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RESEARCH OF MECHANICAL DEGRADATION PROCESSES OF POLYPROPYLENE + NANOCLAY COMPOSITES AFTER EXPOSURE TO EXTERNAL FACTORS

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Abstract. The mechanical strength (σ) of nanocomposites based on polypropylene (PP) with the addition of nanoclay (NC) after exposure to an electric discharge and orientation has been researched. Depending on the time of exposure to an electric discharge in a nanocomposite, σ first increases and then decreases, and the rate of destruction of the nanocomposite is lower than that of PP. Depending on the degree of orientation, the increase σ in PP is greater than in the nanocomposite. NC plays a more active role in destructive processes (the effect of an electric discharge) than in stabilizing processes (the effect of orientation).

Keywords: *polypropylene, nanoclay, mechanical strength, electrical discharge, orientation.*

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1. Introduction

Polymeric materials, which play an important place in the industry and life of modern man, have very different structures and properties. The suitability of some polymeric materials depends on the mechanical and electrical properties of these materials. Polymers are mainly used in the production of plastic pipes for both water supply and sewerage, various household items, coatings (in greenhouses), electrical and thermal insulation materials, etc. Therefore, various physical and chemical properties of polymers are widely studied (Vera-Serna *et al.*, 2023; Alimirzayeva, 2023; Gojayev *et al.*, 2019).

Increasing in the durability (lifetime) of products made of polymers is facing researchers as an urgent problem of polymer physics. Durability can be increased in many ways. One of these methods is the incorporation of organic and inorganic additives in polymers (Boydag *et al*., 2006; Ozcanli *et al*., 2007; Sadygova *et al*., 2019; Ozcanli *et al*., 2017; Ramazanov *et al*., 2014). No matter how high-quality the products made from

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newly obtained polymeric materials (composites) are, depending on the conditions of their operation, they are exposed to external factors (electric field, electric discharge, mechanical load, temperature, radiation, humidity, etc.), and their degradation is inevitable. Since it is difficult to reuse polymer products that have become unusable, they cause environmental pollution. It is scientifically and practically important to study the degradation of polymeric substances after exposure to external factors. By studying the cause of degradation, it may be possible to change mechanical and electrical properties and prevent degradation during operation.

In the given article, the causes of degradation were studied by comparing changes in the mechanical properties and structure of a nanocomposite based on PP with the addition of NC after exposure to an electric discharge and orientation.

2. Sample preparation and measurement methods

Thin samples (50-80 μm) were obtained by hot pressing (438K, 15 MPa, 10 min) after mechanical mixing by adding various amounts of NC (1,0 %, 2,0 %, 3,0 %, 4,0 %, 6,0 %, 8,0%, 10,0 %) to the pure PP used in the experiment. NC used as an additive is montmorillonite (MMT) layered silicate and the dimensions of these layers are approximately: length 200 nm, width 1-3 nm (Jeffrey et al., 2000). Al, Mg, and Fe atoms are located in the center of the layers, and they are surrounded by a SiO_2 layer. The imbalance inside the clay with this structure increases, and an increase in negatively charged particles outside the layer is expected. Negatively charged particles are neutralized due to the absorption of Na^+, Ca^+ ions. The planar shape of the MMT particles creates a layered structure with a polymer matrix due to the arrangement of layers on top of each other.

Two types of influence were chosen as external factors: aging, destructive, disintegrating, in short, destabilizing factors (electric discharge, electric field, mechanical load, temperature, radiation, humidity, etc.) and stabilizing factors (orientation, microadditives, fillers etc.). Electrical aging of polymers can be achieved by many methods (Sadygova *et al*., 2019; Yumusak *et al*., 2002). To study the effect of electric discharge and orientation, special devices were used.

To study the role of the NC additive in changing the mechanical properties, mechanical strength of nanocomposites preliminarily aged and oriented to different degrees under the action of an electric discharge for different hours was measured using a tensile testing machine (Boydag *et al*., 2006). Changes in the structure of PP and nanocomposite under the influence of external factors were compared with their mechanical strength by refining the spectra obtained in the frequency range of 400-2500 cm^{-1} using an IR absorption spectrometer.

3. Results and discussion

Products made from pure polymers and nanocomposites based on them wear out depending on the service life and their durability decreases. Since wearing out takes place over many years, such an operation can be performed in a laboratory conditions.

The dependence of the mechanical strength of PP on the amount of NC is shown in Figure 1. An increase in the value of σ is observed up to 2.0%, and a decrease in the following percentages. At 2.0% of NC, σ of the nanocomposite is the highest, increasing

by 38% compared to PP. Further experiments will be carried out comparatively on PP+2.0% NC nanocomposite and PP samples with optimal properties.

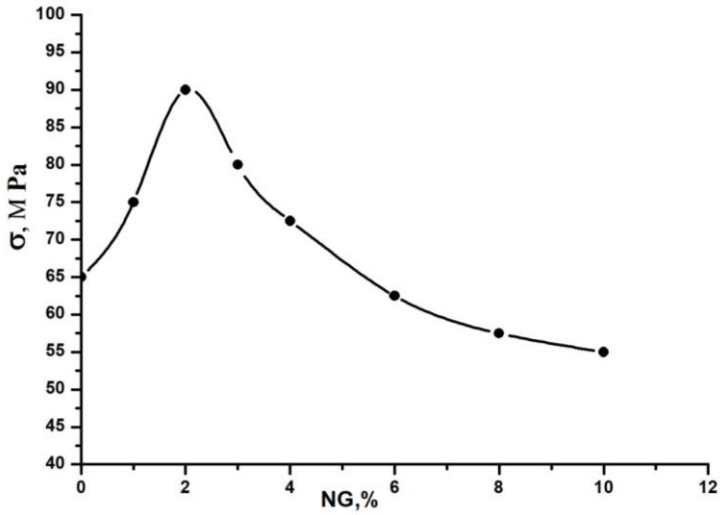

Fig. 1. Dependence of the mechanical strength of PP on the amount of NC

The dependence of σ on the duration of the electric discharge is shown in Figure 2. As can be seen, in both samples, σ increases during the first hours of electric discharge and decreases after 3 hours. After the 15th hour, the decrease in PP was 30%, and 17% in PP+2,0 % NC nanocomposite. Depending on the aging time, the rate of decline in PP is greater. It is known (Sadygova *et al*., 2021; Yumuşak *et al*., 2008; Guliyev *et al*., 2021), that macromolecules are first ionized and then oxidized under the influence of electric discharge, abrasions are formed in amorphous regions, along with the rupture of chemical bonds (as the duration of exposure increases), cross-linking (recombination of broken bonds) is observed, micro-breaks and cracks appear, etc. as a result, intermolecular interactions are weakened. In nanocomposites, NC prevents the breaking of bonds, formation of microvoids and cracks against the action of an electric discharge, as well as formation of carbonyl groups (C=O) as a result of oxidation (Regel *et al*., 1988).

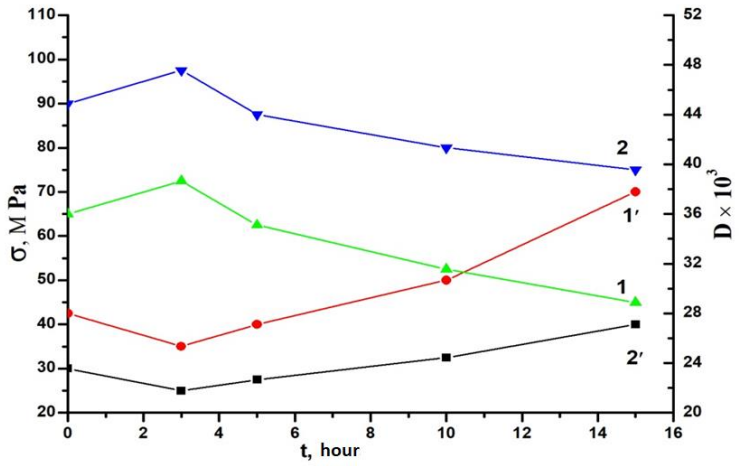

Fig. 2. Dependence of mechanical strength and optical density on t. 1, 1′ ~ PP; 2,2′ ~ PP+2.0%NC; 1,2~σ; 1′,2′~D_{1720}, T = 295 K; $U = 9 \cdot 10^3\ V$

Dependence of σ on the degree of orientation is shown in Figure 3. The increase in the value of σ with increasing degree of orientation is different for both samples. The increase in PP is greater than in PP+2.0% NC.

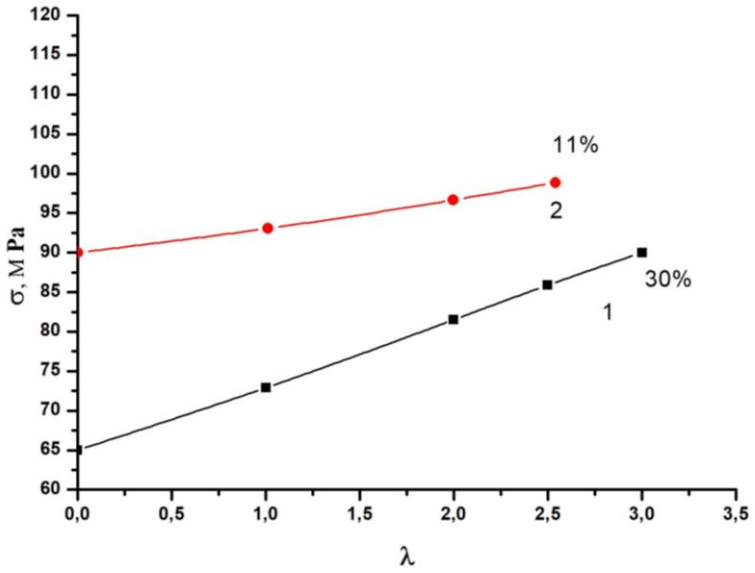

Fig. 3. Dependence of the mechanical strength of PP on the degree of orientation. 1~PP, 2~PP+2.0%NC

To explain the slight increase and subsequent decrease in σ depending on the aging time for a short period of time at a certain voltage ($U = 9 \cdot 10^3$ V), changes in the structure were measured by the IR spectroscopy. The dependence of the optical density (D_{1720}), calculated from the results obtained from the spectra, on the aging time is shown in Figure 4. An increase in the value of D_{1720} is associated with the formation of C=O groups (oxidation) due to broken bonds in macromolecules. The decrease in D_{1720} (increase in σ) occurs as bonds that are reunited at short intervals outnumber broken ones. The increase in D_{1720} (decrease in σ) accelerates as bond breaking occurs more intensely during the discharge aftereffect. In the nanocomposite, NC prevents oxidation due to bond breaking; NC plays the role of an antioxidant.

The value of σ for PP and nanocomposite before and after exposure to an electric discharge and orientation is presented in the Table 1.

Table 1. Mechanical strength of PP and PP+2.0%NC before and after to exposure external factors

Samples	σ, MPa		$\Delta\sigma$%	σ, MPa		$\Delta\sigma$%
	Unoriented	Oriented $\lambda = 2{,}5$		Unaged U = 0, t = 0	Aged $U = 9 \cdot 10^3 V$, t = 15 hours	
PP	65	80	30	65	45	30
PP+2.0%NC	90	100	11	90	75	17

As can be seen, after the impact of an electric discharge in the PP σ decreases faster than in the nanocomposite, and after the impact of the orientation, it increases faster.

Mechanical and electrophysical properties depend on changes in the supramolecular structure (Sadygova *et al.*, 2021; Ramazanov *et al*., 2007; Ramazanov *et al.*, 2010). Additives introduced into polymers, orientation, heat treatment, etc. can change or affect the supramolecular structure. The reason that σ in PP varies more depending on λ than in nanocomposite, is due to the fact that the orientation process overcomes the role of NC. While σ in PP increased by 30%, in PP+2.0 % NC it increased by 11%. After exposure to an electric discharge, the decrease in PP was 30%, and in the nanocomposite – 17%. That is, NC plays a more active role in destructive processes than as a stabilizing factor.

4. Conclusion

Depending on the volume fraction of NC particles added to PP, the mechanical strength increases up to 2.0% and then decreases. σ of PP+2.0%NC nanocomposite increased by 38% compared to PP. σ of the PP+2,0%NC nanocomposite with optimal properties and PP samples increased over a short period of time depending on the duration of exposure to an electric discharge, and then decreased with increasing aging time. The decrease in PP is greater than in the nanocomposite, NC prevents the formation of carbonyl groups in destructive processes. σ of both samples increases depending on the degree of orientation, the rate of increase in PP is greater than that of PP+2.0%NC. NC plays a more active role in destructive processes than under the influence of stabilizing factors.

Acknowledgments

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References

Alimirzayeva, N.A. (2023). The effect of metal-containing nanoparticles on the thermo - oxidative properties of thermoplastic elastomers based on isotactic polypropylene and ethylene propylene diene rubber. *New Materials, Compounds and Applications*, *6*(3), 220-229.

Boydag, F.S., Ozcanli, Y.L., Alekberov, V.A., Hikmet İ. (2006). Temperature and time dependence of electrical and mechanical durability of LDPE / diamond composites. *Composites Part B: Engineering*, 37, 249-254.

Gojayev, E.M., Salimova, V.V., Jabarov, S.H. (2019). IR absorption spectra of high-pressure polyethylene modified by fish scales. *Modern Physics Letters B*, *33*(33), 1950412.

Jeffrey, W.G., Catheryn, L.J., Alexander, B.M., Harris, R. (2000). Flammability properties of polymer-Layered-silicate nanocomposites. Polypropylene and polystyrene nanocomposites. *Chemistry of Materials*, *12*(7), 1866-1873.

Ozcanli, Y.L., Boydag, F.S., Alekberov, V.A., Hikmet, I., Canturk, M. (2007). Similataneons effect of mechanical tension on electrical lifetime of some inorganic composites. *Modern Physics Letters B*, *21*(21), 1415-1424.

Ozcanli, Y., Beken, M., Kosovalı, Çavus, F., Hadıyeva, A.A., Sadigova, A.R., Alekperov, V.A. (2017). Artificial neural network modelling of the mechanical properties of nanocomposite polypropylene-nanoclay. *Journal of Nanoelectronics and Optoelectronics*, *12*(4), 316-320.

Ramazanov, M.A., Agakishiyeva, P.B., Abbasov, S.A., Ali-Zade, R.A. (2007). The influence of temperature–time crystallization mode on the mechanical strength and on the structure of polymeric magnetic nano-composites on PVDF+Fe_3O_4 basis. *Azerbaijan Journal of Physics*, *13*(5), 47-49.

Ramazanov, M.A, Ali-Zade, R.A, Agakishieva, P.B. (2010). Structure and magnetic properties of nanocomposites on the basis PE+Fe_3O_4 and PVDF+Fe_3O_4. *Digest Journal of Nanomaterials and Biostructures*, *5*(3), 727-733.

Ramazanov, M.A., Hadiyeva, A.A., Alekperov, V.A. (2014). Influence of electric field (aging in electric field) on stucture and properties of nanocomposite polypropilene-nanoclay. *Journal of Ovonic Research*, *10*(4), 101-107.

Regel, V.R., Slutsker, A.I., Tomashevsky, E.E. (1988). *Kinetic Nature of Strength of Solids.* Moscow, Nauka, 560.

Sadygova, A.R., Abbasov, I.I, Safiev, E.S., Sadig, Kh.O., Alekperov, V.A. (2021). Molecular processes in electric destruction of nanocomposites polyethylene+nanoclay after exposure to electric discharge and orientation. *Nanosistemi, Nanomateriali, Nanotehnologii, 19*(1), 103-110.

Sadygova, A.R., Abbasov, I.I., Safiev, E.S., Asilbeyli, P.B., Alekperov, V.A. (2019). Influence of nanoclay microadditives on the molecular processes and kinetics of electrical and mechanical destruction of polyethylene. *Nanosistemi, Nanomateriali, Nanotehnologii*, *17*(1), 155-165.

Vera-Serna, P., Tenorio-González, F.N., Garrido-Hernández, A., Castro, T.L., Cetina-Quijano, G.M. (2023). Advantage of pet on polymers in magnetization in composite material with nanometric oxides. *New Materials, Compounds and Applications*, *7*(1), 5-14.

Yumuşak, C., Alekberov, V.A. (2008). The effects of electrical discharge on the mechanical properties of Bombyx mori silk fibroin. *Fibers and Polymers*, *9*(1), 15-20.