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Polypropylene/(Polyethylene Terephthalate/Polybuthylene Terephthalate) Blend Fibres: Phase Structure and Mechanical Properties

Abstract

This paper deals with conditions for preparation, phase structure and selected properties of polypropylene (PP)-polyester (PES) blend fibres. The dispersed polyester phase in PP matrix is represented by both polyethylene terephthalate (PET) and polybuthylene terephthalate (PBT), as well as by their blends (PES). The phase morphology of the blend fibres with regard to the rheological properties of the components of PP/PES blend fibres was investigated by the microscopic method. The DSC analysis and wide-angle X-ray scattering (WAXS) methods were used to evaluate the supermolecular structure of blend fibres. The correlations between the rheological properties of polymer components and the phase structure & mechanical-physical properties of the PP/PES blend fibres are discussed in this paper. We found a positive effect of the PBT in the PES-dispersed phase on the rheological properties of the blend and mechanical properties of the PP/PES blend fibres.

Key words: *polypropylene, polyethylene terephthalate, polybuthylene terephthalate, phase structure of blend fibres, mechanical properties.*

■ Introduction

The polymer blends are physical 'alloys' of the structurally different polymers which do not have any clearly identifiable covalent bonds between the macromolecule chains of components. The chemical interactions in the real polymer blends often lead to a certain share of the copolymers, e.g. between two kinds of polyesters by a re-esterification reaction. Polymer blends permit new materials to be prepared without any synthesis of the new polymers. The properties of the blends depend to a decisive degree on the properties of individual components and on the blend phase structure. The mutual compatibility of polymers and blending conditions play a very important role in creating the phase structure of polymer blends [1]. The phase structure of the fibres based on a heterogeneous polymer blend is significantly affected by the rheological properties of components and adhesive interactions at the interphase [2, 3]. The deformation of polymer melt in both the spinning and drawing of fibres leads to deformation of the particles of the dispersed phase, and a polyfibrilar system of blend fibres is formed [4 - 6].

According to Taylor & Cox's theory, the shape of the particles in the dispersed phase of immiscible polymers in the steady uniform shear or extensional flow can be expressed by two dimensionless parameters [7, 8]: the capillary number $Ca = \eta_m \cdot \gamma \cdot r / \sigma$ and the viscosity ratio $K = \eta_d / \eta_m$, where γ is the shear rate,

r the radius of the undeformed drop, σ the interfacial tension, η_d the viscosity of the dispersed phase, and η_m the matrix viscosity. The deformation ε is expressed by the length l and diameter d of the deformed particles:

$$\varepsilon = (l\text{-}d)/(l\text{+}d)$$

Competition between drop breakup and coalescence results in critical deformation ε_{cr}. For shear flow, the minimum of ε_{cr} is within the range of K value 0.1 - 1.0, and for elongation flow, it is within K=1 - 5.

In any case, the deformation of the dispersed phase is expressed by the shear rate γ, which is indirectly proportional to K [9]. The experimental results from various authors concerning the polymer blends are not unambiguous in harmony with the theory. Some authors have found the maximum of the deformation of the dispersed phase to be of the same viscosity as that of the matrix [10].

Almost all polymer blends consisting of semi-crystalline polymers in solid state display a micro-phase, heterogeneous structure [11]. Some of these blends are miscible above melting temperature in molten state, and the miscibility of components in the amorphous region has also been noted after individual crystallisation. This specific structure has been observed in some polyester blends (PET/PBT, PET/PTT) [12, 13] and polyamide blends (PA6/PA66, PA6/PA10) [14]. In particular, polyester blends have a structure and some positive properties which

are interesting from the point of view of their application in PP/PES blends, and PP/PES blend fibres with PP as a majority phase, in comparison with pure PET.

The structure and properties of the PET/PBT blends have been studied, particularly in recent years. PET/PBT blends have a lower glass temperature T_g [11] and a lower melting temperature T_m [15, 16] relative to PET despite having the same crystallinity. The minority phase in the concentration range under 10 wt.% cannot create its own crystalline phase. The low content of copolymer in the blend which is formed above T_m provides good deformability without the necking phenomena which is characteristic for PET. Further, PET/PBT blends exhibit one glass transition T_g without regard to composition. This confirms the thermodynamic miscibility of the components in the amorphous state [11, 15]. Interphase interactions and adhesion between the crystalline phase of components, resulting from their miscibility in the amorphous phase, improves mechanical-physical properties such as the tenacity and modulus of elasticity of the PET/PBT blend (referring to individual components). It can be assumed that these positive properties of the PET/PBT blends result from the interactions of aromatic rings of terephthalic acid in polymer chains, whereas the flexibility of the butandiol part of the PBT enables the development of these interactions.

In this paper, the structure and selected mechanical properties of the fibres based on

on a ternary PP/(PET/PBT) blend were studied and compared with known binary PP/PET and PP/PBT blend fibres. The rheological properties of the polymer components and the final polymer additive blends were correlated with the phase structure and selected properties of PP/(PET/PBT) blend fibres in dependence on the composition of PET/PBT's polyester dispersed phase. Two kinds of the blend fibres were prepared: PP fibres modified by the PET/PBT blend with 8 wt.% of the total PES content, and blend fibres with 16 wt.% of the PES dispersed phase in the PP matrix. We used the DSC and WAXS analyses, as well as microscopic observations, to investigate the phase and the supermolecular structure of the PP/(PET/PBT) fibres. The results are correlated with the mechanical-physical properties of the blend fibres.

■ Experimental

Materials

Polymers and additives
Polypropylene TF 331 (PP), MFI = 18.0 g/10 min (Slovnaft AG)

Polyethylene terephthalate L (PET), Intrinsic viscosity = 0.55 $l.g^{-1}$ (phenol-tetrachlor ethane 1:3) (SH Senica)

Polybuthylene terephthalate Celanex 2000 (PBT), MFI = 19.8 g/10 min (Ticona AG)

Polyester wax (montane wax) Licowax E (LiE), (Ciba Specialty Ltd)

Preparation of the final polymer additive (FPA) and blend fibres
We applied a two-step process, commonly used in modifying the polymer fibres with additives, for preparation of the PP/PES fibres:

a. Preparation of the final polymer additives
The polymers (PP, PET, PBT) are mixed in powder state. The pre-dispersed final polymer additive (FPA) blend chips are prepared by melt blending, using the laboratory twin-screw extruder with a diameter of 28 mm at 275 °C. The pure PET and PBT components were regranulated. FPA is represented by the pure polymers PET and PBT and by blends of PET/PBT and PP/PET/PBT, without and with Licowax E compatibilisers (LiE). The following FPAs were prepared: 1. PET; 2. PBT; 3. PET/PBT blends; 4. PP/PET/PBT blends and 5-8. FPA 1-4 containing 1.5 wt% LiE. The compatibiliser based on polyester montane wax Licowax E (LiE) in 1.5 wt.% concentration was used to improve the blending of PP with FPA during spinning.

b. Spinning of PP/PES blend fibres
The PP and FPA chips are mixed; the PP/PES blend fibres are blended and spun using a laboratory spinning plant with a one-screw extruder with a diameter of 30 mm. The content of the PES dispersed phase in the PP matrix of the PP/PES fibres was 8 wt.% and 16 wt.%, without regard to the content of compatibiliser in the FPA. The parameters of the spinning process were as follows: temperature 275 °C, spinneret with 48 holes, spinning speed 400 m/min^{-1}. The fineness of the undrawn multifilaments was T_{dt} = 960 dtex. The multifilaments were drawn using the laboratory drawing equipment. The drawing ratio was 1 : 3, the temperature 110 °C. The fineness of the drawn multifilaments was T_{dt} = 320 dtex x f48. The fibres were annealed without shrinkage at 110 °C for a period of 30 min.

Methods

Rheological measurements
The rheological properties of the components and polymer blends (FPA) were measured using a Göttfert N 6967 capillary extrusiometer with extruder ϕ = 20 mm at 275 °C. The conditions of measurement were close to those in the spinning equipment, namely dynamic conditions in extruder before extrusion of the blend melt. We used the Newton & Oswald de Waele law to determine the basic rheological parameters: apparent viscosity $\eta = \tau/\gamma$ and power law exponent n ($\tau = k \cdot \gamma^{\cdot n}$), which characterises the Newtonian behaviour of the polymer melt, where τ is the shear stress, $\gamma^{\cdot}$ the shear rate, η the apparent viscosity, n the power law exponent, k the coefficient. The viscosity ratio $K = \eta_d/\eta_m$ was calculated for a constant shear rate of 100 s^{-1} (K_{100}) and 500 s^{-1} (K_{500}), where η_d is the viscosity of the dispersed phase and η_m the matrix viscosity.

DSC measurement
A Perkin Elmer DSC 7 was used to evaluate the thermal properties of the PP/PES blend fibres and to estimate the supermolecular structure and mutual interaction of the components at interface. The heating rate was 10 °C/min.

Wide-angle scattering (WAXS) method
The structure of fibres was evaluated by the wide-angle X-ray scattering (WAXS) method. The investigations were carried out using a Seifert X-ray diffractometer. The diffraction patterns were registered for samples powdered on a Hardy microtome within a range of angles from 4° to 40°. The pattern analysis was performed calculating a theoretical curve approximating the experimental data. The theoretical curve was constructed as a sum of functions describing a background scattering, an amorphous halo and crystalline or mesophase peaks. The parameters of component functions were found by minimising the sum of squared deviations of the theoretical curve from the experimental one. The minimisation was carried out by means of Rosenbrock's method using the OptiFit computer program [17]. On the basis of the WAXS patterns, the parameters characterising the fibre structure were determined. The crystallinity index and the content of the mesophase were calculated as a ratio of the area under the crystalline or mesophase peaks to the total area.

Morphology of PP/PES fibres
The size and shape of the deformed particles of the PES dispersed phase were observed, after etching the PP matrix with xylene at 140 °C, and after separation of the PES microfibres. The light microscopy observation technique was used [18].

Mechanical properties of PP/PES blend fibres
Instron type 1122 was used to evaluate the mechanical properties (tenacity and elongation) of the PP/PES blend multifilaments. The initial length of fibres was 10 cm, and the clamp rate was selected according to the limiting time to break ≈ 20 s (modified ISO 2062). The variation coefficients (from 30 measurements) of the tensile strength and elongation at break were used as a measure of the internal (structural) unevenness of the PP/PES blend fibres.

■ Results and discussion

Rheology of the polymer blends (FPA) and phase structure of the PP/PES blend fibres

The dependence of the melt viscosity on share rate indicated in Figures 1. a-d and the rheological parameters in Table 1 reveal the differences in flow properties of the PP, PET, PBT polymers and their blends. The almost Newtonian flow is
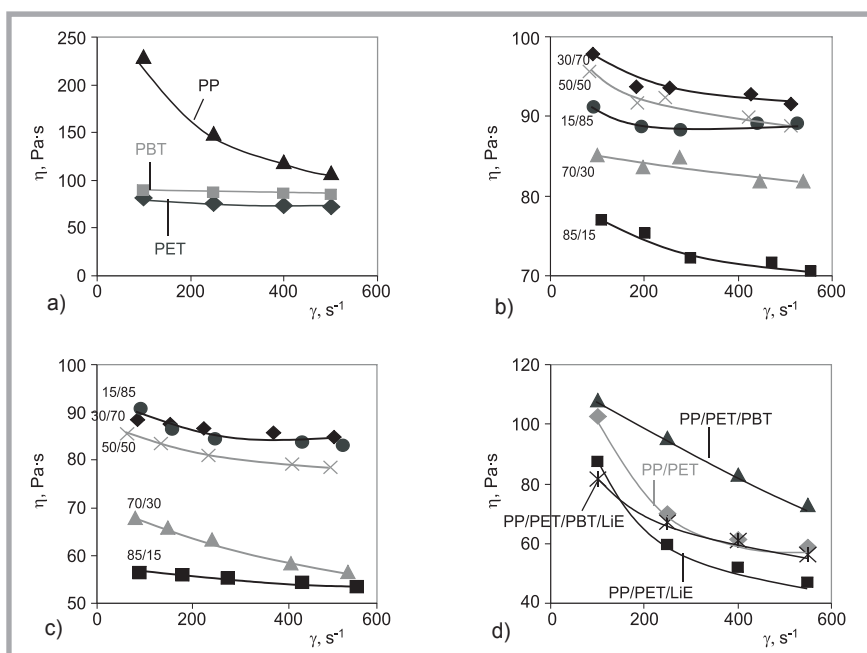
Figure 1. Dependence of the melt viscosity versus shear rate at 275°C for PP, PET and PBT polymer components (a), for binary PET/PBT blends (b), for binary PET/PBT blends with 1,5 wt.% of LiE compatibiliser (c) and for ternary polymer blends PP/PET 30/70 and PP/PET/PBT 30/60/10, content of LiE ~ 1,5 wt.% (d).

Table 1. Power law exponent n (Ostwald de Weale law) for PET, PBT and their blends (FPA) and viscosity ratio K of FPA to PP at 275°C, n_{PP}=0,53; $K=\eta_{disp}/\eta_{matrix}$.

Blend composition, %		n	K_{100}	K_{500}	K_{100LiE}	K_{500LiE}
PET	100	0.93	0.35	0.67	0.36	0.48
PET/PBT	85/15	0.95	0.33	0.66	0.25	0.50
PET/PBT	70/30	0.93	0.36	0.69	0.29	0.53
PET/PBT	50/50	0.96	0.41	0.83	0.37	0.73
PET/PBT	30/70	0.97	0.42	0.85	0.38	0.79
PET/PBT	15/85	0.96	0.41	0.81	0.39	0.77
PBT	100	0.97	0.39	0.79	0.36	0.66
PP/(PET/PBT)	30/70/0	0.58	0.41	0.44	0.36	0.43
PP/(PET/PBT)	30/60/10	0.75	0.37	0.53	0.36	0.53

high deformation of the PES microphase in the extensional flow throughout the whole range of the deformation gradient. Particularly convenient conditions for deformation of the dispersed FPA are indicated for FPA based on the PP/PET and PP/PET/PBT blends with the lowest K_{500} values (Table 1).
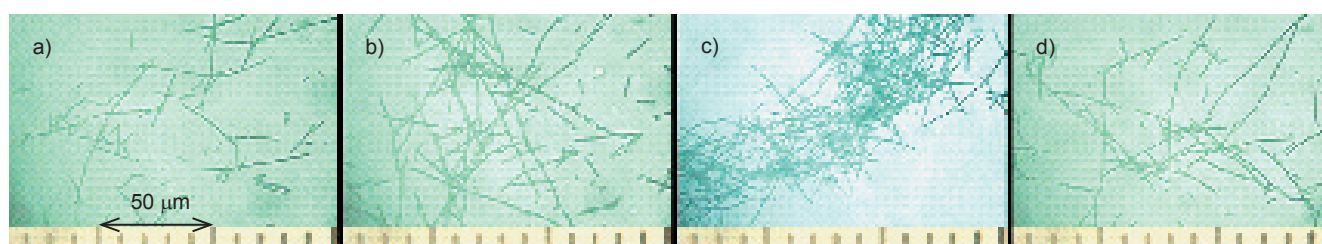
The LiE compatibiliser decreases the viscosity of the polyester phase, which is already at a small concentration (1.5 wt.%), and contributes to the greater deformation of the dispersed phase and the formation of the polyfibrillar structure of blend fibres (PES microfibres in PP matrix).

The final shape of the PES microfibres results from the deformation of the polymer melt in both the spinning and drawing processes. Drawing the fibres can significantly contribute to an increase in length of the original PES microfibres after spinning [6]. A qualitative analysis of the results obtained confirms these assumptions (Figure 2).

Supermolecular structure

A DSC analysis of the PET/PBT blends has shown that the majority component in the blend suppresses crystallisation from the melt of the minority component (up to 30 wt.%) below, by the DSC measurable value (Table 2). At the same time, the melting temperature of the majority component decreases with the increase of content of the minority polyester. From this point of view, the PES dispersed phase can significantly affect the supermolecular structure of the PP/PES blend fibres. The results of the DSC and WAXS analyses indicate the changes in supermolecular structure of both the PES dispersed phase and the PP matrix (Figures 3 & 4, and Tables 2 & 3).
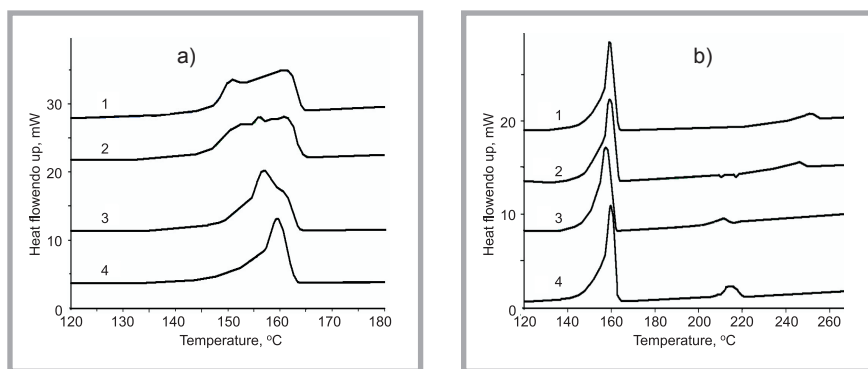
The PET component in PP/PET blend fibres exhibits a clear melting temperature which is characteristic for the individual PET polymer (248-250 °C), (Table 2). In the PP/PET/PBT, (PP/PES) fibres, the

characteristic of the PET & PBT polyesters and their blends, with lower melt viscosities in comparison with PP. The non-Newtonian flow of the PP melt, characterised by a low power-law exponent (n~0.53), causes a significant decrease in melt viscosity in dependence on the shear rate, approaching the viscosity of the polyester phase (Figure 1.a). A particularly low viscosity at higher shear rate was obtained for FPA based on PP/PET blends with the majority of the PET phase (Figure 1.d). The lower

viscosity of the polyester FPA relative to PP enables the PP/PES blend fibres to be prepared with deformed particles of the dispersed PES phase (microfibres) in the PP matrix [6]. The deformation of the PES microphase into microfibres is also supported by the lower elasticity of the melt, resulting from its almost Newtonian flow ($n \approx 1$), (Table 1). The dimensionless viscosity parameter K, which is responsible for shape of the dispersed phase particles, does not exceed 1 (Table 1). It leads to the assumption of the

Figure 2. Microscopic evaluation of size and shape of the PES particles dispersed in the PP/PES fibres after separation of PP matrix. PET (a), PBT (b), PET/PBT 30/70 (c), PET/PBT 70/30 (d).

Table 2. *Melting temperature T_m and melting enthalpy ΔH_m (related to weight unit of the blend) of components of the PP/PES blend fibres, (* unmeasured value).*

c_{PES}, wt.%	Comp. of FPA PP/PET/PBT	PP		FPA=PET/PBT			
		Tm, °C	ΔH_m, J·g^{-1}	Tm, °C		ΔH_m, J·g^{-1}	
8	0/100/0	154.1	72.3	248.5	-	2.5	-
	0/0/100	155.8	80.0	-	214.0	-	2.6
	0/30/70	156.6	79.0	*	210.0	*	1.8
	0/70/30	156.5	76.1	241.6	*	1.7	*
	30/70/0	157.5	76.9	249.0		2.4	-
	70/30/0	160.3	78.3	248.5		2.5	-
16	0/100/0	159.3	68.1	250.2	-	8.4	-
	0/0/100	159.8	72.0	-	214.0	-	8.5
	0/30/70	157.3	71.0	*	211.0	*	3.8
	0/70/30	159.0	71.5	245.0	*	6.6	*
	30/70/0	159.6	70.7	250.2	-	7.3	-
	70/30/0	159.8	68.9	249.1	-	6.0	-

Figure 3. *DSC thermograms of PP/PES blend fibres (16 wt.% of PES in PP matrix); a) Pure PP fibre (1), FPA = PP/PET 70/30 (2), PP/PET 30/70 (3), PET (4), b) FPA = PET (1), PET/PBT 70/30 (2), PET/PBT 30/70 (3), PBT (4).*

melting temperature of the PET component decreases with the increase of the content of PBT in the PES phase. The heat effect of the minority PES component (PET, PBT) disappears at concentrations under 30 wt.% in the PES phase. The same behaviour was observed for the PBT component (Table 2). The melting enthalpy of the PES phase is higher with the higher content of the crystallising component (Table 2). Unmodified PP fibre exhibits a wide melting endotherm, with clear peaks at 151°C and 162.5 °C. The endotherm is gradually changed with the PET (PBT) content into one peak shape above 16 wt.% of the PES phase (Figure 3). The melting temperature of 154 - 156 °C is characteristic of the PP matrix with 8 wt.% of the PES dispersed phase, and reaches about 159 °C for 16 wt.% of the PES phase (Table 2). The results of the DSC measurements of the PP/PES fibres reveal that the PES phase can act as a nucleating agent, and induces a uniform crystalline structure (with regard to polymorphic forms and crystallite dimensions) of the PP matrix, with one melting temperature about 159 °C.

The peaks observed on the WAXS patterns result from the overlapping of two broader mesomorphic peaks (at 14.8° and 21.2°), seven crystalline peaks characteristic for the α modification of polypropylene ((110) at 14.09°, (040) at 16.84°, (130) at 18.44°, (111) at 21.22°, (041) at 21.8°, (060) at 25.2° and (220) at 28.7°), and one broader amorphous peak (Figure 4). On the basis of the analysis of the WAXS patterns, the structure of the PP/PES blend fibres which are formed consists of three phases: amorphous, mesophase and crystalline phase. The maximum crystallinity index and minimum mesophase index were found for the PP/PBT fibres and for the PP/PES fibres with higher PBT content. In this case, a near-perfect supermolecular structure of the PP matrix is formed, and a positive effect of PBT on the mechanical properties of the PP/PES blend fibres is expected. There is practically no difference in the mesophase and crystallinity content between blend fibres containing different concentrations of the PES (8 - 16 wt.%), (Table 3).

## Mechanical properties of the PP/PES-annealed blend fibres

The mechanical-physical properties of fibres depend on many variables in the molecular and supermolecular structure of the oriented polymer. The mechani-

cal properties of the blend fibres are also affected by the properties of the individual polymer components, the phase structure of the blend fibres and both their internal and external unevenness. The phase structure of the blend fibres based on immiscible polymers depends on the microrheological properties of the polymer system. This is determined by the size and shape of the dispersed phase. The internal structure unevenness of fibres results from the higher probability of weak points in individual fibres, leading to lower tensile strength and its higher variation coefficients. The structural unevenness of fibres is very often connected with external-geometrical unevenness, which may be expressed e.g. by a coefficient of variation of the fibre diameter. From these aspects, the experimental results of the tensile strength and elongation of the PP/PES blend fibres can contribute to an estimation of the technological compatibility of the components in blend-oriented fibres, as well as to identification of the main structure parameters which influence the fibres' mechanical properties.

The tensile strength of the ternary PP/PES blend fibres growths proportionally with the content of the PBT in the PES dispersed phase. The higher PES concen-

Table 3. *Crystallinity index and mesophase content of the PP/PES blend fibres, obtained by WAXS analysis.*

c_{PES}, wt.%	Comp. of FPA PP/PET/PBT	Crystallinity index	Mesophase index
0	-	0.45	0.10
8	0/30/70	0.52	0.04
	0/70/30	0.50	0.07
	30/70/0	0.48	0.08
	70/30/0	0.45	0.10
16	0/30/70	0.52	0.04
	0/70/30	0.50	0.07
	30/70/0	0.48	0.07
	70/30/0	0.45	0.10
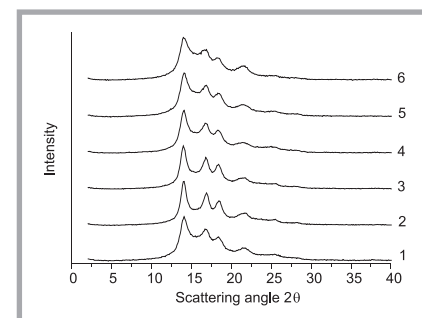
Figure 4. *Series of WAXS patterns for PP/PES annealed blend fibres (16 wt.% of PES) with dispersed phase: 1. PET, 2. PBT, 3. PET/ PBT 30/70, 4. PET/ PBT 70/30, 5. PP/PET 30/70, 6. PP/PET 70/30.*
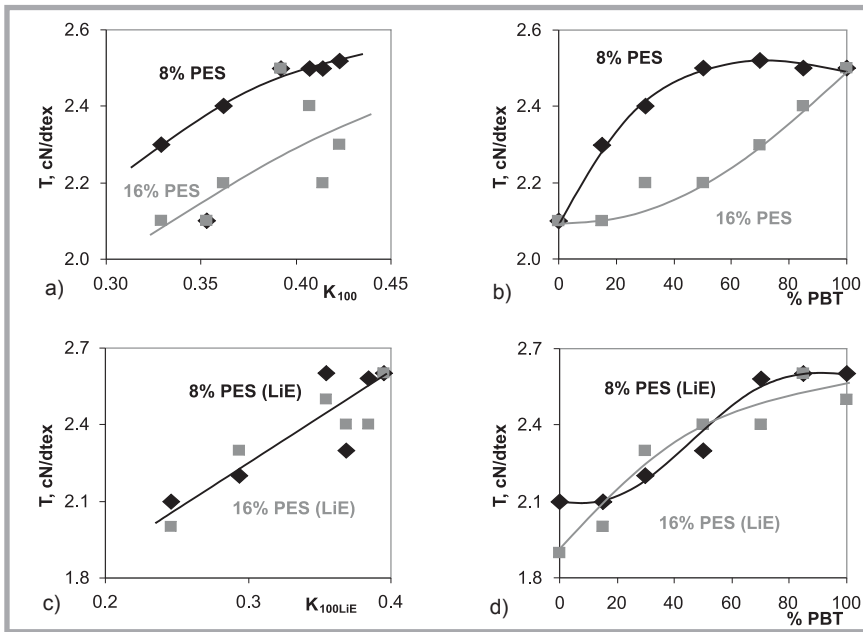
Figure 5. *Dependence of the tenacity of the PP/PES annealed blend fibres (a) and PP/PES blend fibres with compatibiliser LiE (c) on viscosity ratio K (K=η$_{disp}$/η$_{matrix}$) as well as dependence of the tenacity of the PP/PES blend fibres (b) and PP/PES blend fibres with compatibiliser LiE (d) on content of PBT in PET/PBT dispersed phase.*

tration (16 wt.%) in the PP matrix provides the lower tensile strength throughout the whole PET/PBT composition range (Figure 5.b). The dispersant LiE exhibits a positive effect on the mechanical properties of the blend fibres, mainly at higher PES concentrations in the PP matrix. The LiE unambiguously supports a component compatibility, which results in the higher structural uniformity of the blend fibres at both 8 wt.% and 16 wt.% concentrations, and also in higher tensile strength (Figures 5.d).

The dependencies of the tensile strength of the PP/PES blend fibres on the rheological properties of FPA (FPA = PET/PBT) reveal a direct proportionality between tensile strength and the viscosity ratio (K), (Figure 5.a). This proportionality is unambiguous, particularly for blend fibres with the LiE compatibiliser (Figure 5.c). The LiE compatibiliser's positive effect on tensile strength has mainly been found for higher values of K, which correspond with the higher PBT content in the PES dispersed phase. The improvement in the tenacity of blend fibres with the compatibiliser is also supported by the lower structural unevenness of fibres, which results in lower coefficient of variation of the

tensile strength and elongation (Tables 4 and 5).

The elongation of the unannealed PP/PES fibres is mainly determined by the PP matrix and exhibits values of 80 - 120%. The elongation of the annealed PP/PES fibres under an average tension decrease of 28% results from the crystallisation and orientation of the PP matrix as well as the PES microfibres.
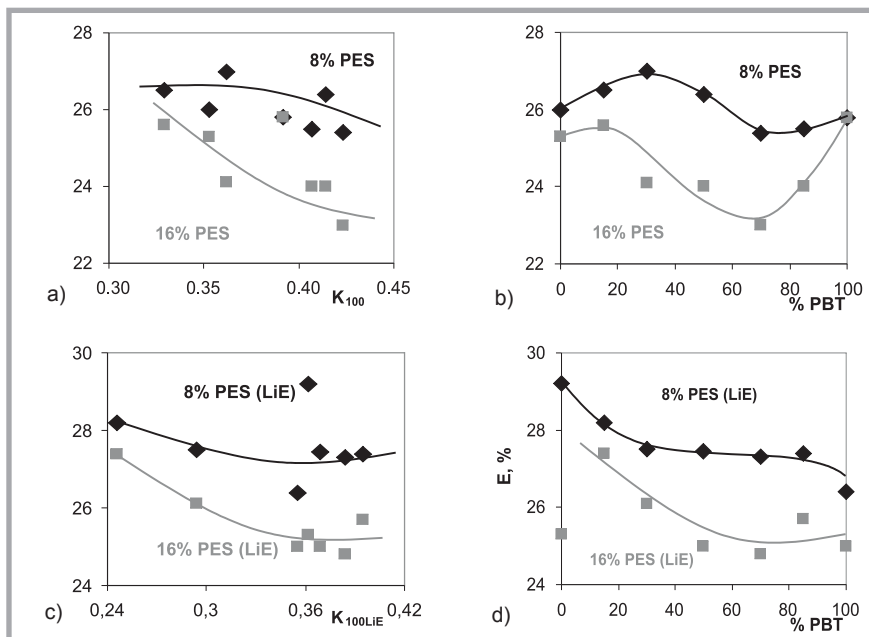
In contrast to tensile strength, the elongation of the PP/PES blend fibres decreases with the increase in viscosity ratio K as well as with the increase in PBT content (up to 70 wt.%) in the PES dispersed phase (Figure 6.a, 6.b). Elongation also decreases upon a higher PES content (16 wt.%) in blend PP/PES fibres (Figure 6.b). The compatibiliser (LiE) slightly increases the elongation of the blend fibres (Figure 6).

The improvement in the mechanical properties of the PP/PES fibres has also been found when the FPA based on binary or ternary (PP/PES) blend was used for blending with the PP before spinning. The influence of the LiE compatibiliser on the mechanical properties of these blend fibres was negligible (Table 6).

■ Conclusions

We investigated the influence of the composition and rheological properties of the final polyester additive based on PET and PBT on the phase & supermolecular structures and on mechanical properties of PP/PES blend fibres. The following conclusions can be drawn from our experimental results:

■ The mutual interactions in the miscible PET and PBT blend in molten state leads to a higher melt viscosity (as well as a higher viscosity ratio K) at higher concentration of the PBT component. The compatibiliser, which was based on the Licowax E polyester montane wax, already decreases the viscosity of the PP/PES blends (as well as the viscosity ratio K) at a low concentration (1.5 wt.%).

■ PP/PES blend fibres exhibit a polyfibrillar structure, with microfibres of the PES dispersed phase in the PP matrix at a high aspect ratio (high deformation ε).

■ The crystallinity of the PP matrix of the PP/PES blend fibres is proportional to the PBT content in the PES dispersed phase.

■ The tensile strength of the PP/PES blend fibres is proportional to the PBT content in the PES dispersed phase,

Table 4. *Coefficient of variation of the tenacity of the blend PP/PES fibres.*

Composition of blend PP/PES fibres	Composition of PES phase, %	CV$_T$, % PES, 8 wt.%		CV$_T$, % PES, 16 wt.%	
		without LiE	with LiE	without LiE	with LiE
PP/PET	100	2.6	2.6	8.1	4.2
PP/(PET/PBT)	85/15	2.5	2.5	4.8	3.0
PP/(PET/PBT)	70/30	3.1	2.1	5.6	2.5
PP/(PET/PBT)	50/50	3.6	2.8	4.8	2.3
PP/(PET/PBT)	30/70	4.2	2.5	4.7	2.4
PP/(PET/PBT)	15/85	4.0	2.3	5.2	2.5
PP/PBT	100	5.7	5.4	5.7	2.8

Table 5. *Coefficient of variation of the elongation of the blend PP/PES fibres.*

Composition of blend PP/PES fibres	Composition of PES phase, %	CV$_E$, % PES, 8 wt.%		CV$_E$, % PES, 16 wt.%	
		without LiE	with LiE	without LiE	with LiE
PP/PET	100	4.7	5.7	8.1	4.9
PP/(PET/PBT)	85/15	7.6	6.6	7.6	8.0
PP/(PET/PBT)	70/30	7.0	6.7	7.9	8.3
PP/(PET/PBT)	50/50	8.5	5.4	7.0	7.6
PP/(PET/PBT)	30/70	8.2	5.6	6.4	8.4
PP/(PET/PBT)	15/85	7.6	4.4	9.4	7.0
PP/PBT	100	9.5	4.4	9.5	7.5

Figure 6. *Dependence of the elongation of the PP/PES annealed blend fibres (a) and PP/PES blend fibres with compatibiliser LiE (c) on viscosity ratio K (K=$\eta_{disp}/\eta_{matrix}$) as well as dependence of the elongation of the PP/PES blend fibres (b) and PP/PES blend fibres with compatibiliser LiE (d) on content of PBT in PET/PBT dispersed phase.*

Table 6. *Influence of ternary FPA and blend fibres composition on tensile strength T, elongation E and their coefficients of variation of the PP/PES blend annealed fibres; Composition of FPA: a) PP/PET/PBT (30/70/0), b) PP/PET/PBT (30/60/10).*

Concentration of PES in blend fibres, wt.%	FPA	T, cN/dtex	CV$_T$, %	E, %	CV$_E$, %
8	a	2.6	2.5	23.0	6.4
	b	2.5	2.8	26.8	3.7
	a with LiE	2.4	4.2	27.1	4.4
	b with LiE	2.5	2.7	26.9	4.0
16	a	2.6	4.1	26.6	4.3
	b	2.5	2.1	25.8	5.1
	a with LiE	2.4	4.6	25.8	5.7
	b with LiE	2.4	2.8	25.6	3.9

and also proportional to the viscosity ratio K of the PES dispersed phase to the PP matrix.

■ The compatibiliser Licowax E causes a significant reduction in the structural unevenness of the PP/PES blend fibres and an increase in their tensile strength, mainly at higher PES phase content (16 wt.%) in the PP matrix.

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