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Polymer Composites on the Basis of the Residual Polyethylene and Modified Minerals

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***Abstract*—The polymer composites on the basis of secondary polyethylene and the minerals spread in Georgia (andesite from Bakuriani, Sachkhere quartz sand and Okami slag) have been obtained. There are studied some physical-mechanical properties, thermal stability and water absorption. It is shown that the ultimate strength and thermal stability of the composites extremely depend on the type and concentration of the filler. Introduction of the fillers modified by tetraetoxisilane to the composites leads to enhancing of the physical properties of the materials because of creation of the buffer zone between polymer matrix and filler particles. For composites containing binary filler the sinergistic effect - anomaly increasing of the ultimate strength at definite ratio of the fillers is shown.**

***Keywords*—polymer materials**

1. Introduction

Different details and constructions of the mobile machines now are made from the polymer materials. Therefore the development of them presents very high significance for progress of transport.

Environment ecological protection and utilization of the industrial wastes present today very important and actual problems. From the scientific- technical literature it is known that if the development of the composites based on secondary thermoplastic materials, in which the different dispersive or natural and artificial fiber fillers are used, about 40 % of the primary ores can be spared. In the secondary polymer composites the industrial technological wastes as trimming, injection molding heads technical tare, films, bottles and so on are used. The content of such wastes was varied in the range 10 - 60 %.

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Polyethylene now is one of more spread polymer, which is due to many positive exploitation properties and low cost [1- 4]. The high pressure polyethylene industrial wastes as binder are used in our work.

2. Experimental

2.1. Research objects and methods of obtaining.

There were used the fine dispersive powders, obtained in result of grinding of different polyethylene bags of domestic destination. Most of them are made from polyethylene of high pressure (with low density). Three types of minerals Bakuriani andesite, Sachkhere quartz sand and Okami slag were used as composite fillers with wide range concentrations.
Below the short characteristics of these fillers are presented.

- *andesite* (word basis - American mountains Ands) volcanic origination dark red color dense, but sometimes is porous material. This mineral is wide spread material in the AdJara- Trialeti mountain (Borjomi-Bakuriani, Tsikhisjvari) kazbegi region (mkinvartsvery, Kabarjina), in the sources of the rivers Liakhvi, Ksani, and Aragvi, on the Javakheti plateau. Andesite isused as a building and acid proof material;
- *Quartz sand from Sachkhere* includes the quartz particles, content of silicon oxide near70-85% and

rest are iron, calcium and magnesium oxides. Besides of the sand includes 5% clay and dust particles.

- *slam from Okami* is red color micro-porous volcanic generated mineral with high specific surface. In Georgia this mineral is used as warm-isolated material. The slam is belonging to basalt type porous variety. It is the glass with alumo-silicate content (75-80%). 20% of this material is crystallic. Density 2630 kg/m^3.

At the initial stage the mixing of composite ingredients in the propeller mill during 2-3 min was fulfilled.
In result of mixing of the polymers and different fillers the homogeneous powder was obtained, which after preliminary drying at 50-70^{o}C underwent to the pressing in the standard press-forms (cylindrical and rectangular). The samples were obtained after pressing at 8-10 MPa and temperature 140-150^{o}C during 10-15 min.

2.2. Methods of samples testing

The samples were tested on the strengthening at compression, bending and impact vidcosity. Mechanical parameters were defined on the Germany device of type Dinstant. The temperature stability was defined on the apparatus of Vica. The water absorption was defined separately.

3. Results and discussion

First of all it was necessary the determination of dependence of material properties on the type and concentration of fillers. With this aim on the basis of polyethylene we obtained the composites, in which mineral powders with concentrations 20-60wt% were included.
On the Figs 1, 2 and 3 the dependences of composite mechanical strengthening at compression, bending and impact viscosity on the filler concentration are presented. From these Figures one can see that this dependence for all samples has an extreme character - on the curves the maximums are appeared.

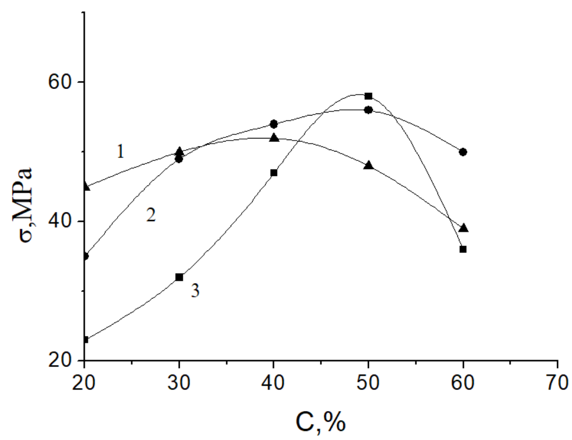

Fig.1. Dependence of the composite ultimate strength (at compression) based on PE containing quartz containing the sand (1), slam(2) and andesite (3) on the filler concentration

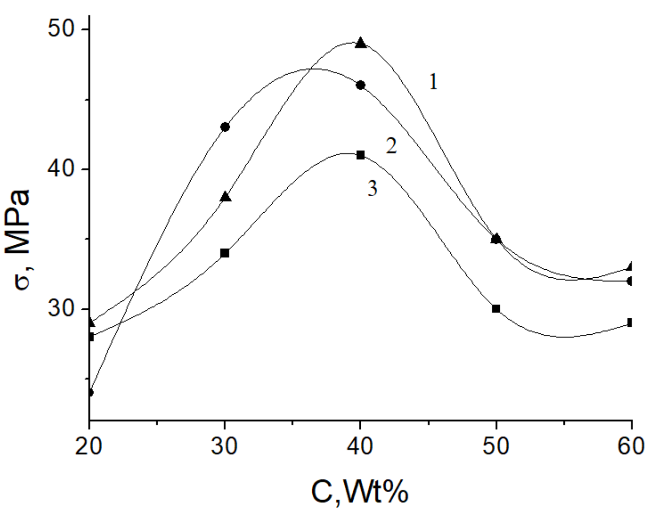

Fig.2. Dependence of ultimate strength (at bending) of composites based on PE containing andesite (1), slam (2) and quartz sand (3) on the filler concentration

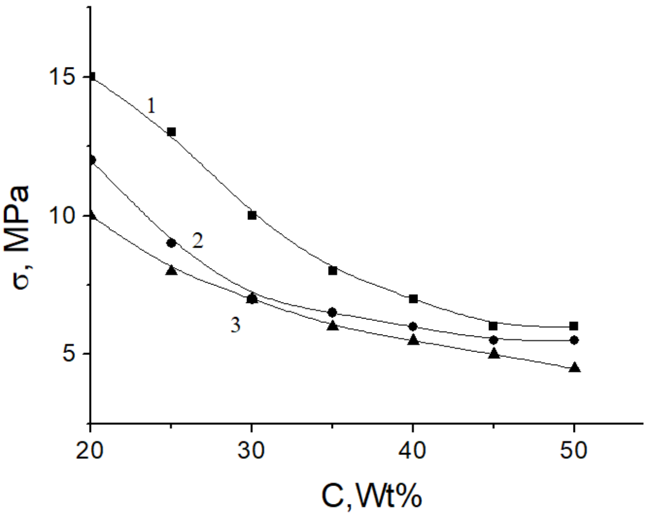

Fig.3. Dependence of impact viscosity of composites on the base of PE containing andesite (1), slam (2) and quartz sand (3) on the filler concentration

The Dependences shown on the Figs 1-3 lead to conclusion that the differences between corresponding curves are determined by different level of intensity of interaction between polymer matrix and filler particles. First of all the essential effect on the mechanical characteristics has a micro structure of the filler particles. It is clear that the higher is a sum surface of filler particles the higher is the inter-phase square and consequently -the adhesive forces between polymer matrix and filler particles. Besides of the existence of active chemical groups on the surface of filler particles additively can enhance composite because of formation of covalent bonds between phases. On the basis of these supposes it can be concluded, that mineral andesite particle surfaces are characterized with relatively inhomogeneous structure and roughness on surface of which some active chemical groups are displaced.

The difference between curves is described by difference of filler types. This difference is expressed in the character of particles surface profile (partially surface smoothness). The particles with deep irregularities contribute to penetration of the polymer segments to the micro-empties of filler particles and formation of engagements. In this way physical bonds are formed (formation of Van-der-Waals bonds), which lead to increasing of mechanical strengthening of the composite. Besides of here it is possibility the formation of chemical bonds between active chemical groups on the filler surface and macromolecules, which will further strengthen the composite.

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The character of the noted dependence appears also in the properties of thermal stability (Fig.4). Namely, the lower are the significances of the maximal deepening of the indentor in the sample (measure by Vicate method) the higher is thermal stability of the composite. From this Figure one can see that thermal stability of investigated materials fully corresponds to mechanical properties of ones and therefore the character of this parameter may be expressed in the same terms as in case of mechanical properties.

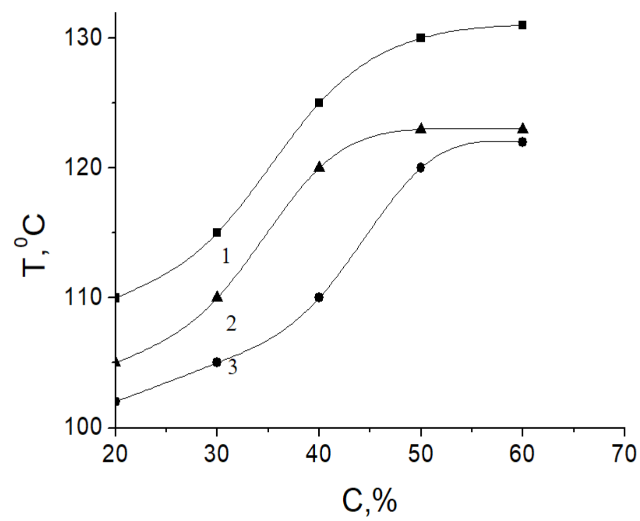

Fig.4. Dependence of the composite softening (by Vica method) of the PE composites containing quartz sand (1), slam(2) and andesite (3) on the filler concentration

It is known that in some cases the physical properties of composites may be increased by use of binary fillers [5].

With this aim we prepared the composites based on PE and binary fillers used above, concentrations of which was varied in two groups of sum concentrations: 40wt% and 50wt%. In accordance with the experimental data on determination of the dependence of ultimate strengthening of composites on the different proportion of the fillers in them these curves are characterized with maximums. On the Fig.5 the maximum of ultimate strength appears for composites containing the fillers slam and quartz sand with proportion 30/70 (curve 1), when the sum of the fillers is 50wt%. Analogical maximum has the curve 2 of the same dependence at proportion of the same fillers 40/60, when the sum of the fillers is 40wt%. The maximums on the curves are corresponded to s. c. synergistic effect - non-additive improving of the material properties at definite proportion of ingredients in the binary filler [6,7].

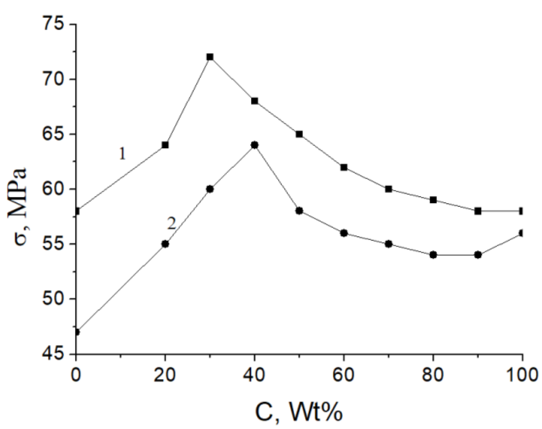

Fig.5. Dependence of the composite ultimate strength (at compression) of the PE composites with binary filler (quartz sand + slam) at the filler sum concentration 50wt % (1) and 40 wt% (2). On the *x* axis - the concentration of the slam in the fillers part

In the table 1 there are presented the numerical data of some physical-mechanical properties of the composites with binary fillers. Comparison of numerical data of obtained dependences for composites containing binary fillers and composites with one filler shows that by combination of the fillers it is possible to enhance the mechanical and thermal properties of the composites.

Table 1

The characteristics of composites based on PE and binary fillers

Filler (proportion of the fillers in composite)	Impact viscosity, kJ/M^2	Ultimate strength at bending, MPa	Ultimate strength at compression, MPa	Thermal stability, ^{0}C (by Vica)
Slam	6.8	45.5	62.3	120
Andesite	6.0	46.8	65.1	125
Quartz sand	5.1	45.5	60.4	122
Slam/andesite (2/3)	8.2	55.5	70.0	135
Slam /quartz sand (1/1)	7.7	56.6	69.5	137
quartz sand / andesite (2/3)	7.8	54.2	80.1	126

With aim of improvement of the exploitation properties of the obtained composites the structural modifier of type tetraethoxisilane (TEOS) was used (it must be noted that early this substance gave essential effect in the composites based on epoxy resin [8]). This modifier was introduced to the composite with amount 5wt% solved in the toluene for obtaining of homogeneous solution, which was evaporated after definite time.

On the Table 2 there are presented some technical characteristics of the composites with modified and unmodified by TEOS fillers. Analysis of the table 2 data shows that TEOS decreases fragility of composites and increases in the same time the compatibility of ingredients, decreases the formation of the defects, as empties (Fig. 6). At high concentrations of andesite appears so called effect of high filling, which is decreased under influence of the modifier. The molecules of modifier envelop the fillers particles and form the buffer zone between polymer matrix and filler (Fig. 7). Comparison of the mechanical properties, softening temperature and water absorption for polymer composites based on residual polyethylene and unmodified and modified by TEOS of used mineral nanofillers leads to conclusion that modify agent stipulates the formation of heterogeneous structures with higher compatibility of ingredients and consequently promote to enhancing of technical characteristics.

Table 2

Technical characteristics of composites based on PE containing modified by TEOS fillers (in brakets corresponding characteristics for analogues with unmodified fillers)

#	Filler (50 wt%)	Specific weight, Kg/m^3	Impact viscosity, kJ/M^2	Ultimate strength at bending, MPa	Ultimate strength at compre-ssion, MPa	Thermal stability, ^{0}C (by Vica)
1	Slam	1082	8,5	48,9	63.8	140
2	Quartz sand	1115	7,0	61,4	64.3	145
3	Andesite	1183	6,6	60,1	65.1	135

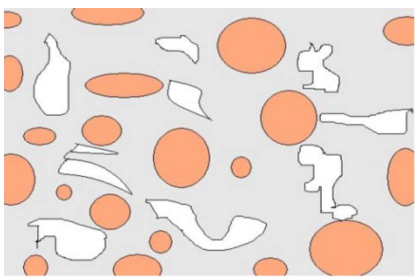

Fig.6. Model of imagination of microstructure composite with unmodified mineral.
The circles - mineral particles, white areas-empties, white grey area - polymer matrix.

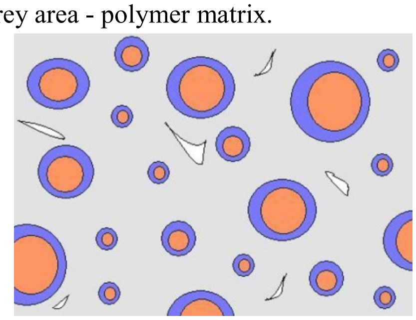

Fig.7. Model imagination of microstructure
The circles - mineral particles, white areas-empties, white grey area - polymer matrix, mineral, rings - TEOS molecules

It must be noted that the experiments on investigation of hydrophobic properties of the composites show that water absorption by composites is rather low (no more that 1.5%). This fact shows that the microstructure of the composites contains a rather low amount of structural defects (partially empties, cracks, etc).

Conclusions

1. On the basis of industrial and domestic wastes of PE there are obtained and studied polymer composites containing fine dispersed andesite, slam and quartz sand.
2. Experimentally is established that the physical-mechanical and thermal properties are essentially depend on the type and concentration of the fillers. At definite (for each fillers separately) concentrations of the fillers the materials with best properties are obtained.
3. In case of the composites containing binary fillers it is fond the optimal proportion of the fillers in the blend, which ensure some physical properties better than for composites containing one filler from binary blend.
4. The composites of PE containing modified by tetraethoxisilane fillers differ from analogues with unmodified fillers with improved technical characteristics.
5. Water absorption by composites is rather low (no more that 1.5%).

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