Color Evaluation of Nylon BCF Loop Pile Carpets

By Kumi Kouno*, Ikuko Hirai* and Toshihiro Gunji*, Members TMSJ

*Faculty of Home Economics, Otsuma Women's University, Tokyo,

Based on the Journal of the Textile Machinery Society of Japan, Proceedings, Vol.43, No.6, P357-P364 (1990-6)

Abstract

The behavior of coloring of loop pile carpet has still been unknown. Color evaluation of nylon BCF (Bulked Continuous Filament) loop pile carpet and lateral side of the pile yarn has been investigated by using various kinds of colorimeters where BCF stands for Bulked Continuous Filaments. The main results obtained are shown as follows:

The measuring area should be varied according to the aim of color measurement.

The relationship should be clarified between chromaticity coordinates (x , y) and the Y -values of lateral side of yarn and loop pile carpet in order to give the color to loop pile carpet.

The color of a color-mixed loop pile carpet shows the weighted average of chromaticity point of each monochrome or fundamental color. In addition, the Y -value of loop pile carpet shows the average Y -value of each monochrome of loop pile carpet. The colorimetry of bright portion (top of the loop) and dark portion (darker portion between the two tops of loops) has shown the remarkable color difference between bright and dark portion. ($\Delta E^*ab=30$)

The color of the loop pile carpet tends to be more affected by the color of light source with increasing the angle of incidence-reflection.

1. Introduction

Though the guilotine method^[1] is used for the coloring^[2] of the cut pile carpet, any reports have hardly been made on the coloring of the loop pile carpet and no one has ever probed into this matter. Therefore, the aim of our study has been to determine the characteristics of the color of the nylon BCF loop pile carpet, and in order to do that, we conducted a series of examinations using several colorimeters on the nylon BCF loop pile carpet's tuft surface and lateral side of yarn and the dope dyed nylon BCF loop pile carpet. The nylon BCF loop pile carpets used in the study were made by tufting the nylon BCF yarn into a loop pile on a primary backing, and they were dyed before measurement.

2. Test Samples

The kinds of nylon BCF loop pile carpets and a dope dyed nylon BCF loop pile carpet shown in table 1 were used as the test samples.

C.I. Acide Blue 277 and C.I. Basic Yellow 45 were used to dye the nylon BCF loop pile carpet and the pile yarn (samples 1 and 2 in table 1). The dope dyed nylon BCF loop pile carpet was chosen from Company D's sample book.

Table 2 Method of dyeing

Dye concentration	0.1, 0.3, 0.5, 1.0 1.5%owf
Leveling agents	Albegal W Albegal FED
	1.0%owf 1.0%owf
Adjusted to PH5	acetic acid sodium acetate
	0.4mℓ/ℓ 1.25g/ℓ
Liquor ratio	1 : 100

1) dyeing 2) rinsing 3) drying

Table 1 Test samples

Sample	denier/filament	Classification	Cross section	Gauge (in)	Stitches (in)	Pile height (mm)	Weight (g/m ²)	Primary backing
1	1300 d/68f	Semi bright regular dyeing type		5/64	13.0	3.0	590	Spunbond
2	2500 d/138f	mixed with deep regular and cationic dyeing type yarn		1/10	8.9	4.7	570	PE plain weave
3	3735 d/207f	dope dyed		5/32	8.0	5.0		Typar®

Table 3 Colorimeters used

Manufacturer		Suga Test Instruments		
Type		SM color computer	Spectrophotometer for measuring small areas	Goniophotometric colorimeter
model		SM-3	MSC-45S	VC-1
Spec.	Optical condition	0°—d	45°—0°	incidence-receiving angle variable
	Measurement area	30, 12mm ϕ	0.1, 0.2, 0.4, 0.8mm ϕ	20mm ϕ
	Light source	halogen 12V, 50W	halogen 12V, 100W	halogen

Samples 1 and 2 in table 1 were first scoured and bleached, then dyed by the method shown in table 2, by using the two kinds of dyes mentioned above.

Three kinds of colorimeters — the SM color computer (SM-3-SCH), the spectrophotometer for measuring small areas (MSC-45S), and goniophotometric colorimeter (VC-1) shown in table 3 — were used in order to measure the color. Specifications such as optical conditions, measurement area, etc. are shown in table 3.

3. Test Method

3.1 The area of loop pile carpet to be measured

It is generally said that the measuring area should be made as large as possible when measuring the color of the carpet. Therefore, in order to determine how the measured values change according to the size of the area measured, the results of the color measurements for area sizes 30mm ϕ and 12mm ϕ were compared.

A loop pile carpet using nylon BCF (sample 1 in table 1 — 1,300d/68f, semi-bright, acide dyeable regular type yarn), which was scoured and bleached, as well as four others which were similarly scoured and bleached, then dyed using C.I. Acid Blue 277 at a concentration of 0.1, 0.3, 1.0 and 1.5% owf respectively were used in the study.

Suga Test Instruments' SM color computer shown in table 3 was used to measure the color, and the measuring areas were 30 mm ϕ and 12 mm ϕ .

3.2 Color measurements of the loop pile carpet's tuft surface and lateral side of yarn

In order to determine the best method for the coloring of the loop pile carpet, the measured values obtained from the tuft surface of the loop pile carpet and the lateral side of yarn were compared. Each of the scoured yarn and the yarns dyed at various concentrations were wound evenly and densely around a transparent FRP plate, through making the wound yarn not to be overlapped.

(1) In the case of the mono-colored nylon BCF loop pile carpet

The colors of the 5 tuft surfaces of the loop pile

carpets used in 3.1 and the colors of the lateral side of the 5 yarns used in these carpets were measured.

The SM color computer was used and the measuring area was 12 mm ϕ .

(2) In the case of the loop pile carpet made of nylon BCF mixed with yarns of different dyeability.

Two samples were prepared: a loop pile carpet made of nylon BCF mixed with yarns of different dyeability which was dyed with C.I. Acid Blue 277, and the same type carpet which was dyed in a mixed dye bath containing C.I. Acid Blue 277 and C.I. Basic Yellow 45. The color of the tuft surface of the above mentioned two samples and the lateral side of the following yarns wound evenly and densely around an FRP plate was measured; deep dyeing type yarn, regular dyeing type yarn, cation dyeing type yarn, and the yarn made by twisting these three types of yarns. (This last type of yarn will be referred to as "twisted yarn" henceforth in the text.)

The SM color computer was used to measure the color and the measuring area was 12 mm ϕ .

3.3 Color measurements of the dope dyed nylon BCF loop pile carpet

The dope dyed nylon BCF loop pile carpet was tested. In this case, instead of comparing the tuft surface and the lateral side of yarn, the colors of a mono-colored and mix-colored nylon BCF loop pile carpet of the same standard were measured and compared. Sample 3 in table 1 was used, and four types were prepared; three mono-colored loop pile carpets of different colors and one mix-colored one made by tufting the yarn made by interlacing the yarns of these three colors. The thickness of the yarn and the standard of the carpet were exactly the same for both the mono-colored and mix-colored carpets.

The colorimeter used was the SM color computer, and the measuring area was 12 mm ϕ .

3.4 Color measurements of the bright portion and dark portion of the carpet using a spectrophotometer for measuring small area

Figure 1 is a microphotograph of the loop pile carpet. In the photo, the top of the loops appear bright and

Fig. 1 Appearance of loop pile carpet

the hollow section among the loops appears dark. We searched for the places where the tristimulus value Y was maximum, and minimum by measuring the color at 20 different places within an area of approximately 1.5 cm^2 for each of the bright and dark portions of the carpet.

The loop pile carpet used for the color measurement was sample 1 in Table 1, and five types — one scoured and four dyed with C.I. Acid Blue 277 at concentrations 0.3, 0.5, 1.0 and 1.5%owf — were prepared. The measuring range of 1.5 cm^2 was determined by assuming that the distance from the eye to the sample was 45 cm and the observing angle was 2° .

The spectrophotometer for measuring small area shown in table 3 was used. This colorimeter can be applied for measuring within areas of 0.1, 0.2, 0.4 and $0.8 \text{ mm}\phi$, but in this experiment, we decided that the bright and dark portions of the samples were most suitable for measuring at an area size of $0.8 \text{ mm}\phi$.

3.5 Variable angle color measurement of the loop pile carpet

An examination using a goniophotometric colorimeter was conducted to determine the degree of color change according to the angle from which the loop pile carpet

can be seen.

The loop pile carpet used for the color measurement was sample 1 in table 1, and five types — one scoured and four dyed with C.I. Acid Blue 277 at concentrations 0.1, 0.3, 0.5 and 1.0% owf — were prepared.

The goniophotometric colorimeter shown in table 3 was applied. The angles of incidence-reflection were set at $45^\circ-0^\circ$, $0^\circ-45^\circ$, $45^\circ-45^\circ$, and the measuring area was $20 \text{ mm}\phi$.

4. Test Results and Consideration

4.1 The area of loop pile carpet to be measured

The results of the color measurement of the nylon BCF loop pile carpet at measuring areas of $30 \text{ mm}\phi$ and $12 \text{ mm}\phi$ are shown in Table 4.

The results show that the color difference ΔE^*_{ab} between the measuring area sizes, $30 \text{ mm}\phi$ and $12 \text{ mm}\phi$ was small with the samples applied this time.

In the conventional method for measuring the color of carpet, one of two measures was taken. Either the measuring area was made as large as possible, say $50 \text{ mm}\phi$ for example, or the color was measured several times for different area sizes between $25-30 \text{ mm}\phi$, and the average value was applied. However, for the samples used in this study, the color difference is small between the measured values for $30 \text{ mm}\phi$ and $12 \text{ mm}\phi$, we can not find out any differences of the coordinates of x and y values in the chromaticity diagram. From this fact, we can conclude that the measured value obtained from an area size of $12 \text{ mm}\phi$ is sufficiently valid. In other words, we can say that the size of measuring area should be changed according to the type of carpet and the purpose of the color measurement.

4.2 Color measurement of the tuft surface and lateral side of yarn of the loop pile carpet

(1) In the case of the mono-colored nylon BCF loop pile carpet

Table 5 shows the results of the color measurement of the tuft surface and lateral side of yarn of the mono-colored nylon BCF loop pile carpet.

Table 4 Measurement area of loop pile carpet

Dye concentration	Measurement area	Y	x	y	L^*	a^*	b^*	ΔE^*_{ab}
Scoured 0 %	$30 \text{ mm}\phi$	49.83	0.309	0.317	75.97	-0.62	0.02	
	$12 \text{ mm}\phi$	45.46	0.309	0.316	73.19	-0.44	-0.14	2.78
Blue 0.1%	$30 \text{ mm}\phi$	21.88	0.223	0.242	53.90	-5.98	-28.11	
	$12 \text{ mm}\phi$	21.12	0.225	0.243	53.09	-5.65	-27.22	1.26
Blue 0.3%	$30 \text{ mm}\phi$	10.44	0.181	0.181	38.62	1.63	-41.47	
	$12 \text{ mm}\phi$	10.12	0.182	0.183	38.05	1.00	-40.27	1.49
Blue 1.0%	$30 \text{ mm}\phi$	3.92	0.161	0.134	23.40	11.97	-43.80	
	$12 \text{ mm}\phi$	4.24	0.162	0.139	24.46	10.52	-43.42	1.74
Blue 1.5%	$30 \text{ mm}\phi$	3.28	0.161	0.130	21.13	12.97	-42.50	
	$12 \text{ mm}\phi$	3.38	0.161	0.132	21.50	12.05	-42.41	0.98

Table 5 Color measurement results of mono-colored nylon BCF loop pile carpet and lateral side of yarn

Dye concentration	Sample	Y	x	y	L*	a*	b*	ΔE^*ab
Scoured 0 %	carpet	45.46	0.309	0.316	73.19	-0.44	-0.14	
	lateral side of yarn	70.88	0.311	0.320	87.43	-1.16	1.50	14.35
Blue 0.1%	carpet	21.12	0.225	0.243	53.09	-5.65	-27.22	
	lateral side of yarn	35.70	0.242	0.262	66.29	-7.34	-24.15	13.66
Blue 0.3%	carpet	10.12	0.182	0.183	38.05	1.00	-40.27	
	lateral side of yarn	17.06	0.191	0.201	48.35	-2.52	-40.91	10.88
Blue 1.0%	carpet	4.24	0.162	0.139	24.46	10.52	-43.42	
	lateral side of yarn	7.69	0.166	0.152	33.33	7.77	-47.71	10.24
Blue 1.5%	carpet	3.38	0.161	0.132	21.50	12.05	-42.41	
	lateral side of yarn	5.39	0.162	0.138	27.89	11.67	-47.19	7.94

The Y-value of the lateral side of yarn is larger than that of the tuft surface. The color difference ΔE^*ab between the two tops of loops was also large. The measured value of the lateral side of yarn was obtained from a sample wound flatly around an FRP plate, so the reflectance of light in this case was large. On the other hand, since the surface of the loop pile carpet was uneven due to the loops, the chances of the light being absorbed and interreflected were increased in the hollow section among the loops. Thus the Y-value of the tuft surface was thus reduced, and this probably accounts for the color difference. Also, the Y-value became smaller for both the tuft surface and the lateral side of yarn as according to increasing the concentration of dye. The difference between the Y-value of the two, tops of loops on the other hand, decreased.

Figure 2 shows the chromaticity diagram for the measurements in Table 5. The diagram shows that the color of the lateral side of yarn was slightly closer to

Fig. 2 Color measurement results of mono-colored nylon BCF loop pile carpet and lateral side of yarn

the color of the light source than that of the tuft surface.

From these results, we deduced that some sort of relationship must have existed between the tuft surface and the lateral side of yarn of the loop pile carpet, and checked the Y-values of both for a correlation. The results of our examination are shown in Fig. 3.

The Y-values of the tuft surface and lateral side of yarn shows are very high correlation, with a coefficient of correlation of 0.99.

From the above mentioned facts, we can conclude that the color of a loop pile carpet can be estimated if the relationship between the Y-values of its tuft surface and lateral side of yarn can be found.

(2) In the case of the loop pile carpet made of nylon BCF mixed with yarns of different dyeability

The color of the tuft surface of the loop pile carpet made of nylon BCF mixed with yarns of different dyeability and the color of the lateral side of the deep dyeing type yarn, regular dyeing type yarn, cation dyeing yarn, and the twisted yarn was measured and the results are shown in Table 6.

The chromaticity diagram for these measurements is shown Fig. 4. The chromaticity diagram shows that the

Fig. 3 Relationship between Y-values of lateral side of yarn and carpet surface

Table 6 Color measurement results of loop pile carpet made of nylon BCF mixed with yarn of different dyeability
(dye: C.I. Acid Blue 277)

sample	Y	x	y	L*	a*	b*
deep dyeing type	4.14	0.165	0.139	24.14	11.31	-42.88
regular dyeing type	6.82	0.163	0.152	30.40	6.19	-45.85
cationic dyeing type	59.45	0.296	0.310	81.54	-4.06	- 4.04
3-twisted yarn	13.95	0.212	0.208	44.18	3.43	-34.38
carpet	9.45	0.220	0.209	36.85	5.22	-29.39

Fig. 4 Color measurement results of loop pile carpet made of nylon BCF mixed with yarn of different dyeability (dye: C.I. Acid Blue 277)

cationic dyeing type yarn is located slightly away from the standard light source C and is slightly stained with blue.

Also, according to the chromaticity diagram show in Fig. 4, the barycenter calculated from the chromaticity points of the deep dyeing type yarn, regular dyeing type yarn, and cationic dyeing type yarn, is roughly in the same position as the chromaticity points of the carpet and the twisted yarn. In other words, the principle of weighted average can be said to be applied to the color mixture in the chromaticity diagram. However, the Y-value is 9.45 for the tuft surface of the carpet and 13.95 for the lateral side of the twisted yarn, and is higher for the lateral side of yarn.

Next, the loop pile carpet made of nylon BCF mixed

with yarns of different dyeability was dyed in a mixed dye bath containing acid dye and cationic dye. Table 7 shows the results of the color measurement of the tuft surface of this carpet and the lateral side of the three yarns of different dyeability and the twisted yarn. Fig. 5 is the chromaticity diagram for these measurements. When the barycenter is calculated from the coordinates of $x \cdot y$ values in the chromaticity diagram of the deep dyeing type yarn, regular dyeing type yarn, and catimic dyeing type yarn, we see that it is roughly in the same position as the coordinates of the chromaticity diagram of the tuft surface of the loop pile carpet and the lateral side of the twisted yarn.

Fig. 5 Color measurement results of loop pile carpet made of nylon BCF mixed with yarn of different dyeability (dye: C.I. Acid Blue 277; C.I. Basic Yellow 45)

Table 7 Color measurement results of loop pile carpet made of nylon BCF mixed with yarn of different dyeability
(dye: C.I. Acid Blue 277; cationic dye, Basic Yellow 45)

Sample	Y	x	y	L*	a*	b*
Deep dyeing type Blue	5.84	0.166	0.160	29.00	3.60	-40.89
Regular dyeing type Blue	11.35	0.184	0.204	40.16	- 6.99	-35.19
Cationic dyeing type Yellow	41.23	0.472	0.485	70.33	- 0.88	86.32
3-twisted yarn	21.38	0.281	0.322	53.37	-11.45	- 1.62
Carpet	8.67	0.297	0.332	35.33	- 6.83	1.62

4.3 Color of the dope dyed nylon BCF loop pile carpet

The results of the color measurement of three mono-colored dope dyed nylon BCF loop pile carpets of three different colors and one mix-colored one made by interlacing yarns of those three colors and tufting the resulting yarn are shown in Table 8. Figure 6 is the chromaticity diagram for these measurements. When the barycenter of the three colors is calculated from the chromaticity points of the three mono-colored carpets, we find that it coincides with the coordinates in the chromaticity diagram of the mix-colored carpet. Since the comparison this time was made among the tuft surfaces of loop

Fig. 6 Color measurement results of dope dyed nylon BCF loop pile carpet

pile carpets, the Y-value of the mix-colored carpet was the same as the average value of the Y-values of the three mono-colored carpets.

4.4 Color measurements of the bright and dark portions of the carpet using a spectrophotometer for measuring small areas

The color of the bright portion of the loop pile carpet (top of the loops) and the dark portion (hollow section among the loops) was measured at 20 locations each within an area of 1.5 cm². The measurements for where the Y-value was maximum and minimum are shown in

Fig. 7 Color measurement results of bright and dark portions of loop pile carpet

Table 8 Color measurement results of dope dyed nylon BCF loop pile carpet

Sample	Y	x	y	L*	a*	b*
Mono-colored 1	4.69	0.266	0.273	-25.84	- 0.23	-9.20
Mono-colored 2	9.59	0.397	0.315	37.10	20.05	7.53
Mono-colored 3	12.82	0.273	0.384	42.49	-25.56	8.98
Mix-colored	8.76	0.309	0.322	34.71	- 1.73	0.90

Table 9 Color measurement results of bright and dark portions of loop pile carpet

Dye concentration	Measurement condition	Y	x	y	L*	a*	b*	ΔE^*_{ab}
Scoured 0 %	tuft max.	60.36	0.312	0.319	82.03	-0.29	1.05	29.55
	direction min.	20.58	0.313	0.319	52.48	0.19	0.79	
Blue 0.3%	tuft max.	17.07	0.223	0.237	34.42	0.89	-38.31	28.19
	direction min.	3.44	0.176	0.145	21.73	10.05	-38.39	
Blue 0.5%	tuft max.	12.65	0.193	0.186	42.23	4.87	-41.61	29.21
	direction min.	2.00	0.161	0.117	15.50	16.37	-40.06	
Blue 1.0%	tuft max.	7.68	0.182	0.152	33.31	14.63	-46.55	24.95
	direction min.	1.08	0.159	0.098	9.62	20.06	-37.81	
Blue 1.5%	tuft max.	6.92	0.181	0.146	31.63	16.59	-47.14	30.21
	direction min.	0.55	0.155	0.082	4.98	19.30	-33.98	

Table 9. The color difference ΔE^*_{ab} between the places where the Y-value had been maximum and minimum was approximately 30, and was large regardless of dye concentration. Figure 7 is the chromaticity diagram for these measurements. The coordinates in the chromaticity diagram for where the Y-value was maximum and minimum are considerably far apart, and the points which represent the maximum Y-value are closer to the color of the light source. It seems that we perceive the color of the loop pile carpet by comparing the bright portion (top of loops) and dark portion (hollow section among loops) of the carpet.

4.5 Variable angle color measurement of the loop pile carpet

The results of the color measurement using a gonio-photometric colorimeter are shown in Table 10. The

Fig. 8 Variable angle color measurement results of loop pile carpet

results show that as the angle of reflection increases, the Y-value also increases. Plotted on a chromaticity diagram, these chromaticity coordinates appear as in Fig. 8. Though the chromaticity coordinates were the same for (45°-0°) and (0°-45°), they move closer to the color of the light source for (45°-45°) or i.e., the direction of the regular reflection. This means that when the angle of reflection increases, we no longer see the carpet's original color, but the color of the shiny section of the pile surface instead. In other words, in a bright place, the color may be affected by the light source, depending on the angle from which we look at the carpet.

5. Summary

In this study, the color of the nylon BCF loop pile carpet was examined using several colorimeters. The results obtained are as follows:

- (1) Although it is generally believed that it is preferable to make the measurement area as large as possible when measuring the color of a carpet, for the carpets used in this study, no significant difference was found between the measured values for area sizes 30 mm ϕ and 12 mm ϕ . We believe, therefore, that the measuring condition and area size should be varied according to the purpose of the color measurement.
- (2) In conducting the coloring of the loop pile carpet, the color of the finished carpet can be estimated if the chromaticity coordinates (x , y) of the yarn's lateral side and the relationship between the Y-values of the lateral side of yarn and the loop pile carpet are determined beforehand. Also, if the pile carpets are of the same standard, the color of a mix-colored carpet can be determined from the measured values of a mono-colored carpet. We found the principle of weighted average to hold true for both the chromaticity coordinates and Y-values in this case.
- (3) With the loop pile carpet, there is a great differ-

Table 10 Variable angle color measurement results of loop pile carpet

Dye concentration	Incidence-receiving angle	Y	x	y	L*	a*	b*	ΔE^*_{ab}
Scoured 0 %	45° - 0°	46.56	0.310	0.317	73.91	-0.52	0.19	1.77
	0° - 45°	49.28	0.309	0.316	75.62	-0.43	- 0.23	
	45° - 45°	57.27	0.309	0.316	80.33	-0.40	- 0.24	
Blue 0.1%	45° - 0°	22.66	0.231	0.243	54.73	-3.32	-27.35	1.27
	0° - 45°	21.48	0.230	0.242	53.48	-3.21	-27.15	
	45° - 45°	29.03	0.238	0.251	60.81	-3.70	-26.41	
Blue 0.3%	45° - 0°	10.72	0.191	0.183	39.10	5.08	-40.39	1.49
	0° - 45°	11.45	0.194	0.187	40.33	4.41	-39.86	
	45° - 45°	14.84	0.199	0.196	45.43	3.16	-39.86	
Blue 0.5%	45° - 0°	7.92	0.182	0.165	33.82	8.54	-42.49	0.76
	0° - 45°	8.23	0.183	0.167	34.46	8.14	-42.44	
	45° - 45°	11.77	0.189	0.178	40.85	6.80	-43.45	
Blue 1.0%	45° - 0°	4.24	0.175	0.144	24.45	12.78	-41.01	0.86
	0° - 45°	4.50	0.177	0.147	25.26	12.62	-40.76	
	45° - 45°	6.38	0.180	0.154	30.35	12.27	-43.34	

ence between the Y -values for the section at the top of the loops and for the hollow section among the loops. In some cases, the color at the top of the loops might not be the color of the pile yarn itself, but that of the light source. It seems that we perceive the color of the carpet by comparing the colors of both its bright and dark portion in place where it is brightly lightened.

(4) When looking at the color of the loop pile carpet, the Y -value becomes greater as the angle of incidence-

reflection increases and the color of the carpet approaches the color of the light source. In such a case, we may be looking at only the color of the shiny parts of the tuft surface.

References

- [1] W. Matthew J.; Amer. Dyestuff Rept. **21**, 587, 1968
- [2] Gunji, Nishira and Tsuboi; J. Text. Mach. Soc. Japan, **24**, T42 (1971)