

Anton Marcinčin,
Marcela Hricová,
Konštantín Marcinčin,
Alena Hoferíková

Study of the Rheological, Thermal and Mechanical Properties of Polypropylene/Organoclay Composites and Fibres

Slovak University of Technology in Bratislava,
FCHFT, Institute of Polymer Materials,
Department of Fibres and Textile Chemistry,
Radlinského 9, 812 37 Bratislava, Slovakia
E-mail: anton.marcincin@stuba.sk

Abstract

In this paper, the spinning of polypropylene (PP)/montmorillonite (MMT) composites, as well as the structure and selected mechanical properties of composite fibres are presented. In the experimental work the commercially available organically modified montmorillonites Cloisite 15A (C15A) and Cloisite 30B (C30B) were used. The organoclays were incorporated into the matrix of PP fibres in the form of concentrated PP/organoclay dispersion before spinning. The rheological properties of concentrated PP and PP/organoclay dispersion were investigated to estimate the melt mixing of these components and spinning conditions. A positive effect of both organoclays on the geometrical and structural non-uniformity of PP composite fibres was found. MMT acts as a nucleating agent in PP and can affect the crystallisation rate and supermolecular structure of PP fibres. PP composite fibres formed at a maximum draw ratio showed a higher tensile strength (tenacity) and Young's modulus in comparison with unmodified fibres.

Key words: polypropylene, organoclay, composites, fibres, non-uniformity, mechanical properties.

other synthetic fibres based on polyamides and polyesters. Besides this, PP fibres have a tendency to creep at room temperature [7].

The reinforcing effect of MMT in polymers results from the exfoliation of the original smectic structure [8]. A high level of exfoliation in PP was obtained when organically pre-treated layered silicates and suitable compatibilisers, such as PP grafted with maleic anhydride (PP-g-MA), were used [9]. A high level of exfoliation was found for a relatively high content of the compatibiliser, up to 22 wt% [10]. In addition, the molecular weight of PP, the efficiency of the melt-mixing equipment and the method of preparation affect the morphology and end-use properties of composites [11, 12]. The lower molecular weight of PP proved more favourable because of the effective thermal diffusion of macromolecules in the interlayer space galleries. On the other hand, the mixing effect of the twin-screw extruder was more limited. More effective kneading elements did not always provide sufficiently higher exfoliation of layered silicates [9]. These results are contrary to those obtained for polyamide composites, where a higher viscosity of the polymer contributes to the higher shear stress and disintegration (exfoliation) effect of nanoclays [13].

Oriented polymer composites such as composite fibres represent a special group of polymer materials. The mechanical properties of such fibres depend on their molecular and supermolecular structures, as well as on the orientation

of crystalline and amorphous regions. Some papers showed slightly enhanced mechanical properties of PP composite fibres, but the results are not unambiguous [14 - 16].

In this paper, the effect of selected commercial organoclays and a non-reactive compatibiliser-dispersant on the rheological properties of concentrated PP/organoclay dispersions, as well as on the structure and thermal/mechanical properties of PP composite fibres, is presented. The "compatibility" of the PP-organoclay-compatibiliser and the processing of the PP composite during spinning were estimated on the basis of the non-uniformity of fibres. The correlation between the mechanical properties and orientation of fibres is also discussed in this paper.

Experimental

Materials used

Polymers: Two commercially available types of polypropylene (PP) were used in the experimental work: Polypropylene HPF (PP HP) with a melt flow index (MFI) of 8.0 g/10 min, in powder form, and fibre-grade polypropylene TG 920 (PP TG) with a MFI of 10.5 g/10 min. Both polypropylenes were produced by Slovnaft a. s., Bratislava, Slovakia

Fillers: The two kinds of treated montmorillonite (MMT) used in this work were Cloisite 15A (C15A) and Cloisite 30B (C30B), both produced by Southern Clay Product, Inc, Gonzales, TX 78629, USA. C15A is a montmorillo-

Introduction

The development of polypropylene (PP) based composites containing layered silicates is focused in particular on improving the mechanical properties of polymers [1 - 3], enhancing their barrier against the permeability of gases [4], thermal stability [5] and on decreasing combustibility [6]. PP composite fibres with enhanced mechanical properties are especially interesting because of their lower elastic modulus as compared to

nite ion exchanged with dimethyl dihydrogenated tallow quarternary ammonium ions. C30B is a montmorillonite treated with methyl tallow bis-2-hydroxyl quarternary ammonium ions.

Compatibiliser: The non-reactive compatibiliser-dispersant Tegopren 6875 (TEG), based on (poly)-alkylsiloxane, produced by Degussa Co., Düsseldorf, Germany, was used for the preparation of the concentrated dispersion of organoclay in PP HP.

Preparation of polypropylene/organoclay composite fibres

The following two step method was used for the preparation of PP/organoclay composite fibres.

1. Preparation of the concentrated dispersion of organoclay in PP:

The PP HP, organoclay and compatibiliser were mixed in a mixer of high r.p.m. for 3 min. The powder mixture was melted and kneaded using a twin screw rotating extruder (ϕ 28 mm). The temperatures of the extruder zones from the feedstock to the head were 80, 150, 220, 225, 225, 225 and 232 °C. The temperature of the extruded melt was 229 °C. The extrudate was then cooled and cut. The concentration of organoclay in the PP HP was 10.0 wt% and the content of compatibiliser 4.0 wt%.

2. Melt mixing of PP TG with concentrated organoclay dispersion using a one screw extruder and the subsequent spinning of the PP composite melt:

The chips of PP TG and concentrated organoclay dispersion were mixed and spun using a single screw extruder (ϕ 30 mm) and a spinneret with 40 orifices. The spinning temperature was 280 °C, the metering of the melt 30 g/min, the spinning speed 360 m/min and the fineness of spun fibres (drawn ratio 1:1, λ_1) was 840 dtex. Fibres were drawn using a laboratory drawing machine at various draw ratios λ at a draw temperature of 120 °C (heating plate).

Methods used

Rheological measurements: The rheological properties of pure polymer components and concentrated PP dispersion of organoclay were measured using a Göttfert N 6967 capillary extrusimeter with extruder (ϕ = 20 mm) at 270 °C. Newtonian and Oswald - de Waele laws were used for the determination of basic

rheological parameters: apparent viscosity and power law exponent (PLE) n :

$$\eta = \tau/\dot{\gamma} \quad (1)$$

$$\tau = k \cdot \dot{\gamma}^n \quad (2)$$

which characterise the non-Newtonian behaviour of the polymer melt, where τ - shear stress, $\dot{\gamma}$ - shear rate, η - apparent viscosity, n - PLE, and k - coefficient.

External non-uniformity of fibres: This was expressed by a coefficient of

variation of the individual fibre diameter d (CV_d), measured for randomly selected lengths of fibres. A light microscope (Olympus BH-2) with Quick Photo Micro 2.0 software was used for the measurement of the diameter non-uniformity of the PP composite fibres.

DSC measurement: A DSC 7 (Perkin Elmer) was used for evaluation of the thermal properties of the PP TG/organoclay composite fibres and for estima-

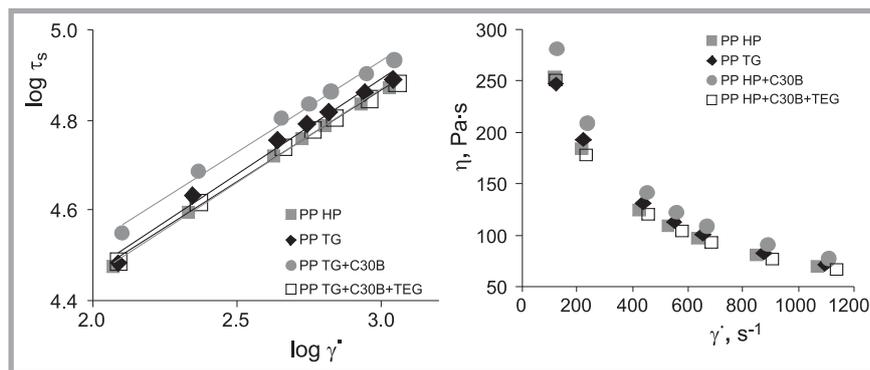


Figure 1. Dependence of shear stress τ (a) and viscosity (b) on the shear rate $\dot{\gamma}$ for PP and PP HP/C30B composites, at 270 °C. The content of organoclay in PP HP was 10 wt %, and the content of the TEG compatibiliser 4 wt %.

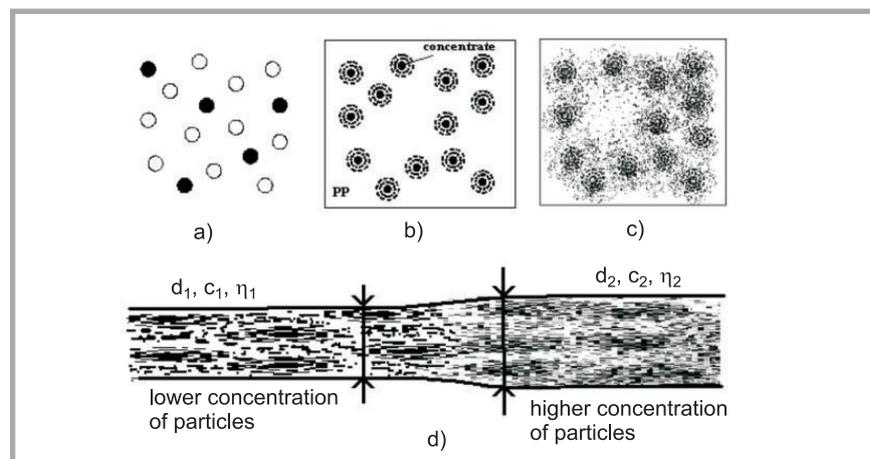


Figure 2. Mechanism of melt mixing a polymer (o) with a concentrated polymer/organoclay dispersion (●). a) chips, b) initial stage of mixing, c) after mixing, (d) non-uniformity of composite fibres due to concentration of particles ($c_1 < c_2$) and viscosity ($\eta_1 < \eta_2$)

Table 1 Power law exponent (n) and viscosity (η) for selected shear rates ($\dot{\gamma}$) of PP and PP/organoclay composites, at 270 °C. The content of organoclay was 10 wt% and that compatibiliser TEG 4 wt%. The coefficient of variation of PLE was $CV_n = \pm 0.15\%$

Sample	n	Viscosity η [Pa.s]			
		$\dot{\gamma} = 100 \text{ s}^{-1}$	$\dot{\gamma} = 300 \text{ s}^{-1}$	$\dot{\gamma} = 500 \text{ s}^{-1}$	$\dot{\gamma} = 1000 \text{ s}^{-1}$
PP HP	0.42	284	149	111	74
PP TG	0.42	293	156	116	78
PP HP+C15A	0.43	310	166	124	84
PP HP+C15A+TEG	0.38	318	162	118	77
PP HP+C30B	0.40	336	175	129	85
PP HP+C30B+TEG	0.41	289	151	111	74

tion of the supermolecular structure of the PP fibres, during which the temperature cycle heating-cooling-heating was used. The heating and cooling rate was 10 °C/min, in the temperature range of 50 - 280 °C.

Mechanical properties of the blended fibres: An Instron (Type 3343) was used for measurement of the mechanical properties of the fibres (according to ISO 2062:1993). Coefficients of variation of the tenacity and elongation were also used as a measure of the structural non-uniformity of the fibres. They were evaluated from 15 measurements. The initial length of fibres was 25 cm, and the time of deformation was about 20 sec.

Orientation of fibres: The average factor of orientation of the fibres (f_α) was evaluated by sonic velocity measurements using a Dynamic Modulus Tester-PPM-5R. The factor of orientation was calculated according to the equation:

$$f_\alpha = 1 - \frac{C_n^2}{C^2} \quad (3)$$

where f_α - average factor of orientation, C - sonic velocity of oriented sample and C_n - sonic velocity of standard isotropic fibre.

Results and discussion

Rheological properties of PP HP/organoclay composites

The melt viscosity in dependence on the shear rate and deviation from Newtonian flow was evaluated for concentrated dispersions of PP and PP HP/organoclay (Figure 1, Table 1). The high deviation of the melt flow from the Newtonian, expressed by PLE, is characteristic for PP in comparison with fibre grade aliphatic polyamides and polyesters. The contribution of organoclays C15A and C30B in the PP HP matrix (concentration of organoclay was 10 wt%) to the non-Newtonian behaviour of dispersion is negligible, which results from the similar power law exponent for both virgin and filled PP (n is within the range of 0.38-0.42). The non-Newtonian behaviour of PP HP/C15A dispersion ($n = 0.43$) is close to that of unmodified PP TG and PP HP. A decrease in PLE was observed for PP HP/C30B dispersions (Table 1). The weak mutual interaction between solid particles as well as low adhesive interactions at the PP/organoclay interface can be deduced from the results.

Table 2. Coefficients of variation of the fibre diameter (CV_d), tenacity (CV_T) and elongation at break (CV_E) for PP TG/organoclay composite fibres, (drawn fibres).

Composition of fibres	Content of organoclay, %	CV_d , %	CV_T , %	CV_E , %
PP TG	-	8.9	1.6	12.2
PP TG+C15A	0.1	5.3	3.4	7.8
	1.0	8.5	5.9	15.4
PP TG+C15A+TEG	0.1	8.8	2.4	6.5
	1.0	6.4	3.1	31.7
PP TG+C30B	0.1	7.9	4.8	12.0
	1.0	9.7	3.7	6.6
PP TG+C30B+TEG	0.1	7.7	1.6	5.4
	1.0	4.6	5.5	11.5

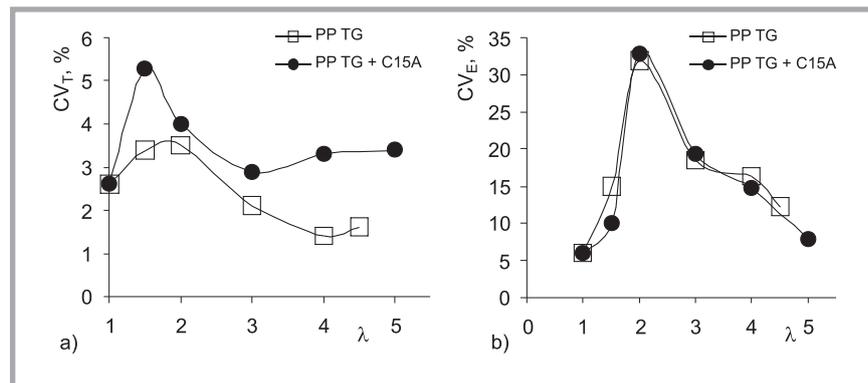


Figure 3. Dependence of coefficient of variation of tenacity CV_T (a) and elongation CV_E (b) on the draw ratio of PP TG/C15A composite fibres. The concentration of organoclay C15A was 0.1 wt%.

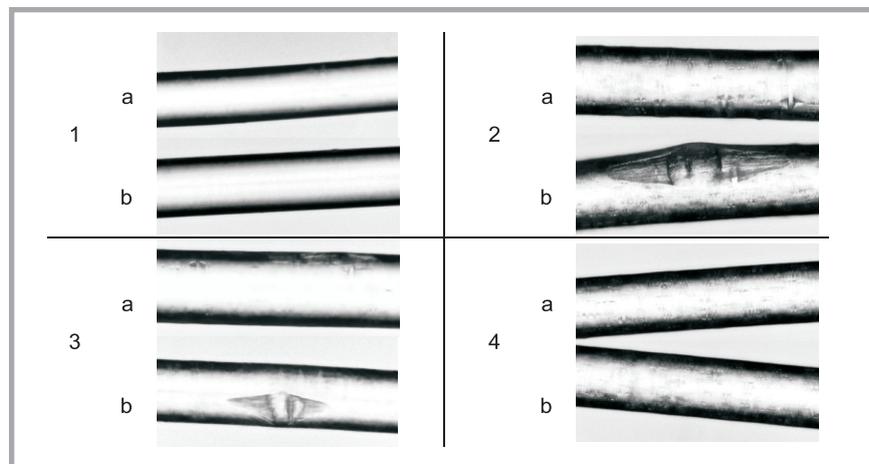


Figure 4. Microscopic pictures of PP TG/organoclay (1.0 wt%) composite fibres at a 10×40 magnification. Demonstration of the distribution of organoclay in the fibres: 1-PP TG; 2-PP TG+C15A; 3-PP TG+C30B; 4a-PP TG+C15A+TEG; 4b-PP TG+C30B+TEG.

The melt viscosity of PP HP/organoclay composites is higher than that of PP TG. The effect of the compatibiliser-dispersant on the rheological properties of PP HP/organoclay composites reveals that the TEG compatibiliser provides a lower melt viscosity for both organoclays in PP HP compared to dispersion without TEG (Table 1). A higher decrease in viscosity was found for PP/C30B dispersion.

The rheological parameters, both PLE and viscosity, of PP HP containing

10 wt% organoclay are characteristic of the micro-dispersion of inorganic fillers in PP, such as TiO_2 and $CaCO_3$. It shows that the treatment of montmorillonite with organic quarternary ammonium ions using a polysiloxane compatibiliser in the dispersion did not provide sufficient conditions for the exfoliation of layered silicates. The similar dynamic viscosity of PP TG and PP HP/organoclay dispersions suggests favourable mixing conditions for PP TG with concentrated orga-

noclay dispersions (equal viscosity of mixing components) before spinning.

Non-uniformity of PP TG/organoclay composite fibres

The cross-sectional (external) and structural (internal) non-uniformities of PP HP/organoclay composite fibres were investigated. Both non-uniformities depend on the variance of spinning parameters and polymer homogeneity. Besides this, the elasticity of polymer melt affects the cross-sectional (diameter) non-uniformity of fibres. At constant spinning parameters the effect of the homogeneity of the polymer before spinning and the melt elasticity on the non-uniformity of fibres is dominant.

According to the microrheology of immiscible polymer blends, the size and shape of particles of the dispersed phase is determined by the viscosity ratio of the dispersed phase to the matrix and adhesive interactions at the interface [17]. This model can also be considered, with limited validity, for “miscible pairs” of concentrated “PP TG” and “PP HP/organoclay dispersion” in the spinning extruder, when the presence of solid particles and the diffusion of polymer components are ignored (Figures 2.a, b, c).

Thus, the non-uniformity of PP HP/organoclay composite fibres results from the mixing conditions of the basic polymer and the concentrated polymer/organoclay dispersion (concentrate) in the extruder before spinning (Figure 2). An ideal uniform distribution of concentrated organoclay dispersion and solid particles in the PP TG matrix can be expected only after a long mixing time. The non-uniform distribution of micro-volumes of a mixture containing a different content of solid particles leads to a change in local viscosity, as well as to an unsteady flow and non-uniform deformation of fibres in the spinning line. The non-uniformity in the cross-section of fibres (external-geometrical non-uniformity) is expected in this case (Figure 2.d). In addition, the solid particles affect the non-uniformity in the morphology and supermolecular structure of fibres (local concentration of particles, crystallinity, size and orientation of morphological elements). They can cause the internal (structural) non-uniformity of fibres. Both non-uniformities affect variance in the properties of fibres e.g. mechanical properties.

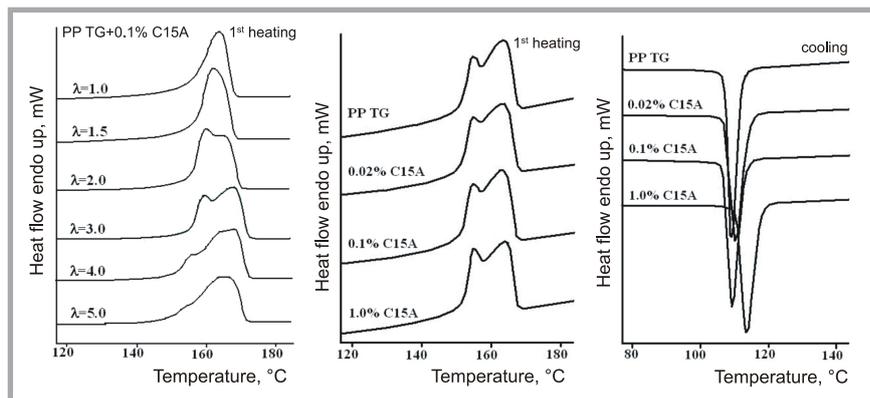


Figure 5. DSC melting thermograms of the PP/organoclay composite fibres drawn in dependence on the draw ratio (a) and concentration of C15A in the PP fibres for a draw ratio of $\lambda 3$ (b), as well as of the crystallisation of the melt in the cooling regime (c).

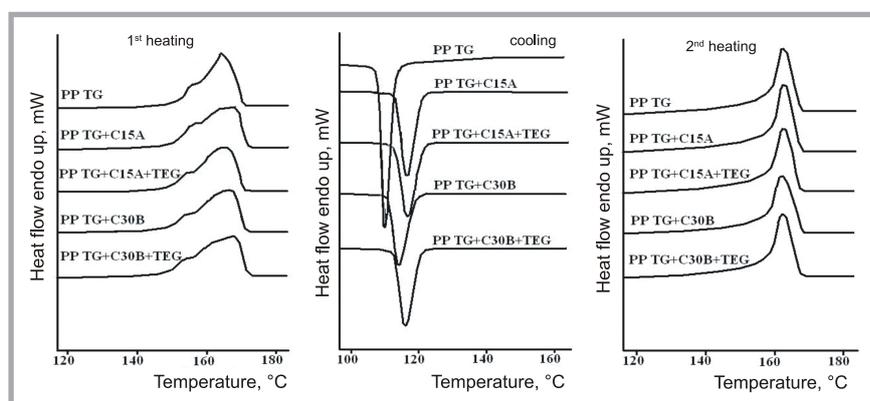


Figure 6. DSC thermograms of the drawn λ_{max} PP/organoclay composite fibres obtained in the following cycle: 1st heating (a), cooling (b) and 2nd heating (c). Concentration of organoclay in the fibres was 1.0 wt% and that of TEG 0.4 wt%.

Table 3. Melting temperature and melting enthalpy of PP/organoclay composite fibres. The compatibiliser content was 40 wt% in relation to the organoclay.

Composition of fibres	Content of organoclay, %	λ_{max}	1 st heating			cooling		2 nd heating	
			$T_{m1}, ^\circ\text{C}$	$T_{m2}, ^\circ\text{C}$	$\Delta H, \text{J}\cdot\text{g}^{-1}$	$T_c, ^\circ\text{C}$	$\Delta H, \text{J}\cdot\text{g}^{-1}$	$T_{m21}, ^\circ\text{C}$	$\Delta H, \text{J}\cdot\text{g}^{-1}$
PP TG	-	4.5	155.1	163.5	92.4	109.3	93.3	158.8	84.5
PP TG+C15A	0.1	5.0	155.0	165.3	113.0	112.6	110.0	161.5	101.5
	1.0	4.5	156.8	167.1	109.5	116.4	111.1	162.7	101.2
PP TG+C15A+TEG	0.1	5.0	154.1	166.0	116.3	112.4	111.1	161.3	102.9
	1.0	4.5	155.0	165.0	112.8	116.8	110.8	162.5	102.3
PP TG+C30B	0.1	4.5	154.6	166.5	115.6	111.4	110.2	161.3	102.2
	1.0	4.5	154.8	166.3	110.3	114.3	106.1	162.0	97.7
PP TG+C30B+TEG	0.1	5.0	154.5	167.6	112.1	112.4	110.6	161.5	101.9
	1.0	4.5	154.6	167.6	109.5	115.8	108.6	162.3	100.0

A simple statistical analysis of the diameter of PP TG/organoclay composite fibres shows the mixing efficiency and “compatibility” of the concentrated dispersion of PP TG with PP HP/organoclay in the extruder before spinning. The results in Table 2 reveal a relatively high non-uniformity of the diameter for unmodified PP TG fibres ($CV_d = 8.9\%$). However, an already small concentration of C15A (0.1 wt%) has a positive effect on the non-uniformity of the fibre diameter and leads to a decrease in the coefficient of

variation CV_d . Organoclay C30B with a lower content of organic phase does not improve the non-uniformity of the fibre diameter. Composite fibres prepared using the alkylsiloxane-based compatibiliser TEG exhibit a lower CV_d at a higher concentration of organoclay (1.0 wt%). In particular, the positive impact of TEG on the non-uniformity of PP TG/C30B composite fibres was found. The favourable effect of organoclay on the external non-uniformity of PP HP/organoclay fibres probably consists in the suppression

of the melt elasticity and the forming of the polymer structure, which facilitates the axial deformation of fibres during spinning and drawing.

The non-uniformity of PP TG/organoclay fibres was also estimated on the basis of the variation coefficient of their mechanical properties: tenacity (CV_T) and elongation at break (CV_E). The individual coefficients of variation express the non-uniformity of the tensile strength and elongation during axial deformation at the same conditions. The CV_T of the basic mechanical properties of PP TG/organoclay fibres increases unambiguously with an increase in filler concentration (Table 2). The low values of CV_E correspond with the lower CV_T for 0.1 wt% of organoclay, compared with 1.0 wt% of nanofiller.

The results in Figures 3.a & b reveal that the coefficients of variation for the basic mechanical properties of fibres are strongly affected by the draw ratio. The dependence of the coefficient of variation for PP and PP TG/organoclay fibres on the draw ratio shows a slight maximum for CV_T and an outstanding maximum for CV_E (Figures 3.a, b). From this point of view, from among the fibres examined, a comparable CV_E was obtained for a maximum draw ratio for the final structure of fibres drawn.

The microscopic observation of PP TG/organoclay composite fibres showed the imperfect dispersion and distribution of organoclay in the polymer matrix (Figure 4). The appearance of micro-particles (agglomerates) was observed mainly for organoclay without the TEG compatibiliser (Figures 4/2b, 4/3b). Significantly improved dispersion and distribution of organoclay was found when the TEG compatibiliser-dispersant was used (Figures 4/4a, 4/4b). In particular, the dispersion of organoclay C30B with the TEG compatibiliser showed the absence of larger non-dispersed agglomerates in the PP matrix (Figure 4/4b). The results of microscopic analysis correspond with the analysis of the non-uniformity of fibres (Table 2).

DSC analysis

The effect of organoclay particles on the supermolecular structure of composite fibres was investigated by DSC analysis. Thermograms of the temperature cycle regime: 1st heating-cooling-2nd heating

Table 4. Factor of the average orientation f_α , tenacity T , elongation at break E and Young's modulus YM of PP TG/organoclay composite fibres at a maximal drawing ratio λ_{max} .

Composition of fibres	Content of organoclay, %	λ_{max}	f_α	T , cN/dtex	E , %	YM , N/tex
PP TG 920	-	4.5	0.72	4.16	33.8	4.73
	0.02	5	0.76	5.42	27.7	4.89
PP TG+C15A	0.1	5	0.76	5.50	25.6	4.54
	1.0	4.5	0.70	4.17	36.1	4.30
	3.0	3	0.64	2.42	98.5	2.34
	0.02	5	0.76	5.22	25.3	4.92
PP TG+C15A+TEG	0.1	5	0.75	5.14	24.1	4.99
	1.0	4.5	0.72	4.38	44.7	4.75
	3.0	5	0.71	4.58	25.8	4.46
	0.02	5	0.74	5.25	29.4	4.99
PP TG+C30B	0.1	4.5	0.75	4.94	27.2	4.83
	1.0	4.5	0.73	4.39	20.3	4.78
	3.0	-	-	-	-	-
	0.02	5	0.74	5.63	25.2	5.31
PP TG+C30B+TEG	0.1	5	0.73	5.51	26.0	4.73
	1.0	4.5	0.72	4.40	28.3	4.68
	3.0	3	0.62	2.24	81.8	2.25
	0.02	5	0.74	5.63	25.2	5.31

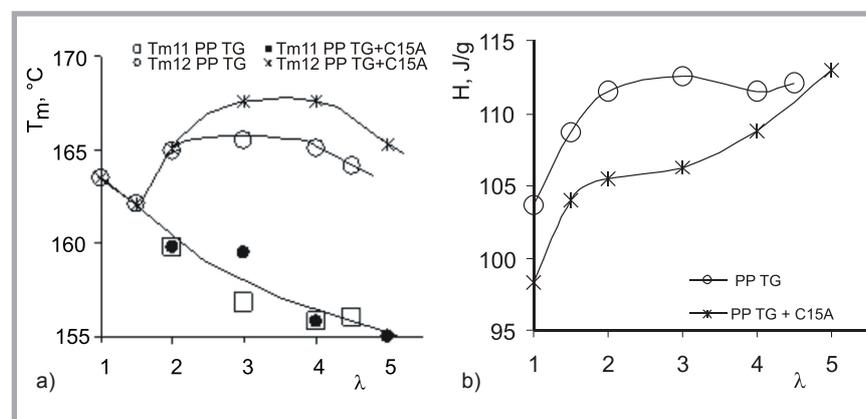


Figure 7 Dependence of the melting temperature (a) and enthalpy (b) of PP composite fibres on the draw ratio.

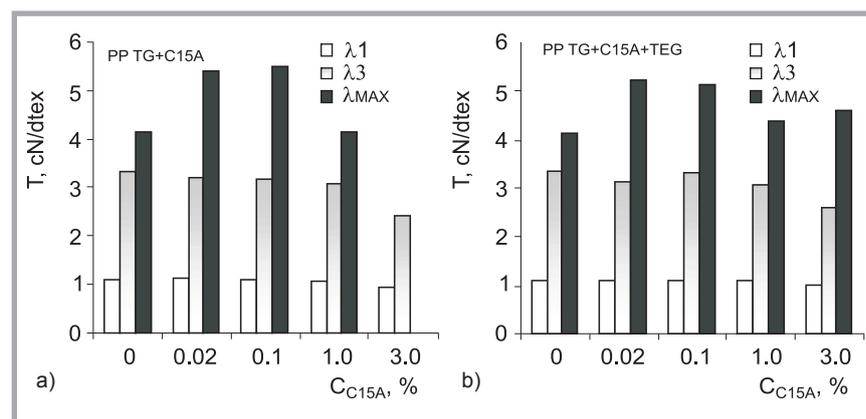


Figure 8. Dependence of the tenacity of PP TG/C15A composite fibres on the organoclay concentration for various draw ratios λ .

were obtained. Some of the thermograms are shown in Figures 5 & 6 and in Table 3.

A simple melting endotherm with a melting temperature of T_{m1} (161 °C) for spun fibres and a double endotherm with two characteristic temperatures T_{m1} (155 °C)

and T_{m2} (164 °C) for drawn (λ_3) PP TG fibres were found (Figures 5.a & 5.b). Originally, the simple melting endotherm for PP TG fibres was split into a double peak endotherm. The lower temperature phase transition T_{m1} decreased gradually at a draw ratio for both unmodified

and composite fibres (**Figure 7.a**). The higher temperature phase transition T_{m2} grew in dependence on the draw ratio and passed through the maximum at the middle draw ratio. The higher melting temperature T_{m2} was found for PP TG/C15A composite fibres (**Figure 7.a**). The melting enthalpy (corresponding with crystallinity) of PP TG/C15A composite fibres is lower in comparison with that of unmodified fibres, which increases gradually with the draw ratio and slightly exceeds the melting enthalpy of pure PP TG fibres at λ_{max} (**Figure 7.b**). In principle, the shape of the endotherms, and as well as the melting temperatures did not change for fibres containing both types of fillers and compatibiliser at a lower organoclay concentration, up to 1.0 wt% (**Figure 6.a**), which means that the supermolecular structure of spun and drawn fibres practically depends on the spinning and drawing conditions of the composite fibres only and is not markedly affected by additives (**Figures 5.b, 6.a**).

In the cooling regime, both organoclays act as nucleating agents and increase the crystallisation temperature of the PP matrix (**Figures 5.c, 6.b** and **Table 3**). A higher nucleating effect was found for PP TG containing C15A as compared to C30B. The nucleating efficiency increased with the rising concentration of organoclay in the PP matrix. The original temperature of crystallisation (109 °C) of the PP increased to 116 - 117 °C for PP TG containing C15A and to 114 - 116 °C for PP TG with a C30B filler of 1.0 wt.% (**Table 3**).

The results of DSC measurements reveal that the presence of organoclay in PP fibres leads to the forming of a supermolecular structure in spun fibres of lower crystallinity, which appears to be more convenient for the deformation of fibres during the drawing process.

Mechanical properties of PP TG/organoclay composite fibres

The mechanical properties of semicrystalline polymer fibres, such as tenacity, elongation at break and Young's modulus, in general, depend on their molecular and supermolecular structure as well as on the axial orientation of the structural elements. Both organoclays positively affected the mechanical properties of fibres only at a low concentration, up to 1.0 wt%. The tenacity of fibres was enhanced more effectively by C15A orga-

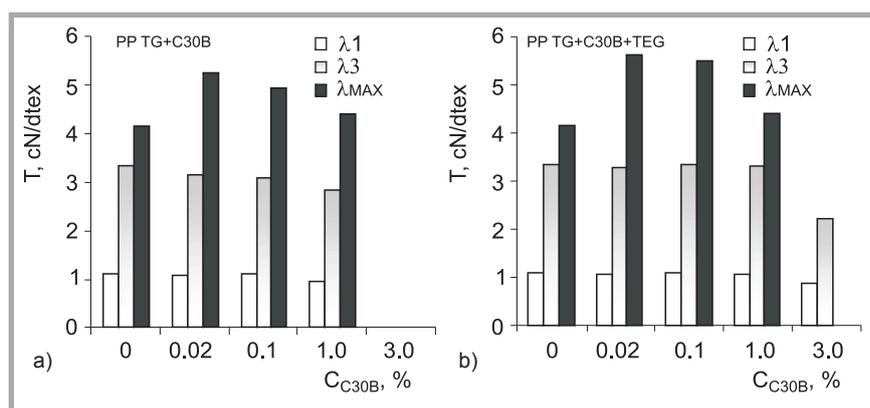


Figure 9. Dependence of the tenacity of PP TG/C30B composite fibres on the organoclay concentration for various draw ratios λ .

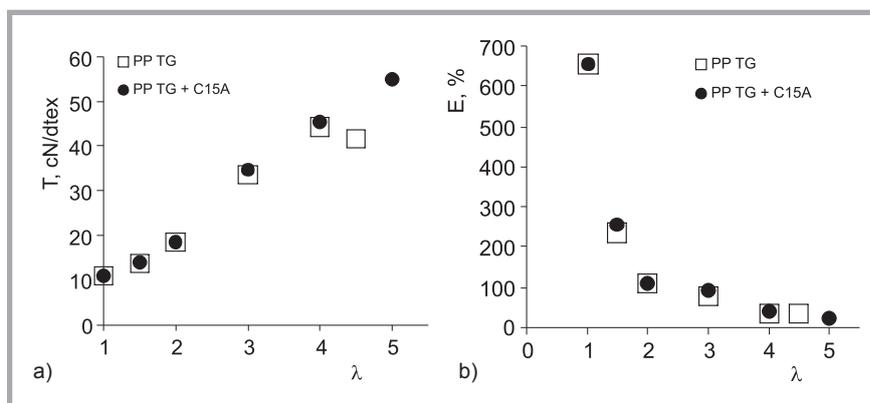


Figure 10. Dependence of the tenacity T (a) and elongation E (b) on the draw ratio of PP TG/C15A composite fibres.

noclay without the TEG compatibiliser, and by C30B when the TEG compatibiliser was used during the dispersion process (**Figures 8, 9**). A lower tenacity was found for PP TG fibres containing C30B without a compatibiliser. The elongation at break of fibres at the maximal draw ratio slightly decreases at a lower concentration of both organoclays when the TEG compatibiliser was used. A decrease in the elongation of composite fi-

bres corresponds with a higher tenacity and Young's modulus of fibres as well as with a higher average orientation (**Figures 10 & 11**).

Analysis of the tensile strength, Young's modulus and elongation of the fibres indicates the primary effect of the orientation of fibres on both the tenacity and Young's modulus. The higher orientation of fibres results from the deformability of fibres during drawing. The positive effect of a low concentration of fillers and compatibilisers on the mechanical properties of PP composite fibres consists only in their favourable deformation during the drawing process. In this case, the higher λ_{MAX} was achieved during the drawing of fibres (**Figures 10 & 11**). Similar results were obtained by Mikołajczyk, Boguń and Szparaga for PAN fibres prepared by wet spinning [18].

Conclusions

The experimental results obtained during the preparation of PP/organoclay (Cloisite) composite fibres as well as the evaluation of their structural parameters and

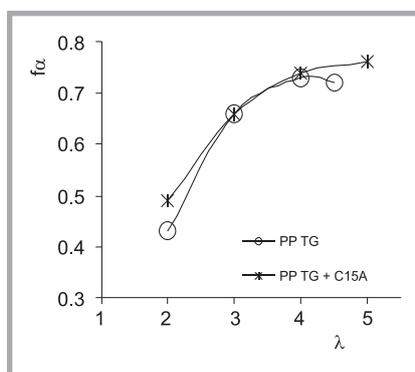


Figure 11. Dependence of the average orientation factor f_α on the draw ratio of PP composite fibres.

mechanical properties led to the following conclusions:

- The viscosity and deviation from Newtonian behaviour of PP HP/organoclay melt show the structure characteristics of micro-dispersion composites.
- The organically treated layered silicates C15A and C30B have a positive effect on the cross-sectional and structural non-uniformity of PP composite fibres at a concentration of up to 1.0 wt%. This effect is supported by the addition of an alkyl polysiloxane compatibiliser.
- Layered silicates (C15A and C30B) have a positive effect on the deformability and orientation of fibres during drawing, enhancing their tensile strength (about 30%) and Young's modulus (at a concentration of 0.02 – 1.0 wt%). The higher deformability of PP/organoclay composite fibres is supported by selected TEG compatibilisers.
- Reinforcing the effect of C30B organoclay in the oriented PP is deduced on the basis of a higher tenacity and Young's modulus in spite of a lower average orientation and higher elongation of fibres compared to the effect of C15A.



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e-mail:

ibwch@ibwch.lodz.pl

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