Attaining Optimal Dyeability and Tensile Properties of Polypropylene/Poly(ethylene terephthalate) Blends with a Special Cubic Mixture Experimental Design

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ABSTRACT: In this investigation, we attempted to enhance the dyeability of polypropylene (PP) with disperse dyestuffs without adversely affecting its tensile properties. To this end, a special cubic experimental design was used to predict the effect of variations in the properties of a tricomponent mixture composed of PP, poly(ethylene terephthalate) (PET), and maleic anhydride grafted polypropylene (PP-g-MA) on the dyeability and tensile properties of the resultant polymer blend. The results illustrate that there seemed to be critical PET content, above which the blend's dye uptake tended to remain constant, but the tensile properties were adversely affected. Further analysis of the results indicated that the PP/PET/PP-g-MA blends in which the PET and PP-g-MA contents were in the range 10–15 and 4–5 wt %, respectively, gave maximal dye uptake and desirable tensile properties. © 2011 Wiley Periodicals, Inc. J Appl Polym Sci 121: 3201–3210, 2011

Key words: dyes/pigments; polyesters; polymer blends; poly(propylene) (PP)

INTRODUCTION

In recent years, much attention has been paid to polypropylene (PP) as a versatile polymer in the plastic and fiber industries because of its low cost, low density, good chemical resistance, and excellent processability.[1] As a textile fiber, PP is incapable of being dyed by conventional dyestuffs from an aqueous dye bath because of its nonpolar, highly crystalline structure. These inherent attributes limit the dye receptivity of PP, and this is considered to be the main drawback of PP usage in the textile industry.[2]

To overcome this problem, there has been considerable research in recent years to improve the dyeability of PP fibers by the use of chemical and/or physical modification methods.[3–8] These modifications include surface chemical reactions, copolymerization, graft polymerization, plasma- and γ-radiation treatments, and blending of PP with polar polymers, metal compounds, organic or inorganic nanoparticles, and many other additives, which have been widely investigated.

It has been observed that melt blending of PP with polystyrene, polyamides and polyesters, before spinning, is an efficient process for enhancing the dyeability of PP fibers.[1,9,10] Among these additives, polyesters, especially poly(ethylene terephthalate) (PET), offer some advantages over the others, including improvements in the dyeability by the classical exhaust mechanism and improvements in the mechanical properties.[11,12] Unfortunately, however, few studies have been carried out on optimization of the dyeability and tensile properties of PP/PET fiber-forming blends.

Notably, PET and PP are incompatible due to their different polarities and chemical natures. Therefore, without compatibilization, their blends exhibit a clear two-phase morphology, where the dispersed phase forms relatively large spherical droplets with no particular adhesion between the phases, and thus, the desired dyeability and mechanical properties cannot be achieved. Hence, appropriate compatibilizers are needed to attain better adhesion between the two phases.[13,14]

It has been shown by many researchers, including Papadopoulou and Kalfoglou,[15] Bataille et al.,[16] Xanthos et al.,[17] Heino et al.,[13] and others, that the compatibilization of PP/PET blends through the addition of thermoplastic copolymers, such as acrylic acid, maleic anhydride and glycidyl methacrylate grafted polyolefins, and modified styrene-butylene-styrene, SBS, block copolymers, provides the means to significantly enhance the properties of the melt blend during extrusion, modifies their interfacial properties, and stabilizes the melt blend. However, the compatibilizers are low-

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molecular-weight compounds in comparison with the blend partners and the incorporation of uncontrolled quantities of these additives may degrade the mechanical strength of the blend.

In this study, we attempted to determine whether it would be possible to predict the optimal disperse dye uptake of PP modified with PET and a maleic anhydride grafted polypropylene (PP-g-MA) as compatibilizer without adversely impairing its mechanical properties. For this purpose, the amounts of three independent variables in the blend composition, namely, the weight fractions of PP, PET, and PP-g-MA, were varied according to a special cubic mixture experimental design. The effects of these variations on the dye uptake and mechanical properties of the resultant blends were determined statistically.

EXPERIMENTAL

Experimental design

To determine the relationships between the response variables and various parameters that influence these responses, experimental designs, such as factorial or mixture designs, are highly efficient.[18] When each response depends on the relative proportion of the components, and their amounts must total a constant value (e.g., 100%), mixture designs are appropriate. For example,[19] in a mixture design with three components, x_1, x_2, and x_3

$$0 \leq x_i \leq 1, \quad i = 1, 2, 3$$
$$x_1 + x_2 + x_3 = 1 \quad (= 100\%) \tag{1}$$

A simplex-centroid design was used to study the dyeability of modified PP as a function of the weight fractions of PP, PET, and PP-g-MA present in the blend. Many models have been proposed for analyzing the data obtained from such mixtures.[18] The most frequently used is the following special cubic equation derived from the Taylor series:

$$A_i = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \beta_{123} x_1 x_2 x_3 \tag{2}$$

where A_i is the response variable and x_i is the selected parameter to model these responses. In our

TABLE I
Additional Constraints Placed on the Component Proportions

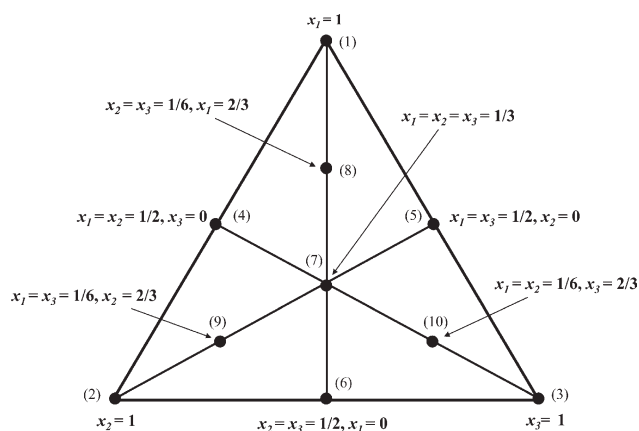| Component	Amount (weight fraction in the blend)	
	Lower	Upper
x_1: PP-g-MA	0	10 wt % (0.1)
x_2: PET	0	20 wt % (0.2)
x_3: PP	80 wt % (0.8)	100 wt % (1)

Figure 1 Constrained experimental region for a simplex-centroid special cubic mixture design.

case, these parameters were the weight fractions of PP-g-MA, PET, and PP in the blend; these parameters were represented by x_1, x_2, and x_3, respectively. The various calculated β constants for each response variable represented the model's coefficients. Because of additional constraints in the form of upper and/or lower bounds on the component proportions, we used a pseudocomponent mixture design, in which the total amounts of the components would also equal 1. These constraints are shown in Table I.

As shown in Table I, the maximum amounts of PET and the compatibilizer in the blends were 20 and 10 wt %, respectively.

In a simplex-centroid special cubic mixture design with three components, the constrained experimental region is conveniently represented on a trilinear coordinate plot, as shown in Figure 1.

As is shown in Figure 1, the design consisted of 10 experimental points: 3 points for the three pseudocomponents (e.g., 1, 0, and 0) at the vertices, 3 points for their binary mixtures (e.g., 1/2, 1/2, 0) at the edges, and an overall center point for the tertiary mixture (1/3, 1/3, 1/3). Three additional points located at the interior of the experimental region were included to validate the accuracy of the experimental design model. The experimental design and the weight percentages of each component present in the blend formulations are shown in Table II.

For instance, the formulation of the blend associated with experimental point 7 was PP-g-MA: 3.33 wt %, PET: 6.67 wt %, and PP: 90 wt %, in which the content of each blend component was one-third of its corresponding maximum amount in the blends.

The model's accuracy was evaluated by an F test, according to eq. (3):

$$F = \frac{(s_1)^2}{(s_2)^2} \tag{3}$$

TABLE II
Blend Formulations Calculated on the Basis of the Experimental Points

Experimental points	Series	Parameter		
		PP-g-MA (wt %)	PET (wt %)	PP (wt %)
Designed points				
Vertices	1	10 (1)	0 (0)	90 (0)
	2	0 (0)	20 (1)	80 (0)
	3	0 (0)	0 (0)	100 (1)
Edges	4	5 (1/2)	10 (1/2)	85 (0)
	5	5 (1/2)	0 (0)	95 (1/2)
	6	0 (0)	10 (1/2)	90 (1/2)
Center point	7	3.33 (1/3)	6.67 (1/3)	90 (1/3)
Test points				
Additional points	8	6.67 (2/3)	3.33 (1/6)	90 (1/6)
	9	1.67 (1/6)	13.33 (2/3)	85 (1/6)
	10	1.67 (1/6)	3.33 (1/6)	95 (2/3)

where s_1 and s_2 are the respective standard deviations for the designed points (i.e., points 1–7) and the test points (i.e., points 8–10), respectively. The calculated F values were compared to the corresponding tabulated F values [i.e., $F_{0.05}(6,2)$] for a 95% confidence limit having 6 and 2 degrees of freedom, respectively. For $F_{\text{calculated}} < F_{\text{tabulated}}$, the difference between the predicted and the observed values were not significant and were due to random variations. Hence, we concluded that the model was a good predictor of the respective response within the experimental errors involved.

Materials and sample preparation

The PP used in the experiments was a fiber-grade homopolymer (Moplen V30S, produced by the Arak Petrochemical Co., Arak, Iran) with a melt flow rate of 18 g/10 min (2.16 kg, 230°C). The PET was a textile-grade polyester, TG-641 provided by the Shahid Tondguyan Petrochemical Co. (Khuzestan, Iran). According to the supplier, it had an intrinsic viscosity of 0.64 dL/g. PP-g-MA was a Dupont commercial product (Fusabond P MD353D), with a very high MA graft content. To prevent the thermal degradation of PP during the melt-blending and melt-spinning processes, an Irganox 1010 thermal stabilizer was purchased from Ciba-Geigy Co. (Basel, Switzerland). Before blending, PET was dried at 120°C for 12 h, and PP and the compatibilizer were dried at 80°C for 12 h in a vacuum oven. The melt blending of the dry-mixed materials was carried out in a Brabender internal mixer, according to formulations dictated by the 10 experimental design points (Table II). The mixing temperature of all 10 samples was 265°C. The blends were mixed under a rotor speed of 60 rpm for 7 min. The amount of thermal stabilizer used in each composition was 0.5 wt % on the basis of PP weight.

Measurement of the mechanical properties

A tensile strength (TS) test was performed on 300-μm sheets prepared from 10 experimental blends at a crosshead speed of 5 mm/min by means of a Galdabini 1890 tensile testing machine (Cardano al Campo, Italy) according to ASTM D 882. Three $10 \times 50 \times 0.3$ mm^3 sheets of each sample were provided for each tensile test, and the resulting TS and tensile modulus data were recorded.

Morphology

The morphology of the blends was characterized from the cross sections of the cryogenically fractured surfaces of thin PP/PET blend sheets with a Philips XL30 scanning electron microscope (Oregon, USA). The samples were fractured after they were dipped in liquid nitrogen, and the fracture surfaces were coated with a thin layer of gold before scanning.

Dyeing

For dyeing, all 10 blends were made into thin films 100 μm thick by compression molding at 260°C. Blue, yellow, and red disperse dyestuffs were selected for dyeing the experimentally designed

TABLE III
Characteristics of the Disperse Dyes Used in the Experiment

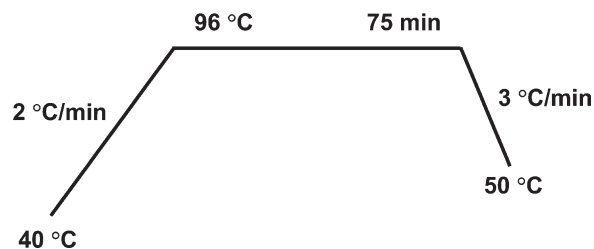| Commercial name	Generic name	Structure	Manufacturer
Terasil Blue BGE	C. I. Disperse Blue 60	Anthraquinone	Ciba-Geigy
Terasil Yellow 4G	C. I. Disperse Yellow 211	Monoazo	Ciba-Geigy
Terasil Red FB	C. I. Disperse Red 60	Anthraquinone	Ciba-Geigy

Figure 2 Dyeing profile of three disperse dyestuffs for the experimentally designed samples.

samples. The characteristics of these dyestuffs are shown in Table III.

Thin films, cut into 2×2 cm^2 squares, were first weighed and then pretreated with 5 g/L of a nonionic detergent (Lotensol from Hansa Co., Stuttgart, Germany) at 80°C for 20 min with a liquor-to-goods ratio of 50 : 1, after which the samples were rinsed and dried. Dyeing was carried out in a Rotadyer (supplied by the Nasaj Sanat Yazd Co., Yazd, Iran) with a liquor-to-goods ratio of 100 : 1 and at pH 4–5 with 1% owf of acetic acid according to the dyeing profile shown in Figure 2.

At the end of all of the dyeings, we removed excess dye by subjecting the dyed films to a reduction-clearing process. Reduction clearing was carried out at a liquor-to-goods ratio of 50 : 1 with 2 g/L sodium hydrosulfite, 1 g/L sodium hydroxide, and 1 g/L of a nonionic detergent for 20 min at 50°C. The reduction-cleared samples were thoroughly rinsed and allowed to dry.

Measurement of the dye uptake

In studying the dyeing properties of the fabrics, we mainly measured the K/S value, namely, the ratio of the absorption coefficient (K) to the scattering coefficient (S), to determine the dye uptake of a specific dyeing, using the Kubelka–Munk one-constant theory shown in eq. (4):[20]

$$\frac{K}{S} = \frac{(1 - R)^2}{2R} \qquad (4)$$

where R is the absolute spectral reflectance of the sample at infinite thickness. To calculate the K/S

values of the dyed samples from eq. (4), the R values of each sample were measured in the range 360–750 nm on a GretagMacbeth ColorEye 7000A spectrophotometer (Michigan, USA). Subsequently, the K/S values were determined at the wavelength of maximum absorption (λ_{max}).

RESULTS AND DISCUSSION

To report the K/S values, λ_{max} of each dyestuff was first specified. For almost all of the dyeings, the absorption maxima for the blue, yellow, and red disperse dyes were at 680, 460, and 520 nm, respectively. All of the practically measured responses inclusive of the K/S values for the blue, yellow, and red disperse dyes at their respective λ_{max} values, represented by K/S (blue), K/S (yellow), and K/S (red), and their corresponding mechanical properties, including TS and Young's modulus (YM), are shown in Table IV.

As shown in the K/S data, for each dyestuff, sample 4 (PP-*g*-MA: 5%, PET: 10%), which was compatibilized, in comparison with the uncompatibilized sample 6 (PET: 10%, without PP-*g*-MA), had a higher K/S value. This illustrated the effective role of PP-*g*-MA as a compatibilizer in the improvement of dyeability of the PP/PET blends. It is generally known that the amount of dyestuff exhausted by a substrate depends on the affinity of dye molecules toward the substrate, their chemical structure, and the existence of a sufficient number of active sites and amorphous areas; this makes it possible to fix the dyestuff molecules into the bulk of the substrate.[2] When PET is blended with PP, small PET particles are incorporated into the PP matrix, and this results in the formation of interfaces, which are considered a third phase in the blend.[2,21] In addition, the crystallinity and structural compaction of PP decreases, and the number of amorphous regions increases as a result of restrictions in the chain mobility and diminished molecular chain orientation.[22]

To investigate the role of the compatibilizer in enhancing the dyeability of the PP/PET blend, the morphologies of the uncompatibilized blend and its equivalent compatibilized blend were analyzed by means of their corresponding scanning electron microscopy (SEM) micrographs (Fig. 3).

TABLE IV
Practically Measured Responses for 10 Experimentally Designed Samples

Series	1	2	3	4	5	6	7	8	9	10
K/S (blue)	0.15	5.42	0.21	4.63	0.10	2.05	2.39	1.47	3.01	1.48
K/S (yellow)	0.14	9.52	0.12	8.68	0.08	3.88	5.12	3.51	7.01	3.13
K/S (red)	0.71	6.67	0.56	5.11	0.41	3.96	5.19	3.31	6.63	3.08
TS	30.39	29.59	33.46	35.33	31.49	29.86	35.06	34.28	32.48	34.03
YM	1062.54	1452.88	1171.20	1379.37	1122.90	1235.10	1325.11	1264.72	1555.49	1235.22

Figure 3(a,b) shows the SEM micrographs of samples 6 and 4, respectively. The uncompatibilized blend (sample 6) exhibited a clear two-phase morphology with relatively large PET particles dispersed in the PP matrix [Fig. 3(a)]. However, in the presence of the compatibilizer, the blend (sample 4) showed a dispersed PET phase with much finer particles [Fig. 3(b)]. This reduction in particle size could be explained by interactions between the MA groups of PP-g-MA and the terminal —OH (or —COOH) functional groups of PET; this caused the generation of an *in situ* PP-g-PET copolymer during the melt-blending process.[23] This graft copolymer accumulated at the blend interfaces, reduced the interfacial tension, and prevented coalescence.[14] Therefore, the size of dispersed PET particles became finer. As a result of particle size minification and the consequent increased interface leading to reductions in the PP crystallinity, the number of accessible active areas within the PP matrix for immobilization of the dyestuffs increased. Therefore, the compatibilized blend had remarkably higher dye uptake and color strength values than the uncompatibilized blend.
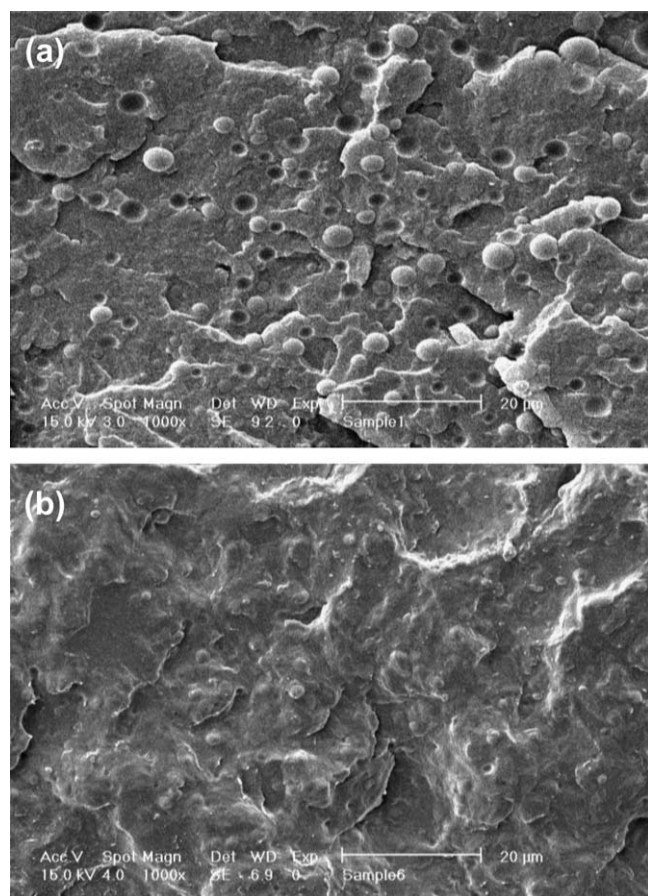

Figure 3 SEM micrographs of the uncompatibilized and compatibilized blends (1000×): (a) sample 6 (90/10/0 PP/PET/PP-g-MA) and (b) sample 4 (85/10/5 PP/PET/PP-g-MA).
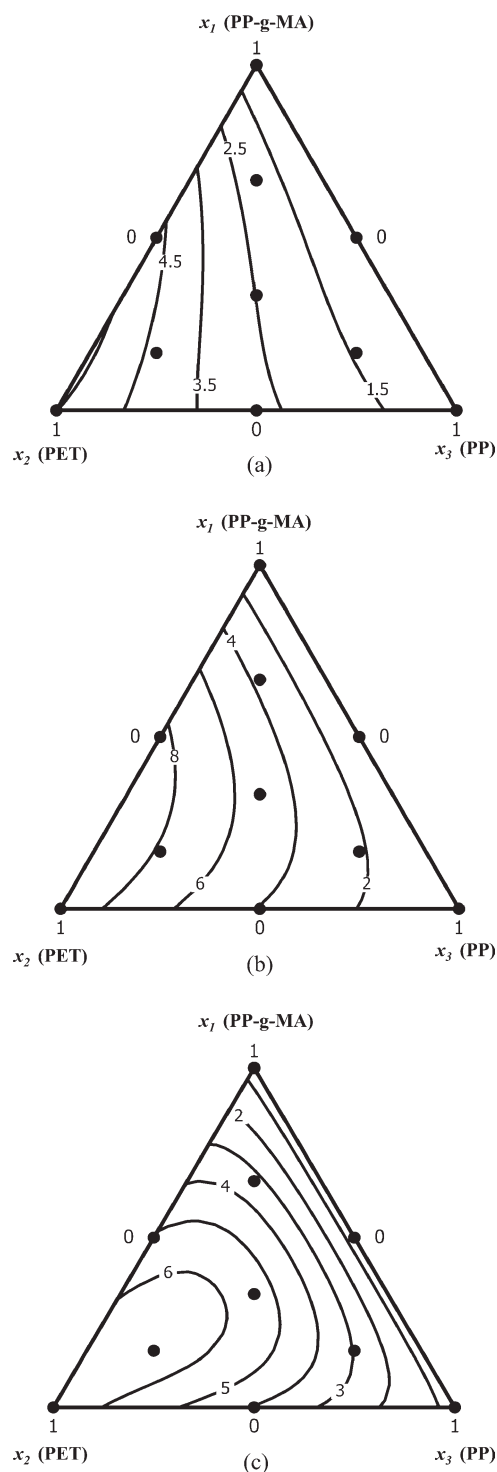

Figure 4 Contour plots for (a) K/S (blue), (b) K/S (yellow), and (c) K/S (red).

The practically measured responses (Table IV) were used to determine the polynomial coefficients in the special cubic model. Equations (5)–(9) show the relationship between the various parameters and the five response variables, namely, the K/S values, TS, and YM:

Predicted and Experimentally Determined Responses for Formulations 8, 9, and 10 and Their Corresponding Calculated *F* Values

Response	Experimental test points			Predicted test points			*F* value
	8	9	10	8	9	10	
K/S (blue)	1.47	3.01	1.48	1.76	4.15	0.91	6.26
K/S (yellow)	3.51	7.01	3.13	3.85	7.65	1.94	6.30
K/S (red)	3.31	6.63	3.08	4.51	5.79	3.10	4.14
TS	34.28	32.48	34.03	34.83	31.46	32.73	6.24
YM	1264.72	1555.49	1235.22	1106.22	1322.56	1175.57	0.64

$$K/S(\text{blue}) = 26.7x_1 + 87x_2 + 0.21x_3 + 285.9x_1x_2$$
$$- 30.1x_1x_3 - 75.9x_2x_3 + 169.3x_1x_2x_3 \quad (5)$$

$$K/S(\text{yellow}) = 19.8x_1 + 122x_2 + 0.1x_3 - 3604.2x_1x_2$$
$$- 21.6x_1x_3 - 93.7x_2x_3 + 5244x_1x_2x_3$$
$$(6)$$

$$K/S(\text{red}) = 82x_1 + 10x_2 + x_3 - 13552x_1x_2$$
$$- 89x_1x_3 + 26x_2x_3 + 16241x_1x_2x_3 \quad (7)$$

$$TS = 174x_1 + 147x_2 + 33x_3 - 17938x_1x_2 - 190x_1x_3$$
$$- 167x_2x_3 + 22444x_1x_2x_3 \quad (8)$$

$$YM = -2090x_1 + 8730x_2 + 1170x_3 - 530550x_1x_2$$
$$- 2410x_1x_3 - 7690x_2x_3 + 663280x_1x_2x_3 \quad (9)$$

The corresponding contour plots of these response variables are given in Figure 4(a–c).

We verified the accuracy of the model by performing *F* tests on formulations 8, 9, and 10, as shown in Table V.

This entailed a comparison between the actual practically obtained responses and their corresponding responses predicted by the model. The corresponding tabulated *F* value [i.e., $F_{0.05}(6,2)$] was 19.33. Because the calculated *F* values shown in Table V were less than the tabulated *F* value for all responses, the accuracy of the models was verified for all of these responses.

As eqs. (5)–(7) and their respective contour lines show, the yellow disperse dye had the highest *K/S* value. This difference in the dye uptake behavior was ascribed to the monoazo structure of C. I. Disperse Yellow 211 in comparison to the anthraquinone blue and red disperse dyes, where the less bulky structure of the monoazo dye facilitated the diffusion of dye molecules within the polymer chains. On the other hand, the *K/S* prediction equations stated that the weight fractions of PP and the compatibilizer in the blend had more pronounced effects on the uptake of the red disperse dye. However, it was clearly observed that the main
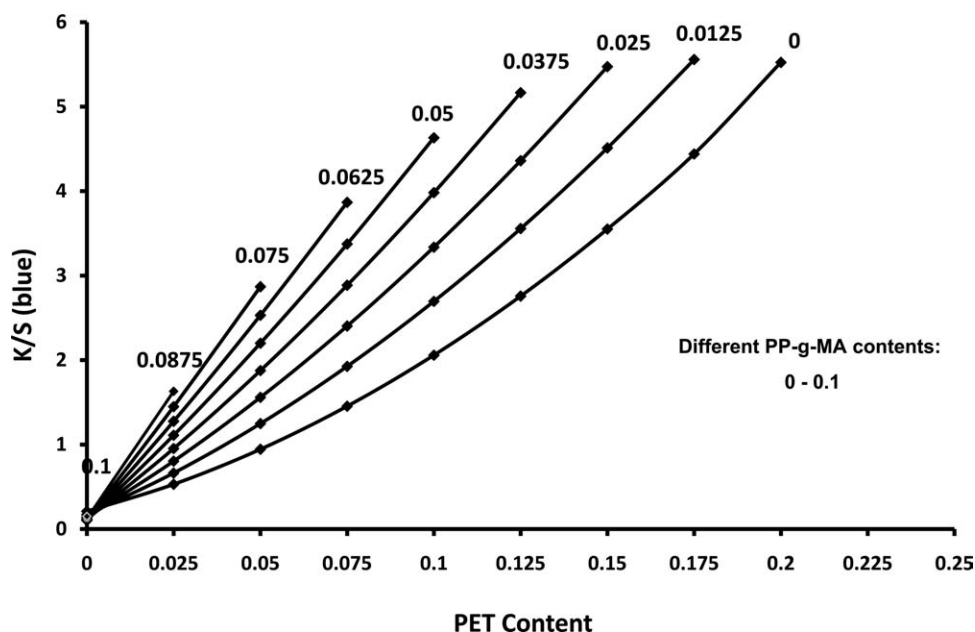

Figure 5 *K/S* values for the blue disperse dye as calculated by eq. (5) for various contents of PET and PP-*g*-MA.
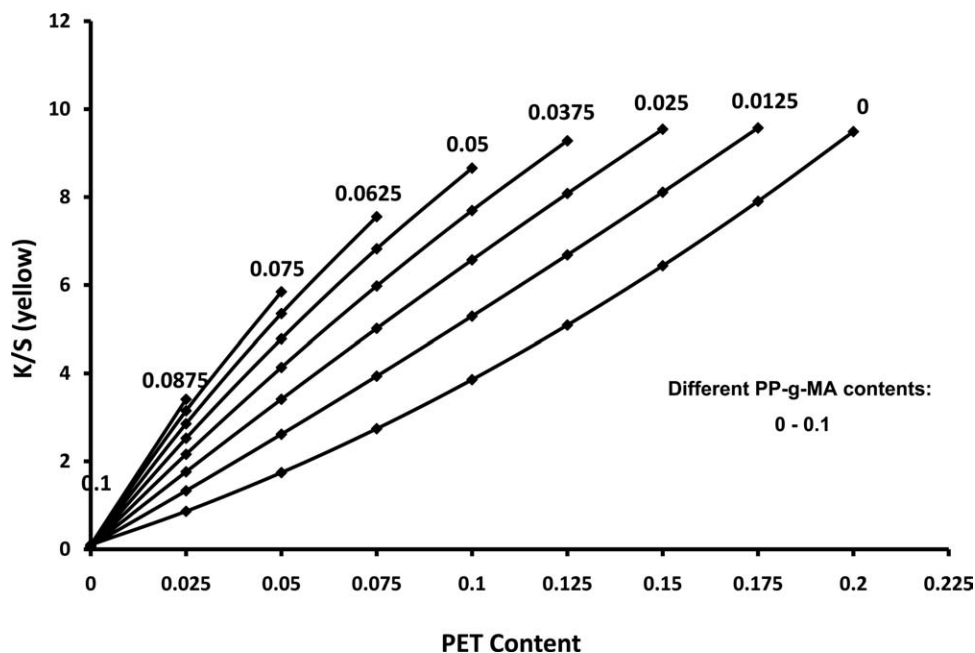
Figure 6 K/S values for the yellow disperse dye [calculated by eq. (6)] for various contents of PET and PP-g-MA.

parameter affecting the K/S values of the blue and yellow dyes was the PET content.

With the weight fractions of PET and PP-g-MA considered to be the main parameters, the affecting K/S values of the three disperse dyestuffs as calculated by eqs. (5)–(7) are shown in Figures 5–7.

As shown for each dyestuff, the K/S values for all of the PP-g-MA contents increased almost linearly with increasing PET content. There was a maximum

K/S value associated with each PP-g-MA content; these maxima remained nearly constant up to a critical weight percentage range between 10 and 15 wt % and then gradually decreased with decreasing PET content. According to this, it seemed that incorporation of more than 15 wt % PET into the PP matrix had no significant influence on the blend's dye uptake. On the other hand, at PET contents lower than 10 wt %, the K/S values tended to decrease. In
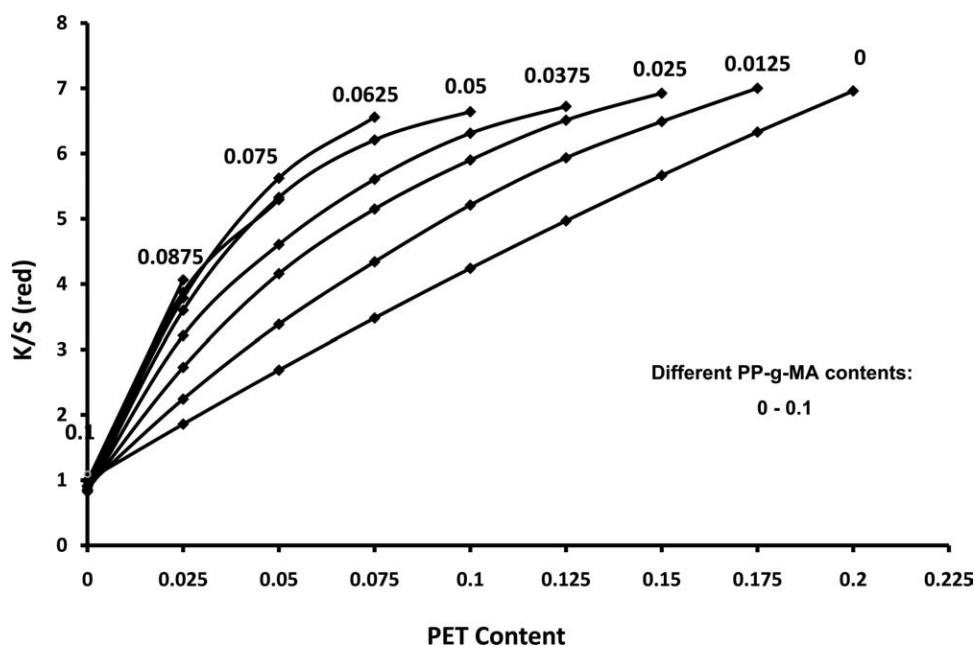

Figure 7 K/S values for the red disperse dye [calculated by eq. (7)] for various contents of PET and PP-g-MA.
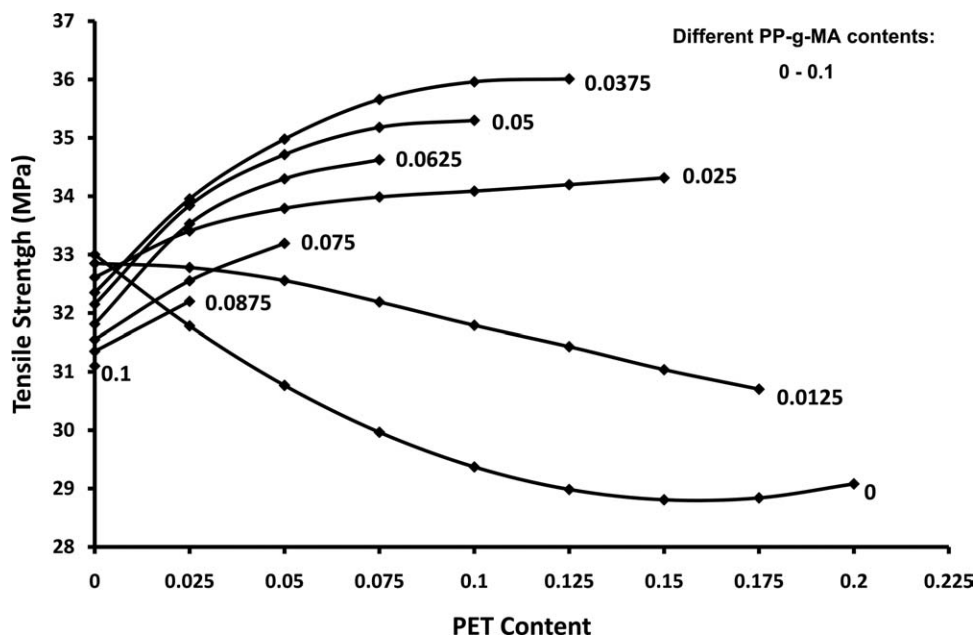
Figure 8 TS [calculated by eq. (8)] for various contents of PET and PP-*g*-MA.

other words, according to Figures 5–7, we concluded that the PP/PET blend having 15 wt % PET and 5 wt % PP-*g*-MA had the highest K/S value.

The variations in TS of the blends with the PET content for various amounts of PP-*g*-MA, as calculated by eq. (8), are depicted in Figure 8.

As shown, apart from low PP-*g*-MA contents (i.e., 0 and 1.025 wt %), in which the TS variations showed a dwindling trend with respect to the PET content, the TS maxima associated for the rest of the PP-*g*-MA contents increased with increasing PET content up to a critical value (≈12.5 wt %). For PET

contents in excess of this critical value, the maximum TS decreased. In other words, the highest value of TS was achieved when the PET content was almost 12.5 wt % and the PP-*g*-MA content was approximately 4 wt %. This behavior was attributed to poor interfacial adhesion between the two polymers and an ineffective stress distribution throughout the blend phases[24] when an insufficient amount of the compatibilizer existed at high PET contents or when low-molecular-weight PP-*g*-MA was incorporated into the blend in large amounts. Herein, the addition of suitable amounts of compatibilizer
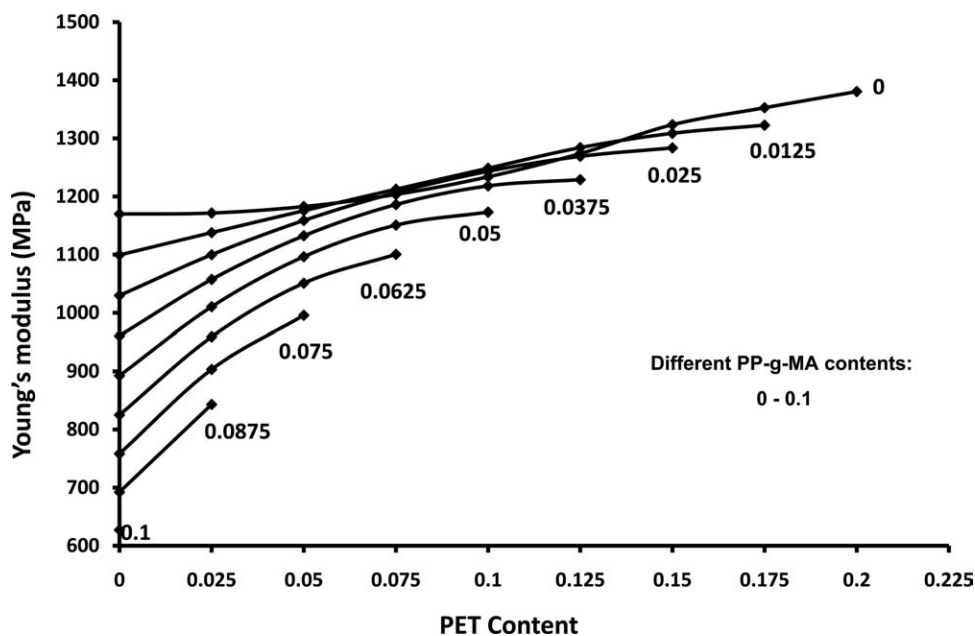

Figure 9 YM [calculated by eq. (9)] for various contents of PET and PP-*g*-MA.
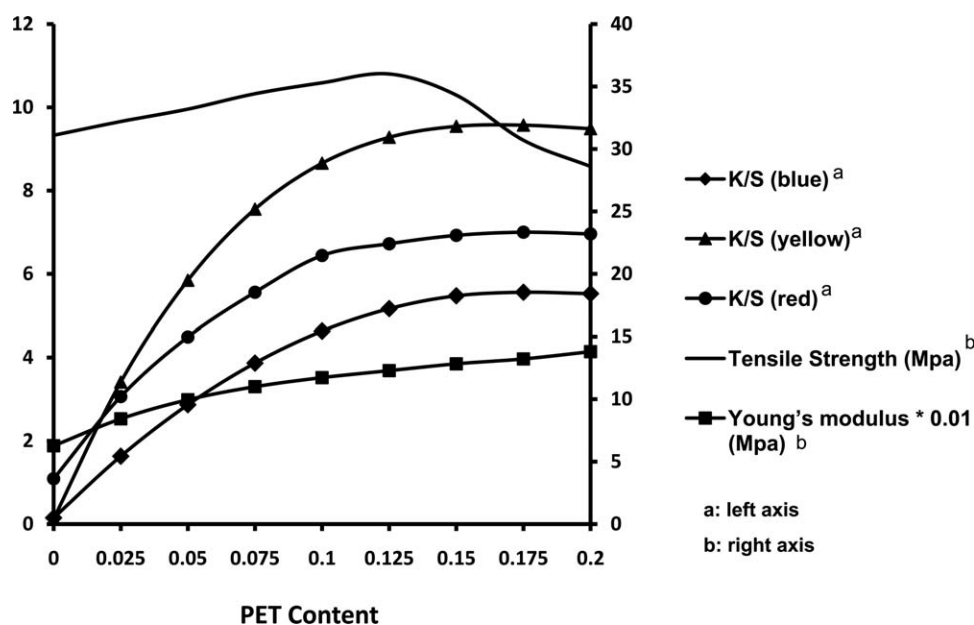
Figure 10 Maximum K/S, TS, and YM values for various contents of PET.

resulted in good adherence of the two immiscible blend components and, thus, improvements in the mechanical properties.[14]

As a textile fiber, the major mechanical drawback of PP is its low YM and recovery properties. On the other hand, PET is a strong polymer with a high YM.[12] Therefore, we expected that the blending of PP with PET would be an effective way to improve the elastic behavior of PP. To put this premise to the test, the variations of YM of the ternary blend with respect to the PET content were investigated. Figure 9 shows the influence of the PET content on YM of the blends, as calculated by eq. (9).

The maximum YM for each PP-g-MA content increased with increasing PET content. In addition, the maximum YM varied only slightly near or above a critical region (10–15 wt %). We confirmed the deterministic role of high-modulus PET in the elastic behavior of the PP/PET blend by looking at the coefficient of x_2 in eq. (9).

To determine suitable amounts of PET and PP-g-MA as compatibilizers for dyeable PP with acceptable mechanical properties, the variation of maximum K/S values of the ternary blends for each dyestuff and the maximum TS and YM data as a function of the PET content are demonstrated in Figure 10.

Figure 10 clearly shows that the addition of PET in excess of 15 wt % did not significantly affect the dye uptake of the resultant blend. As mentioned before, one of the most probable mechanisms for enhancing the dyeability of PP modified with PET is the creation of interfacial areas as active sorption sites for the dye molecules. At low concentrations of the dispersed phase, the number of domains increased as the weight fraction of PET increased;

this indicated an increase in the interfacial areas. However, the size of the dispersed PET particles was small. Hence, at low PET concentrations, the number of harvested dye molecules by the blend increased with increasing PET content. On the other hand, when the fraction of PET in the blend became too high, an additional increase in the PET content led to growth of the particle size, and the number of domains approached saturation. Therefore, the interfacial area remained almost unvaried and demonstrated a negligible increase in the total dye uptake.

Furthermore, as shown in Figure 10, TS tended to decrease with increasing PET content above 15 wt % and below 10 wt % as a result of imperfect compatibilization. Figure 10 also shows an almost linear relation between YM of the blends and the PET content. In other words, increasing the content of the strong PET in the trivariate composition enhanced YM in a linear manner. Considering the obtained results from the experimental design, we concluded that a PP/PET/PP-g-MA blend with a PET content in the range 10–15 wt % and a PP-g-MA content in the range 4–5 wt % guaranteed a modified PP with desired dyeability and acceptable mechanical properties.

CONCLUSIONS

To make PP dyeable by an aqueous dye bath by an exhaustion mechanism, its melt blending with a more polar polymer, namely, PET, was investigated. Analyzing the blend morphology with SEM micrographs revealed the efficiency of PP-g-MA as a compatibilizer in improving the compatibility and,

hence, optimizing the dyeability and mechanical properties of the resultant blends.

By use of a special cubic experimental design, we demonstrated that the desired dyeability was attained by the addition of limited amounts (10–15 wt %) of PET. The results also show that there was a critical PET content, above which the mechanical properties of the blend tended to deteriorate. Furthermore, on the basis of the experimental design results, the amount of PP-*g*-MA as a compatibilizer had to be in the range 4–5 wt % to obtain a dyeable and strong PP/PET blend. On the basis of these results, we concluded that an optimum PET:PP-*g*-MA ratio of 3 : 1 provided a PP/PET/PP-*g*-MA blend with desired dyeability and acceptable mechanical properties.

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