POLYMER COMPOSITES WITH FIBER REINFORCEMENT

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Abstract: *Polymers are used in every walk of life now-a-days. They are not even hundred years old but playing significant role in every sector of life such as sports, defense, medical, automobile, electrical, agricultural etc. In the beginning, polymers were considered as excellent insulators but conductive polymers are available now. Polymers have good water resistance but some polymers are good absorber of water. The present article deals with monitoring the changes in the mechanical properties of composites with polymer matrix. The composite was formed from the PA matrix and glass fibers. The mechanical properties, impact strength (Charpy) and micro-hardness (Vickers) were evaluated on samples of the composite before and after UV radiation on the sample.*

Keywords: POLYMER COMPOSITES, IMPACT STRENGTH - CHARPY , VICKERS MICRO-HARDNESS, GLASS FIBERS

1. Introduction

The mechanical behavior of polymers is dependent on many factors, including polymer type, molecular weight, and test procedure. Modulus values are obtained from a standard tensile test with a given rate of crosshead separation. In the linear region, the slope of a stress-strain curve will give the elastic or Young' s modulus E. Polymeric material behavior may be affected by other factors such as test temperature and rates. This can be especially important to the designer when the product is used or tested at temperatures near the glass transition temperature where dramatic changes in properties occur [1, 2,].

The term fillers refers to solid additives that are incorporated into the plastic matrix. They are generally inorganic materials and can be classified according to their effect on the mechanical properties of the resulting mixture. Inert or extender fillers are added mainly to reduce the cost of the compound, while reinforcing fillers are added to improve certain mechanical properties such as modulus or tensile strength. Although termed inert, inert fillers can nonetheless affect other properties of the compound besides cost. In particular, they may increase the density of the compound, reduce the shrinkage, increase the hardness, and increase the heat deflection temperature. Reinforcing fillers typically will increase the tensile, compressive, and shear strengths, increase the heat deflection temperature, reduce shrinkage, increase the modulus, and improve the creep behavior. Reinforcing fillers improve the properties via several mechanisms. In some cases, a chemical bond is formed between the filler and the polymer, in other cases, the volume occupied by the filler affects the properties of the thermoplastic. As a result, the surface properties and interaction between the filler and the thermoplastic are of great importance. A number of filler properties govern their behavior. These include the particle shape, the particle size and distribution of size, and the surface chemistry of the particle. In general, the smaller the particle, the greater the improvement of the mechanical property of interest (such as tensile strength). Larger particles may give reduced properties compared to the pure thermoplastic. Particle shape can also influence the properties. For example, plate-like particles or fibrous particles may be oriented during processing. This may result in properties that are anisotropic [3]. The surface chemistry of the particle is important to promote interaction with the polymer and to allow for good interfacial adhesion. It is important that the polymer wet the particle surface and have good interfacial bonding so as to obtain the best property enhancement. Examples of inert or extender fillers include china clay (kaolin), talc, and calcium carbonate. Glass spheres are also used as thermoplastic fillers. They may be either solid or hollow, depending on the particular application. Talc is a filler with a lamellar particle shape. Carbon black is used as a filler primarily in the rubber industry, but it also finds application in thermoplastics for conductivity, UV protection, and as a pigment. Fillers in fiber form are often used in thermoplastic. Types of fibers include cotton, wood flour, fiberglass, and carbon. Table 1 shows the fillers and their forms [4,5].

Table 1: *Forms of various fillers*

Spherical	Lamellar	Fibrous
Sand/quartz powder	Mica	Glass fibres
Silica	Talc	Asbestos
Glass spheres	Graphite	Wollastonite
Calcium carbonate	Kaolin	Carbon fibers
Carbon black		Whiskers
Metallic oxides		Cellulose
		Synthetic fibers

2. Experimental methods and materials

As an experimental material was used a composite of polymeric matrix (PA + PAI) and filler (glass fiber). The glass fiber strand have manufacturing marking GF 672, fiber diameter is 10 μm and the fiber length of 4 mm. They were supplied by three types of composite to be different in filler loading (10 %, 20 % and 30 %). It is a modern material that should be used in interior and exterior of cars. It should also resist UV radiation due to the addition of UV stabilizers. The experimental implementation of mechanical and thermal tests, samples in the form of rods and paddles which were produced from the granules of the polymer injection molding technology.

Testing degradation of polymeric materials is one of the most important tests to the lifetime of polymer product. Ageing tests can be either in real conditions of use of the polymer in a particular application, or using artificial accelerated ageing conditions. Accelerated ageing methods provide test results significantly faster natural aging tests. Testing is based on exposing test bars to man-made climate. After a fixed interval of exposure changes are detected in end points (aesthetic, physical, electrical, etc.). The apparatus for man-made weather ageing (Fig. 1) ensure continued maintaining of artificial climatic conditions (day and night cycles, changing humidity, drought and wet, etc.) [6,7].

Fig. 1 *SolarBox 1500 E with flooding*

A source of light radiation guarantees a radiant flux of radiation intensity 550 W m^{-2}. The source of light is a xenon arc lamp, but other sources of radiation are allowed too. The device must be equipped with a thermometer built into the black panel, which senses the temperature of the black panel. The black panel temperature of exposure time was selected at 65 °C, the liquid phase lasted for 102 minutes and the wet phase for 18 minutes. If it necessary wetting by distilled or deionised water can be applied. The numbers of man-made climate factors that simultaneously affect the test bars is selected by the test program. Test runs continued for a period fixed in the testing program. The duration of the test was 750 hours.

3. Results and discussion

The test samples were evaluated by the selected mechanical parameters (impact strength - Charpy and micro-hardness - Vickers) regarding the effects of UV radiation. The same parameters were assessed after 1 run, 750 hours of UV radiation acting on the sample. The test also included evaluation of the structure and changes in the structure before and after UV irradiation.

Samples for the structure test were embedded in Bakelite in the first step and then cut and polished. Grinding of the samples was carried out using the device Struers Tegra Pol-15 under a program designed for polyamides. SiC abrasive paper with grain size 500, 1 200 and 4 000 was used for grinding. Each grit sandpaper was used to grind the sample for 1 minute. Grinding was followed by polishing using Mol plate for 3 minutes. This was followed by 2 minute polishing with Nap-B, and finally polishing was finalized using wet disc and Chem-OP-S (diamond slurry) for 1 minute. The samples prepared in the above-mentioned way were evaluated for structure changes by light microscope Neophot 32.

The test took place at a temperature of 23 ° C (23 ± º2C). The hammer, which rotates about its axis was placed in the initial position and the shift indicator is set to the scale also pointed position. In the lowest position the hammer and also the place with the fastest speed on two supports placed sample without a notch. At the moment of the breakout indicator sample is transferred to a certain amount, which is read directly the value of the energy needed to puncture the sample. The samples were appropriately adjusted before the measurement such that the surface is smooth and unnotched. The samples had the following parameters: width: 10 mm, thickness: 4 mm and a length of 80 mm. Results of measurements are shown in Figure 2.

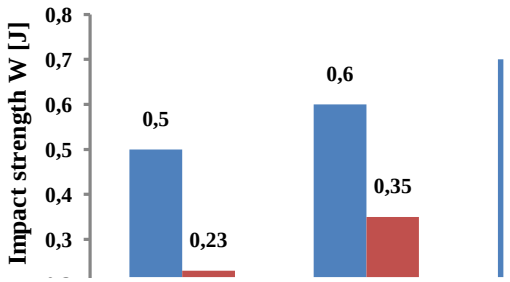


Fig. 2 *Effect of UV radiation on the change of impact strength*

The results show that the impact resistance to the most impact volume of glass fibers, wherein the amount of the impact strength values increase. The values of impact resistance by the action of UV radiation halved. One of the important properties of the polymer material, and the impact strength, which is a combination of strength, plasticity, and durability of the material. When polymers mechanical resistance is dependent on the speed with which a force is applied to the material. At lower speeds the polymer occurs to a relatively large deformation, while at higher speeds has a brittleness of the material, because the mechanical energy is not enough to dispose the material. Because of this feature, the polymer is gradually becoming a better design choice for a variety of applications.

Microhardness testing was carried out using equipment ZHVμ Micro Vickers. This durometer allows the measurement in the range of 0.01 to HV HV2 with motor load variations to the steps 10, 25, 50, 100, 200, 300, 500, 1000, 2000 (gf). The model is controlled by a PC software High Definition (HD) device includes 4 lenses of the microscope's built, the sliding base that allows you to move in the x, y, z. The image is captured by the camera and evaluated software where digital screen displays the results. The test force can be selected on the control panel, load change takes place automatically. The software for the conduct of the test, and the processing is able to completely control the parameters of the contamination of the test sample, view the progress of force and depth of the indentation with respect to time, and the like. An important feature in this case is the ability to directly evaluate the microhardness (HV) of the material.

Test conditions:

- The temperature of the experiment is from 10 ° C to 30 ° C.
- Load force used must be to measure the micro hardness less than 2 N.
- The test specimen is placed on the test solid, a solid support so as to not move during the test.
- The load is perpendicular to the sample surface, without shocks and vibrations.
- The period from the beginning of loading for achievement test force shall not be less than 2 seconds and longer than 8s.
- Duration of the test force is in the range of 10 to 15 seconds.

Results of measurements are shown in Figure 3.

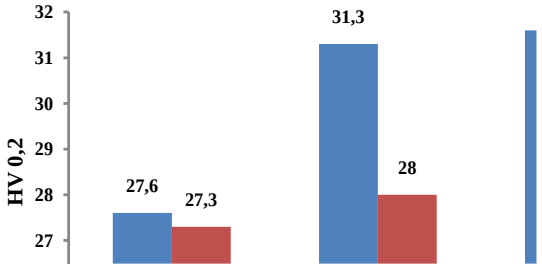
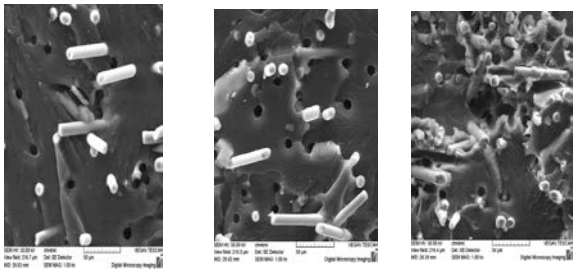


Fig. 3 *Microhardness HV*

In practice, very often enhanced hardness is an important complementary method to determine the mechanical properties of materials. Hardness can be defined as material resistance against penetration of a foreign body into its surface. The hardness of not one of the physical quantities, the resulting value is dependent on the complex surface properties of the material and the conditions in which measurements are taken. Measurement of hardness and polymer composites, and has specific differences in contrast to other materials. Since polymeric materials have a certain proportion of elastic deformation, and can be said to plastics in general, "flexible", not all methods are suitable for measuring the hardness.

From the measured results show that the total microhardness depends mainly on the amount of glass fibers. For materials with a hardness of 30% it is the highest, but where it also depends on it, at which point exactly measurement made, whether it is the place where is worth more glass fibers, or is this polymer matrix. The largest differences in microhardness are especially at 10% volume glass fibers, that is where most of the matrix to which the UV radiation is the most evident effect and microhardness reduced to a small extent.

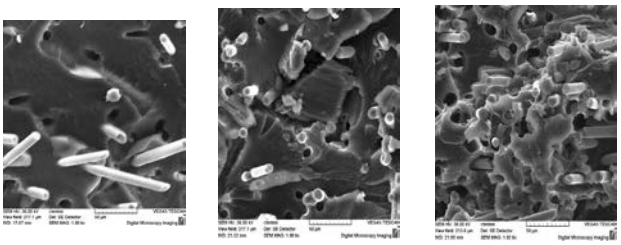
The experiment also included evaluation of the structure of the composite PA + GF before and after UV irradiation by a electron microscope (SEM). Used accelerating voltage should exceed 30 kV, and magnification was 1000x. We monitored homogeneity of the composite, the manner of distribution of glass fibres in the polymer matrix, and cracking caused by UV radiation.



a) 10 % GF b) 20 % GF c) 30 % GF

Fig. 4 *Composite structure with different filler content, 0 hrs. UV*

Observation of each image can be seen the amount and distribution of glass fibers in a polymer matrix, fiber and detail violation occurrence holes after removal fibers (Fig. 4b, 5b).



a) 10 % GF b) 20 % GF c) 30 % GF

Fig. 5 *Composite structure with different filler content, 750 hrs. UV*

The distribution of individual fibers is uneven, with the increased volume join together and form clumps. Fracture leads to an overall majority tearing fibers, as evidenced by the longer of pulling the fibers. The individual glass fibers after removal from the matrix, leaving regular oval holes (Fig. 4a, 5a), with a higher volume of glass fibers is made up of holes. Progressively with increasing volume of the fibers, but they have the irregular shaped holes (Fig. 5b).

The fibers in the smaller volume of draw out completely by the matrix, due to poor adhesion at the interface. At a higher volume of glass fiber matrix, however, the pieces remain stuck on a train (Fig. 4c, 5c). For prolonged UV exposure cracks appear, which gradually spread, as is well. The actual fracture of the sample also varies, whereas the 10% fiber volume is almost equal to, the volume of 30% is irregular and the surface of the polymer matrix layer.

4. Conclusions

Based on the experiments performed on composite PA + PAI with different content of the filler (GF) we can conclude:

- By measuring the micro hardness of the material is confirmed that the increasing volume of glass fibers increases the microhardness, the UV light had almost no effect on its value. Little effect was seen only in the sample containing 10% glass fiber where UV treated aggressively to die and caused a reduction in its hardness.
- In examining the impact strength material with an increasing volume of glass fibers increases. After UV irradiation, this value clearly decreased, although the figures are volatile and vary. This is due to the partial cross-linked polymer by the action of UV radiation.
- From the observation of the morphology of the composite show that the increased volume of glass fibers, the fibers form clusters and their distribution is uneven. Fracture, and irregularities are formed on the surface of the laminate of the matrix observed. The combination of UV radiation and higher glass fiber content rise to cracks, which gradually spread matrix. This caused a degradation of the matrix and the peeling in the form of flakes.

Acknowledgements

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