

Disperse and Cationic Dyeable Tertiary Polyblend Fibres of Polypropylene: Cationic Dyeable Polyester: Polystyrene

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Abstract— Polypropylene (PP) based polyblend fibres are made disperse and cationic dyeable by melt blending PP with cationic dyeable polyester (CDPET) and polystyrene (PS). The polyblend fibres were characterized for their thermal, mechanical and dyeability properties. Thermal analysis showed that the blend fibres are formed with reduced crystallinity favouring the dyeability of the fibres. The polyblend fibres were evaluated for disperse and cationic dyeing. The disperse dyeability increased in the range of 1050 to 1300%, while cationic dyeability in the range of 1300 to 1700% with excellent wash and light fastness. The increase in dyeability with respect to changes in the internal structure of the fibres is studied and optimal level of blending was predicted keeping in view of tenacity and thermal stability of melt blend fibres.

Index Terms— Polypropylene, polyblend fibre, melt-bending, disperse dyeability, cationic dyeability.

I. INTRODUCTION

Polypropylene fibres (PP) are known as technical fibre due its excellent physical properties and low cost. However, PP being highly crystalline structure and inert with total absence of polar groups, is very difficult to be dye. In an effort to produce dyeable polypropylene fibres, small amount of less crystalline polymers such as polyester, nylon and polystyrene, etc. are added into PP during melt-spinning process through melt blending technique [1-3]. The fibres thus formed are termed as polyblend fibres and they showed good disperse dyeability.

In our previous work, we studied the effect of melt blending of cationically dyeable polyester (CDPET) and polystyrene (PS) with PP, on the dyeability of polyblend fibres [4]. With addition of CDPET, polyblend fibres formed exhibited both disperse and cationic dyeability. The disperse dyeability was much higher for CDPET based polyblend fibre, as compared to PS based polyblend fibre.

In the present work, tertiary blend of PP:CDPET:PS were formed by keeping PP content constant at 80% and varying the other two minor components of the blend as shown in Table 1. The study was carried out to form polyblend fibres. These fibres were then subjected to disperse and cationic dyeing and the results are studied with respect to changes in fibre structure.

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Table 1. Tertiary polyblend fibres denotation and their compositions.

| Sr. No. | Denotations (PP:CDPET:PS) | Composition (% by weight) | | |
|---------|---------------------------|---------------------------|-------|----|
| | | PP | CDPET | PS |
| 1 | 100:0:0 | 100 | 0 | 0 |
| 2 | 80:5:15 | 80 | 5 | 15 |
| 3 | 80:10:10 | 80 | 10 | 10 |
| 4 | 80:15:5 | 80 | 15 | 5 |

II. EXPERIMENTAL

PP polymer chips Repol H2000FG were supplied by Reliance Industries Ltd, India. CDPET polymer chips were procured by J K Synthetics, India. PS polymer chips were procured from Polychem, India. Disperse dyes Dianix Blue ER and Dianix Rubine S-2G 150% were obtained from Dystar India Pvt. Ltd, whereas cationic dye Coracryl Red C4G and Coracryl Blue C2R were provided by Colourtext Industries Ltd, India.

PP, CDPET and PS were melt blended using twin-screw extruder (APV Baker, UK). The melt blended polymer chips were melt spun into fibres using laboratory melt spinning machine (Fair Deal Associates, India). The polyblend fibres were extruded and subsequently drawn over two-stage drawing zone at an optimized draw ratio.

The disperse and cationic dyeing of pre-scoured tertiary polyblend fibres was carried out in a high temperature / high pressure beaker dyeing machine using a standard method of the dyeing of synthetic fibres [5]. The dyed samples were then subjected to reduction clearing treatment followed by neutralization, washing and drying.

The thermal properties and crystallization behaviour were studied using differential scanning calorimetry (Shimadzu, Japan). X-ray diffraction analysis was performed by powder technique on XRD-6100 (Shimadzu, Japan) to understand the crystalline form and percentage crystallinity. The thermal stability of the samples was studied by carrying out thermogravimetric analysis (TGA) from 30 to 500°C under nitrogen inert atmosphere using DTG-60H thermogravimetric analyzer (Shimadzu, Japan). Tensile testing of filaments was carried out on tensile testing machine (Tinius Olsen, USA). The fibre sample was tested by keeping gauge length 100 mm

Table 2. The melting behaviour data of PP:CDPET:PS tertiary polyblend fibres obtained from DSC analysis

| Fibre (PP:CDPET:PS) | Onset temp (°C) | Endset temp (°C) | Melting peak (°C) | Heat of melting (J/g) | Crystallinity (%) |
|---------------------|-----------------|------------------|-------------------|-----------------------|-------------------|
| 100:0:0 | 163.18 | 170.83 | 168.27 | 138.34 | 66.19 |
| 80:5:15 | 160.88 | 171.16 | 167.11 | 100.08 | 47.88 |
| 80:10:10 | 159.16 | 170.38 | 166.46 | 94.17 | 45.05 |
| 80:15:5 | 157.52 | 169.73 | 164.94 | 86.09 | 41.19 |

and strain rate was kept at 50 mm/min. Average readings of ten samples are reported.

The dyed samples were evaluated for colour depth in terms of Kubelka Munk function (K/S), using Spectra Flash SF 300 computer colour-matching system (Datacolor International, USA) [6]. Kubelka Munk function (K/S) is given by the following equation:

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

where, R is reflectance at complete opacity, K is the absorption coefficient and S is scattering coefficient.

Colour fastness to washing was evaluated as per ISO 105-C10:2006 B and colour fastness to light was evaluated as per BS 1006 test method.

III. RESULTS AND DISCUSSION

A. Thermal Analysis

Results of DSC analysis for tertiary polyblend fibres are given in Table 2. The polyblend fibres showed single melting peaks. The very presence of PS and CDPEP has distinctly influenced the crystallization process of the polyblend fibres formed by shifting their melting peak to a slightly lower temperature and reduced crystallization of PP component. Thus the polyblend fibres formed showed overall reduced crystallinity in comparison to that of virgin PP fibres, thus forming open fibre structure which is very essential to improve the dyeability as it increases the accessibility of dyes to fibre structure.

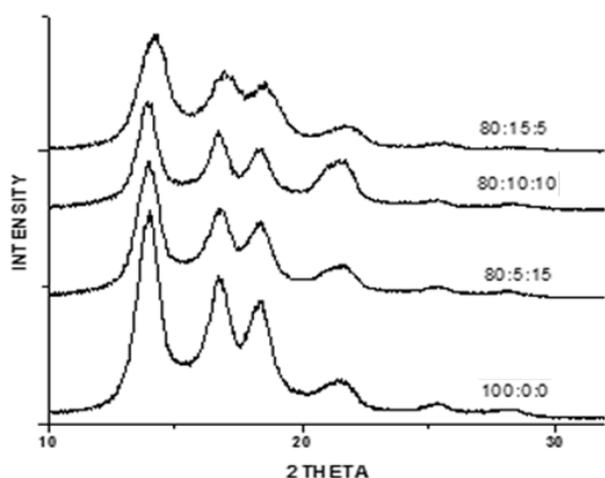


Fig.1. X-ray diffractogram of PP:CDPET:PS polyblend fibres.

B. XRD Analysis

The X-ray diffractograms of polyblend spun fibres shown in Fig. 1 indicate that the presence of PS and CDPEP has affected the PP crystallization process, resulting in polyblend fibres with overall reduced crystallinity. The crystallinity of fibres decreased from 60.52% for pure PP to 45.45%, 42.72% and 38.64% for 80:5:15, 80:10:10 and 80:15:5 PP:CDPET:PS blends, respectively.

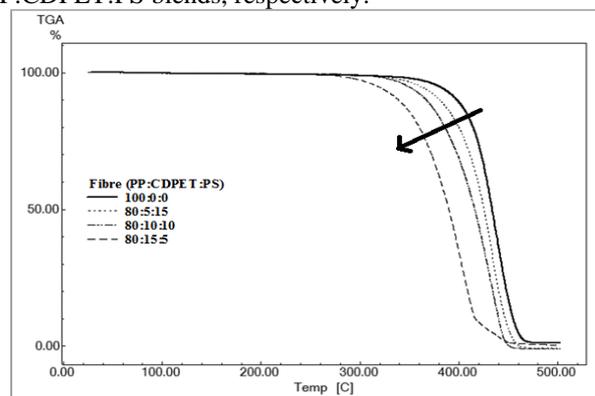


Fig. 2. Thermogravimetric analysis of PP:CDPET:PS tertiary polyblend fibres.

C. Thermal Stability

The thermal properties depicted by thermograms of the polyblend fibres are shown in Fig 2. The introduction of CDPEP and PS has slightly decreased the thermal stability of the fibres in comparison to that of PP fibres. The changes in the thermal stability of the fibres could be attributed to the reduced crystallinity of the fibres which leads to early onset of thermal degradation. However, the onset temperature for degradation of polyblend fibres is above 365°C and rapid degradation starts around 390°C which is much above the processing temperature of the fibres. Thus the polyblend fibres formed can be easily processed and applied for various applications.

Table 3. Tensile properties of PP:CDPET:PS tertiary polyblend fibres

| Fibre (PP:CDPET:PS) | Tenacity (gf/d) | Peak Elongation (%) | Strength Loss (%) |
|---------------------|-----------------|---------------------|-------------------|
| 100:0:0 | 4.14 | 18.94 | -- |
| 80:5:15 | 3.65 | 20.72 | 11.83 |
| 80:10:10 | 3.38 | 23.18 | 18.35 |
| 80:15:5 | 3.06 | 27.63 | 26.08 |

Table 5. Wash and light fastness properties of PP:CDPET:PS tertiary polyblend fibres (shade 3%).

| Fibre (PP:CDPET:PS) | Wash Fastness | | | | Light Fastness | | | |
|------------------------|-------------------|--------------------------|----------------------|---------------------|----------------------|--------------------------|----------------------|---------------------|
| | Dianix Blue ER | Dianix Rubine S-2G | Coracryl Blue C2R | Coracryl Red C4G | Dianix Blue ER | Dianix Rubine S-2G | Coracryl Blue C2R | Coracryl Red C4G |
| 100:0:0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 80:5:15 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| 80:10:10 | 3 | 3 | 3 | 3 | 4 | 5 | 4 | 4 |
| 80:15:5 | 3 | 4 | 3 | 3 | 5 | 5 | 4 | 4 |

D. Tensile Properties

Results in Table 3 indicate that tenacity for tertiary polyblend fibres was lower in comparison with that of pure PP fibres. The reduced tenacity of the fibres could be attributed to reduced crystallinity of the fibres and an indication towards formation of incompatible blend. The presence of CDPET as compared to PS had slightly more adverse impact on tensile properties. Thus a compromise has to be made with respect to restricting the loss in tensile strength well within 20% which is tolerable.

E. Dyeability

The presence of PS and CDPET made the tertiary polyblend fibres dyeable with both disperse and cationic dyes as seen from results in Table 4. The dyeability increased with increase in CDPET content in the fibre as it led to formation of internal fibre structure conducive for dye diffusion by decreasing the crystallinity. It also increased anionic dye sites for cationic dye-fibre interaction, imparting the blend fibres cationic dyeability.

The resultant polyblend fibres showed increase in the disperse dyeability in the range of 1050 to 1300 % over that of virgin PP fibres. The increase in disperse dyeability can be attributed to the very presence of PS and CDPET which has affected the crystallization process during fibre formation. The fibres formed have reduced crystallinity with more open structure due to bulkier polymer molecules of PS and CDPET. The presence of interfaces between the tertiary phases gave increased surfaces for dye diffusion.

Table 4. K/S values of disperse and cationic dyed tertiary polyblend fibres (shade 3%).

| Fibre (PP:CDPE T: PS) | Disperse Dyeing | | Cationic Dyeing | |
|-----------------------------|-------------------|--------------------------|----------------------|---------------------|
| | Dianix Blue ER | Dianix Rubine S-2G | Coracryl Blue C2R | Coracryl Red C4G |
| 100:00:0 0 | 1.8653 (100) | 2.3904 (100) | 0.8027 (100) | 0.7663 (100) |
| 80:05:15 | 23.8733 (1280) | 25.1373 (1052) | 11.2543 (1402) | 10.0517 (1312) |
| 80:10:10 | 24.0225 (1288) | 26.8394 (1123) | 12.1184 (1510) | 10.4703 (1366) |
| 80:15:15 | 24.5591 (1317) | 27.3685 (1145) | 13.6446 (1700) | 11.4559 (1495) |

^a Values in bracket represent percentage increase in K/S values over that of pure PP

While diffusion plays a very important role in determining the disperse dyeability, cationic dyeability is dependent upon the presence of specific anionic bonding sites in the fibres. The presence of CDPET has resulted in cationic dyeability of tertiary polyblend fibres and it increased with increase in CDPET content from 5 to 15% thus eventually leading to increase in colour strength values in the range of 1300 to 1700%. The tertiary polyblend fibres thus formed can be termed as disperse and cationic dyeable.

The fastness evaluation results for tertiary polyblend fibres dyed with disperse and cationic dyes are given in Table 5. Results show that wash fastness ratings for disperse and cationic dyed fibres are in the range of 3-4 and light fastness ratings are in the range of 4-5. Thus the polyblend fibres formed showed very good fastness ratings in comparison with that of the virgin PP fibres.

IV. CONCLUSION

PP fibres which are very difficult to dye can be made disperse and cationic dyeable by formation of PP:CDPET:PS tertiary polyblend fibres. Such a multi-fold increased dyeability imparted to the blend fibres could be attributed to the formation of more open structure due to reduced crystallinity and presence of anionic dyesites in the fibre structure as a result of introduction of CDPET in the blend. The thermal stability was though slightly reduced it was well within the acceptable limit. Similarly the reduced crystallinity resulted in reduction in tensile strength. However PP:CDPET:PS 80:10:10 blend could give strength loss below 20% (18.35%) while depicting enhanced dyeability in the range of 1100 to 1200% for disperse dyes and 1300 to 1500 % for cationic dyes. Hence such a tertiary blend can be used very easily for multiple applications in textiles.

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