Investigation on Physical Properties of Textured Yarns Produced from PP/ LDPE Blends

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ABSTRACT

Presently, for economic and technological concerns, production of blended fibers has attracted the attention of industrial technologists and academic researchers. The importance of blended fibers can be derived from its use in the various fields such as geotextiles, composites, and insulation. In this study, PP/LDPE blended filament yarns with blend ratios of 100/0, 99/1, 97/3, 95/5, 93/7, 90/10 were melt spun, drawn, and textured at temperatures of 110, 120,130,140 and 150°C. Tensile properties (except modulus) of the textured yarns spun from PP/LDPE blends were found to be higher than those of pure PP at most applied texturing temperatures. Crimp properties of samples were improved by increasing the texturing temperature. By increasing the LDPE fraction in samples, especially at 140°C and 150°C, however, lower crimp properties were observed.

Keywords: polypropylene, low density polyethylene, blend, textured yarn, physical properties, crimp properties

INTRODUCTION

Polypropylene fibers have good technical properties, such as, low specific weight, good mechanical properties, and good processability. If stabilizer is added to the PP, light and weather stability can be improved. The dyeability of PP fibers, however, is weak. Therefore, for production of colored fibers, pigment must be used and mixed with the polymer prior to melt spinning; dyes can be used when PP is modified by grafting with polar polymers [1, 2].

Fibers produced from blends of two or more polymers have different properties compared to the parent polymers. The lower melting point and greater adhesive nature of low density polyethylene (LDPE) in comparison with PP allows PP/LDPE blends to be used in thermalbonding nonwoven [3]. In general, the processability and rheological properties of polymer blends can be affected by parameters such as blend ratio, interfacial tension, differences in viscosity and elasticity of two polymers and processing conditions (i.e. temperature, residence time, shear rate, shear stress and total strain). Processing temperature, however, is one of the most important parameters affecting the properties of blended fibers [1, 4].

In addition, among different parameters such as overfeed, twist, and temperature which have a significant influence on textured yarns, the tempe`rature during the texturing process has a more profound influence on propylene textured yarns [5]. Increasing both contact time and heater temperature increases crimp rigidity. Moreover, enhancing the rate of cooling and annealing causes a considerable increase in crimp rigidity [6, 7].

Although PP/LDPE blends are used in textile and various industrial applications, less attention has been paid to their application as textured yarns. Prior research has focused on the production of fibers from PP/LDPE blends and pure PP textured yarns [8, 9].

There are no reports about PP/LDPE blended textured yarns. Therefore, in this study, as-spun PP/LDPE blended filament yarns with blend ratios of 100/0, 99/1, 97/3, 95/5, 93/7, 90/10 were produced using a previously-reported melt spinning and drawing process [8, 9]. The drawn samples were textured at five different temperatures (110,120,130,140 and 150°C). Then tensile and crimp properties of textured fibers were evaluated.

EXPERIMENTAL

Material

Fiber grade isotactic PP granules (Subic's PP 512P) having a melt flow index of 25g/10min and density of 0.901g/cm^3 and LDPE granules (Subic's HP4023W) having melt flow index of 4g/10min and density of 0.923g/cm^3 were used as starting materials.

Melt Spinning

First, the PP and LDPE portions of each sample were physically mixed and then fed to the melt spinning machine. Melt spinning was performed on an automatic melt spinning machine with a single-screw extruder and two spinnerets containing 36 holes with a diameter of 0.25mm [L/D=2]. The spinning temperature of 230°C and take-up speed of 2000m/min were based on previous work [8, 9]. The linear density of the as-spun filament yarns was 108.10±0.10 dtex.

Drawing Process

As-spun filament yarns were drawn on a Zinser drawing machine. For production of drawn filament yarns with the breaking elongation of 50±5%, draw ratios were determined by using Eq. (1):

$$\lambda_{real} = \frac{1+\frac{e_{bu}}{100}}{1+\frac{(e_{bd} \pm k)}{100}} \quad (1)$$

Where, e_{bu} and e_{bd} are the breaking elongation of as-spun and drawn filament yarns, respectively. λ_{real} is the draw ratio and k is a correction factor [8]. The draw ratios and drawing conditions are given in *Table I* and *Table II*, respectively. The linear density of drawn yarn was 67.50±0.15 dtex.

TABLE I. Draw ratios.

PP/LDPE Blend ratio	100/0	99/1	97/3	95/5	93/7	90/10
First draw ratio (set of godets no.1)	1.008	1.008	1.008	1.008	1.008	1.008
Second draw ratio (set of godets no.2)	1.709	1.718	1.795	1.774	1.700	1.800

TABLE II. Draw conditions.

Take up speed	400m/min
Spindle speed	4000 rpm
Feed godet temperature	80°C
Hot plate temperature	140°C

Specifications of as-spun and drawn samples are summarized in *Table III* and *Table IV*, respectively. Values inside the brackets indicate standard deviation.

TABLE III. Properties of as-spun filament yarns.

Number of samples	PP/LDPE Blend ratio	Tenacity (cN/tex)	Breaking Elongation (%)	Modulus (cN/tex)
1	100/0	17.79 (0.74)	201.10 (9.87)	73.53 (12.08)
2	99/1	15.78 (1.21)	215.00 (12.02)	69.11 (14.65)
3	97/3	15.07 (0.91)	226.00 (11.19)	64.86 (10.59)
4	95/5	14.89 (0.97)	237.3 (7.97)	68.11 (9.29)
5	93/7	14.3 (0.99)	226.89 (8.84)	65.72 (12.84)
6	90/10	12.93 (0.76)	226.90 (14.42)	65.98 (8.80)

TABLE IV. Properties of drawn filament yarns.

Number of samples	PP/LDPE Blend ratio	Tenacity (cN/tex)	Breaking Elongation (%)	Modulus (cN/tex)
1	100/0	26.76 (0.89)	45.58 (10.54)	207.20 (15.25)
2	99/1	26.50 (1.17)	47.10 (10.66)	203.00 (10.07)
3	97/3	25.71 (0.80)	45.09 (7.84)	189.10 (10.49)
4	95/5	23.61 (1.180	45.21 (9.81)	178.90 (12.62)
5	93/7	22.31 (0.78)	46.47 (10.21)	172.21 (12.97)
6	90/10	20.13 (1.09)	46.13 (7.95)	125.70 (10.06)

Texturing Process

The drawn filament yarns were textured by using a Scragg Shirely CS 12600 false twist machine. The texturing conditions are summarized in Tab*le V*.

TABLE V. Texturing conditions.

Texturing speed	100m/min
Texturing temperature	110,120,130,140,150°C
TPM	3000
Draw ratio	1.066

CHARACTERIZATION PROCEDURES

Melt Flow Index

The melt flow index of PP and LDPE was measured using a Plastometer 2000 manufactured (Nasj Sanj Company, Iran) according to ASTM (D1238) [10].

Tensile Properties

The tensile properties of textured yarns at room temperature were measured using an EMT-3050 machine (Elima Co., Iran). For the textured yarns, gage length and cross-head speed were 30cm and 50cm/min, respectively. The SPSS software was used for statistical analysis of data at $p<0.05$ for ten measurements.

Measurement of Crimp Properties

The crimp properties; crimp contraction, crimp modulus, and crimp stability were measured according to DIN 53840 [11]. The SPSS software was used for statistical analysis of data at $p<0.05$ for five measurements.

RESULTS AND DISCUSSION

Tensile Properties

Tenacity

The tenacity of textured yarns at different texturing temperatures is shown in *Figure 1*. According to this figure and statistical analysis, the tenacity of all yarns was increased by increasing the texturing temperature. At texturing temperatures of 110°C to 130°C, however, blend samples with 3 to 7 percent LDPE exhibited higher tenacity in comparison to neat PP textured yarns. No significant differences among tenacity of textured yarn samples at 140°C (apart from the sample with 10%LDPE) were observed. With a texturing temperature of 150°C, the blend samples showed a downward trend in tenacity compared to neat PP. The results of previous work [8, 9] show that there were no significant differences in the density and crystallinity of neat PP filament yarns and blend filament yarns with the increasing LDPE content. Moreover, it has been shown that the degree of crystallinity of textured yarns increases with the increasing heater temperature [6, 9, 12]. Therefore, it seems that the occurrence of increasing tenacity in all yarns with increases in heating temperature would be as a result of increasing crystalinity in the samples.

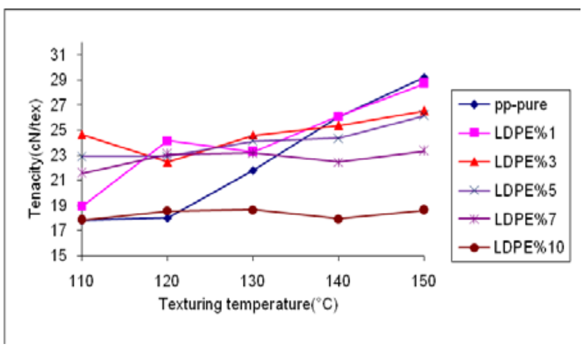


FIGURE 1. Tenacity of textured yarns vs. texturing temperature.

Breaking Elongation

The breaking elongation of textured yarns at different texturing temperatures is illustrated in *Figure 2*. According to the figure and statistical analysis, the breaking elongation of all samples increased with increasing texturing temperature. Moreover, the breaking elongation of PP/LDPE textured yarns was greater than the neat PP textured yarn at the texturing temperatures of 110°C to 140°C. The results also show that the breaking elongation of textured yarns was increased by increasing the LDPE content in the blends. Presumably, this observation may be related to the higher chain flexibility and higher elongation at break of LDPE comparing to PP [13]. The most likely reason for this observation would be the effect of disorientation in the amorphous regains [6, 7]. At the texturing temperature of 150°C, however, very similar breaking elongations were observed for the neat PP and blend samples. This observation might be due to enhancement in the chain flexibility and segmental motion of neat PP at this temperature, but also it could be a result of using closer texturing temperature (150°C) to melting point of PP (170°C).

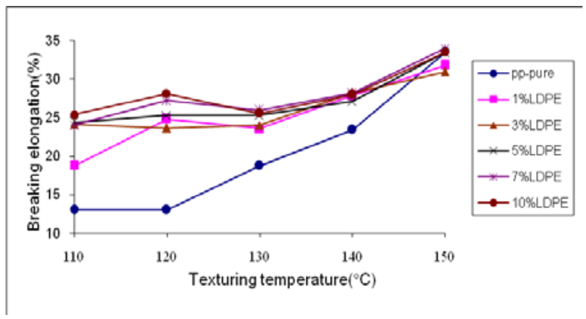


FIGURE 2. Breaking elongation of textured yarns vs. texturing temperature.

MODULUS

Figure 3 shows the modulus of the yarns textured at different texturing temperatures. According to this figure and statistical analysis, when the texturing temperature increased, the modulus of all samples showed a general downward trend. In addition, the modulus of all samples demonstrated a downward trend by increasing of LDPE content in blend samples. No noticeable differences, however, were observed in the modulus of blend samples with 1 to 5 percent LDPE content. As expected, the modulus of neat PP textured yarn was always higher than blend samples.

According to Sengupta and coworkers [6], while the degree of crystalinity of textured yarns increases with the increase in the heater temperature at applied texturing temperatures, the extent of decrystallization in heating zone appeared to be greater than the extent of recrystallization. Therefore, the internal structure of the yarn samples seems to be loosened by texturing process. This phenomenon might be the reason for the decrease in modulus which occurred in all samples by increasing texturing temperature.

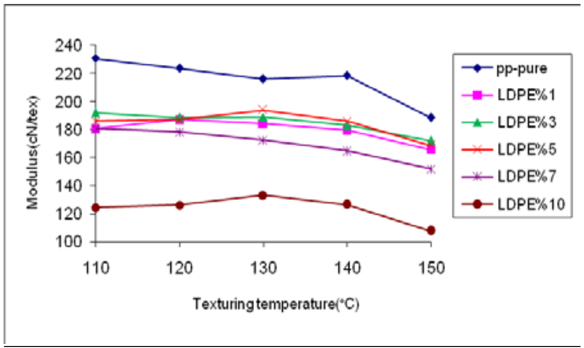


FIGURE 3. Modulus of textured yarns vs. texturing temperature.

Crimp Properties

Crimp Contraction

The crimp contraction versus the percentage of LDPE in yarns textured at different texturing temperatures is shown in *Figure 4*. Generally, crimp contraction in all samples increased with increasing texturing temperature. No noticeable changes were observed in the crimp contractions of yarns textured at 110°C and 120°C. However, the crimp contractions of all samples decreased with increasing LDPE content in the blend samples textured at higher temperature, namely 130°C to 150°C.

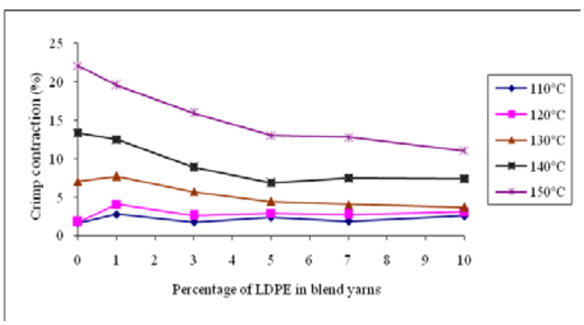
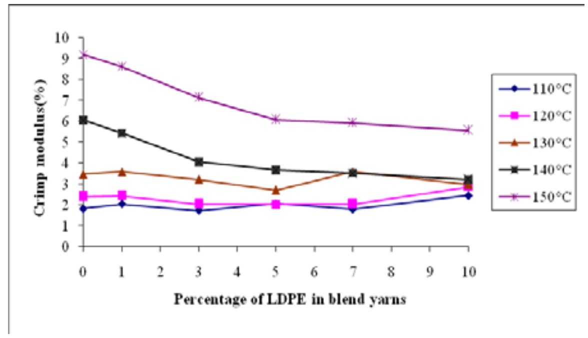


FIGURE 4. Crimp contraction vs. percentage of LDPE in textured yarns.

Crimp Modulus

Figure 5 shows the crimp modulus versus the percentage of LDPE in yarns textured at different texturing temperature. The crimp modulus of all samples generally increased with increasing texturing temperature. At texturing temperatures of 140°C and 150°C, the crimp modulus showed a downward trend with increasing LDPE content in the yarns. On the other hand, LDPE content did not produce significant differences in crimp modulus for samples textured under other applied temperatures (110°C to 130°C).



FLGURE 5. Crimp modulus vs. percentage of LDPE in textured yarns .

Crimp Stability

The crimp stability versus the percentage of LDPE in yarns textured at five different temperatures is illustrated in *Figure 6*. According to this figure and statistical analysis, increasing texturing temperature produced an upward trend in the crimp stability of all samples. A downward trend in crimp stability, however, was observed with increasing LDPE content in blend yarns textured at 130°C and 140°C. On the other hand, no significant differences in crimp stability were observed for all samples textured at150°C. Therefore, it might be concluded that the existence of LDPE up to 10% in all samples had no sensitive influence on crimp stability at texturing temperature of 150°C.

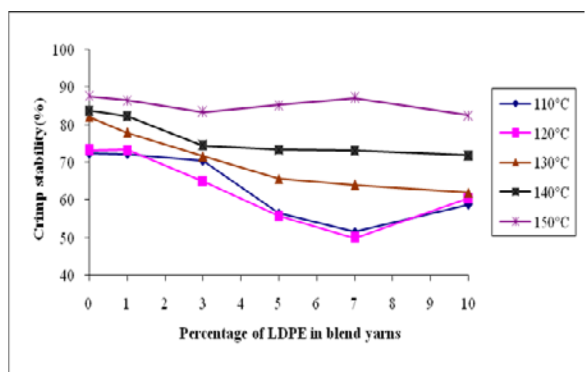


FIGURE 6: Crimp stability vs. percentage of LDPE in textured yarns.

According to the presented results and statistical analysis, it was seen that by increasing texturing temperature, crimp properties of all samples have been increased. These increases can be related to improved relaxation of stresses induced by the texturing process at higher texturing temperatures and the higher mobility of the molecular chains. A slower increase in the crimp properties, however, was observed with increasing LDPE content in blend samples. This phenomenon can be related to the existence of branched chains in LDPE which may prevent the easy movement of molecular segments, and consequently cause greater difficulty in the setting of deformed structure created during texturing process.

CONCLUSION

As spun, drawn, and textured blend yarn samples at applied conditions produced successfully. The tenacity of PP/LDPE textured yarns was higher than neat PP textured yarn at texturing temperatures of 110°C to 130°C (apart from samples containing 10 percent of LDPE). The tenacity of the neat PP textured yarn, however, was higher than blended textured yarns at 150°C. The blended textured yarns exhibited greater breaking elongation values in comparison to neat PP yarns at texturing temperature below 150°C. The modulus of the blended textured yarns was lower than the modulus of the neat PP sample and modulus of all samples decreased with increasing texturing temperature. At texturing temperatures below 140°C, the addition of LDPE to PP caused tenacity and breaking elongation to be improved compared to neat PP. Consequently, texturing of PP/LDPE blend yarns could be performed at lower temperatures which may be considered as an economic advantage for this blend. Crimp properties of all samples were enhanced by increasing the texturing temperature, but with different trends depending on the LDPE content in blended yarns.

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