

UV DEGRADATION OF POLYMER-MATRIX COMPOSITES PA + GF

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Abstract: 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 composite contains 10 – 30 % glass fibers. The mechanical properties, tensile strength and flexural strength were evaluated on samples of the composite before and after UV radiation on the sample. The largest decline endpoints was recorded in 500 hours of UV exposure. Light microscopy was evaluated distribution of glass fibers in the polymer matrix and the presence of cracks caused by UV radiation.

Keywords: UV DEGRADATION, POLYMER-MATRIX COMPOSITES, MECHANICAL PROPERTIES, GLASS FIBERS

1. Introduction

Composite materials are composed of two or more chemically different components, of which at least one, referred to as matrix, is continuous. The second component is dispersed in the matrix and the filler is referred to as. Hybrid composites are materials which are formed of three or more components. The hybrid matrix comprises two types of polymers, hybrid filler is composed of two or more types of fillers. In addition to the filler and matrix composites contain a third component, referred to as the intermediate phase. The term intermediate phase is often wrongly confused with interfacial interface. In the past, some of the additives, fillers was glad because, like additives (e.g., stabilizers, flame retardants, lubricants, nucleating agents), and the fillers are added to polymers to improve their properties. However, while it is a priority task additives modify the physical and processing properties of polymers (viscosity, the proportion of crystalline phase, thermal stability and etc.), addition of fillers to polymers is followed primarily improve the mechanical. The resulting composite is therefore compared the original polymer matrix often diametrically different physico - mechanical properties. Depending on the type of composite, the filler content varies widely. While in polymer nanocomposites nano filler content generally does not exceed a few percent by weight (3-5% by weight), in the case of composite fiber it is much higher and may be up to 80-85% by weight. The selection of the filler, and the content in the composite is always facing in order to maximize the improvement of the desired properties [1, 2, 3].

Polymeric materials are perhaps the most sensitive to material changes in the chemical structure under external influences, and the resulting physical and especially the mechanical and chemical properties. The most significant factors that trigger the chain mechanism of chemical change in the polymeric material to UV light, heat, oxygen, and the presence of particular of ozone. To accelerate chemical degradation processes typically it contributes the mechanical stresses and the possible presence of chemicals, in particular organic solvents. Testing degradation of polymeric materials, generally well-established, the term aging of polymers, is one of the most important tests for estimating the life of the polymeric product. Ageing may be made either in real conditions of use of the polymer in a particular application, or use artificial accelerated aging conditions. Accelerated aging methods provide significantly faster test results than testing natural aging, because many times it is not possible to carry out tests of natural aging, especially for reasons of time. Test methods of susceptibility testing of polymeric materials degradation (aging) reflect the diversity of their application utilization, especially conditions in which the finished products will be used. It must also be taken into account the susceptibility of different types of polymers to each initiation of degradation mechanisms. Rubber products are generally more susceptible to degradation and thermooxidation the action of ozone, plastics, in particular polyolefins, are susceptible to ultraviolet radiation. When choosing a method for testing polymeric

material to be considered application area of the finished product as well as the characteristics of the polymer. It is utterly unrealistic to test the rubber seal under the heating element on the light stability, but it is necessary first to know its resistance to thermal, respectively. He thermooxidation action. Conversely, window profiles, it is necessary to test the light stability and should be considered as relatively high temperatures during the summer months. The components in the automotive industry have generally resist and ultraviolet radiation and high temperatures [4, 5, 6].

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 mm 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.)



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 $65 \text{ }^\circ\text{C}$, 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 500, 750 and 1000 hours.

3. Results and discussion

The test samples were evaluated by the selected mechanical parameters (tensile strength and hardness) regarding the effects of UV radiation. The same parameters were assessed after 3 runs (500, 750 and 1000 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.

A tensile test was performed using the device WDW 20. The speed of a moving jaw was set at $1 \text{ mm} \cdot \text{min}^{-1}$ with. The sample was pinned to the jaw and force was exercised in the longitudinal axis until the sample break. We measured the maximum force required to break the test samples. From the acquired data, we calculated the tensile strength, σ_M (Fig. 2).

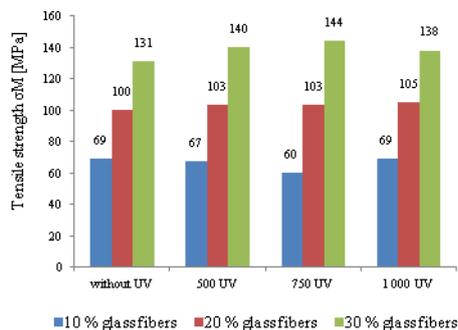


Fig. 2 Effect of UV radiation on the change in tensile strength

Figure 2 shows that the highest tensile strength of the composite is reached with 30% glass fiber content on the other hand the smallest tensile strength composite with a filler content of 10%. It follows that the strength characteristics of the composite depends mainly on the content and distribution of the glass fibers in the polymer matrix. UV radiation is the strength values did not change significantly. The filler content of 10% of the original σ_M was 69 MPa after 500 and 750 hours exposure to UV radiation σ_M slightly decreased at 67 and 60 bar, but under the action of UV radiation for 1000 hours, the σ_M returned to the original value of 69 MPa. At 20% and 30% filler content, the strength values slightly increase. Since a partially crystalline PA, stroke causes the chains straighten it, undergoing its subsequent solidification. And we can also say that UV radiation can cause partial crosslinking chains and therefore also with increasing UV exposure increases the strength characteristics of the composite.

Hardness test was conducted durometer INNOVATEST NEXUS 3002XLM-INV1. Loading force was set to 250 kP, injection time was 10 seconds and the indentation diameter balls of 5 mm. Measured by the average of the indentation beads. The microscope was counted using a scale diameters which are

perpendicular to each other, then the resulting hardness was calculated. Each sample was made 5 measurements. The final hardness is shown in Figure 3.

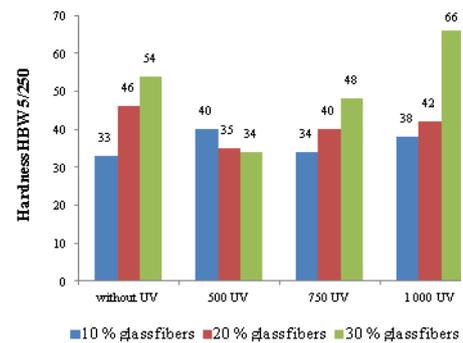


Fig. 3 Effect of UV radiation on the change in hardness

Hardness (HBW) of the composite depends mainly on the content and distribution of the glass fibers in the polymer matrix. HBW largest composite reached the 30% filler loading, whereas in the matrix occupy the bulk of the glass fibers as the filler content of 10%, which was occupying a larger volume of polymer matrix. The filler content of 10% HBW value slightly fluctuated. After 500 hours of UV HBW is slightly increased, after 750 hours of UV HBW it decreased to its original value, and after 1000 hours of UV irradiation was again to the small increase. At 20% and 30% filler content HBW hand the value after 500 hours of UV irradiation, and then decreased gradually decreased. It could result in a partially crosslinked chains to UV radiation. HBW values depended mainly from the point at which the measurement was carried out, ie whether it was a place where there was more accumulated fiberglass or was it a polymer matrix. A 3D CAD data of a part are imported into the procedural software of the printer EOSINT M 270¹. Software designed to the data preparation allows choosing the appropriate thickness of production layers with regard to accuracy / resolution and speed of production (0.020 mm or 0.040 mm – thinner layer means higher accuracy, but longer production time).

The experiment also included evaluation of the structure of the composite PA + GF before and after UV irradiation by a light microscope. We monitored homogeneity of the composite, the manner of distribution of glass fibres in the polymer matrix, and cracking caused by UV radiation.

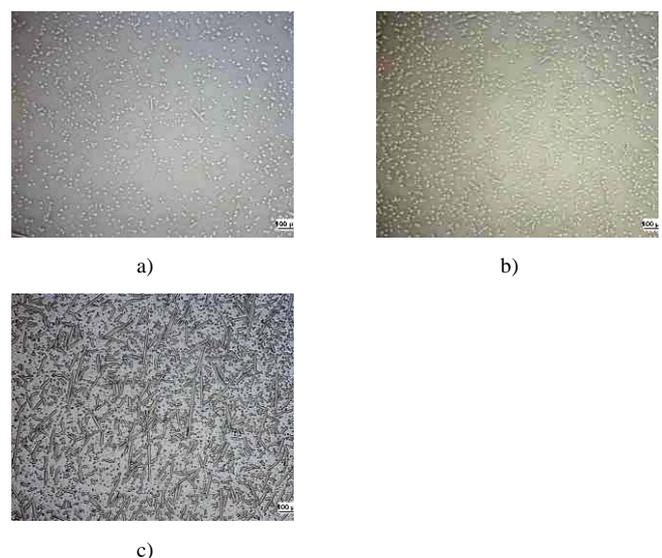


Fig. 4 Distribution of glass fibers in the polymer matrix
a) 10%, b) 20%, c) 30%

The filler content of 10%, the structure more evenly - glass fibers are evenly distributed in the polymer matrix. Fiber size was also about the same. To 20% filler content sites began to appear smaller clusters of glass fibers and emptier place in the matrix. Size fiberglass was also maintained at the approximate size. At 30% filler content, the structure of the least uniform. Fiberglass seats were piled on each other. Processing technology will brake the fibers into smaller pieces, so the material was located fibers of different sizes. Different size glass fiber in a polymer matrix was dependent on its percentage (Fig. 4).

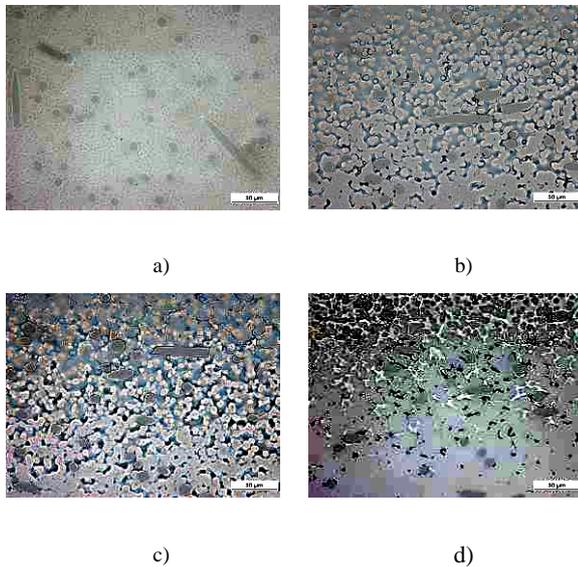


Fig. 5 The action of UV radiation on the degradation of the polymer composite, the glass fiber content of 10%

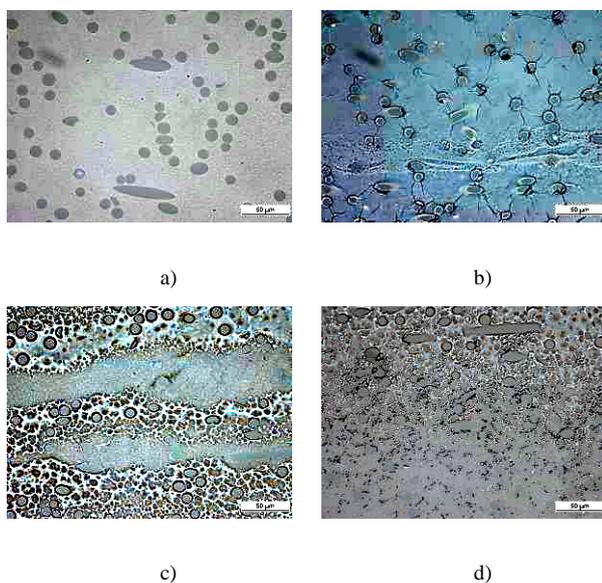


Fig. 6 The action of UV radiation on the degradation of the polymer composite, the glass fiber content of 20%

UV radiation caused us changes in structure and material degradation. Fibers started to separate from the matrix and pulled out and left by a row in the blanks - hole. At higher glass fiber content had holes tend to be linked. The fibers are broke, segregated and were pulling without residue matrix, due to poor adhesion interface fiber - matrix (Fig 7). Degradation is gradually spread from the material surface to the center. The material causing rupture of which initiates have just glass fibers and the cracks gradually spread from the surface of the matrix (Fig.6 b, c). Coloring cracks us determine its depth. At the beginning of fine hairline cracks emerged that the picture can be seen as white with a slight hint of blue. Prolonged exposure to UV radiation has been associated crack

spread and in depth. These cracks can be seen in the figures as deep black. The biggest changes in the structure (degradation) we can see a material with 10% glass fiber content, where most of the matrix to which the UV radiation is the most evident effect (Fig. 5).

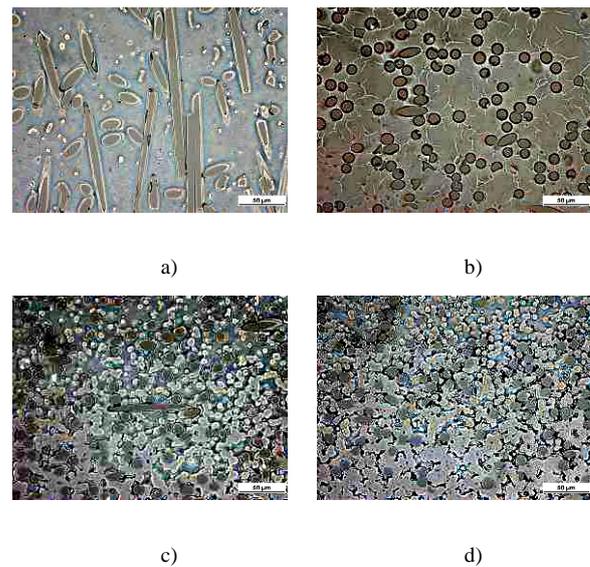


Fig. 7 The action of UV radiation on the degradation of the polymer composite, the glass fiber content of 30%

The optimum amount of filler for the composite is a glass fiber content of 30%, whereas the content of the best values were registered endpoints. As for the structure, are in the filler content of a site having marked heterogeneity in the distribution of the filler, be toxic to the mechanical properties of the composite. UV radiation is one of the most aggressive modes of degradation of polymers, which in the case of the composite expressed considerable degradation of the matrix in the glass fiber content of 10% even at the time of UV radiation 500 hours.

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