



## THE TEMPERATURE INFLUENCE ON SELECTED MECHANICAL PROPERTIES OF PET MATERIAL

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### **Abstract:**

*Plastic bottles are one of the most custom packing materials in market. The contribution deals about the analysis of changes of mechanical properties changed by influence of temperature of selected PET bottles as incoming plastic waste. The low temperature simulates the cold weather in winter and the high temperature simulates the hot weather in summer. To find out changed mechanical properties of PET bottles was made the tensile test where were defined certain parameters. Achieved values of selected mechanical properties – yield strength, tensile strength and relative elongation were compared with the measured values in natural (standard) environment.*

### **Keywords:**

*PET bottles, tensile test, degradation, mechanical properties.*

## **INTRODUCTION**

Nowadays the plastics are one of the most used material which is capable to replace the products of wood, glass, metal or ceramic. It is evidenced by their wide application in households or in different sectors of industry. Plastic products are after ending of their life-time transferred into waste which with its effects is the burden on the environment.

One of the most popular plastic product and also plastic waste is the plastic bottle. Plastic bottles have the wide using as packaging for nonalcoholic drinks, also for food oils and motor oil.

The time of natural decomposition of one plastic bottle is about 450 years. This process is supported by sun radiance, principally by ultraviolet radiance. Next one is the rain, temperature, wind and other weather factors. There is appreciable impact of chemicals and also mechanical aspects acting on the waste.

Plastic waste is generated in the production and processing of plastics as production waste and processing waste as well as municipal waste. The consumption of plastics is increasing every year in Europe about 3% – 5%. The global consumption of plastics increased in 1939 from one million ton up to 250 million ton in 2005 – Figure 1. [1], [2]

From 2009 to 2010 the global production of plastics increased by 15 million tonnes (6%) to 265 million tonnes, confirming the long term trend of plastics production growth of almost 5% per year over the past 20 years. In 2010 Europe accounted for 57 million tonnes (21.5%) of the global production and China overtook Europe as the biggest production region at 23.5%. [2]

The plastics industry also plays an important role in enabling growth through innovation in a wide range of key European industries such as automotive, electrical and electronic, building and construction and food and beverage sectors. [2]

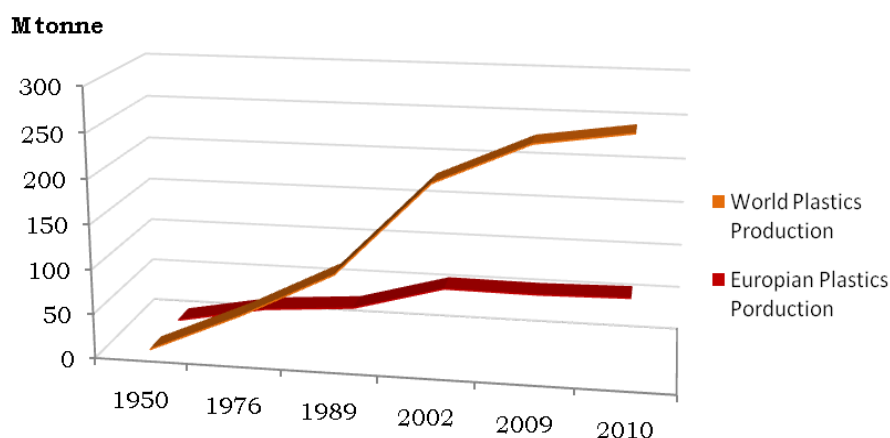


Figure 1: World plastics production in years 1950-2010 [2]

The most popular thermoplastic polyester nowadays is polycondensate terephthalic acid and ethylene glycol – the polyethylene terephthalate (PET). Much chemical resistance of PET is given by its organized structure. [1], [3]

Very important products of PET are fibers and foils. They have great resistance to abrasion, chemicals, weathering, aging and they are dimensionally stable. Polyethylene terephthalate fibers are used in production of industry fabric and textile fabric. The possibilities of using of PET material in practice is shown at Figure 2. [1]

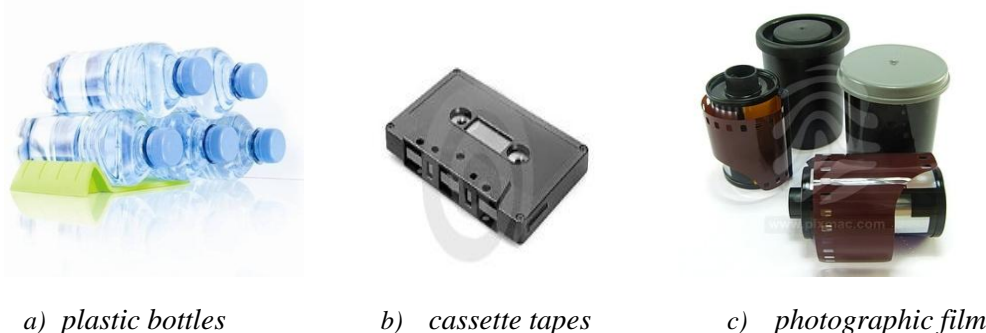


Figure 2: Possibilities of using of PET material in practice

*Degradation* of plastics is possible to define like a file of physical and chemical processes ongoing at plastics and leading gradually to irreversible changes of their properties. We know *natural* and *artificial* degradation. By *natural degradation* we understand slow change of plastics properties by effect of the light, air, carbon dioxide and the water. At first, these changes limit the using of product and finally, they make it impossible at all. In the most of plastics aging is manifested by yellowing and increased fragility. The main cause of deteriorating of plastics properties and truncating their life are physical, physically-chemical and chemical influence of environment and also the biological degradation of polymers. The *artificial degradation* is defined as degradation of plastic at artificial conditions [4], [5].

Degradation is limited by life of product. The durability of material is the time, during which are important properties kept on the specified level, which is enough for the right function of product. It depends on material properties and conditions of product use. The self-degradation of polymers can be in progress in the cause of exposition of surface of polymers at sunlight, temperature, cold, chemical compounds or microorganisms. The polymer surface can be corrupted by next diffusion of external

environment into polymer. Polymer can react with the environment. Because of reactions the diffusion products can occur at polymer's surface or they can be released into the environment [6], [7], [8].

Polymers are very heat sensitive. This sensitivity is caused by weak strength of covalent bonds which create the polymer structure. The effect of increased temperature of polymers can show in two ways. The first one is the softening of polymer or increasing the kinetic energy from received heat up to overcoming the attractive forces and after that the polymer behaves as a liquid. The second one is the structure change of polymer. Some polymers are broken down into low molecular products or into monomers without chemical change of structure – they depolymerize. [6], [9]

## MATERIALS AND METHOD

In experiments were used the plastics bottles mainly made from PET material. To production of test samples were chosen two types of used plastics bottles with different thickness and color. First group obtains transparent bottles with thickness about 0,16 mm (marked like white PET), second group obtains colored green PET bottles with thickness about 0,27 mm (marked like green PET). From PET bottles were made by shearing the test samples in size 200 x 20 mm in 5 pieces in other environment and exposition in hot environment and cold environment.

Natural environment – test samples were saved in laboratory before test in test conditions, by the temperature  $20 \pm 2$  °C. Five test samples were exposed in environment with low temperature for simulation environment in winter. Five test samples were exposed in environment with higher temperature for simulation environment in summer.

For simulation of environment in summer the test samples were exposed in environment with higher temperature  $50 \pm 2$  °C. For simulation of environment in winter the test samples were exposed in environment with lower temperature  $-20 \pm 1$  °C. The test samples were positioned in all environments and exposed for 7 days, 14 days and 21 days (168 hours, 336 hours and 504 hours). This temperature was measured by contactless method by the type of pyrometer IRtec MicroRay HVAC – Figure 3. After individual days of exposition the static tensile test was made for test materials.



*Figure 3: The pyrometer IRtec MicroRay HVAC*

The main test to determine the mechanical properties – tensile test was chosen from spectrum of tests. In experiments was proceed under standard for finding tensile properties of plastics STN EN ISO 527-1 (64 0605). Tensile test was made by tensile test machine TIRA – test 2300 – Figure 4.

Every test sample from natural environment and after selecting from degradation environments was caught in jaw of tensile machine and by speed of transom in 20 mm/min it was tested until breaking. It was on mind by catching then axis of test sample was the same as tensile direction. On Figure 4 there

is the sample in jaw of tensile machine during tensile test. After breaking test sample, the machine evaluated strength characteristics (yield strength, tensile strength and relative extension) by program.



Figure 4: The tensile test machine

## RESULTS

The results from tensile test are noticed and created in graphs.

### Natural environment

Measured and calculated values of tensile test – yield strength ( $\sigma_Y$ ), tensile strength ( $\sigma_M$ ) and relative extension ( $\epsilon_M$ ) – from natural environment are given on Figure 5.

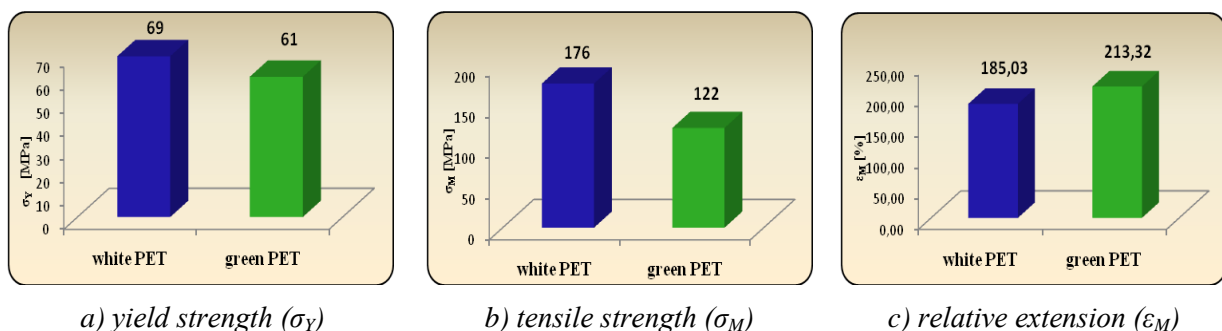


Figure 5: The average values of tested samples in natural environment

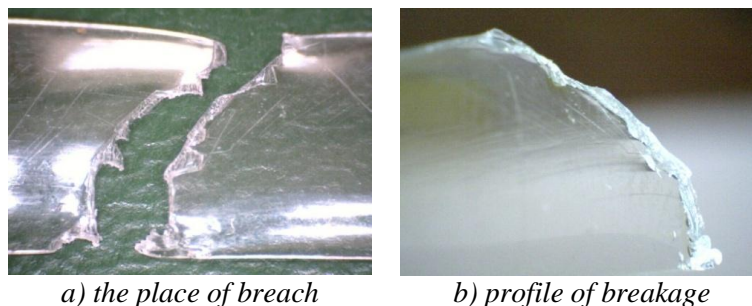
The breach of tested sample from natural environment and the detail of breach after done tensile test on this material are on Figure 6 and Figure 7.

Under experimental test for tensile properties determination of tested materials from natural environment was given next conclusion:

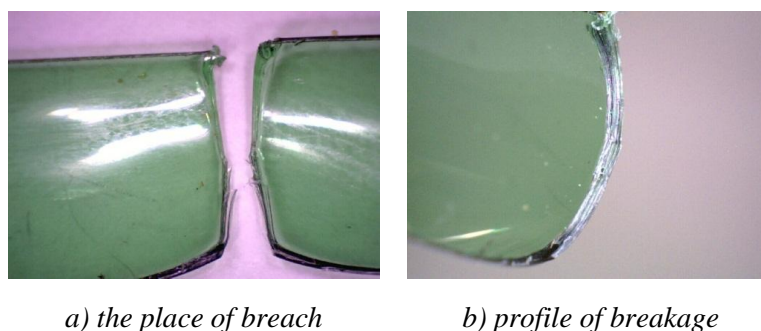


- The yield strength value of green PET material has slightly decreasing tendency against white PET material, about 10,30 %.
- The tensile strength value of green PET material is about 30,70 % lower than white PET material.

The relative extension value of green PET material was about 13,30 % higher value than white PET material.



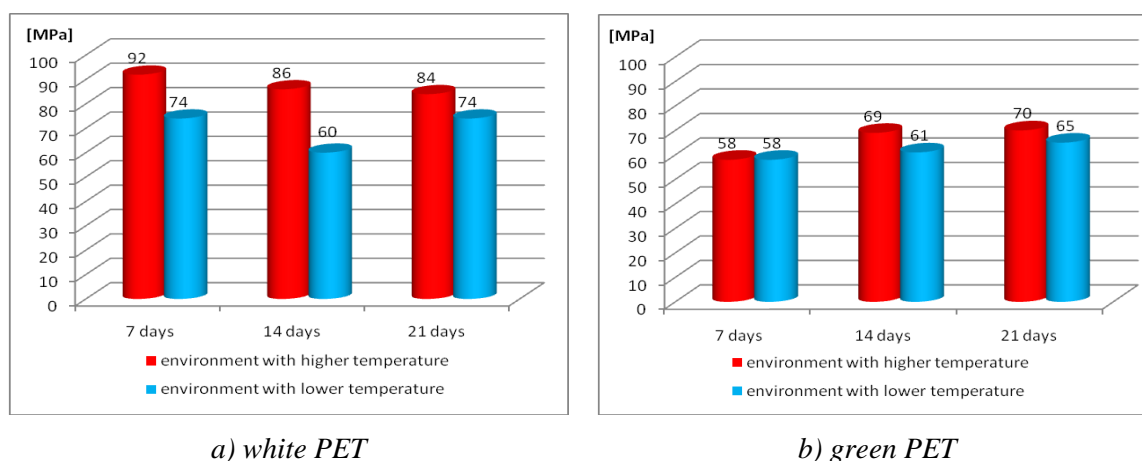
*Figure 6 The breach of tested sample white PET in natural environment*



*Figure 7 The breach of tested sample green PET in natural environment*

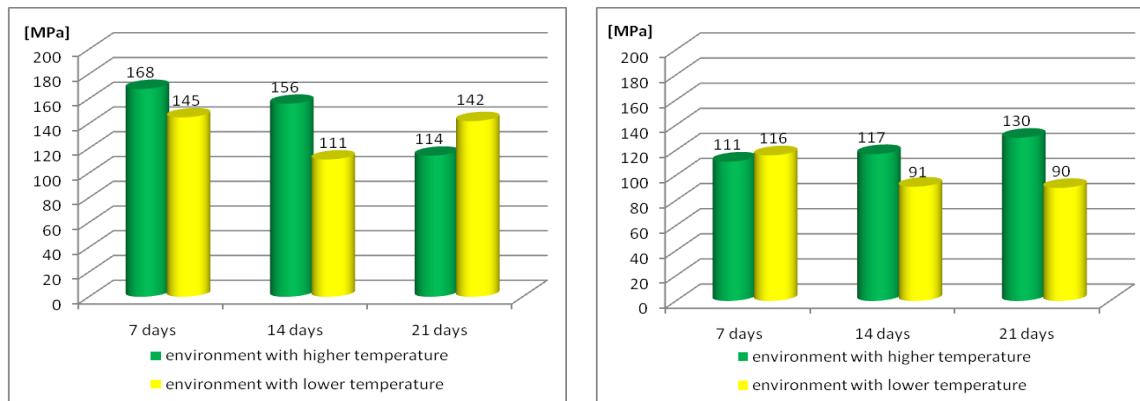
### **Environment of higher temperature and environment of lower temperature**

The measured and calculated values from tensile test – yield strength ( $\sigma_Y$ ) – from environment of higher temperature and also from environment of lower temperature are given on Figure 8.



*Figure 8 The average values of yield strength of white PET and green PET*

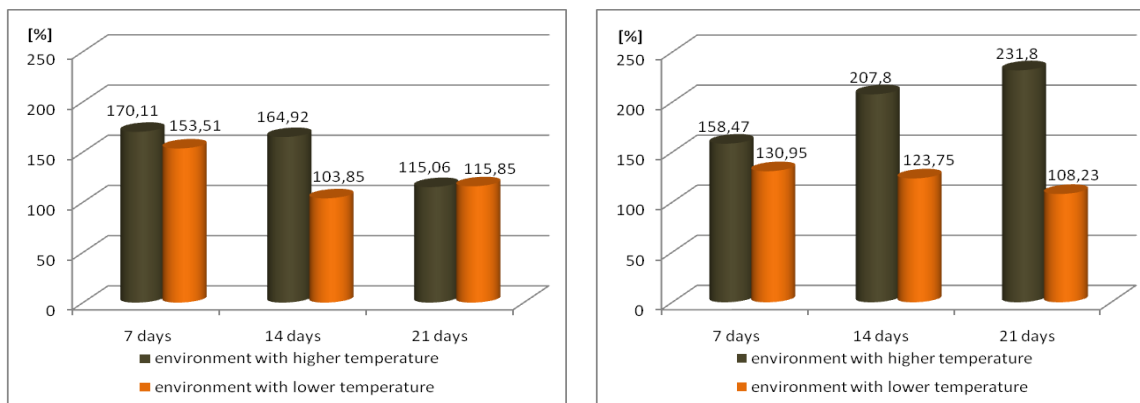
The comparison of values of tensile strength ( $\sigma_M$ ) measured by tensile test from environment of higher and lower temperature is shown on Figure 9.



*a) white PET* *b) green PET*

*Figure 9 The average values of tensile strength of white PET and green PET*

Figure 10 shows the relative extension ( $\epsilon_M$ ) values from tensile test of environment of higher and lower temperature.



*a) white PET* *b) green PET*

*Figure 10 The average values of relative extension of white PET and green PET*

Under experimental test for tensile properties determination of tested materials from environment with **higher** temperature and from environment with **lower** temperature were given next conclusions:

PET material – white:

- The yield strength value of exposed material to higher temperature was about 6,5 % lower after 14 days of exposition and after 21 days of exposition was about 8,7 % lower in comparing with the measured value after 7 days of exposition.
- The yield strength value of exposed material to low temperature was about 18,9 % lower after 14 days of exposition in comparing with the measured value after 7 days of exposition, and after 21 days of exposition the value was the same as the measured value after 7 days of exposition.

- The tensile strength value of exposed material to higher temperature after 14 days of exposition was about 7,1 % lower and after 21 days of exposition was about 32,1 % lower in comparing with the measured value after 7 days of exposition.
- The tensile strength value of exposed material to low temperature after 14 days of exposition was about 23,4 % lower and after 21 days of exposition was about 2,1 lower in comparing with the measured value after 7 days of exposition.
- The relative extension value of exposed material to higher temperature after 14 days of exposition was about 3,1 % lower and after 21 days of exposition was about 32,4 % lower in comparing with the measured value after 7 days of exposition.
- The relative extension value of exposed material to low temperature after 14 days of exposition was about 32,3 % lower and after 21 days of exposition was about 24,5 % lower in comparing with the measured value after 7 days of exposition.

PET material – green:

- The yield strength value of exposed material to higher temperature was about 19 % higher after 14 days of exposition and after 21 days of exposition was about 20,7 % higher in comparing with the measured value after 7 days of exposition.
- The yield strength value of exposed material to low temperature after 14 days of exposition was about 5,2 % lower and after 21 days of exposition was about 12,1 % higher in comparing with the measured value after 7 days of exposition,
- The tensile strength value of exposed material to higher temperature after 14 days of exposition was about 5,4 % higher and after 21 days of exposition was about 17,1 % higher in comparing with the measured value after 7 days of exposition.
- The tensile strength value of exposed material to low temperature after 14 days of exposition was about 21,6 % lower and after 21 days of exposition was about 22,4 % lower in comparing with the measured value after 7 days of exposition,
- The relative extension value of exposed material to higher temperature after 14 days of exposition was about 31,1 % higher and after 21 days of exposition was about 46,3 % higher in comparing with the measured value after 7 days of exposition.
- The relative extension value of exposed material to low temperature after 14 days of exposition was about 5,5 % lower and after 21 days of exposition was about 17,4 % lower in comparing with the measured value after 7 days of exposition.

## CONCLUSION

The tested samples of both types tested PET material show interesting mechanical properties. While by white PET material exposed to higher temperature the values of mechanical properties decrease with increasing time exposition, by green PET material exposed to higher temperature get to increasing values of mechanical properties with increasing time exposition.

The environmental degradation of low temperatures caused the change of mechanical properties of test samples from green PET. The environment at low temperatures with increasing duration of exposure show increasing yield strength and reduction of yield strength and elongation. Test samples of white PET show significant changes in mechanical properties.

The increasing quantity of plastics waste relates to problems in environment and with health problem of population. As we know recycling is processing used materials into new products to prevent waste of potentially useful materials. It saves starting materials and also energy needed to produce new products. Under this results we can state than this materials is possible to recycle again because of it was not refer negative deterioration of mechanical properties of tested materials.

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