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TECHNOLOGICAL ASPECT OF INFLUENCE ON LONG-TERM CONSTRUCTIONAL PROPERTIES UNDER COMPRESSION OF THERMOPLASTIC POLYMER COMPOSITES

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Abstract. Feasibility of complex research of technological aspects and long-term structural properties of the thermoplastic polymer composite that allowed to define a perspective direction to improve the practical appeal and, accordingly, provided the requirements thoroughly to search the fibrous filler of polymeric nature with predictable provision roughness to the surface relief are provided.

Keywords: polypropylene, emergency support, thermoplastic polymer composite, surface relief.

1. Introduction

In order to improve safety of tire vehicles it was suggested to refit wheel bearing engine with a special insert – emergency support, which as it has been found during previous investigations, is advisable to make of polymer composite materials. This maintains operational properties of traditional wheel bearing engine under stationary mode of rolling and their acceptable reproduction in case of sudden damage, i.*e.* loss of carrying capacity of the tire [1-3].

At the same time, taking into account the current requirements for resource conservation and environmental impact of new products, the technological aspect of material-constructional solutions is of great significance. So, on this occasion appropriate analysis was conducted that allowed to give the fundamental idea regarding the possibility of using during the manufacture of emergency support, the specially created thermoplastic polymer composite (TPC), which, unlike traditional polymer thermosetting composite of tire products – rubber – is capable of recycling. This provides the opportunity to realize alternative technology and thus almost avoid environmental problems of production, exploitation and processing [4-6]. Within the frame of this work we suggest to consider validity of expectations from the technological appeal.

Constructional and technological performance of non-pneumatic emergency support involves only using TPC of a single composition and absence of any reinforcing elements that while providing the relevant list and the level of long-term constructional properties at compression [7-9] allows to avoid as needless, the issue of manufacturing, assembly, fixation, decomposition and recycling of reinforcing elements. Single-service emergency support after exploitation under emergency mode of rolling at a specified speed during limited time is recycled into a new product for the same purpose. Under these circumstances, the principal technological scheme of production and processing of emergency support from TPC requires consistent implementation of a number of manufacturing operations based on extrusion methods.

2. Experimental

2.1. Objects of Research

Preliminary conducted researches [6-8] substantiate the feasibility of polypropylene (PP) as a polymer matrix PM in modeling the TPC application. Among the prevailing thermoplastic polymers PP has the lowest value of density ρ and even too high value of relative modulus of elasticity E. This allows to apply fiberfill (FF) in TPC, which technological attractiveness lies in maintaining the capacity of composites to multiple processing. Avoiding the influence of the geometric factor FF are selected with close sizes: Polyamide fiber Anid (AnF), polymer nature of which causes smooth surface relief at almost the same level of ρ index with PP and Basalt fiber (BF), mineral nature of which provides rough relief of surface at too large level of parameter ρ.

Following materials were selected as objects in this research work.

As a thermoplastic matrix we used polypropylene of LIPOL A4-71E brand (POJ "Lisichansk petroleum investment company" Lisichansk, Ukraine) with commercial forms as granules of 2.0–5.0 mm, taking into account its sufficient prevalence and accessibility. Its basic physical and mechanical properties are given in Table 1.

Table 1

Basic physical and mechanical properties of polypropylene

Characteristic	Value
Density, g/cm^3	0.900
The melting temperature, K	433–443
The softening temperature, K	353–363
Parameter of the melt flowability, g/10min	2.75
Tensile strength, MPa	25–35
Relative elongation at break, %	200–800
Thermostability by Vika, K	428
Water absorption for 24 h maximum, %	0.005

As fibrous fillers we selected polyamide fibers Anid (AnF) and basalt fiber (BF) in accordance with the surface relief and considering their sufficient prevalence and availability of filaments to grind into cylindrical fragments.

Polyamide fibers Anid are cylindrical fragments with smooth surface relief (diameter 13 ± 0.5 microns and length of 12 ± 2 mm) obtained during the fragmentation of polyamide 66 filaments (density 1.14 g/cm^3) in accordance with the standards (JSC "Chernihivske Khimvolokno", Chernihiv, Ukraine).

Basalt fibers are cylindrical pieces fiber with a surface rough relief (diameter 14 ± 0.5 microns and length of 12 ± 2 mm), obtained by fragmentation of basalt roving filaments of ZHBTR 1-2540 brand (density 2.30 g/cm^3) in accordance with the standards (originated from Berestovesk field and produced at JSC "Teplozvuko-izolyaciya", Bilychi, Ukraine).

2.2. Physico-Mechanical Researches

Density (ρ, g/cm^3) was determined using the method of hydrostatic weighing due to which equal by volume samples of the new and known materials are compared [9-13].

The sample is weighed on analytical balance, determining the mass M_1. To determine the mass M_2 the sample is weighted in a glass with a working fluid density of which is known. Then the sample removed and dipped in a glass with liquid and M_3 is determined.

The liquid mass M_7 is calculated by the formula:

$$M_7 = M_1 - (M_2 - M_3) \qquad (1)$$

where M_1 – weight of the sample in the air, g; M_2 – weight of the sample with a pendant in the working fluid, g; M_3 – weight of pendant in a liquid, g.

The research material density is calculated by the formula:

$$\rho = (M_1 / \mathrm{M}_7)\cdot\rho_{liquid} \qquad (2)$$

where ρ_{liquid} – density of the working fluid, g/cm^3.

Determination of the ***melt flowability*** (PMF, g/10 min) is the measurement of material leakage for controlled time through a calibrated hole under pressure at a given temperature [9-13]. To determine the PMF the plastomer is used, which consists of thermal chamber (internal diameter is 10 ± 0.5 mm and a height is not less than 115 mm), plunger, capillary (calibrated hole with a diameter of 2.095 mm) and load which is sufficient to create the necessary pressure on the material for measurement.

Granules of research material are loaded in preheated to the desired temperature chamber with closed capillary, and the plunger with the load required to create appropriate pressure is set. After sustaining the capillary is opened and leakage of tested material is controlled by time. The segments of material leakage is cooled and weighed.

The level of PMF parameter (g/10 min) is calculated by the formula:

$$\mathrm{PMF}_{(T,\ p)} = (m / t)\cdot\tau \qquad (3)$$

where T, p – temperature (K) and pressure (MPa) during the experiment, respectively; m – weight of material leakage, g; t – duration of material leakage, s; τ – given time, which is 600 s.

Relative modulus of elasticity (E, MPa) is determined by calculation of the ratio: conventional tension / relative deformation or loading / height at loading under compression of test samples of a certain shape and size [9-13]. The determination is conducted on tensile machine TT M/D 10 kN-1 class 0.5, equipped with two flat areas, one of which is centered by its own. Test conditions in general are in compliance with [9-13] but keeping to individual features is provided, in accordance with the needs of the most approximate reproduction of load bearing of emergency support of safe wheeled engine of the vehicle.

Exploitation of emergency support under load is provided at the level of emergency rolling values: the term of emergency rolling $t_{e.r.} \leq 1$ h and speed $V_{e.r.} \leq 40$ km/h. They correspond to the emergency rolling frequency $\nu_{e.r.} \leq 5$ Hz and speed $\upsilon_{e.r.} \leq 1400$ mm/min. Therefore, long-term constructional testing should be implemented following the combination of special requirements:

–loading speed $\upsilon_{e.r.} = 1400$ mm / min or loading frequency $\nu_{e.r.} \leq 5$ Hz;

–the term of loading $t_{e.r.} = 1$ H or cycles of loading $N_{e.r.} = 18\,000$ cycles.

The parameter *E* is calculated by the formula:

$$E = \sigma / \varepsilon = (F / A_0) / (\Delta l / l_0) \quad (4)$$

where σ – conventional tension at compression, MPa; *F* – loading at compression, MN, A_0 – initial cross-sectional area of the sample, m^2; ε – relative deformation at compression equals to $(\Delta l / l_0) \cdot 100$, %; Δl – change of sample height, mm; l_0 – sample initial height, mm.

Hysteresis index (*H*, rel. units) is determined by calculation of the geometric area ratio under the dependencies loading-unloading at compression of test samples of certain shape and size [9-13]. *H* is determined on tensile machine TT M/D 10 kN-1 class 0.5. Test conditions are in general compliance with [9-13] but keeping to individual features is provided, in accordance with the needs of the most approximate reproduction of long-term loading:

– loading speed $\upsilon_{e.r.}$ = 1400 mm / min or loading frequency $\nu_{e.r.} \leq 5$ Hz;

– term of loading $t_{e.r.}$ = 1 or loading cycle $N_{e.r.}$ = = 18000 cycles.

The value *H* can be calculated as:

$$H = (S_1 - S_2) / S_1 \quad (5)$$

where S_1 – area under the height-loading dependence at compression, m^2; S_2 – the area under the height-unloading dependence at compression, m^2.

To determine the ***relaxation of tension*** ($\sigma(t)$, MPa) it is necessary to calculate the residue of conventional tension during long-term loading at compression of test samples of a certain shape and size [9-13]. Determination is carried out using the bursting machine TT M/D 10 kN-1 class 0.5. Test conditions in general are in compliance with [13-15] but keeping to individual features is provided, in accordance with the needs of the most approximate reproduction of load bearing of emergency support of safe wheeled engine of the vehicle.

The conditions of emergency rolling ($t_{e.r.} \leq 1$ h and $V_{e.r.} \leq 40$ km/h) are given above. However, it can be realized within the guaranteed duration of the stationary rolling, which is defined as the level of guaranteed term $t_{serv}. \leq 5$ years. The level of guaranteed tension $\sigma_{serv.} \geq$ ≥ 0.1 MPa, which is necessary for tires while damage with pressure loss, is sufficient to keep the tires on the rim. Mounting involves compression between bead of the emergency support tire with speed of mounting $\upsilon_{mount}. \leq$ ≤ 100 mm/min to provide sufficient guaranteed tension $\sigma(t_{serv.}) \geq 0.1$ MPa. Therefore, long-term constructional testing should be implemented while the following special requirements should be followed:

– speed of tension $\upsilon_{mount.}$ = 100 mm/min;

– guaranteed tension $\sigma(t_{serv.})$ = 0.1 MPa.

The parameter $\sigma(t_{serv.})$ can be calculated by the formula:

$$\sigma(t_{serv.}) = \sigma \times t_{\mathrm{serv.}}{}^{-z} \quad (6)$$

where σ – initial conventional tension at compression, MPa; $t_{serv.}$ – the guaranteed term at compression, s; *z* – coincidence of tension at compression, rel. units.

Therefore, the technological suitability of TPC for the emergency support manufacturing, designed to refit wheel bearing engine of cargo vehicle, was investigated to change the levels of long-term constructional properties under static and dynamic compression:

* relative modulus of elasticity (*E*, MPa), which summarizes the elastic-hard properties, providing prediction of changes in kinematics of wheel bearing engine in an emergency situation. The level of *E* is determined under dynamic compression (emergency rolling speed $V_{e.r.} \geq 40$ km/h and the term $t_{e.r.} \geq 1$ h within the guaranteed time $t_{serv.}$ = 5 years) in accordance with the following criteria: conventional tension of contact $\sigma_{cont}. \leq$ 1.5 MPa for tire rubber, which saves it from destruction, and the relative deformation $\varepsilon_{sup}. \geq 2.5$ % – for the support geometry under contact conditions;

* hysteresis (*H*, rel. units.), which summarizes absorbing ability, providing prediction of changes in wheel bearing engine comfort in an emergency situation. The parameter *H* is determined under the same conditions of compression;

* relaxation of tension ($\sigma(t)$, MPa), which summarizes the long-term resistance, providing prediction of wheel bearing engine integrity regardless of conditions. The value of $\sigma(t)$ is determined at static compression (stationary and emergency rolling) as test conditional tension $\sigma(t_{serv.}) \geq 0.1$ Mpa, which retains traction capability.

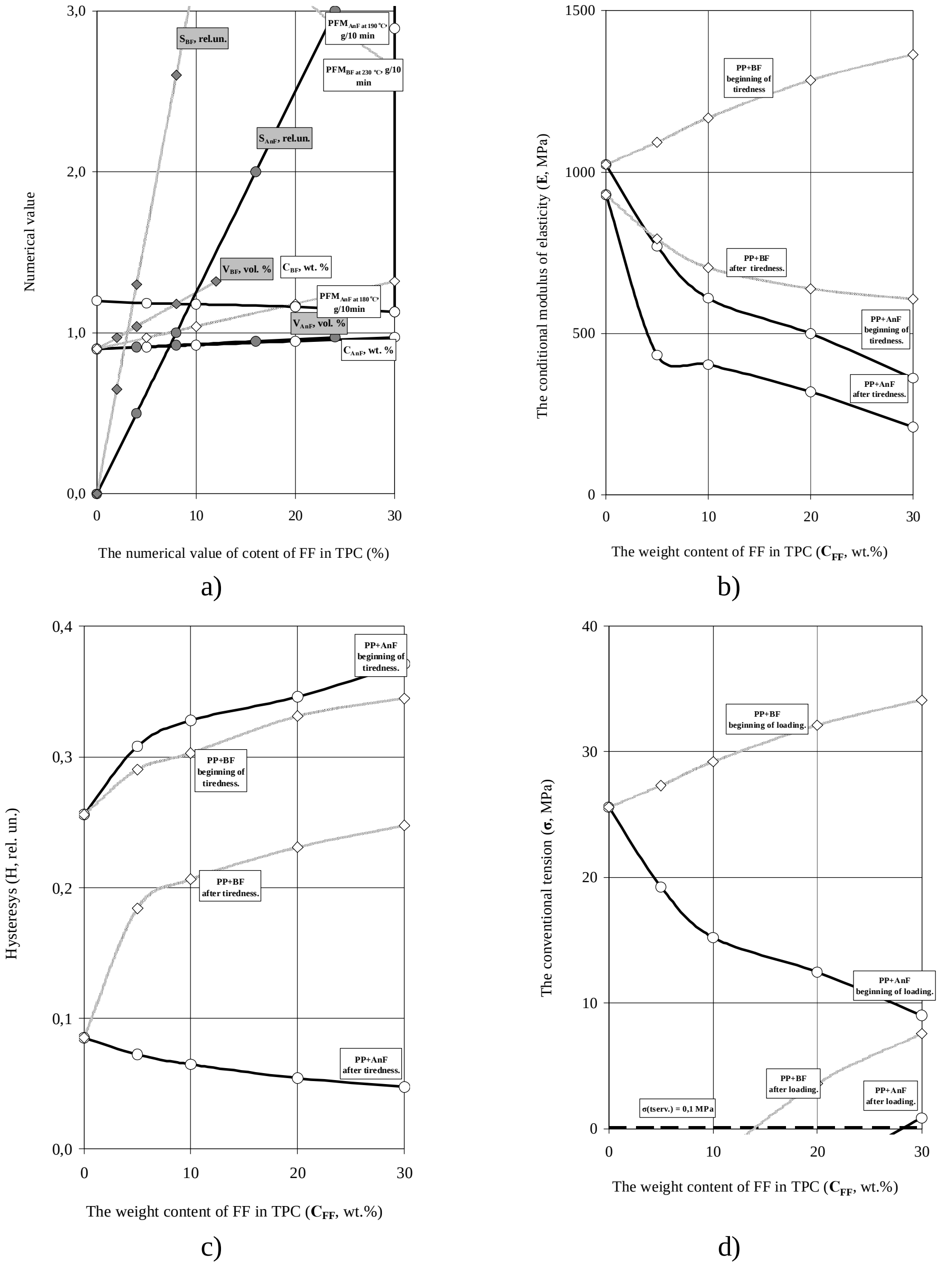
3. Results and Discussion

Previously conducted researches [14-16] justify the feasibility of polypropylene (PP) application as polymer matrix (PM) in TPC modeling. Among the most prevalent thermoplastic polymers (including polyamide and polyethylene) PP has the lowest value of density (ρ, g/cm^3) and even too large value of *E* parameter. This combination of properties provides a unique opportunity to vary not only the material performance of TPC, but the constructional performance of emergency support as well. The creation of TPC based on PP allows to realize a double effect while minimizing of emergency support weight – too low density is combined with too large relative modulus of elasticity at compression.

Selected thermoplastic material PP has significant advantages only as PM for TPC, the creation of which involves reduction of the elastic-hard properties, the increase of absorptive capacity and preservation of sufficient long-term resistance without significant changes during their recycling.

On the basis of previously established impact [13, 14] of FF surface relief on the long-term constructional properties of TPC by choosing anid fiber (AnF) with a smooth surface relief and basalt fiber (BF) with rough surface relief, the technological aspect was examined. Since selected FF have a significant difference by the recommended level of temperature processing, according to their polymer (AnF) and mineral (BF) nature, the temperature mode of manufacturing operations deserves special attention.

According to created possibilities let’s consider the constructional-technological properties when measuring TPC of the same composition and manufacture method (Fig. 1).



a) b)

c) d)

Fig. 1. TPC parameters depending on FF (AnF or BF) weight content (C_{FF} = 0–30 wt %, the white background) and volume content (V_{FF} = 0–25 vol % , the grey background): density (ρ, g/cm^3), the relative area of PM-FF contact (S_{FF}, rel. units) and the flowability of the melt at the processing temperature ($PFM_{FF\ \mathrm{at}\ T_{proc}\,(K)}$, g/10 min) (a); relative modulus of elasticity (E, MPa) (b); hysteresis (H, rel. units.) at the beginning and after dynamic compression tiredness under ε = 2.5 % and ν = 5 Hz (c); relaxation of tension ($\sigma(t)$, MPa) at the beginning and after (prediction $t_{serv.}$ = 5 years) static loading compression under υ = 100 mm / min and ε = 2.5 % to $\sigma(t_{serv.})$ = 0.1 MPa (dashed line) (d)

Clearly, from the practical point of view it would be advisable to use weight content value (C_{TPC}, wt %), however (Fig. 1a), the presence of significant differences in the density of selected components it is suggested to use volume content value (V_{TPC}, vol %) at the same time:

$$\boldsymbol{C_{\text{TPC}} = C_{\text{PM}} + C_{\text{FF}} = C_{\text{PP}} + C_{\text{AnF}} = C_{\text{PP}} + C_{\text{BF}}} \text{ and } \boldsymbol{V_{\text{TPC}} = V_{\text{PM}} + V_{\text{FF}} = V_{\text{PP}} + V_{\text{AnF}} = V_{\text{PP}} + V_{\text{BF}}}$$

where: $\boldsymbol{C_{\text{PM}} = C_{\text{PP}}}$ – weight content of PM, in this case it is PP, which varies from 100 to 70 wt %;
$\boldsymbol{V_{\text{PM}} = V_{\text{PP}}}$ – volume content of PM, in this case it is PP, which varies from 100 to 75 vol %;
$\boldsymbol{C_{\text{FF}} = C_{\text{AnF}}}$ – weight content of FF, in this case it is AnF, which varies from 0 to 30 wt %;
$\boldsymbol{V_{\text{FF}} = V_{\text{AnF}}}$ – volume content of FF, in this case it is AnF, which varies from 0 to 25 vol %;
$\boldsymbol{C_{\text{FF}} = C_{\text{BF}}}$ – weight content of FF, in this case it is BF, which varies from 0 to 30 wt %;
$\boldsymbol{V_{\text{FF}} = V_{\text{BF}}}$ – volume content of FF, in this case it is BF, which varies from 0 to 12 vol %.

The value V_{TPC} gives the possibility to define the corresponding area of PM-FF contact at V_{FF} = 10 vol %, $\rho_{\text{TPC with AnF}} = 0.924$ g/cm^3 and $\rho_{\text{TPC with BF}} = 1.040$ g/cm^3 [15, 16]. At the same level of FF volume content (V_{FF} = = 10 vol %) and almost the same level of calibrated diameter ($d_{\text{AnF}} \approx 13$ microns and $d_{\text{BF}} \approx 14$ microns) it is possible to compare the area of PM-FF contact, which is equal to the ratio between AnF and BF – 1.0:1.3.

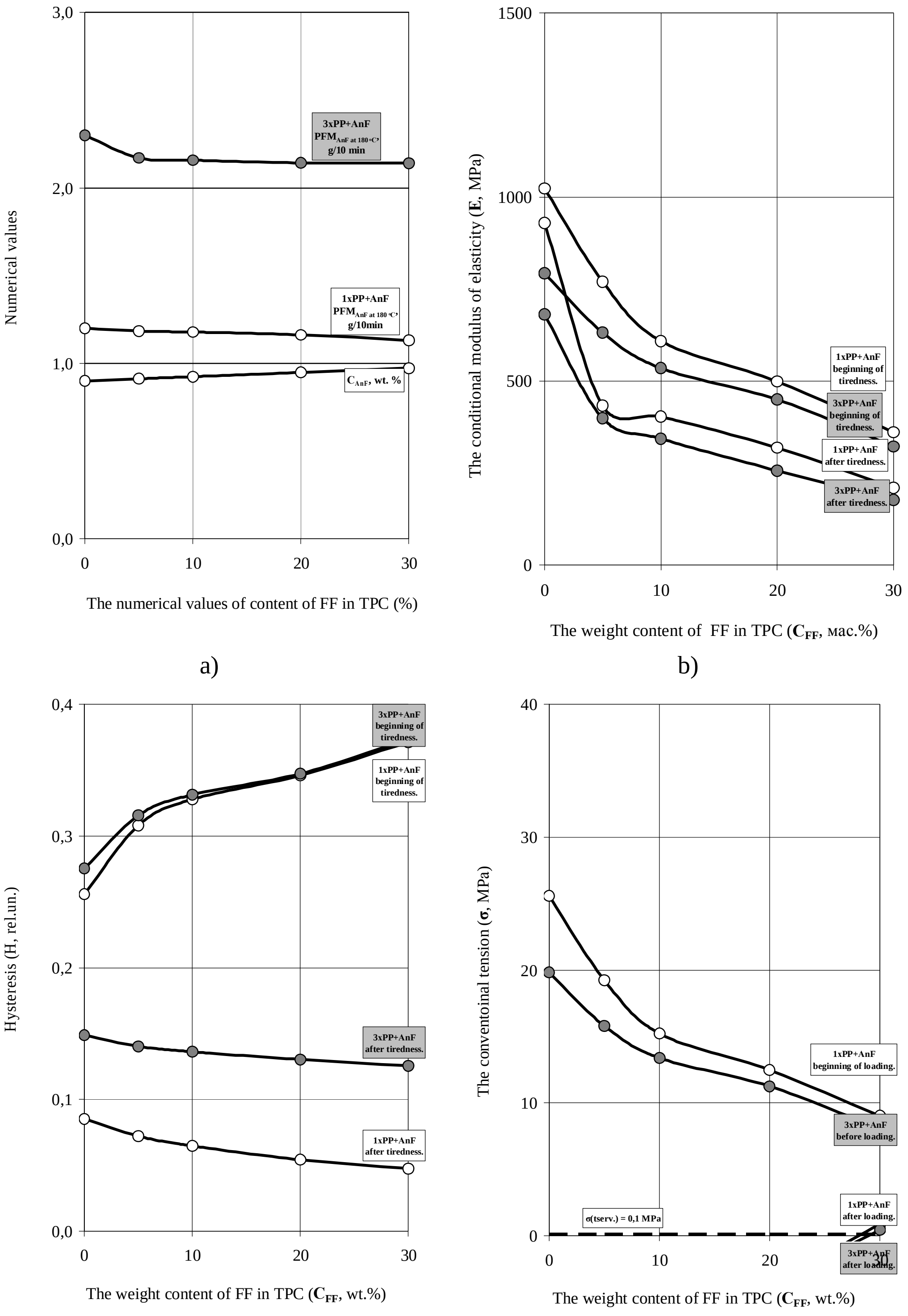
Accepting as a comparative basis a reference point at TPC composition in accordance with the volume content ($V_{\text{TPC}} = V_{\text{PP}} + V_{\text{AnF}}$ = PP92 + AnF08 = 100 vol %) or weight one ($C_{\text{TPC}} = C_{\text{PP}} + C_{\text{AnF}}$ = PP90 + AnF10 = = 100 wt %) and calculating the change of relative area of PM-FF contact (S_{FF}, rel. units) much more rapid increase in its level is observed for the composite PP + BF compared with PP + AnF. The result is that the same level, *e.g*. S_{FF} = 3.0 rel. units for composites with BF, corresponds to $C_{\text{TPC with BF}}$ = 9 wt %, while the AnF has the same value only when $C_{\text{TPC with AnF}}$ = 24 wt %.

Such a big difference in S_{FF} demonstrates not only quantitative but also qualitative difference of technological properties of the composite by PFM. The increase of S_{BF} significantly reduces PFM of the composite, the increase of S_{AnF} does not essentially change it. Under standard conditions $\text{PFM}_{\text{FFat503 K}}$ for the composite with C_{BF} = 30 wt % is inferior even to $\text{PFM}_{\text{FFat463 K}}$ for the composite with C_{AnF} = 30 wt %. This fact allows us to consider the possibility of not only recycling, but also production of prototypes at the "cold" technological process, that means T_{proc} = 453 K. Taking into account the obvious economic interest in reducing energy intensity of production and the above mentioned positive aspects of the application of FF of the polymeric nature having significant temperature limitations, further research should be conducted using the PP + AnF composites at T_{proc} = 453 K.

There are similar trends of technological and structural properties change. According to them:

- index *E* (Fig. 1b), the numerical value of which significantly increases at the beginning of tiredness and considerably decreases after FF tiredness depending on weight content of rough surface relief (BF); whereas it significantly decreases at the beginning and after tiredness with smooth one (AnF). The difference between the values the beginning and after tiredness significantly increases with BF, whereas remains almost unchanged with AnF;
- index *H* (Fig. 1c), the numerical value of which significantly increases at the beginning of tiredness and slightly decreases after tiredness depending on FF weight content with a smooth relief surface, whereas it significantly increases at the beginning and after tiredness with rough one. The difference between the values at the beginning and after tiredness significantly increases with AnF, while remains almost unchanged with BV;
- index $\sigma(t)$ (Fig. 1d), the numerical difference between the values of tension measurement at compression at the beginning and after loading significantly decreases depending on FF weight content with a smooth relief surface, while remains almost unchanged with the rough one. The sufficient level of tension $\sigma(t_{serv.})$ = 0.1 MPa after loading at compression is at twice as much weight content of AnF compared with that of BF.

There is a possibility to use the above mentioned technological process with expansion of operations for PM + FF mixture processing, including their performance for several times. This allows to model the recycling process, *e.g*., three-multiplied process (1→2→3). PM + FF mixture is provided in the form of PM spherical granules and FF fragments by weight in accordance with TPC composition when the first processing (1) was carried out and cylindrical granules of PM + FF mixture after the second (2) and third (3) processing. The mixture is processed by consistent (1→2→3) thermomechanical mixing using ED-2.2 worm-disk extruder at the speed of worm-drive n_{extr} = 20 rev/min and processing temperature T_{proc} = 453 K with strand profiling and its mechanical granulation. The granules forms are close to the cylinder. Other operations remain unchanged, and obtained samples meet the standardized requirements [9-13].



a) b)

c) d)

Fig. 2. TPC parameters depending on FF (AnF or BF) weight content (C_{FF} = 0–30 wt %) and number of processing (first – 1x, the white background, and the third – 3x, the grey background): density (ρ, g/cm^3) and flowability of the melt at the processing temperature (PFM$_{FF\ at\ Tproc.\ (K)}$, g/10 min) (a); relative modulus of elasticity (E, MPa); hysteresis (H, rel. units.) at the beginning and after dynamic compression tiredness under ε = 2.5 % and ν = 5 Hz (c); d) relaxation of tension ($\sigma(t)$, MPa) at the beginning and after (prediction t_{serv} = 5 years) static loading compression under υ = 100 mm/min and ε = 2.5 % to $\sigma(t_{serv}.)$ = 0.1 MPa (dashed line) (d)

Taking into account the interest for the creation of TPC with the least possible density, *i.e.* using the most promising composition PP + AnF, let us consider the impact of recycling on its constructional and technological properties (Fig. 2).

The same tendency depending on the number of recycling (1 and 3) is expected. Thus:

- index ρ (Fig. 2a), the numerical value of which is proportional to the weight content and remains unchanged with the increasing number of recycling, whereas PFM value increases significantly;

- index E (Fig. 2b), the numerical value of which significantly decreases with the increasing number of recycling and AnF weight content; the difference between values at the beginning and after tiredness is almost invariable;

- index H (Fig. 2c), the numerical value of which slightly increases with the increasing number of recycling and significantly depends on AnF weight content at the beginning of tiredness. After tiredness it increases significantly with the increasing number of recycling accompanied with insignificant reduction of AnF weight content. The difference between values at the beginning and after tiredness significantly decreases with the increasing number of recycling and significantly increases depending on AnF weight content;

- index $\sigma(t)$ (Fig. 2d), the numerical value of difference between compression tension at the beginning and after loading significantly decreases with the increasing number of recycling and AnF weight content. The sufficient level of $\sigma(t_{serv.})$ = 0.1 MPa after loading corresponds to a slight increase in the AnF content.

On the basis of mentioned dependencies we make the assumption concerning appropriate search for fibrous filler of polymeric nature with necessary rough of the surface relief. Using such filler will allow to influence predictably the constructional and technological properties of TPC.

4. Conclusions

According to the needs of practical application the dependences of technological aspect impact on long-term constructional properties of TPC, considering for this purpose the most attractive composition – PP + AnF – are suggested to interpret as follows.

Elastic-hard properties, which are summarized by the relative elastic modulus (E, MPa), show a positive trend of reducing the dependency numerical value and the difference between the values at the beginning and after dynamic tiredness by compression in the presence of FF with the relief close to a smooth surface and by the number of recycling. The growth of FF content does not affect productivity of production technology, since it almost does not change the flowability of the melt, moreover at its tendency to a significant increase with increasing processing temperature. This fact is in a good agreement with established engineering requirements and it is subjected to prediction when calculating the kinematics of emergency support.

The absorption capacity, which is generalized by hysteresis index, demonstrates a positive trend of increasing the numerical value and reducing the difference between the values at the beginning and after dynamic tiredness by compression in the presence of FF with the relief close to the rough surface and the number of recycling. The growth of FF content has a negative influence on the productivity of production technology since it significantly reduces the flowability of the melt in the absence of opportunities to improve it due to the processing temperature restriction. This fact does not agree with established engineering requirements, although it is subjected to prediction when calculating the comfort of emergency support.

Long-term resistance, which is generalized by relaxation of tension shows a positive trend of increasing the numerical value and, unfortunately, the difference between the values at the beginning and after the static loading by compression in the presence of FF with the relief close to the rough surface and the amount of recycling. The growth of FF content adversely affects the productivity of production technology due to the above mentioned reasons. This fact does not agree with established engineering requirements, although it is subjected to prediction when calculating the guaranteed holding of emergency support from shifting on the wheel rim and provide functional fitness of the wheel bearing engine to the transmission time.

Thus, the advisability of complex research of technological aspects and long-term structural properties of TPC has been proved. It allows to define a promising direction to improve the practical appeal and, accordingly, provide the requirements to search fibrous filler of the polymeric nature with the predicted rough of surface relief.

References

[1] Naumenko A., Burmistr M., Bashtanyk P. and Naumenko M.: VI Ukr. Mezhdunarod. Nauchno-Techn. Konf. Rezinshikov. Ukraine, Dnepropetrovsk 2006, 27.

[2] Naumenko A., Burmistr M., Bashtanyk P. and Naumenko M.: Vopr. Khimii i Khim. Techn., 2007, **5,** 144.

[3] Verbas V., Naumenko A., Burmistr M. *et al.*: Vopr. Khimii i Khim. Techn., 2008, **2,** 82.

[4] Verbas V., Naumenko A., Burmistr M. *et al.*: Vopr. Khimii i Khim. Techn., 2009, **6**, 58.

[5] Verbas V., Naumenko A., Burmistr M. *et* al.: Vopr. Khimii i Khim. Techn., 2010, **3**, 89.

[6] Naumenko M., Bashtanyk P. and Burmistr M.: IV Mizhnar. Nauk.-Techn. Konf. Stud., Aspir. ta Mol. Vchenykh. Ukraine, Dnipropetrovsk 2009, 169.

[7] Naumenko M., Bashtanyk P. and Burmistr M.: 6th International Student's Scientific Conference. Poland, Radom 2009, 202.

[8] Naumenko M., Bashtanyk P. and Burmistr M.: Geotehnichna Mehanica. Mizhvid. Zb. Nauk. Prac/Inst. Geotehnichnij Mehaniky, 2011, **96**, 10.

[9] Malkin A., Askadskij A. and Kovruga V.: Metody Izmereniya Mechanicheskykh Svoistv Polymerov. Khimiya, Moskwa 1978.

[10] Nilsen L.: Mechanicheskie Svoistva Polymerov. Khimiya, Moskwa 1978.

[11] Averko-Antonovuch Y., Omelchenko P., Ochotina N. and Ebich Y.: [in:] Kirpichnikov P. (Ed.), Technologiya Rezinovykh Izdeliy. Khimiya, Leningrad 1991.

[12] Suberlyak O. and Bashtanyk P.: Technologiya Perepobky Polymernykh ta Kompozyciynykh Materialiv. Vyd-vo «Rast-7», Lviv 2007.

[13] Naumenko M.: Geotehnichna Mehanica. Mizhvid. Zb. Nauk. Prac/Inst. Geotehnichnij Mehaniky, 2012, **106**, 111.

[14] Naumenko M., Bashtanyk P. and Burmistr M.: II Mizhnar. Nauk. Konf. Mol. Vchenykh. Ukraine, Lviv 2011, 48.

[15] Naumenko M., Bashtanyk P., Burmistr M. and Naumenko O.: Vopr. Khimii i Khim. Techn., 2011, **6**, 86.

[16] Naumenko M., Bashtanyk P. and Burmistr M.: VIIth Polish-Ukrainian Conf. Poland, Radom 2012, 53.

ТЕХНОЛОГІЧНИЙ АСПЕКТ ВПЛИВУ НА ДОВГОТРИВАЛІ КОНСТРУКЦІЙНІ ВЛАСТИВОСТІ ПРИ СТИСНЕННІ ТЕРМОПЛАСТИЧНИХ ПОЛІМЕРНИХ КОМПОЗИТІВ

Анотація. *Наведена доцільність комплексного дослідження технологічного аспекту та довготривалих конструкційних властивостей термопластичного полімерного композиту, що дало можливість визначити перспективний напрямок підвищення його практичної привабливості. Наведені вимоги для пошуку волокнистого наповнювача полімерної природи з прогнозованим наданням шершавості рельєфу поверхні.*

Ключові слова: *поліпропілен, аварійна опора, термопластичний полімерний композит, рельєф поверхні.*