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ТЕОРЕТИЧЕСКИЕ АСПЕКТЫ ПРОЦЕССА ЛИТЬЯ ПОД ДАВЛЕНИЕМ МНОГОКОМПОНЕНТНЫХ НАНОКОМПОЗИТОВ НА ОСНОВЕ ПОЛИОЛЕФИНОВ

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В работе приводятся результаты исследования влияния технологических параметров литья под давлением на основные физико-механические свойства нанокомпозитов. Под технологическими параметрами имеется ввиду давление и температурный режим материального цилиндра, температура прессформы, время выдержки под давлением, расположение литника в прессформе по отношению к формующейся детали. В качестве объекта исследования использовали многокомпонентные нанокомпозиты на основе полиэтилена высокой плотности, полиэтилена низкой плотности и сополимера этилена с гексеном с такими наполнителями, как технический наноуглерод и алюминиевая пудра. Для улучшения технологической совместимости полимерной основы с наполнителями использовали компатибилизатор, представляющий собой привитой сополимер рандом полипропилена с 5,7%масс. малеинового ангидрида. В связи с необходимостью придания нанокомпозитам антистатических свойств и высокой адгезионной прочности к поверхности металлов дается обоснование выбору этих наполнителей. Исследуются такие физико-механические свойства нанокомпозитов, как разрушающее напряжение, относительное удлинение, модуль упругости на изгиб, объемная усадка, адгезионная прочность, удельная электропроводность. Приводятся результаты исследования влияния температурного режима и давления литья на разрушающее напряжение и относительное удлинение нанокомпозитов на основе полиолефинов, содержащих технический углерод, алюминиевую пудру и компатибилизатор. Показано, что с увеличением температурного режима и давления литья наблюдается закономерное повышение физико-механических показателей. Приводятся данные по влиянию температуры прессформы в пределах 25-70 °С на свойства композитных материалов. Дается теоретическое обоснование процессам, протекающим при переработке нанокомпозитов. Рассмотрено влияние расположения литника в прессформе (вдоль или поперек) на свойства отлитых образцов. Доказано, что при расположении изделия вдоль впрыскиваемого потока расплава, прочность и удлинение образцов становится выше, чем у изделий, расположенных поперек к литнику. Дается подробное описание ориентационным процессам, имеющим место в объеме отливаемого изделия.

Ключевые слова: привитой сополимер, технологические параметры, нанокомпозиты, литье под давлением, полиолефины, разрушающее напряжение, относительное удлинение, модуль упругости на изгиб, совместимость, адгезия

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THEORETICAL ASPECTS OF THE INJECTION MOLDING PROCESS OF MULTICOMPONENT NANOCOMPOSITES BASED ON POLYOLEFINS

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The paper presents the results of a study of the influence of technological parameters of injection molding on the main physicomechanical properties of nanocomposites. Technological parameters mean the pressure and temperature of the material cylinder, the temperature of the mold, the holding time under pressure, the position of the sprue in the mold in relation to the part being formed. As an object of research, we used multicomponent nanocomposites based on high-density polyethylene, low-density polyethylene, and an ethylene-hexene copolymer with fillers such as technical nanocarbon and aluminum powder. To improve the technological compatibility of the polymer base with fillers, a compatibilizer was used, which is a graft copolymer of random polypropylene with 5.7 wt. % maleic anhydride. In connection with the need to impart antistatic properties and high adhesion strength to the metal surface to nanocomposites, the rationale for the choice of these fillers is given. Such physicomechanical properties of nanocomposites as ultimate tensile stress, elongation at break, flexural modulus, volumetric shrinkage, adhesive strength, electrical conductivity are investigated. The results of a study of the effect of temperature regime and injection molding pressure on the ultimate tensile stress and elongation at break of nanocomposites based on polyolefins containing technical carbon, aluminum powder, and compatibilizer are presented. It is shown that with an increase in the temperature and injection molding pressure, a natural increase in physicomechanical parameters is observed. The data on the influence of the temperature of the mold in the range of 25-70 °C on the properties of composite materials are given. The theoretical substantiation of the processes occurring during the processing of nanocomposites is given. The influence of the sprue location in the mold (along or across) on the properties of the cast specimens is considered. It has been proven that when the product is positioned along the injected melt flow, the strength and elongation of the samples becomes higher than that of the products located across the sprue. A detailed description of the orientation processes taking place in the volume of the cast product is given.

Key words: graft copolymer, technological parameters, nanocomposites, injection molding, polyolefins, ultimate tensile stress, elongation at break, flexural modulus, compatibility, adhesion

A lot of polymer composite materials are produced in the world, which are characterized by high strength, elasticity, adhesive strength, hardness, thermal and heat resistance, resistance to aggressive media, UV and radiation exposure, etc. [1-3]. And each time to achieve this goal, different types of fillers are used, the loading of which into the composition of polymers contributes to the formation of composite materials with predetermined properties [4-6]. But, it should be noted that, along with this, there are very limited studies aimed at studying the processability of new types of composite materials by standard methods of polymer processing: injection molding and extrusion. Many interpret this circumstance by the fact that at enterprises the choice of the technological mode of polymer processing, as a rule, is carried out experimentally and is based on the experience of specialists working in this direction [7-10]. However, this approach, firstly, is accompanied by certain material and energy losses, and secondly, the absence of criteria for selecting and assessing the quality of a polymer composite creates certain difficulties in choosing the optimal technological mode of their processing [11-14].

In connection with the above, in this work, we focus on the use of such criteria for assessing the quality of a polymer material, which show significant sensitivity to the main technological parameters of their processing.

EXPERIMENTAL PART

In this work, we used composites based on polyolefins: high density polyethylene (HDPE), low density polyethylene (LDPE), and ethylene hexene copolymer (EHC).

HDPE – ultimate tensile stress – 31.3 MPa, flexural modulus 753 MPa, elongation at break 435%, density 946 kg/m^3, melt flow index (MFİ) 5.6 g/10 min, heat resistance 119 °C, melting point 131 °C, degree of crystallinity 80%.

LDPE – ultimate tensile stress – 11.2 MPa, flexural modulus – 196 MPa, density – 927 kg/m^3, elongation at break – 720%, heat resistance -85 °C, melting point – 101 °C, MFİ = 1.9 g/ 10min, degree of crystallinity 57%.

EHC – which is a heat-resistant linear low-density polyethylene brand SP980.

The compatibilizer (RPP-MA) of the Exxeler PO 1020 brand is a graft copolymer obtained in the process of reactive extrusion as a result of the mechanochemical synthesis of random polypropylene (RPP) with maleic anhydride (MA). The grafting degree of MA in the composition of the RPP was 5.7 wt. %.

Technical carbon (TC) of the Printex XE 2-B brand with a nanoparticle size of 18-40 nm.

As a metal filler used aluminum powder with a particle size of 0.5-2 μm.

The ultimate tensile stress and elongation at break of the nanocomposites were determined from the results of analytical data (out of 5 measurements) in accordance with GOST 11262-80. The relative experimental error is 3-5%.

The flexural modulus was determined in accordance with GOST 9550-81.

The MFI of polymer materials was determined on a capillary rheometer of the MELT FLOW TESTER brand, CEAST MF50 (INSTRON, Italy) at a temperature of 190 °C and a load of 5 kg. The relative experimental error is 5%.

The volumetric shrinkage was determined by measuring the change in the length of the bar from the original length of the forming part of the mold 55.5 mm. Shrinkage (Δ) was calculated according to the equation: $\Delta = (55.5 - L)\ 100\%/55.5$, where: L is the current value of the sample length. The shrinkage value was determined as the average of 5 experiments carried out for each sample.

All studies on the development of the technological mode of processing nanocomposites by injection molding were carried out in the company METAK LLC in Baku city, which is one of the leading enterprises for the production of pipe and injection molded plastic products in Azerbaijan.

Polymer nanocomposites based on HDPE were prepared in the process of preliminary dry mixing in a ball mill. Then the resulting mixture was loaded into the hopper of the injection molding machine. To carry out studies to assess the physicomechanical properties of polymer compositions, samples were inject on a ДЕ3132.250Ц1 injection molding machine. The material cylinder of this equipment consists of 4 heated zones, has a worm-type auger (ratio L/D = 24) with preliminary plasticization, which rotates and can simultaneously move forward and backward. The design of the injection molding machine allows using its capabilities simultaneously for intensive mixing of the components of the mixture and cast molding the product in the mold. The mold makes it possible to carry out the process of forming a polymer product. Molded products are blades for determining the ultimate tensile stress and elongation at break in accordance with GOST 11262-80 and bars 4×6×55.5mm in size for evaluating the modulus of elasticity in bending in accordance with GOST 9550-81.

RESULTS AND ITS DISCUSSION

The task of the study was to show the optimal technological mode of their processing by injection molding using the example of polyolefins, aluminum powder and technical nanocarbon. The choice of these complex objects of study was due to the fact that the considered composites based on HDPE, LDPE, and EHC are characterized by rather good physicomechanical properties. The loading of TC into the composition of polyolefins makes it possible to significantly reduce static electricity, and the presence of an aluminum filler made it possible to significantly increase the adhesion to the metal surface. We are talking about obtaining products that have antistatic properties and are used in contact with a rubbing metal surface in the environment of oil products. In the course of the studies carried out, it was found that polymer composites containing aluminum and TC in their composition are characterized by relatively good values of electrical conductivity and adhesion to an iron surface. According to the data in Table-1, the following composites meet these requirements to the greatest extent: HDPE + + 5.0 wt. % TC + 5.0 wt. % aluminum + 2.0 wt. % RPP-MA; EHC + 7.0 wt. % TC + 5.0 wt. % aluminum + 2.0 wt. % RPP-MA; LDPE + 10 wt. % TC + 5.0 wt. % aluminum + 2.0 wt. % RPP-Ma. As can be seen from this table, at a higher concentration of technical carbon and aluminum in the composition of the composites, the samples are characterized by relatively low values of strength indicators and elongation at break. At a lower concentration of the fillers used, the effect in improving the adhesion properties and electrical conductivity was insufficient.

Table 1

Influence of TC, aluminum (Al) and compatibilizer (K) concentration on the properties of composites based on LDPE, HDPE, and EHC

Таблица 1. **Влияние концентрации ТУ, алюминия (Ал) и компатибилизатора (К) на свойства композитов на основе ПЭНП, ПЭВП и СЭГ**

№№	Composition of the composite, wt. %	Ultimate tensile stress, MPa	Elongation at break, %	Iron peel resistance A, N/m	Specific electrical conductivity σ_e $(Om\cdot m)^{-1}$
1	88LDPE+5TC+5Al+2K	14.2	235	82.4	$4.6x10^{-4}$
2	83LDPE+10TC+5Al+2K	14.4	145	75.3	$7.1x10^{-4}$
3	78LDPE+15TC+5Al+2K	12.1	75	71.2	$9.3x10^{-4}$
4	90HDPE+3TC+5Al+2K	35.3	215	92.7	$2.6.x10^{-3}$
5	88HDPE+5TC+5Al+2K	36.0	210	99.5	$5.2x10^{-3}$
6	83HDPE+10TC+5Al+2K	31.4	115	89.3	$7.9x10^{-3}$
7	88 EHC +5TC+5Al+2K	22.1	350	84.6	$2.4x10^{-5}$
8	86 EHC +7TC+5Al+2K	23.3	350	85.0	$5.7x10^{-5}$
9	83 EHC +10TC+5Al+2K	21.0	270	72.8	$7.8x10^{-5}$

It seemed interesting to use the example of the considered composites to determine the influence of the technological parameters of injection molding on the basic physicomechanical properties. Carrying out this type of experimental research makes it possible to get as close as possible to the selection of optimal conditions for processing multicomponent polymer composites. The optimal mode means good miscibility, technological compatibility of the components of the mixture, provided that the basic properties of the composite material are maintained at a sufficiently high level. In order to improve the compatibility and miscibility of fillers with a polymer matrix, we used a compatibilizer (RPP-MA), which at the same time has technological compatibility with HDPE, EHC, and LDPE. Technological compatibility implies satisfactory miscibility of the components of the mixture without stratification in the polymer matrix.

There is reason to believe that the loading of fillers into the composition of the considered polyolefins will be accompanied by the fact that some of the solid particles will contribute to the formation of heterogeneous nucleation centers. Another part of the fillers, in the process of crystallization of the polyolefin and the growth of crystal structures simultaneously from homogeneous and heterogeneous nucleation centers, will be pushed into the interspherolite amorphous region. With the growth of crystals from various crystallization centers, as a rule, it leads to the formation of small-spherolite crystalline formations [15, 16]. In all likelihood, the use of RPP-MA as a compatibilizer will contribute to the fact that MA-free segments of the macrochain will participate in the formation of spherulite formations, and the RPP macrochains containing MA units will be redistributed predominantly in the interspherlite region together with filler particles [15-17]. Concentration of MA units, TC nanoparticles and aluminum particles in the amorphous interfacial region will improve the compatibility of the mixture components with a subsequent increase in the basic physicomechanical properties of the composites.

It seemed interesting to consider the influence of the main technological parameters of processing by injection molding on the properties of the composites under consideration. The main factors of the technological regime of injection molding are the temperature of the material cylinder, the rotation speed of the screw, the injection pressure, the temperature of the mold, the holding time under pressure and the position of the product in the mold in relation to the sprue (along or across). The most sensitive properties to a change in the technological mode of moulding condition, in our opinion, are ultimate tensile stress, elongation, flexural modulus and volumetric shrinkage.

Tables 2-4 show the results of a study of the effect of temperature and injection pressure on the above properties of composites based on LDPE, HDPE and EHC. Analyzing the data given in these tables, it can be established that with an increase in the temperature regime in the zones of the material cylinder and the injection pressure, there is a natural tendency to an increase in strength characteristics, elongation at break of composites and a decrease in their volumetric shrinkage. The most pronounced effect on the properties is the temperature regime of processing.

If we pay attention to the strength properties of composites based on EHC, we can see that they occupy intermediate values between the composites of HDPE and LDPE. The influence of injection pressure on ultimate tensile stress and elongation, properties is mainly manifested in the transition from 50 to 100 MPa. A further increase in pressure from 100 to 150 MPa has a lesser effect on the increase in the value of these indicators. The flexural modulus increases continuously with increasing injection temperature and pressure. With a injection pressure of over 100 MPa, the growth of this indicator slows down sharply.

Therefore, from an energy point of view, the injection molding process of nanocomposites at a pressure of 150 MPa will be ineffective. In this case, it will be correct to assert about the most optimal injection pressure for the considered composites, equal to 100 MPa.

Table 2

Influence of temperature and injection pressure on the properties of nanocomposites based on LDPE + 10% wt. TC+ 5.0% wt. aluminum + 2.0 wt.% RPP-MA

Таблица 2. **Влияние температурного режима и давления литья на свойства нанокомпозитов на основе ПЭНП+10% масс. ТУ+5,0% масс. алюминий +2,0% масс. РПП-МА**

Temperature by zones, °C	Injection pressure, MPa	Ultimate tensile stress, MPa	Elongation at break, %	Shrinkage, %	Flexural modulus, MPa
120-130-140-150	50	10.3	105	0.51	235
120-130-150-160		10.3	110	0.51	256
120-130-150-170		11.5	120	0.50	261
120-130-160-180		12.0	135	0.43	272
120-130-140-150	100	10.7	120	0.42	251
120-130-150-160		11.0	125	0.42	266
120-130-140-170		13.2	130	0.35	281
120-130-160-180		14.4	145	0.35	292
120-130-140-150	150	10.7	120	0.32	254
120-130-150-160		11.2	125	0.32	264
120-130-140-170		13.7	135	0.24	285
120-130-160-180		14.5	140	0.22	297

Table 3

Influence of temperature and injection pressure on the properties of nanocomposites based on HDPE + 5.0wt.% TC + 5.0wt.% aluminum + 2.0wt.% RPP-MA

Таблица 3. **Влияние температурного режима и давления литья на свойства нанокомпозитов на основе ПЭВП+5.0% масс. ТУ+5,0% масс. алюминий +2,0% масс. РПП-МА**

Temperature by zones, °C	Injection pressure, MPa	Ultimate tensile stress, MPa	Elongation at break, %	Shrinkage, %	Flexural modulus, MPa
140-160-170-180	50	29.3	115	0.56	425
140-160-180-190		30.3	130	0.55	456
140-165-190-200		33.1	150	0.47	461
140-170-190-210		33.6	175	0.42	522
140-160-170-180	100	30.5	140	0.44	451
140-160-180-190		31.5	175	0.32	486
140-165-190-200		34.7	200	0.25	581
140-170-190-210		35.7	200	0.25	652
140-160-170-180	150	30.7	200	0.44	454
140-160-180-190		31.9	195	0.30	488
140-165-190-200		35.2	220	0.21	591
140-170-190-210		36.0	210	0.21	655

An increase in the strength properties and elongation at break of composites at a relatively high temperature regime of injection molding is due to the fact that under these conditions there is a uniform dispersion and mixing of filler particles throughout the volume of the polymer matrix. This process is especially intense in the dosing zone of the injection unit, since it is in this zone that the screw thread depth is minimal [18].

One of the important technological factors affecting the properties of a molded product is the temperature of the mold and the holding time of the product under pressure. The results of an experimental study on the influence of these factors on the properties of composites based on LDPE, HDPE and EHC are shown in Table 5.

As can be seen from this table, the maximum mold temperature for composites based on LDPE is 50 °C, for composites based on HDPE and EHC – 70 °C. This is because the melting point of LDPE is lower than that of HDPE and EHC. According to the data presented, with an increase in temperature and time of holding under pressure, there is a definite tendency towards an increase in the ultimate tensile stress and elongation at break. In some cases, compositions that are cast in a relatively cold mold (25 °C) have a comparatively insignificant improvement in elongation. This is due to the fact that the greater the temperature drop, the faster the cooling of the surface areas of the polymer matrix in contact with the surface of the mold occurs. Since polymers are characterized by a relatively low thermal conductivity, it would be natural to assume that a peculiar temperature gradient appears over the sample cross section. In other words, depending on the thickness of the sample, the process of cooling or crystallization of the composite proceeds at different rates. Therefore, the surface areas of the cast sample are characterized by a fine-spherolite structure, and in relatively deep areas the crystallization process proceeds relatively slowly with the formation of larger crystalline formations [18-20]. Therefore, the process of injection molding samples into relatively heated molds to some extent contributes to their more uniform cooling throughout the entire mass of the polymer matrix. The latter circumstance, in fact, explains a certain increase in the ultimate tensile stress and elongation at break of the composites. It is important to note that as the holding time under pressure increases, there is also a slight tendency to improve the properties of the composites. Apparently, this fact is due to the fact that with an increase in the cooling time of the sample in the mold, their volumetric shrinkage occurs, and holding under pressure and feeding a fresh portion of the polymer mass contributes to the preservation of the external dimensions of the product according to the forming part of the mold [17, 21].

Table 4

Influence of temperature and injection pressure on the properties of nanocomposites based on EHC + 7.0wt.% TC + 5.0wt.% aluminum + 2.0wt.% RPP-MA

Таблица 4. **Влияние температурного режима и давления литья на свойства нанокомпозитов на основе СЭГ+7.0% масс. ТУ+5,0% масс. алюминий +2,0% масс. РПП-МА**

Temperature by zones, °C	Injection pressure, MPa	Ultimate tensile stress, MPa	Elongation at break, %	Shrinkage, %	Flexural modulus, MPa
140-150-160-170	50	18.5	165	0.58	321
140-150-170-180		19.2	190	0.56	356
140-160-180-190		20.1	270	0.50	364
140-170-180-200		20.8	285	0.47	429
140-150-160-170	100	19.7	180	0.49	341
140-150-170-180		20.5	235	0.42	384
140-160-180-190		22.8	315	0.35	421
140-170-180-200		23.3	350	0.29	512
140-150-160-170	150	20.0	190	0.45	354
140-150-170-180		20.9	295	0.36	385
140-160-180-190		23.0	320	0.29	428
140-170-180-200		23.3	350	0.29	523

It should also be taken into account that the process of polymer cooling in the mold proceeds throughout the entire molding cycle, accompanied by the occurrence of residual stresses. As a rule, residual stresses are concentrated in those parts of the product where the orientation of polymer macromolecules took place. For example, in the first molding stage, the mold is quickly filled with the polymer melt. As a result, the process of cooling and solidification of the polymer occurs primarily near the surface of the mold with the formation of a highly oriented thin film with the retention of residual stresses in them. At the second stage of the molding cycle, the product is compressed and completely cooled with a constant inflow of a fresh portion of the polymer into the forming part of the mold. In this case, an additional orientation arises, which also leads to the accumulation of residual stresses. An increase in the mold temperature will undoubtedly affect a decrease in the temperature difference between the melt and the mold wall, thereby contributing to a decrease in the crystallization rate and the likelihood of residual stress formation [18, 20]. The danger of residual stresses is that during operation, under the influence of temperature and variable mechanical loads, the product can deform with a change in its structural dimensions. This circumstance is extremely undesirable, since it can lead to product breakdown and to emergency situations.

In the process of injection molding, the polymer matrix is subjected to thermomechanical action, as a result of which various side reactions of destruction and crosslinking can occur in the composite, affecting their quality characteristics. In this case, depending on the arrangement of the sprue in the plastic product, processes associated with the orientation of macromolecules along the melt flow in the forming part of the mold can take place. Depending on the type of polymer composite used, all these factors, to a greater or lesser extent, affect the basic physicomechanical properties. At the same time, there are a lot of factors influencing the orientation processes and this is due not only to the location of the sprue, but also to the wall thickness and thickness variation of the product. It is quite obvious that the thinner the walls of the product, the more pronounced the orientational effect is.

When designing a mold, the most important consideration is the position of the plastic product relative to the sprue (along or across). In this regard, it seemed interesting to consider the influence of the sprue location in relation to samples (in the form of blades) intended for testing for ultimate tensile stress and elongation at break. The results of the study of composites based on the considered polyolefins are summarized in Table 6. Analyzing the data presented in this table, one can find a significant effect of the position of the sprue in the change in the properties of composites.

In this case, regardless of the type of the initial polymer matrix, the samples obtained along the direction of injection of the melt are characterized by higher values of the ultimate tensile stress and elongation at break. This circumstance is interpreted by the fact that, as a result of the orientation of macromolecules relative to each other, the crystallization process proceeds uniformly over the entire volume of the sample with the formation of crystal structures with a minimum defectiveness of the supramolecular structure [17, 18, 20].

Table 5

Influence of mold temperature and holding time under pressure on ultimate tensile stress and elongation of nanocomposites based on LDPE, HDPE and EHC. Injection pressure 100 MPa

Таблица 5. **Влияние температуры прессформы и времени выдержки под давлением на разрушающее напряжение и относительное удлинение нанокомпозитов на основе ПЭНП, ПЭВП и СЭГ. Давление литья 100 МПа**

Mold temperature, T, °C	Holding time under pressure, s	Ultimate tensile stress, MPa	Elongation at break, %
LDPE + 10 wt. % TC + 5.0 wt. % aluminum + 2.0 wt. % compatibilizer Injection temperature by zones, 120-130-160-180 °C			
25 40 50	5	13.6 13.9 13.9	125 140 145
25 40 50	10	14.0 14.4 14.8	150 145 145
25 40 50	20	14.0 14.5 14.2	150 145 155
HDPE + 5.0 wt. % TC + 5.0 wt. % aluminum + 2.0 wt. % compatibilizer Injection temperature by zones, 140-170-190-210 °C			
25 40 50 70	5	34.6 35.0 35.5 36.8	210 200 200 220
25 40 50 70	10	35.0 35.7 36.0 37.2	210 200 200 220
25 40 50 70	20	35.0 35.8 36.2 37.0	210 200 200 210
EHC + 7.0 wt. % TC + 5.0 wt. % aluminum + 2.0 wt. % compatibilizer Injection temperature by zones, 140-170-180-200 °C			
25 40 50 70	5	22.4 22.8 23.1 23.1	350 355 355 360
25 40 50 70	10	23.0 23.3 23.6 24.3	360 360 360 370
25 40 50 70	20	23.3 23.5 23.9 24.5	370 360 365 370

Table 6

The influence of the position of the blade in the mold on the physicomechanical properties of HDPE and its nanocomposites obtained under optimal technological conditions of injection molding

Таблица 6. **Влияние расположения лопатки в пресс-форме на физико-механические свойства ПЭВП и его нанокомпозитов, полученных при оптимальных технологических условиях литья под давлением**

Composition of the nanocomposite, wt.%	The location of the blades in the mold	Ultimate tensile stress, MPa	Elongation at break, %
LDPE+10TC+5Al+2K	along	14.8	145
	across	12.2	110
HDPE+5TC+5Al+2K	along	36.2	200
	across	33.7	155
EHC +7TC+5Al+2K	along	23.9	355
	across	21.4	305

Thus, on the basis of the foregoing, it can be stated that for a number of nanocomposites based on LDPE, HDPE, and EHC, the technological modes of injection molding have been developed. It was shown that with an increase in the injection pressure, the temperature regime of the material cylinder, the temperature of the mold, and the holding time under pressure, an increase in the strength parameters and elongation at break of nanocomposites is observed. The filler used TC, aluminum powder and a compatibilizer based on RPP-MA.

The influence of the sprue location in relation to the forming part of the mold is considered. It was found that the samples located in the forming part of the mold along the melt injection are characterized by comparatively better physicomechanical properties.

The authors declare the absence a conflict of interest warranting disclosure in this article.

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