbol{l_x}}{\boldsymbol{l_0}} \cdot \mathbf{100}\ [\%]$$

Stress σ is the ratio of the deforming force to the initial cross-sectional area of the tensile sample, measured before applying the load.

$$\boldsymbol{\sigma} = \frac{\boldsymbol{F}}{\boldsymbol{A_0}}\ \ [\boldsymbol{MPa}]$$

where: F – deforming force [N], A_0 – initial cross-sectional area, [mm^2]

As a result of the measurement, a graph σ = f(ε) is obtained, which allows to follow the behavior of the material subjected to tension during the entire test. The schematic graph of tension is shown in Figure 4.

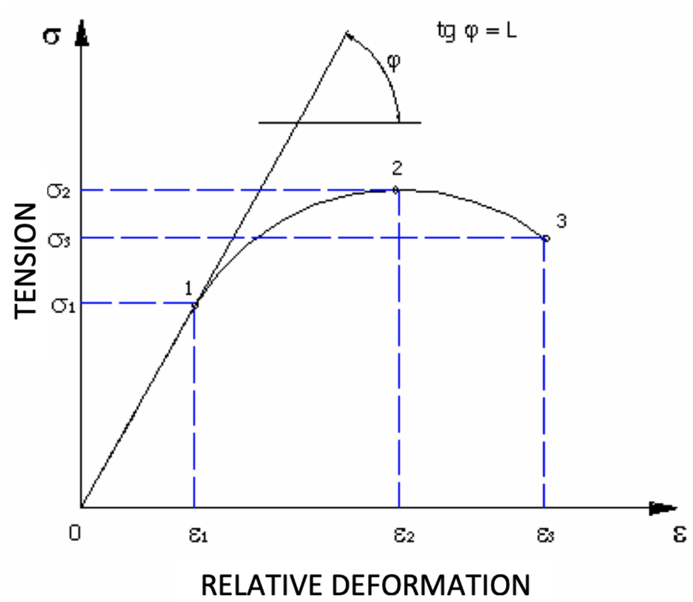

Figure 4. Schematic diagram of the stretching of plastic mixtures

The maximum stress recorded during stretching σ is the so-called. The immediate tensile strength. It corresponds to the elongation ε_2. The maximum elongation observed during stretching ε_3 is called the relative elongation at break. The ordinate of the point, i.e. the stress observed at the moment of sample breakage is called the breaking stress σ_3. The presented graph illustrates the plastic-brittle behavior of many materials and is also typical for polymer blends.

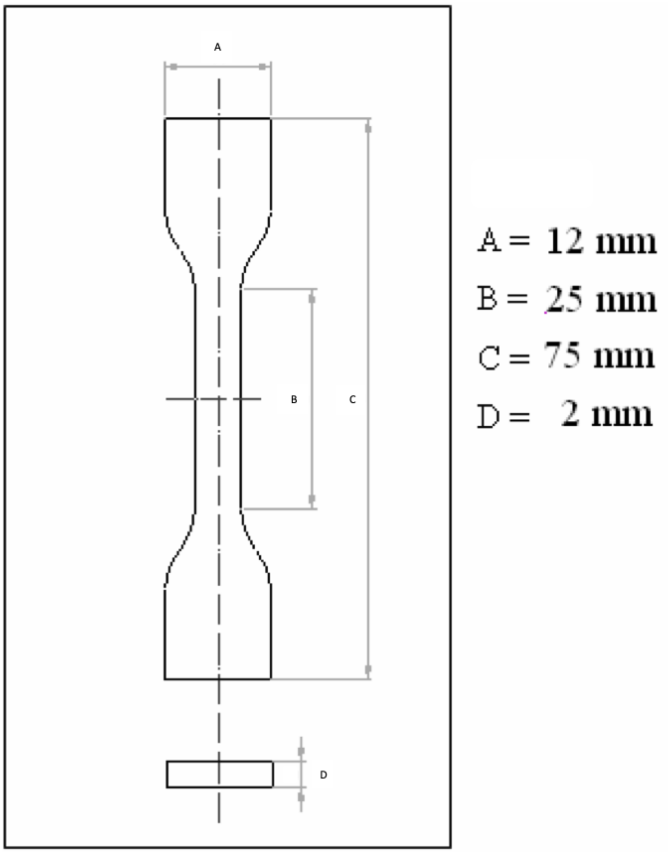

Figure 5. Dimensions of samples for strength tests

During the tests, the following are determined:

- Young's modulus, the modulus of longitudinal elasticity, characterizes the deformability of the material [MPa].
- Stress at break, the ratio of the force applied to the cross-section of the sample at the moment of its break [MPa].
- Elongation at break, specifying the percentage by which the sample will elongate in relation to the measurement base until it breaks [%].
- Maximum stress, the ratio of the maximum force applied to its cross-section of the sample [MPa].
- Elongation at maximum load, i.e. the percentage elongation of the sample at the moment of applying the greatest force [MPa].

2. Charpy impact test

Impact strength is a measure of the brittleness of materials defined by the energy required to dynamically fracture the sample and related to the size of the cross-section of the sample (profile). Impact strength α_c is expressed as the quotient of the impact energy absorbed during fracture of the profile and the initial cross-sectional area of the profile. Impact strength, depending on the type of profile, is calculated using the following formulas:

- impact strength of unnotched shapes:

$$\boldsymbol{a_{cU} = \frac{E_c}{h \cdot b}};$$

- impact strength of notched shapes:

$$\boldsymbol{a_{cN} = \frac{E_c}{h \cdot b_N}}$$

where: E_C [J] – corrected energy absorbed at test specimen fracture, h [mm] – thickness of the test specimen, b [mm] – width of the test specimen, b_N [mm] – remaining width of the test specimen with the notch.

Impact strength is expressed in **kJ/m^2**, which numerically corresponds approximately to the formerly used unit $kGcm/cm^2$. The latter value gives a better idea of impact strength as the work of breaking a beam with a 1 kg weight falling on a beam with a cross-section of 1 cm^2 from a height of 1 cm. The unit J/cm^2 is also commonly used [2].

Charpy impact strength is determined using devices called pendulum impactors. The method consists in striking a test specimen in the form of a beam, supported near its ends and placed horizontally, with a single blow of an impact hammer in the middle between the supports and bending at a high, nominally constant speed. Charpy impact tests allow determining the work required to destroy a sample of a standard shape in a very short time. In order to concentrate stresses, it is therefore permissible to cut an appropriate notch into the sample. The standards used for this device (DIN 53453, ISO 179, ASTM D 5942, ASTM D 256, BSI 2782-359).

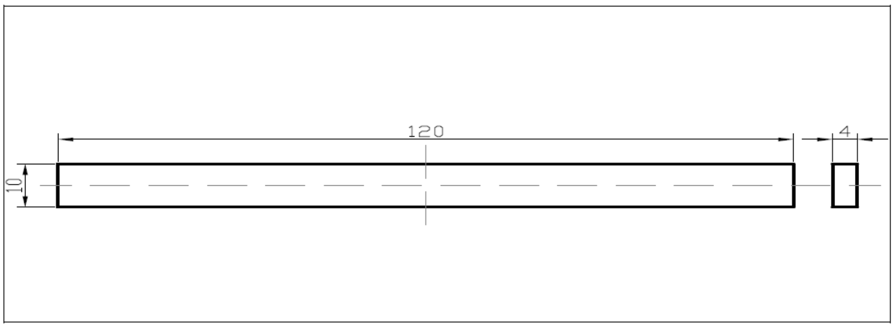

Figure 3. Dimensions of impact test samples

The results obtained during impact bending with a notch are comparable with the results obtained when testing samples with the same dimensions and notch shapes under the same conditions. Impact strength is therefore a conventional comparative index. Contrary to static tension, the plastic deformation of the sample is minimal.

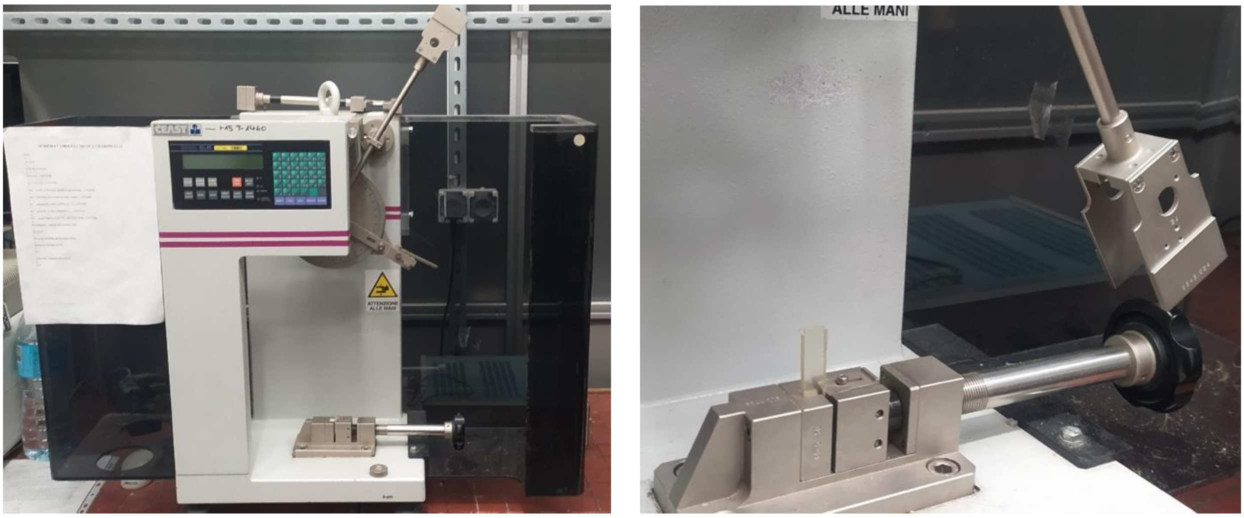

Figure 4. CEAST RESIL 5.5 impact hammer

3. References:

[1] http://www.tworzywa.pwr.wroc.pl
[2] http://www.kkiem.agh.edu.pl