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A Study on the Effect of the Method of Tops Production used in Semi-Worsted Yarns for Carpet

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Abstract

Carpets in homes are typically subjected to static and dynamic loads. This paper presents research on two carpet types with different piles (yarns) of 10.5/2 Nm acrylic spun in semi-worsted using card and Tow-to-tops machines.

Yarns from the Tow-to-tops machine exhibit roughly twice the initial modulus of yarns from the card machine due to greater fiber orientation. Conversely, the breakage elongation of carded yarns is 1.86 times that of yarns spun from Tow-to-tops. The parallel fiber arrangement in Tow-to-tops yarns results in higher inter-fiber friction due to increased contact area.

Static load, dynamic load, and yarn pull-out tests were performed on carpets made from both yarn types. Results indicate that a greater force is required to pull yarn from carpets produced with carded yarns. This is attributed to yarn locking due to their higher hairiness.

Keywords: Semi-Worsted; Carpet; Yarns

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1. Introduction

Carpets are composed of three fundamental components: warp, weft, and pile yarns. The warp yarns are wound on the warp beams. The number of warp yarns on a beam depends on the reed count. The role of weft yarns is to reinforce the carpet and make it stiff. Therefore, thick jute yarns are used as weft. These yarns can absorb the adhesive materials used to finish carpets [1]. The pile yarns covering the surface determine the properties of the carpet. Moreover, these yarns specify the pattern, beauty, color, and other appearance characteristics of the carpets. A vital factor influencing the quality of the carpet is the decrease in its thickness under static and dynamic loads. When the thickness decreases, its appearance is affected, and the carpet's resiliency lowers. The compression in carpet thickness usually occurs when it is subjected to static and dynamic loads such as chair legs and foot traffic [3]. Some research has been carried out to study the effect of static and dynamic loads on the physical properties of hand-woven and machine-made carpets [4-7]. Pile yarns are made from wool, polyamide, polyester, polypropylene, acrylic, or blends thereof. Specifically, 10.5/2 Nm acrylic yarns are used as pile yarns. This research aims to produce acrylic yarns using two common spinning methods and analyze their physical properties and performance in carpets.

2. Experimental

2.1. Methods of yarns Spinning

In the first method of spinning, the pile yarn is produced in the semi-worsted system using a card machine. In this method, the acrylic filaments are initially cut into staple fibers and packed in the bales. The fibers from different bales are combined before being fed to card machines. The slivers produced by card machines are mixed and parallel in gill box machines. The output slivers of the gill box machines are thinner due to the draft applied to the slivers. These slivers are fed into finisher machines to produce roving. The rovings are then fed to ring machines to spin the yarn. The count of the yarn spun by ring machines is 10.5Nm. These yarns are doubled and twisted to produce 10.5/2Nm used as pile yarns in the carpet.

In the second method, the semi-worsted yarns are spun after chopping the filaments of two and producing staple fibers in the form of tops. In this method, the filaments are cut and directly converted to tops. This process briefly is known as tow to tops. The filaments are drawn and fixed thermally before they are cut. In fact, in the old method, the filaments are cut by a cutter, whereas in the new method, filaments are broken due to the high draft applied. In the newly used method to change the average length of the fibers, the distance between the rollers in the draft zone is adjusted. In the present work, we produce the staple fibers using two tops. The continuation of the production line is similar to the first method of yarn production. The resulting staple fibers formed into slivers (tops) or packed as bales [7].

2.2. Materials

In this research work, we used the same fibers specified in Table 1. The fibers were divided into two parts and were fed to two production lines. The output of both production lines was 10.5/ Nm acrylic yarns. The yarns were used to produce two similar Wilton carpet types. The warp and weft yarns used in both carpets and the pile length of both carpets were the same. The carpets differed on the pile yarn spinning systems.

Table 1. The specifications of the fibers used

Manufacturer	Dtex	Length(mm)
AKSA AKRILIK KIMIYA SANAYI A.S. TURKEY	8.9	95

3. Results and Discussions

3.1. Yarn Tenacity

To understand the role of the spinning method on the characteristics of the yarns and the quality of the carpet, the researchers measured the mechanical properties of the yarns. The yarns stayed under standard conditions. The researchers prepared ten 50cm samples according to relevant standards. The yarns should be ruptured in 20±3 sec., with an elongation rate of the Instron equipment of 340mm/min for the pile yarn spun in the first method and 170mm/min for the pile yarn spun in the second method of spinning. The equipment was connected to the PC to plot the curves of Force-Elongation, the peaks of all curves. Tables 2 and 3 demonstrate the mechanical characteristics of the yarns spun in two methods of spinning, respectively. Figure. 1 and Figure. 2 show the Force-Elongation of the yarns spun in two methods of spinning. Carpets made from two pile yarns were tested for thickness compression under static loading. Carpet thickness was measured before and after applying 2 kPa pressure using a digital gauge, according to BS4939. Following BS1051, carpets conditioned for 24 hours were subjected to a 700 kPa static load for 24 hours. Thickness was then measured at 2, 15, and 30 minutes, 1 hour, and 24 hours after load removal.

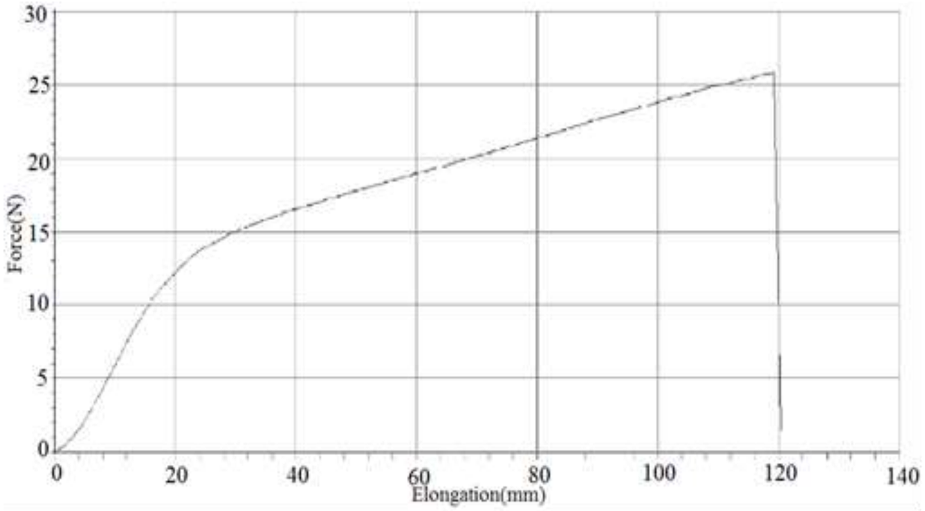

Figure 1. The diagram of force- elongation of the yarn, spun in first method

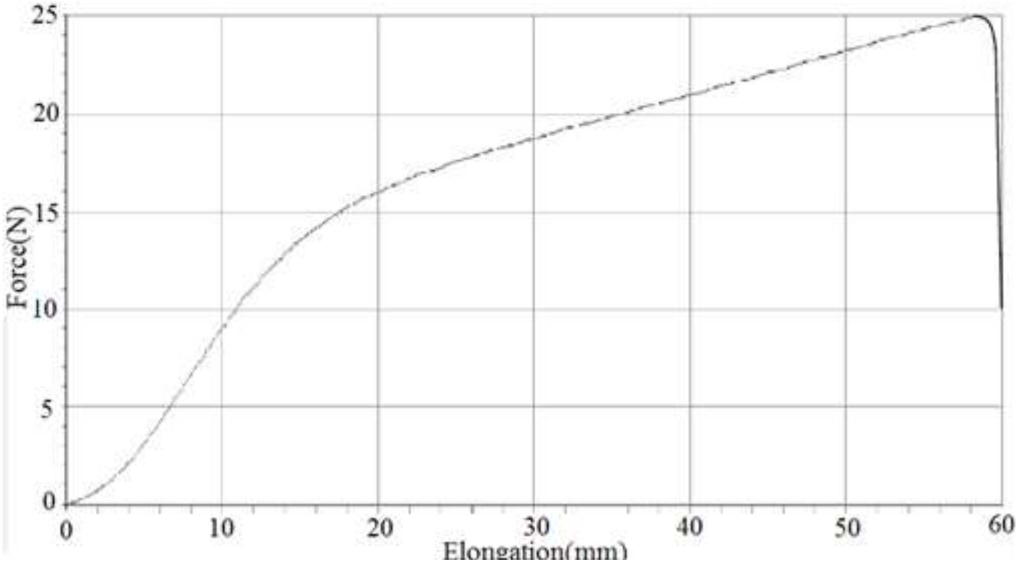

Figure 2. The diagram of force- elongation of the yarn, spun in second method (Tow to Tops)

The properties of the carpets were studied under dynamic loading according to BS4052. After conditioning, the carpets were subjected to dynamic loads in the form of strikes, and the thickness was measured after 50, 100, 200, 500, and 1000 strikes.

Additionally, the pullout force required to withdraw the pile from the carpet structure was measured on 50 samples according to relevant standard instructions, using a tuft withdrawal tension meter.

Table 2. The mechanical properties of the yarn, spun in the first method

Test No	**E**p (mm)	**E**R (mm)	**F**p(N)	**E**Ru(N.m)	**M**Initial (cN/Tex)	**T** (cN/Tex)	**T**Ru (cN/Tex)
1	115.05	115.05	21.14	1.68	329.452	22.197	22.197
2	124.56	124.56	26.5	2.252	389.388	27.825	27.825
3	99.86	99.86	27.04	1.847	445.437	28.392	28.392
4	119.16	120.25	25.89	2.131	396.822	27.184	1.596
5	114.36	115.44	24.31	1.926	363.77	25.525	17.02
6	132.29	133.38	28.41	2.609	414.571	29.83	3.79
7	135.37	136.48	27.42	2.584	398.475	28.791	17.325
8	118.24	119.32	23.47	1.903	357.77	24.643	1.995
9	127.25	128.34	23.88	2.131	352.779	25.074	24.391
10	127.67	128.78	25.45	2.257	363.716	26.722	19.971
Min	99.86	99.86	21.14	1.68	329.452	22.197	1.596
Mean	121.381	122.146	25.351	2.132	381.218	26.619	16.45

Max	135.37	136.48	28.41	2.609	445.437	29.83	28.392
S.D.	10.361	10.664	2.176	0.306	34.146	2.285	10.389
C. of V.	8.536	8.73	8.585	14.348	8.957	8.585	63.155
L.C.L.	113.969	114.517	23.794	1.913	356.791	24.984	9.018
U.C.L.	128.793	129.775	26.908	2.351	405.645	28.253	23.883

Table 3. The mechanical properties of the yarn, spun in the second method (Tow to Tops)

Test No	**E**p (mm)	**E**R (mm)	**F**p(N)	**E**Ru(N.m)	**M**Initial (cN/Tex)	**T** (cN/Tex)	**T**Ru (cN/Tex)
1	66.87	67.44	26.38	1.182	658.593	27.699	27.268
2	57.12	57.67	22.66	0.884	616.774	23.793	8.421
3	58.35	58.35	24.94	0.966	638.979	26.187	26.187
4	54.65	55.2	23.89	0.878	634.314	25.084	9.114
5	69.59	70.69	29.54	1.394	703.525	31.017	1.659
6	60.87	61.42	25.2	1.043	641.135	26.46	26.449
7	63.06	63.6	24.26	1.029	606.942	25.473	24.559
8	61.6	62.14	23.96	0.998	610.912	25.158	13.702
9	66.08	66.96	25.5	1.14	628.196	26.775	26.701
10	56.25	56.79	22.97	0.882	620.055	24.118	9.776
Min	54.65	55.2	22.66	0.878	606.942	23.793	1.659
Mean	61.444	62.026	24.93	1.04	635.943	26.176	17.384
Max	69.59	70.69	29.54	1.394	703.525	31.017	27.268
S.D.	4.963	5.143	1.978	0.163	28.415	2.077	9.793
C. of V.	8.077	8.292	7.935	15.653	4.468	7.935	56.334
L.C.L.	57.894	58.347	23.515	0.923	615.615	24.691	10.378
U.C.L.	64.994	65.705	26.345	1.156	656.27	27.662	24.389

The following parameters, given in Tables 2 and 3, are calculated by a PC connected to Instron equipment:

EP: Yarn elongation at maximum force applied on the yarn in mm

FP: Yarn tension at maximum elongation at breakage point in N

ER: Yarn elongation at breakage point in mm

MInitial: The initial modulus of the yarn in CN/Tex

T: Yarn tenacity in CN/Tex

TRu: Yarn tenacity to rupture in CN/Tex

As observed in Tables 2 and 3, the elongation at break for the yarns produced by the first and second methods is 122.15 mm and 62.026 mm, respectively. This means that the elongation ratio of the yarns from the two methods is approximately 2 mm. The lower orientation of the fibers in the yarn spun using the first method results in less parallel alignment, which consequently reduces friction between the fibers. This allows the fibers to slip past one another more easily, leading to greater elongation of the yarn produced by this method.

Tables 2 and 3 also show the yarn tenacity at the breakage points for the yarn spun by both methods, recorded at 16.45 CN/Tex for the first method and 17.38 CN/Tex for the second method. There is no significant difference in tenacity between the two types of pile yarns. However, the lower friction between the fibers, as indicated by the differences in elongation, has a notable impact on the tenacity of the yarns. The energy at the breakage of the yarns is defined as the area under the Force-Elongation curve or the Stress-Strain curve. As shown in Tables 2 and 3, the values of this parameter for the yarns spun using the first and second methods are approximately 2.13 and 1.04, respectively, or about 2:1.

Considering the initial modulus of the yarns from Tables 2 and 3, which reflects the slope of the Force-Elongation curve at the start point, it suggests that the modulus of the yarns spun by the second method is significantly higher than that of the yarns spun by the first method. This difference can be attributed to the higher friction force between the fibers with greater orientation in the second method, resulting in a higher initial modulus for this group of yarns.

Another difference stemming from the lower orientation of the fibers in yarn affects the uniformity of the yarns, so the Standard Deviation (S.D.) and C.V. % of the mechanical properties of the yarns spun using the first method are higher in comparison to those produced by the second method. In fact, the unevenness of the first group of yarns increases due to a greater number of thin and thick sections in the respective yarns.

3.2. Loss Thickness of the carpets

After producing carpets, the following parameters are measured under static loading conditions:

h_0: Carpet thickness before applying static load

h_1: Carpet thickness 2 minutes after removing static load

h_2: Carpet thickness 25 minutes after removing static load

h_3: Carpet thickness 30 minutes after removing static load

h_4: Carpet thickness 60 minutes after removing static load

h_5: Carpet thickness 24 hours after removing static load

The results of the thickness loss of the carpets, under static loads have been given in Tables 4 and 5.

Table 4. The effect of static load on carpet C2 (Produced from carding yarns)

Thickness Parameter	sample 1	sample 2	sample3	sample4	sample5	Mean	Thickness Loss(mm)
h0	13.58	13.54	13.44	13.52	13.46	13.5	0
h1	9.48	8.83	8.72	9.2	8.78	9	4.5
h2	10.24	9.89	9.68	10.12	9.8	9.95	3.55
h3	10.39	10.46	10.08	10.41	10.24	10.32	3.18
h4	10.74	10.68	10.31	10.64	10.48	10.56	2.94
h5	12.16	12.16	12	12.12	12.08	12.1	1.4

Table 5. The effect of static load on carpet C1(Produced from tow to tops)

Thickness Parameter	sample 1	sample 2	sample3	sample4	sample5	Mean	Thickness loss(mm)
h0	13.35	13.56	13.52	13.65	13.42	13.5	0
h1	8.32	8.88	9.02	8.45	8.64	8.66	4.84
h2	9.26	9.56	10	9.5	9.31	9.58	3.92
h3	9.45	10	10.39	9.72	9.67	9.84	3.66
h4	9.81	10.5	10.76	10.21	10.08	10.27	3.23
h5	10.91	11.1	11.21	11.2	11	11.08	2.42

The following parameters are also measured after applying a dynamic load on the carpets:

h_0: Carpet thickness before applying dynamic load

h_1: Carpet thickness after applying 50 times strikes (Dynamic load)

h_2: Carpet thickness after applying 100 times strikes (Dynamic load)

h_3: Carpet thickness after applying 200 times strikes (Dynamic load)

h_4: Carpet thickness after applying 500 times strikes (Dynamic load)

h_5: Carpet thickness after applying 1000 times strikes (Dynamic load)

Table 6. The effect of dynamic load on carpet C2 (Produced from carding yarns)

Thickness Parameter	sample 1		sample 2		Mean	Thickness Loss(mm)
	A	B	A	B		
h_0	13.36	13.46	13	13.1	13.23	0
h_1	12.34	12.44	12.24	12.31	12.33	0.9
h_2	12.08	12.3	12.08	12.22	12.17	1.06
h_3	11.99	12	11.49	11.72	11.8	1.43
h_4	11.7	11.7	10.85	11.12	11.34	1.89
h_5	11.34	11.44	10.48	10.75	11	2.23

Table 7. The effect of dynamic load on carpet C1 (produced from tow to tops method)

Thickness Parameter	sample 1		sample 2		Mean	Thickness Loss(mm)
	A	B	A	B		
h_0	13.1	13.12	13.37	13.18	13.19	0
h_1	11.83	11.91	12.16	12.13	12	1.19
h_2	11.74	11.76	11.9	11.84	11.81	1.38
h_3	11.54	11.56	11.7	11.6	11.6	1.59
h_4	11.41	11.44	11.33	11.26	11.36	1.83
h_5	11.22	11.32	10.97	10.84	11.08	2.11

As Tables 6 and 7 show the initial thickness of both carpets was almost the same, the thickness loss of carpet C2 is somewhat larger than carpet C1 under 50 strikes. When the number of strikes increases, the difference between the thickness loss decreases.

3.3. Withdrawal Force

In measuring the withdrawal force required to pull out pile yarn from the carpet, x represents the force in kilograms and $\bar{x}$ is the average withdrawal force in kilograms. As mentioned earlier, this parameter was measured 50 times for each carpet. The results of this test are presented in Tables 8 and 9 for carpets C1 and C2, respectively. As shown in Tables 8 and 9, the pullout force necessary to remove pile yarns from carpet C2 is significantly greater than that from carpet C1. Since carpet C2 has a higher hairiness of pile yarns than carpet C1, the pile yarns interlock with other parts of the carpet, requiring a higher force for removal withdrawn.

Table 8. The pullout force to remove pile yarn from carpet C1 (Kg)

	0.37	0.4	0.2	0.25	0.4	0.3	0.2	0.27	0.4	0.4
	0.5	0.3	0.4	0.2	0.3	0.4	0.2	0.5	0.3	0.2
X=	0.2	0.4	0.27	0.4	0.3	0.5	0.3	0.2	0.3	0.3
	0.4	0.2	0.3	0.5	0.27	0.4	0.35	0.4	0.3	0.2
	0.3	0.3	0.3	0.4	0.37	0.35	0.25	0.3	0.27	0.4
$\bar{x}$ =0.324										

Table 9. The pullout force to remove pile yarn from carpet C2 (Kg)

	0.4	1.3	0.6	0.65	1	0.8	0.8	0.4	0.5	0.6
	0.4	0.5	0.6	0.45	1	0.4	0.65	0.65	1.4	0.65
X=	0.65	0.55	0.4	0.8	1.5	0.5	1.1	0.37	0.5	1.5
	0.6	0.55	0.5	0.6	1.1	0.6	0.4	1.4	0.6	1.3
	1.5	0.55	0.5	0.5	0.8	0.5	0.4	0.5	0.55	0.6
$\bar{x}$ =0.713										

4. Conclusions

In this research work, two methods were used to spin pile yarns for machine carpets. In the second method of yarn production, tow to tops, the fibers in the yarn structure are more parallel compared to the first method, known as the carding method. This structural difference between the produced pile yarns causes: 1- Higher fiber orientation in the second method leads to increased tenacity and decreased elongation of the pile yarns. The energy at the rupture point of the yarns is also directly affected by fiber orientation, so the pile yarns produced in the second method have higher energy at rupture compared to those produced in the first method. 2- The initial modulus of the yarns is influenced by fiber orientation in the yarn structure. Greater fiber orientation results in a larger initial modulus for the relevant yarns. 3- As fiber orientation in the yarn structure improves, the unevenness, thin and thick spots in the yarns, standard deviation, and coefficient of variation percentages decrease. 4- The orientation of the fibers positively influences the resiliency of the yarns, leading to better resiliency of the pile yarns in the carpet when a static or dynamic load is applied to the carpets. 5- The hairiness of the yarns decreases, and the interlock between the fibers of the pile yarns and other parts of the carpet diminishes. Therefore, the pile yarns are pulled out with lower withdrawal force.

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