Investigating the Effect of False Twist Texturing Process on the Color Coordinates Variation of Spun-dyed Polyester Filament Yarns

Mohammad Amani Tehran, Bahareh Azimi, Mohammad Reza Mohades Mojtahedi

Department of Textile Engineering, Amirkabir University of Technology, Tehran, IRAN

Correspondence to:
Mohammad Amani Tehran email: amani@aut.ac.ir

ABSTRACT

In this study, color coordinates variation of spun-dyed polyester filament yarns subjected to the false twist texturing process was investigated. Furthermore, the effect of different processing parameters including D/Y ratio, twist, heater temperature, texturing speed, overfeed, the draw ratio and intermingling process on the color coordinates variation of textured yarns was studied. Finally, the magnitude of color variation was analyzed by studying the structure, crimp and tensile properties of the yarns. The results show that the nature of texturing and intermingling process had a significant effect on the color variation of yarns but different processing parameters had no significant effect. The level of these variations can be expressed by observing the fiber geometry change along the texturing process.

INTRODUCTION

As a modern alternative approach to conventional wet-dyeing methods, spun-dyeing of polyester filament is becoming increasingly widespread. It involves the intermixing of colorant with the polymer prior to fiber extrusion and overcomes the shortages of conventional methods and provides products with excellent characteristics, such as uniform coloration, level shade, a high degree of light fastness and relatively low cost. Therefore, it has been widely applied to many fields, such as military uniform, sport uniform and other special professional uniforms as well as automotive textiles, etc [1-4]. However, the production of spun-dyed yarns with predefined color has some problems in recipe prediction because the spun-dyeing process is long and complex and there is the possibility of color variation during the production process. Since the 1950s, there have been a few studies on this problem. Beevers [5] briefly analyzed the influence on the appearance of colored fibers in yarns by factors including quality of materials and twist as well as count. Chen et al. [6] investigated the effect of several technological parameters on the color variation of spun-dyed polyester filaments during processing. However, the effect of texturing, as an important textile process, on color coordinates variation of spun-dyed filament yarns has never been precisely investigated. There are a lot of studies about the effect of texturing parameters on structure, dyeability, crimp and tensile properties of yarns. Gupta et al. [7-8] investigated the changes in the structure and dyeability characteristics of commercial polyethylene terephthalate yarn when it is textured on a spindle false-twist machine over a range of heater temperatures and heater contact times. Hardegree and Buchanan [9] studied the effects of primary heater temperature, center disc spacing, draw ratio, and D/Y ratio (Disk Speed/second delivery speed) on the resultant textured yarn properties including crimp contraction, dye uptake, linear density, density, tenacity, elongation, and modulus. Karakaş and H. Dayioğlu [10] investigated the effect of texturing parameters in a false-twist draw-texturing process on the mechanical properties and the structure of polyamide yarns. Yildirim et al. [11] studied the effect of the D/Y ratio and draw ratio on the crimp and tensile properties of the yarn. In available published papers, the effect of texturing parameters on color coordinates variation of spun-dyed filament yarns has never been investigated. In this study, the effect of false twist texturing and intermingling process on color coordinates variation of spun-dyed polyester filament yarns was investigated. Furthermore, the effect of different texturing parameters including D/Y ratio, twist, heater temperature, texturing speed and overfeed on color coordinate variation of textured yarns were studied.

EXPERIMENTAL

Design

To study the effect of false twist texturing process on color coordinates variation of yarns, various samples including set, stretch with pin twister, stretch with friction twister, intermingled set and intermingled stretch yarns were produced on industrial texturing machines and compared with POY yarn. These experiments were repeated on five different colors. To study the level of drawing effect in texturing process on fibers diameter and color coordinates variation of yarns, POY yarn were drawn with the same draw ratio of texturing process. *Table I* shows production conditions of different textured yarns. It is known that many variables including D/Y ratio, twist, heater temperature, overfeed, texturing speed and so forth, influence the properties of textured yarns. Therefore to study the effect of these parameters on samples characteristics such as color coordinates, crimp and tensile properties, two series of set and stretch yarns were prepared in different texturing parameter levels. So, different texturing effects were obtained by adjusting the values of the D/Y, first heater temperature and overfeed in production of set yarns. Accordingly for stretch yarns the twist, heater temperature and texturing speed were changed. The parameter change levels were obtained based on statistical 2f factorial design which provided two border values for each parameter. Finally there were 8 different running for each color. Production conditions of set and stretch samples are shown in *Tables II and III* respectively. Statistical analyses were carried out to specify the significant level of different processing parameters. ANOVA test was used to declare the significance of level of variables. The 95 percent confidence levels were used for all conclusions. This means that the P values less than 0.05 shows significant levels. In addition, the color, crimp and tensile properties of set, stretch and intermingled yarns were compared with each other by aid of ANOVAs tests.

Materials

Spun-dyed POY samples (250 denier, 48 filaments, and zero twist) with 5 different colors (red, green, yellow, brown and cream) which were dyed by master batch method were used as feed yarns in the false-twist texturing process. The master batches were prepared by Poddar Pigment Co.

Texturing Unit

Barmag FK 1000 false twist texturing machine was used for preparing stretch, set and intermingled yarns with the friction twister and Scragg Shirley CS 12600 Minibulk false twist texturing machine was used for stretch yarns with the pin twister. *Figure 1* shows schematic of false twist apparatus.

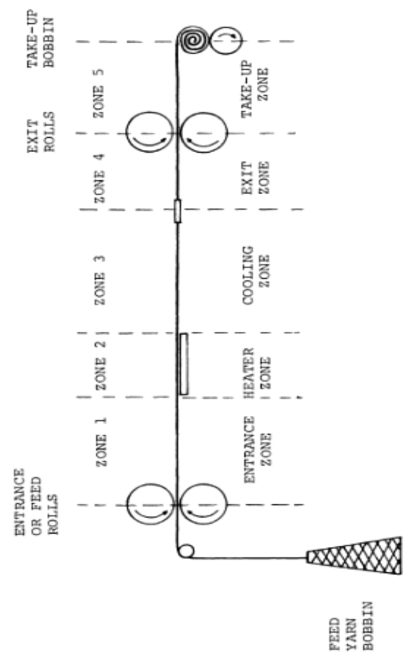

FIGURE 1. Schematic of the false twist apparatus.

Drawing Unit

A Zinser drawing machine was used for preparing drawn yarns. *Figure 2* shows schematic of drawing unit.

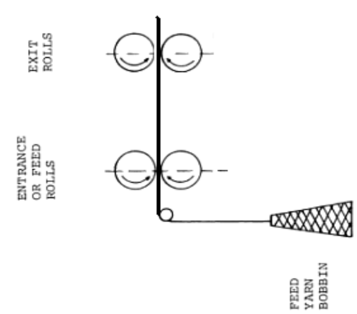

FIGURE 2. Schematic of drawing unit.

Measurement Methods

The spectral reflectance of the spun-dyed polyester filament yarns were carried out on a color eye 7000A spectrophotometer made by Gretag Mac Beth Co, using large aperture window in include measurement mode with 10 nm wave length resolution and the color coordinates were calculated under D65 light source with CIE 1964 10°standard observer. The spun-dyed polyester filament yarns were wound on white paperboard until they turned opaque against background. The crimp properties including crimp contraction, crimp modules and crimp stability were measured according to the DIN 53840. Tensile properties including initial modules, tenacity, work of rupture and breaking elongation were also measured.

RESULTS AND DISCUSSION

The Effects Of Texturing Process On Color Coordinate Variations Of Textured Yarns

The CIEDE2000 was used for measuring of Color coordinates variations of yarns. The 0.3 color differences value in CIEDE2000 are equal with 1 unit color differences in CIELAB which is an observable human color differences. Color coordinates variations of drawn and different textured yarns are shown in *Tables IV-VIII.* All values are reported as differences from POY baseline measurement. Based on these tables there are significant color variations between POY and different textured yarns in all colors, whereas applied drawing in the texturing process had no considerable effect on color coordinates variation of yarns. Referring to the tables, the ΔELAB between POY and different textured yarns is clearly larger than between POY and drawn yarns. This shows that the color coordinates variation of textured yarns is more correlated to fiber geometry changes than fiber diameter changes. Burlone[12] investigated numbers of possibilities for a light beam incident on a fibers bundle. As it can be seen in *Figure 3* a portion of the light can be reflected from fiber surfaces and returned without passing through fibers, some of them will enter the fiber bodies, pass through a region of absorption and scattering, emerge from the bottom of the fiber and then be reflected from the surface of an underlying fiber where it may either be returned or enter to another fiber. The next portions of light are reflected from the surface of an underlying fiber and enter an overlying fiber from the rear. For dyed fibers, the scattering is almost completely independent of contributions from the dyes. Even for pigmented fibers, the contribution to scattering by the pigment is generally small compared with the reflection or scattering of the fiber bundle. Therefore, the observed amount of scattering changes is not surprising according to the nature of the fiber geometry. It is expected that if the dye types, its concentration and the polymer weren't changed, the absorption and scattering behavior remained unchanged. So the color variation can only be originated by the nature and number of the reflective fiber surfaces. Obviously, in the drawing stage of the texturing process, the diameter of filaments will decrease.

TABLE I. Production conditions of different textured yarns.

Yarn type	D/Y	Twist (tpm)	First heater temperature (°C)	Second heater temperature(°C)	Draw ratio	Setting Overfeed (%)
Set	1.95	—	195	180	1.775	5.5
Stretch (pin twister)	—	2560	190	—	1.730	—
Stretch (friction twister)	1.95	—	195	—	1.775	—
intermingled Set	2.05	—	195	180	1.775	5.8
intermingled Stretch	2.05	—	195		1.775	—

TABLE II. Production conditions of set samples.

Yarn sample number	First heater temperature(°C)	D/Y	Setting overfeed (%)
1	180	1.8	4
2	180	1.8	7.5
3	180	2.1	4
4	180	2.1	7.5
5	205	1.8	4
6	205	1.8	7.5
7	205	2.1	4
8	205	2.1	7.5

TABLE III. Production conditions of stretch samples.

Yarn sample number	First heater temperature(°C)	Twist (tpm)	Speed (m/min)
1	170	1969	50
2	170	2954	50
3	170	1969	120
4	170	2954	120
5	205	1969	50
6	205	2954	50
7	205	1969	120
8	205	2954	120

The Effects Of Texturing Process On Color Coordinate Variations Of Textured Yarns

Color coordinates variations of drawn and different textured yarns are shown in *Tables IV-VIII* in different colors. Based on these tables there are significant color variations between POY and different textured yarns in all colors, whereas applied drawing in the texturing process had no considerable effect on color coordinates variation of yarns. Referring to the tables, the ΔELAB between POY and different textured yarns is clearly larger than between POY and drawn yarns. This shows that the color coordinates variation of textured yarns is more correlated to fiber geometry changes than fiber diameter changes. Burlone[12] investigated numbers of possibilities for a light beam incident on a fibers bundle. As it can be seen in *Figure 3* a portion of the light can be reflected from fiber surfaces and returned without passing through fibers, some of them will enter the fiber bodies, pass through a region of absorption and scattering, emerge from the bottom of the fiber and then be reflected from the surface of an underlying fiber where it may either be returned or enter to another fiber. The next portions of light are reflected from the surface of an underlying fiber and enter an overlying fiber from the rear. For dyed fibers, the scattering is almost completely independent of contributions from the dyes. Even for pigmented fibers, the contribution to scattering by the pigment is generally small compared with the reflection or scattering of the fiber bundle. Therefore, the observed amount of scattering changes is not surprising according to the nature of the fiber geometry. It is expected that if the dye types, its concentration and the polymer weren't changed, the absorption and scattering behavior remained unchanged. So the color variation can only be originated by the nature and number of the reflective fiber surfaces. Obviously, in the drawing stage of the texturing process, the diameter of filaments will decrease. Therefore, the surface-area to volume ratio and surface reflection of the filaments increase and results the increase of samples lightness. As shown in *Figure 4*, the surface of POY and drawn yarns are smooth and published. So when the light beam strikes this smooth surface, the reflected rays are mostly

TABLE IV. Color differences with POY as a baseline measurement for red sample.

Red	Drawn yarn	Set	Stretch (pin twister)	Stretch (friction twister)	Intermingled set	Intermingled stretch
ΔE_{00}	1.04	4.04	3.86	3.72	3.11	3.21
ΔL^*	2.16	5.83	4.31	5.93	4.03	3.71
ΔC^*	1.55	9.65	9.75	8.79	7.75	8.32
$\Delta h°$	-0.40	-0.30	0.07	-0.65	-0.12	-0.19

TABLE V. Color differences with POY as a baseline measurement for green sample.

Green	Drawn yarn	Set	Stretch (pin twister)	Stretch (friction twister)	Intermingled set	Intermingled stretch
ΔE_{00}	1.34	6.30	5.72	6.25	5.06	4.90
ΔL^*	2.21	8.90	8.14	9.42	7.00	6.46
ΔC^*	1.05	10.77	9.65	9.91	8.80	8.67
$\Delta h°$	-1.17	-6.90	-6.37	-6.52	-5.71	-5.91

TABLE VI. Color differences with POY as a baseline measurement for brown sample.

Brown	Drawn yarn	Set	Stretch (pin twister)	Stretch (friction twister)	Intermingled set	Intermingled stretch
ΔE_{00}	1.69	6.88	6.56	6.82	5.90	5.92
ΔL^*	2.66	8.10	7.26	8.17	5.96	5.25
ΔC^*	2.59	12.46	12.14	12.27	11.05	11.35
$\Delta h°$	0.09	6.61	6.34	6.47	5.91	6.20

TABLE VII. Color differences with POY as a baseline measurement for cream sample.

Cream	Drawn yarn	Set	Stretch (pin twister)	Stretch (friction twister)	Intermingled set	Intermingled stretch
ΔE_{00}	1.42	5.06	4.91	5.38	4.35	4.20
ΔL^*	2.84	10.00	9.72	10.88	8.50	8.13
ΔC^*	0.08	2.35	2.21	2.08	2.02	2.05
$\Delta h°$	-0.73	2.70	1.98	2.32	1.94	1.51

TABLE VIII. Color differences with POY as a baseline measurement for yellow sample.

Yellow	Drawn yarn	Set	Stretch (pin twister)	Stretch (friction twister)	Intermingled set	Intermingled stretch
ΔE_{00}	2.32	4.82	5.05	3.89	3.34	3.52
ΔL^*	0.01	3.50	2.55	4.14	3.12	2.57
ΔC^*	-4.95	-9.95	-10.07	-8.89	-7.10	-7.31
$\Delta h°$	2.84	5.81	6.39	4.00	3.77	4.20

parallel to each other, whereas the small crimps and irregularities on the surface of textured yarns lead to the light scattering. On the other hand, in spite of POY or DTY yarns, in the textured yarn, the light beams passes in a longer path. Therefore, there are considerable color differences between POY and different textured yarns. *Figure 5* shows CIE L*a*b*values of POY, drawn and different textured yarns. It is necessary to explain that the axes of graphs are selected based on the maximum changes of CIE L*a*b*values for each color. For example the red yarn has great difference in a* and the others in b*. It can be seen from *Figure 5* that the color coordinates variation of samples depends on the color centers so that the color variations of darker hues like brown, green, and red are greater than yellow and cream. In yellow samples which absorb only small parts of the light spectrum, the lightness variation is less than the others.

The Effect Of Texturing Parameters on Color Coordinates Variation of Yarns.

Different texturing conditions usually affect the morphological properties of a filament, so the reflection behavior will change, and results in color variation within texturing process. To study the effect of different processing parameters on color coordinates variation of set yarns, at first attempt, the color was considered as a main effective variable. Statistical analyses showed that the color had a significant effect on color coordinates variations of the yarns whereas different processing parameters had no significant effect. In the next assumption, the color was considered as a random variable. So, the sum of squares (SS) of color will add to the sum of squares of error (SSE). Again the same statistical results were obtained, and it confirmed that the processing parameters had no significant effect on color coordinates variations. Finally, the effect of processing variables was separately studied in each color sample. Spectral curves of POY and different textured set and stretch yarns are shown in *Figures 6 and 7* respectively. In spite of the noticeable difference between spectral curves of POY and textured yarns, there is no considerable difference between the spectral curves of different textured yarns, which have been produced in different condition of texturing. Statistical analyses confirmed these results, so in all colors, none of the parameters had the significant effect on color coordinates variations of yarns.

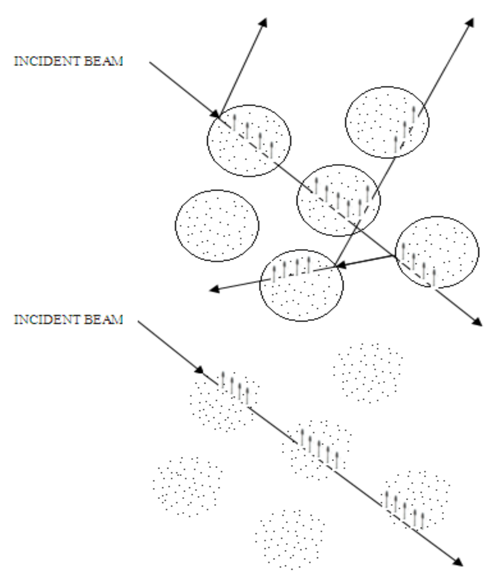

FIGURE 3. Scattering of light by fibers.

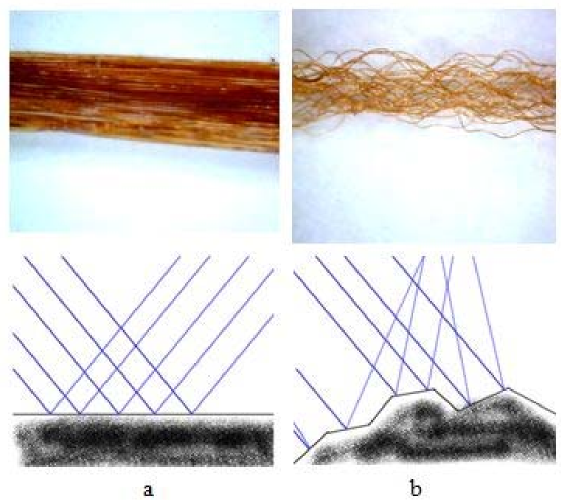

FIGURE 4. Geometrical structure of a) POY and b) textured yarn.

Same results were obtained for stretch yarns. The significant level of parameters for set and stretch yarns, are shown in *Tables IX and X* respectively.

Effect of Texturing Parameters on Crimp and Tensile Properties

Different processing parameters had significant effects on some crimp and tensile properties of yarns. For example, D/Y had a significant effect on yarns strength. However the dependency of strength on D/Y is not monotonous and in some cases, with increasing of D/Y, the strength increases and in some cases decreases. The expression for these phenomena is provided on *Figure 8* which indicated the variation of twist versus D/Y. According to this figure, in regions where the twist increases with increasing of D/Y, molecular orientation and yarn strength decrease and in the regions where the twist decreases with increasing of D/Y, molecular orientation and yarn strength increases. First heater temperature had a significant effect on the strength, modules, crimp contraction and crimp modulus of yarns. Temperature variations cause changes in crystalline and non-crystalline orientation and have effect on strength and modulus of samples. With rising the first heater temperature, samples made to be well sets. Therefore, crimp properties of the yarn will developed on high temperature. Over feed of the second heater had significant effects on crimp properties in which increasing of the overfeed lead to higher crimp properties. The same results were abstained for stretch yarns and in spite of significant effect of processing parameters on tensile and crimp properties, none of them had significant effect on color coordinates variation of the yarns.

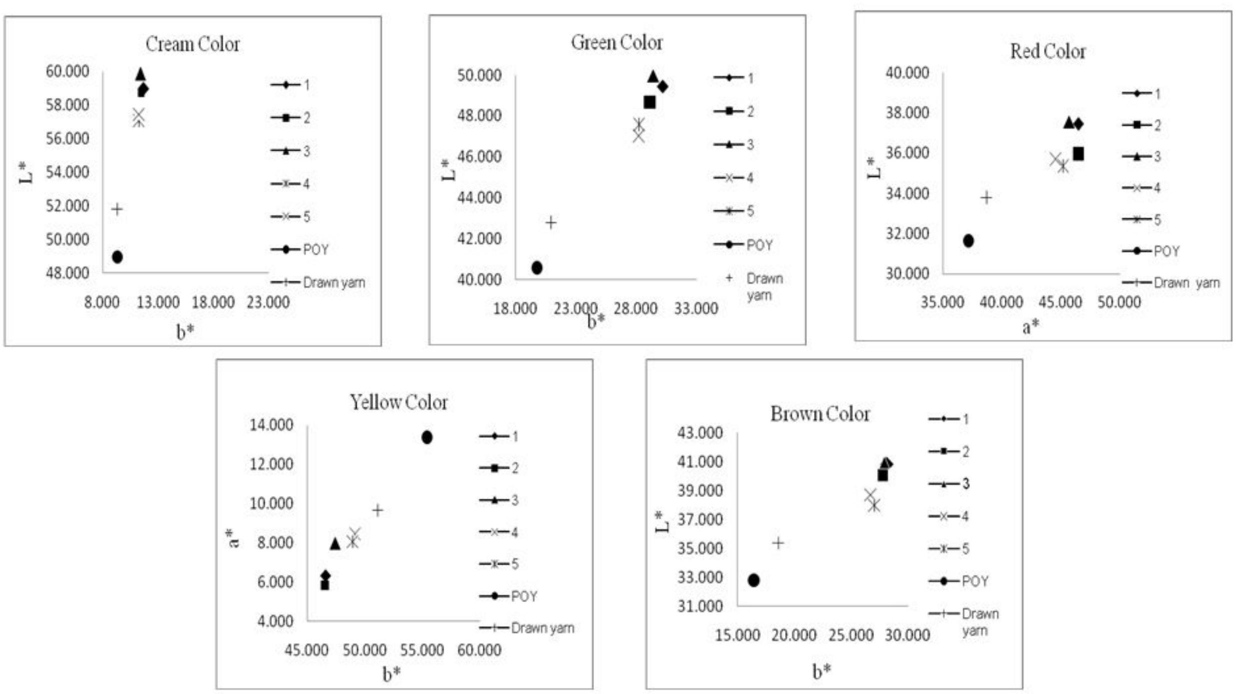

FIGURE 5. Color variations of yarns in 6 different colors.
1. Set, 2. Stretch with pin twister, 3. Stretch with friction twister, 4. Intermingled set, 5. Intermingled stretch.

The Color Variations Among the Set, Stretch and Intermingled Yarns

Statistical results showed in spite of significant difference between crimp properties of set and stretch yarns, there is no significant difference between color coordinates variation of the yarns. It can be concluded that second heater temperature applied on set yarns had no significant effect on color variations. The same result is obtained for stretch yarns with pin and friction twister. So, there is no color difference between yarns made by pin and those made by friction twister. But the intermingling process had a significant effect on color coordinates variation of samples and there are considerable differences between color coordinates of set and intermingled set yarn. The same result is obtained for stretch and intermingled stretch yarns. Statistical analyses confirmed these result, so that significant level of intermingling is obtained (sig=0) for both groups of yarns. *Figure 9* shows the Geometrical structure of set, stretch and intermingled yarn. It seems that the existence of intermingled points in yarns was the source of color difference and related to difference light reflection between usual and intermingled yarns.

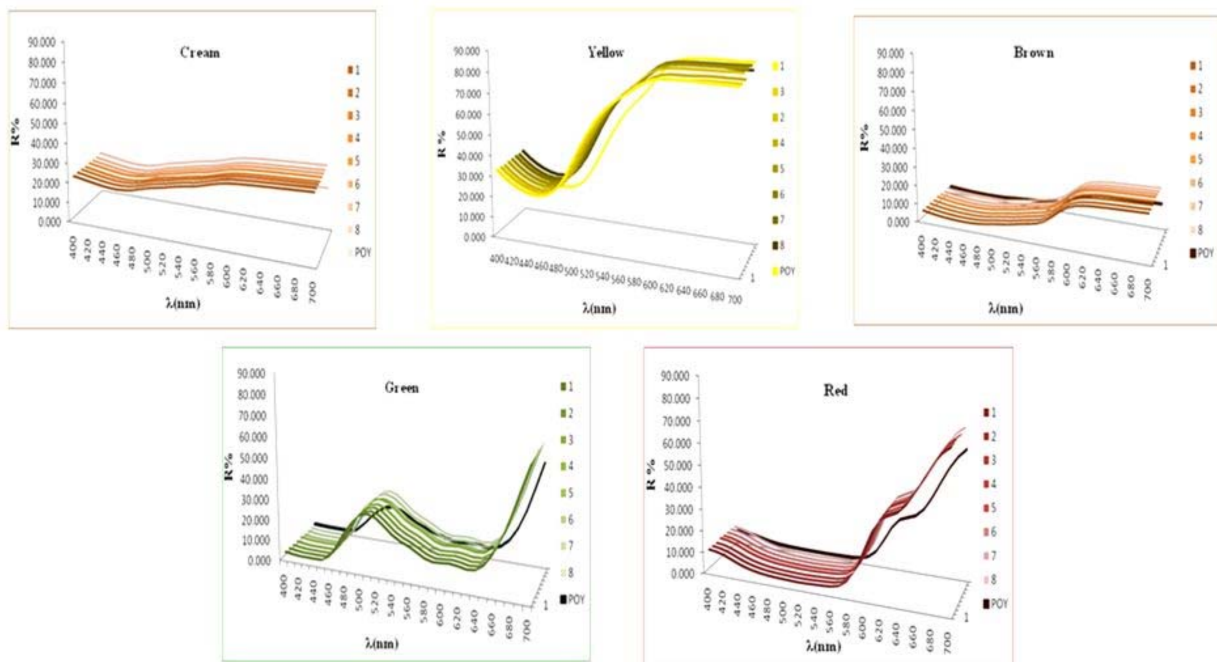

FIGURE 6. Spectral curves' reflectance of POY and different set yarns.

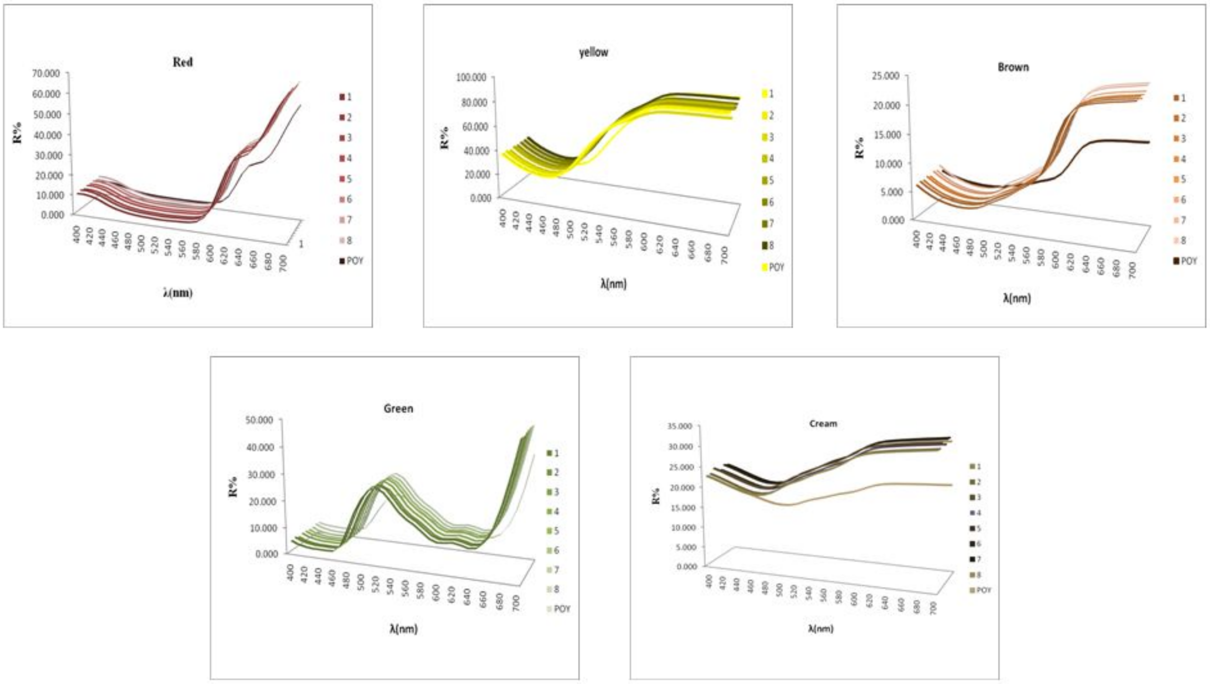

FIGURE 7. Spectral curves' reflectance of POY and different stretch yarns.

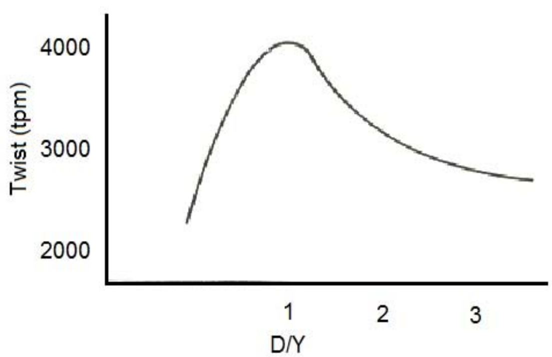

FIGURE 8. Variations of twist with D/Y ratio.

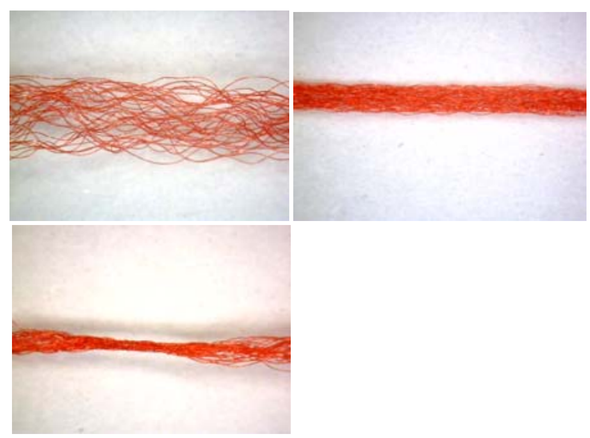

FIGURE 9. The Geometrical structure of set, stretch and intermingled yarn.

TABLE IX. Significant level of parameters on color variation of set yarns.

	Brown	Red	Green	Yellow	Cream
D/Y	0.80	0.55	0.08	0.51	0.83
First heater temperature	0.16	0.82	0.29	0.33	0.70
Setting overfeed	0.33	0.24	0.21	0.80	0.19

TABLE X. Significant level of parameters on color variation of stretch yarns.

	Brown	Red	Green	Yellow	Cream
First heater temperature	0.98	0.44	0.02	0.62	0.99
Texturing speed	0.84	0.32	0.34	0.89	0.67
Twist	0.06	0.41	0.02	0.33	0.48

CONCLUSION

The effects of texturing, intermingling and different processing parameters on color variation of textured yarns were investigated. The results show that the texturing process had a significant effect on color variation of the yarns which caused a great ΔE00 color difference between POY and different textured yarns with mean value of 4.90. The color variations were strongly dependent on the color center, it started with ΔE00=3.58 for red and approached to ΔE00=6.41 for brown. Yarn drawing during of texturing process had small contribution on color variations, (average ΔE00=1.56). In a similar manner the intermingling process had a significant effect too. Processing parameters including twist, D/Y ratio, heaters temperature, overfeed, twister type and texturing speed had no significant effect on color coordinates variation of the textured yarns, though they had significant effects on crimp and tensile properties. It discussed that fiber morphologies can help to explaining these phenomena.

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AUTHORS' ADDRESSES

Mohammad Amani Tehran
Bahareh Azimi
Mohammad Reza Mohades Mojtahedi
Department of Textile Engineering,
Amirkabir University of Technology,
Hafez St.
Tehran, ISLAMIC REPUBLIC OF IRAN