Influence of the Nature of Metal-Containing Polymer-silicate Filler on the Physico-mechanical Properties of Polypropylene

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Abstract – The influence of Ni-containing polymer-silicate filler modified by polyvinyl alcohol on the physico-mechanical (surface hardness, strength at breaking, elastic modulus, coefficient of structure) properties of thermoplastic composites based on polypropylene has been found.

Keywords – metal-containing polymer-silicate fillers, polypropylene, physico -mechanical properties.

I. Introduction

Today, for the development of modern technologies and their effective implementation it is necessary to use the innovative materials with specific required properties. The increased attention have thermoplastic and thermoset polymer-inorganic (nano-)composites based on inorganic fillers including silicates, which have the required for a particular application unique set of operating and technological characteristics.

Usually the inorganic fillers are previously modified for enhancing the technological compatibility with the polymer matrix and directional adjustment of technological and exploitation properties of polymer composites. Among the methods of modifying of silicate fillers physico-chemical method, based on coprecipitation of water-soluble silicates and functionality surface-active polymers modifiers under the influence inorganic acids and (or) salts of metals is effective and ensures even distribution of the modifier on the surface and in the structure of the filler. The functional-active water-soluble polymer – polyvinyl alcohol (PVA), which has a high surface activity and is able to intermolecular and interfacial interactions is advisable to use for modification. Polypropylene (PP) occupy a special place among the wide range of polymer matrices used for development of new composite materials.

II. Experimental

To filling polypropylene and polyester resin was used metal-containing modified silicate fillers that was obtained due to coprecipitation of sodium silicate and polymer modifier – polyvinyl alcohol under the influence of metals chlorides of different nature [1]. The developed method of coprecipitation are provided the obtaining of silicate filler with a specific active surface area of the within 60-76 m^2/g and the number of active sites on it 77-99 $\cdot 10^6$ mol/g and reduced of water absorption value by 40-60% and even distribution of the modifier on surface and in silicon-oxygen skeleton.

To create a polymer composite materials as a polymer matrix were used – polypropylene Moplen HF501N («LyondellBasell» Netherlands). For polymer composites based on PP with Ni-containing silicate filler, which are modified by polyvinyl alcohol (Ni-PVA-SF), was pre-mixing the bulk components in the desired ratio in the mixer drum (applying powder of silicate filler on granular of thermoplastic polymer). After receiving mechanical mixture carry out drying and homogenization of components by mixing in viscous state on extruder Cellier followed by squeezing material in the form of rods.

Production of standard samples from granular material for future research carry out in injection molding machine mark 25 KUASY 32/2. Filler content – 10% by weight.Physical-mechanical properties of samples: ultimate tensile strength at breaking, border fluidity during stretching, the relative elongation during tearing was determined according to ISO 527-1, -2.

Research elastic-deformation properties of obtained materials carried on consistometers of Hepler at 293 K by indentation of conical indenter under load of 120 N and determine the characteristics of the module and deformation by calculation according to the methodology.

The surface hardness by conical point of fluidity determined on consistometers of Hepler at 293 K indentation in the polymer sample steel cone with an angle sharpening 58^0 08' under load of 50 N for 60 s

III. Results and Discussion

The performance properties of composite materials based on thermoplastic polymers, including polypropylene differ significantly from unfilled thermoplastics. For polymeric composition materials these properties over a wide range can be adjusted by physical condition and nature of the initial components, the nature of the distribution of the ingredients in the bulk material, heat treatment, technological parameters of processing and more. In this regard, considerable interest is the study of basic physical, mechanical and thermophysical properties of materials based on PP filled with modified Ni-containing silicate filler.

Physicomechanical properties of the composites are one of the most important performance properties and largely determine the field and terms of the products in their basis. Mechanical testing under static loads by using stress-elongation curve can determine the key indicators of strength during stretching.

Stretching curves of developed polymer composites are typical for crystalline polymers. In particular, there are areas that meet certain state of supramolecular structure of the material under the applied load. Because the elastic deformation, which is fully reversible, meaning tension in the material initially is proportional elongation that is similar to a crystalline solid bodies and significant restructuring of the crystallites happens [2]. The basis of curves defined border tension strength (σ_b) and relative elongation (ε_b). These characteristics and surface hardness values before (F) and after (F_T) heat treatment shown in table. 1.

TABLE 1

PHYSICOMECHANICAL PROPERTIES OF COMPOSITES BASED ON PP

No.	Filler	σ_b, MPa	ε_b, %	F, MPa	F_T, MPa
1	Without filler	41,2	66	195,7	213,4
2	Ni-SF	43,4	30	190,2	228,7
3	Ni-PVA-SF	45,6	40	231,7	240,94

The composites based on filled PP the ultimate tensile strength values is higher compared to unfilled materials, which is obviously due to the higher degree of crystallinity. Thus, the largest value σ_b is observed during use as Ni-PVA-SF – 45,6 MPa. This feature is associated with the creation of more favorable conditions for crystallization of PP with the direct participation of the modified filler.

As a result of intermolecular interactions (mostly hydrophobic character) filler with macromolecules of PP occur changes in interphase layers that lead to some relative orientation of macromolecules to form denser supramolecular structures, resulting is increases a surface hardness of the composites.

For polymer composite of constructive and thermotechnical appointment are important resilient, highly elastic and plastic properties. The study of deformation properties of composites based on PP are essential for understanding the behavior of a material under load different types (static or dynamic, short or long, etc.) and the correct choice of the application. The elastic-deformation properties for composites based on PP are shown in table. 2.

TABLE 2

ELASTIC-DEFORMATION PROPERTIES OF COMPOSITES BASED ON PP

No.	Parameter	Filler		
		–	Ni-SF	Ni-PVA-SF
1	Module strain E_g, MPa	512	614	677
2	The equilibrium modulus E_m, MPa	1248	1568	1677
3	Conditionally instantaneous modulus E_0, MPa	1727	2169	2165
4	Highelasticity module E_h, MPa	4496	5662	7446
5	Proportion of the elastic component in the overall deformation ε_e,	0,296	0,283	0,313
6	Proportion of the highelasticity component in the overall deformation ε_h	0,113	0,108	0,09
7	Proportion of the plastic component in the overall deformation ε_p	0,589	0,608	0,596
8	Coefficient of plasticity K_p	0,092	0,089	0,085
9	Coefficient of structure K_s	5,66	5,7	5,71

Modulus (E_m) that defined by a small displacement of atoms, changing the interatomic and intermolecular distances and bond angles of the investigated PP material increases with the introduction of Ni-containing silicate filler, modified by polyvinyl alcohol. That demonstrates the reinforcing effect of polymer-modified silicate filler because of orienting influence of active centers filler and modifier on macromolecule PP, which results in limiting their mobility and the formation in a force field around fine particles of adsorbed layers of ordered supramolecular structures. This effect of filler involves a reduction in the number of possible conformations of macromolecules in these layers, the growth medium of relaxation times, increased relaxation spectra and density packing of macromolecules. High elastic deformation (E_h) that associated with conformational changes of macromolecules somewhat reduced due to the using of modified filler, that is associated by additional intermolecular interactions filler-modifier-polymer matrix. The increase in the overall deformation proportion of plastic deformation (ε_p) that was caused irreversible movement of macromolecules for filled materials, also reflects the influence of the filler on the formation of tighter structure of the polymer, which is unable to inverse deformation. The established of module strain shows that derived materials can be attributed to low deformability materials, which are characterized mainly strong inverse deformation and elastic aftereffect. At the same time, the introduction of filler leads to increase of the coefficient of structure, which is characteristic of spatial fluctuation network

Conclusion

Composites based on polypropylene and metal-containing polymer-silicate filler due to equitable distribution of modifier, directed influence on the surface properties of the filler and high technological compatibility between components have the value of ultimate tensile strength at breaking of composites is increased by 5-10%, modulus – by 20-30%, surface hardness by 10-15%. Increased mechanical, elastic-deformational, thermal and technological properties of developed composites provide their effectiveness for use in the production of materials for constructional purposes.

References

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