# TEKSTİL VE MÜHENDİS

## (Journal of Textiles and Engineer)

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# A STUDY ON PERFORMANCE OF POLYPROPYLENE CARPETS PRODUCED WITH DIFFERENT FILAMENT FINENESS AND SLIP ADDITIVE RATIOS UNDER STATIC LOADING

# FARKLI FİLAMENT İNCELİKLERİ VE YUMUŞATICI KATKI ORANLARI İLE ÜRETİLMİŞ POLİPROPİLEN HALILARIN STATİK YÜKLEME ALTINDAKİ PERFORMANSININ İNCELENMESİ


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Online Erişime Açıldığı Tarih (Available online):31 Mart 2024 (31 March 2024)


**Bu makaleye atıf yapmak için (To cite this article):**

Gülbin FİDAN, Cemile Emel YAZ (2024): A STUDY ON PERFORMANCE OF POLYPROPYLENE CARPETS PRODUCED WITH DIFFERENT FILAMENT FINENESS AND SLIP ADDITIVE RATIOS UNDER STATIC LOADING, Tekstil ve Mühendis, 31: 133, 29-33.


**For online version of the article:** https://doi.org/10.7216/teksmuh.1459906

*Araştırma Makalesi / Research Article*

# A STUDY ON PERFORMANCE OF POLYPROPYLENE CARPETS PRODUCED WITH DIFFERENT FILAMENT FINENESS AND SLIP ADDITIVE RATIOS UNDER STATIC LOADING

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*Gönderilme Tarihi / Received: 24.11.2023*
*Kabul Tarihi / Accepted: 18.03.2024*

***ABSTRACT:*** Polypropylene, which is one of the most used polymers in machine carpet production as pile yarn, has some disadvantages need to be developed, such as lower resilience, flattening, matting etc. For this reason, there are so many studies in order to improve the inferior properties of polypropylene in carpet industry. In this study, eight carpet samples were produced by polypropylene BCF yarns with two filament fineness (3.7 and 9.5 dpf) and four ratios of slip additive (0 wt%, 0.5 wt%, 1 wt%, 2 wt%). In order to determine the effects of different filament fineness and additive percentage on thickness loss and resilience, carpet samples were exposed to short-term static loading test. According to the results, samples with 9.5 dpf filament fineness had lower thickness loss values compared to those of samples with 3.7 dpf filament fineness. Besides, the resilience behaviours of samples with 9.5 dpf filament fineness were also obtained to be better than samples with 3.7 dpf filament fineness. In consideration with slip additive percentages, although a trend was not observed between the increased additive ratio and mechanical responses of carpets, a difference was obtained between pure and 2 wt% additive blended samples. The blended samples with 2 wt% additive had shown lower thickness loss and higher resilience compared to neat samples.

***Keywords:*** Polypropylene, carpet, thickness loss, resilience.

# FARKLI FİLAMENT İNCELİKLERİ VE YUMUŞATICI KATKI ORANLARI İLE ÜRETİLMİŞ POLİPROPİLEN HALILARIN STATİK YÜKLEME ALTINDAKİ PERFORMANSININ İNCELENMESİ

***ÖZ:*** Makine halısı üretiminde en çok kullanılan polimerlerden biri olan polipropilenin düşük rezilyans, hav düzleşmesi ve keçeleşme gibi iyileştirilmesi gereken bazı dezavantajları bulunmaktadır. Bu nedenle halı endüstrisinde polipropilenin zayıf özelliklerini geliştirmeye yönelik pek çok araştırma mevcuttur. Bu çalışmada, iki farklı filament inceliğinde (3,7 ve 9,5 dpf) ve dört farklı yumuşatıcı katkı oranında (%0, %0,5, %1 ve %2) polipropilen BCF iplik kullanılarak toplamda sekiz halı numunesi üretilmiştir. Farklı filament inceliği ve yumuşatıcı katkı yüzdesinin kalınlık kaybı ve rezilyans üzerindeki etkilerini belirlemek amacıyla halı numuneleri kısa süreli statik yükleme testine tabi tutulmuştur. Elde edilen sonuçlara göre, 9,5 dpf filament inceliğine sahip numunelerde, 3,7 dpf filament inceliğine sahip numunelere göre daha düşük kalınlık kaybı değerleri görülmüştür. Ayrıca 9,5 dpf filament inceliğine sahip numunelerin rezilyans davranışlarının da 3,7 dpf filament inceliğine sahip numunelerden daha iyi olduğu sonucu elde edilmiştir. Yumuşatıcı katkı yüzdeleri dikkate alındığında, artan katkı oranı ile halıların mekanik davranışları arasında doğrusal bir ilişki görülmemekle birlikte, katkısız ve %2 yumuşatıcı katkılı numuneler arasında anlamlı bir fark elde edilmiştir. %2 yumuşatıcı katkılı numuneler, katkısız numunelerle kıyaslandığında daha düşük kalınlık kaybı ve daha yüksek rezilyans değerleri gösterdikleri tespit edilmiştir.

***Anahtar Kelimeler:*** Polipropilen, halı, kalınlık kaybı, rezilyans.

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***DOI:*** *https://doi.org/10.7216/teksmuh.1459906* *www.tekstilvemuhendis.org.tr*

*This study was presented at "International Congress on Sustainability and Technological Developments in Textiles (TESTEG October 13-15, 2023)". Peer review procedure of the journal was also carried out for the selected papers before publication.*

## 1. INTRODUCTION

In the last decades, synthetic fibers have become more popular in machine-made carpet manufacturing thanks to their some advantages such as durability, low cost, easy and wide range production possibility. Polypropylene (PP) has desired properties for the usage as pile yarn such as high durability, wool-like handling, low cost, etc. For these reasons it is a common preferred raw material in bulked continuous filament (BCF) yarn technology for the usage as pile. However, some mechanical behaviors of PP pile yarns are need to be enhanced, such as surface flattening on carpet after a period of usage [1-3]. In the industry, polymer additives are used as auxiliary chemicals in order to develop the physical and mechanical characteristics of polymers. Slip additives are one of the mostly preferred chemicals in polymer processing for the reason of they enable polypropylene to have good handling [4-6].

In the literature investigated, it is clearly seen that mixing different types of polymers and additives, structural parameters of carpets and pile yarns, have examined by many researchers. The effects of mixing polypropylene with different types and percentages of pigments and polymers in BCF yarn production have studied in some searches [7-9]. In addition, very few researches have studied the carpet performance depending on blending polypropylene with different types of polymers [10-11]. Besides, there are many researches in literature which focused on mechanical performances of carpets produced by different raw materials such as acrylic, polypropylene, wool and carpet structural parameters such as pile density and height [12-17]. In many other studies, different yarn structures with yarn cross-section, linear density and filament fineness were also investigated [18-20].

As seen in the literature, both polymer blending and structural characteristics of pile yarn have influence on the properties of carpets. Therefore, thickness loss and resilience behaviors of carpet samples produced with different filament fineness and slip additives ratios were investigated in this study.

## 2. MATERIALS AND METHODS

In this study, with the aim of investigating the effect of different filament fineness and slip additive concentrations, eight carpet specimens were produced from BCF polypropylene yarns with two filament fineness (3.7 and 9.5 dpf) and four slip additive percentages (0 wt%, 0.5 wt%, 1 wt%, 2 wt%). Compositions of BCF yarns and properties of carpet samples are shown in Table 1 and Table 2, respectively.

With the aim of determining the resilience performance of carpet samples, brief moderate static loading test was performed according to the standard of TS 3378. The specimen was exposed to 220 kPa pressure for 2h and then the load was removed at the end of the duration. The thickness of the samples measured under 2 ± 0.2 kPa after 15 min, 30 min and 60 min recovery periods. The thickness loss and resilience percentages of carpet samples were calculated with Equations (1) and (2), respectively, where $h_0$ is the initial thickness, $h_c$ is the thickness after 2 h compression, and $h_r$ is the thickness after 60 min recovery time.

$$\text{Thickness Loss (\%)} = \frac{h_0 - h_c}{h_0} \times 100 \qquad (1)$$

$$\text{Resilience (\%)} = \frac{h_r - h_c}{h_0 - h_c} \times 100 \qquad (2)$$

**Table 1.** Composition of BCF yarn samples.

| Sample code | Yarn linear density (denier) | Number of filaments | Filament fineness (dpf) | Slip additive (wt%) |
|---|---|---|---|---|
| 95f/0 | 1710 | 180 | 9.5 | 0 |
| 95f/05 | 1710 | 180 | 9.5 | 0.5 |
| 95f/1 | 1710 | 180 | 9.5 | 1 |
| 95f/2 | 1710 | 180 | 9.5 | 2 |
| 37f/0 | 1710 | 460 | 3.7 | 0 |
| 37f/05 | 1710 | 460 | 3.7 | 0.5 |
| 37f/1 | 1710 | 460 | 3.7 | 1 |
| 37f/2 | 1710 | 460 | 3.7 | 2 |

**Table 2.** Properties of carpet samples.

| Ground weave | Pile density (piles/m²) | Weft sett (picks/10cm) | Weft yarn (Nm) | Pile yarn linear density (denier) | Warp sett (ends/10cm) | Stuffer warp yarn linear density (denier) | Chain warp yarn linear density (denier) | Pile height (mm) |
|---|---|---|---|---|---|---|---|---|
| 1/2 V | 288000 | 90 | 1.3<br>Jute | 1710<br>PP | 32 | 1850<br>PET | 800<br>PET | 12 |

## 3. RESULTS AND DISCUSSION

Thickness loss results after static loading of the samples are illustrated in Figure 1. According to Figure 1, the highest thickness loss percentages are observed after 220 kPa loading for 2 h. In addition, as the recovery period increases, the thickness loss of all carpet samples decreases obviously. Among all carpet samples, the highest and the lowest thickness loss values are obtained from 95f/0 and 95f/05, respectively. As far as the thickness loss of samples after 60 min recovery period are considered, it can be stated that for both filament fineness, additive blended samples perform lower thickness loss compared to pure ones. In other respects, as the additive concentration increases for the samples with 3.7 dpf filament fineness, the thickness loss is observed to be diminished. On the other hand, in despite of a trend cannot be established between additive ratio and thickness loss, the blended samples perform lower thickness loss compared to pure one, in the group of samples with 9.5 dpf filament fineness. Similarly, a linear relationship is not also seen between filament fineness and thickness loss of all carpet samples.

Resilience results of carpet samples after static loading are shown in Figure 2. As it is expected, all samples have performed higher resilience values as the recovery time increases after loading. When the resilience results of carpet samples after 60 min recovery period are examined, the resilience values are observed to be enhanced with the increased percentage of additive for the samples with 3.7 dpf filament fineness. However, although a trend is not seen between resilience and additive ratios in 9.5 dpf filament fineness sample group, it can also be stated that the resilience of blended samples are detected to be higher than that of pure sample. In addition, when the results are evaluated in terms of filament fineness, no trend is detected, similar to thickness loss results.

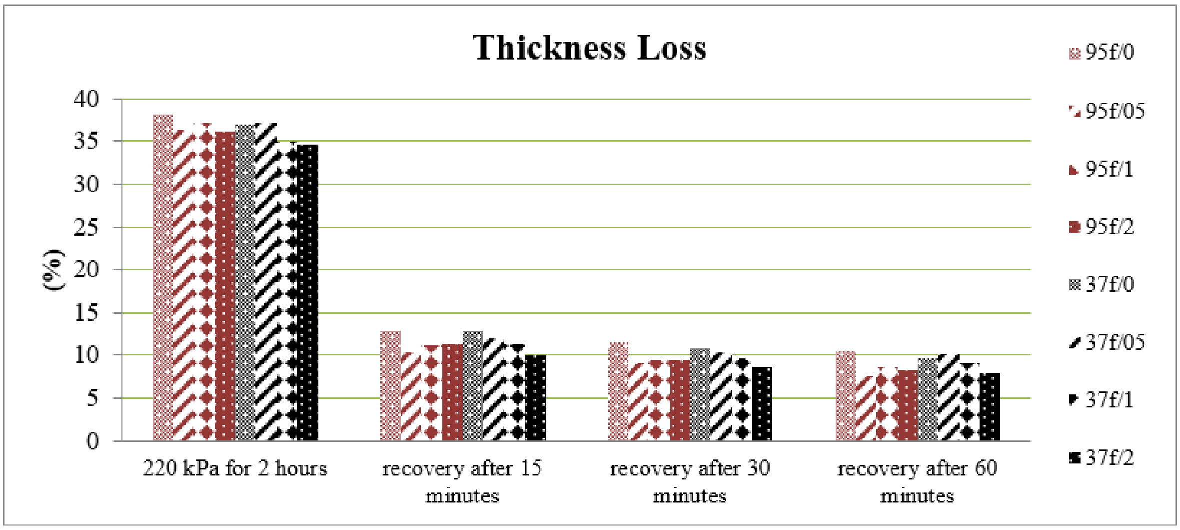


**Figure 1.** Thickness loss of carpet samples after static loading

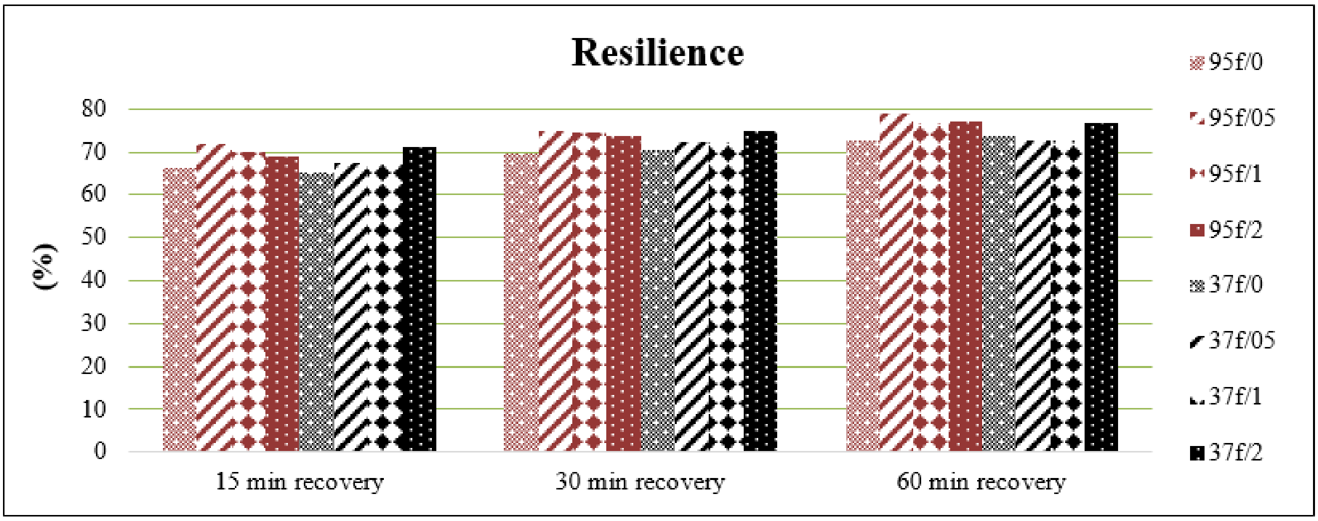


**Figure 2.** Resilience values of carpet samples after recovery periods

Two-way ANOVA and multiple comparisons results of carpet samples for thickness loss and resilience after 60 min recovery period of static loading are given in Table 3 and Table 4, respectively. According to Table 3, filament fineness is not found to be statistically significant on thickness loss (p=0.304>0.05), whereas it is observed to have significant effect on resilience (p=0.043<0.05). In addition, slip additive ratio is determined to have significant effect on both thickness loss (p=0.035<0.05) and resilience (p=0.047<0.05) values. Besides, it can be observed that, the interaction between filament fineness and additive percentage is not statistically significant for thickness loss (p=0.070>0.05), but it is significant for resilience (p=0.035<0.05).

As far as the multiple comparisons results for thickness loss are evaluated, there is only significant difference between pure ones and 2 wt% additive blended samples (p=0.023<0.05). When multiple comparisons results for resilience are considered, it is detected similar to thickness loss results that there is a significant difference between neat ones and 2 wt% additive blended samples (p=0.036<0.05).

**Table 3.** Two-way ANOVA for thickness loss and resilience after 60 min recovery period of static loading of carpet samples.

| Source | Dependent Variable | F | Sig. |
|---|---|---|---|
| Corrected Model | Thickness loss | 2.648 | 0.028 |
| | Resilience | 3.293 | 0.009 |
| Intercept | Thickness loss | 1585.384 | 0.000 |
| | Resilience | 24772.088 | 0.000 |
| Filament fineness | Thickness loss | 1.093 | 0.304 |
| | Resilience | 4.448 | **0.043** |
| Slip additive ratio | Thickness loss | 3.224 | **0.035** |
| | Resilience | 2.964 | **0.047** |
| Filament fineness * slip additive | Thickness loss | 2.590 | 0.070 |
| | Resilience | 3.238 | **0.035** |

**Table 4.** Multiple comparisons for thickness loss and resilience after 60 min recovery period of static loading of carpet samples.

| Dependent Variable | (I) slip additive | (J) slip additive | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|
| Thickness loss | 0 | 0.5 | 1.2210 | 0.63906 | 0.244 | -0.5104 | 2.9524 |
| | | 1 | 1.2930 | 0.63906 | 0.201 | -0.4384 | 3.0244 |
| | | 2 | 1.9450* | 0.63906 | **0.023** | 0.2136 | 3.6764 |
| | 0.5 | 0 | -1.2210 | 0.63906 | 0.244 | -2.9524 | 0.5104 |
| | | 1 | 0.0720 | 0.63906 | 0.999 | -1.6594 | 1.8034 |
| | | 2 | 0.7240 | 0.63906 | 0.672 | -1.0074 | 2.4554 |
| | 1 | 0 | -1.2930 | 0.63906 | 0.201 | -3.0244 | 0.4384 |
| | | 0.5 | -0.0720 | 0.63906 | 0.999 | -1.8034 | 1.6594 |
| | | 2 | 0.6520 | 0.63906 | 0.739 | -1.0794 | 2.3834 |
| | 2 | 0 | -1.9450* | 0.63906 | **0.023** | -3.6764 | -0.2136 |
| | | 0.5 | -0.7240 | 0.63906 | 0.672 | -2.4554 | 1.0074 |
| | | 1 | -0.6520 | 0.63906 | 0.739 | -2.3834 | 1.0794 |
| Resilience | 0 | 0.5 | -2.9530 | 1.35521 | 0.151 | -6.6248 | 0.7188 |
| | | 1 | -2.4120 | 1.35521 | 0.301 | -6.0838 | 1.2598 |
| | | 2 | -3.8610* | 1.35521 | **0.036** | -7.5328 | -0.1892 |
| | 0.5 | 0 | 2.9530 | 1.35521 | 0.151 | -0.7188 | 6.6248 |
| | | 1 | 0.5410 | 1.35521 | 0.978 | -3.1308 | 4.2128 |
| | | 2 | -0.9080 | 135521 | 0.908 | -4.5798 | 2.7638 |
| | 1 | 0 | 2.4120 | 1.35521 | 0.301 | -1.2598 | 6.0838 |
| | | 0.5 | -0.5410 | 1.35521 | 0.978 | -4.2128 | 3.1308 |
| | | 2 | -1.4490 | 1.35521 | 0.710 | -5.1208 | 2.2228 |
| | 2 | 0 | 3.8610* | 1.35521 | **0.036** | 0.1892 | 7.5328 |
| | | 0.5 | 0.9080 | 1.35521 | 0.908 | -2.7638 | 4.5798 |
| | | 1 | 1.4490 | 1.35521 | 0.710 | -2.2228 | 5.1208 |

Based on observed means.
The error term is Mean Square(Error) = 9.183.
*. The mean difference is significant at the 0.05 level.

## 4. CONCLUSION

In this experimental study, the effects of different filament fineness and slip additive percentages on behaviours of carpet samples after static loading were investigated. The thickness loss results after 60 min recovery period indicated that additive blended samples had lower thickness loss than those of pure ones, for both filament fineness. Additionally, the thickness loss of the samples with 3.7 dpf filament fineness decreased, as the additive ratio increased. However, although a relationship between additive percentage and thickness loss was not observed, the blended samples performed lower thickness loss than that of neat sample, for the samples with 9.5 dpf filament fineness. On the other side, resilience results of carpet samples after 60 min recovery period are considered, the resilience was observed to be improved with the highest additive ratio in the 3.7 dpf filament fineness sample group. On the other hand, in despite of a linear relation was not determined between resilience and additive ratios in 9.5 dpf filament fineness sample group, it can also be deduced that the resilience of blended samples are found to be higher than that of neat one. In addition, as far as the results are considered in terms of filament fineness, a trend was not seen, similar to thickness loss results.

***ACKNOWLEDGEMENT***

*The authors wish acknowledge to company of GRAND HALI TEKS. SAN. ve TİC. A.Ş., Gaziantep, Türkiye, for their technical support for production of yarn and carpet samples.*

## REFERENCES

1. Crawshaw, G. H. (2002), *Carpet manufacture*, Woodhead Publishing Limited.
2. Gong, R. H. (2011), *Specialist yarn and fabric structures developments and applications*, Woodhead Publishing Limited.
3. Goswami, K. K. (2009), *Advances in carpet manufacture*, Woodhead Publishing Limited.
4. Höfer, R. (2012), *Polymer Science: A Comprehensive Reference*, Elsevier.
5. Bishop, C. A. (2015), *Vacuum Deposition onto Webs, Films and Foils*, Elsevier.
6. https://www.avient.com/sites/default/files/2022-03/CESA%20 Slip %20Product%20Selector%20Guide.pdf (11/07/2023)
7. Tavanai, H., Morshed, M. and Hosseini, S.M. (2003), *Effect of on-line melt blending of polypropylene with polyamide 6 on the bulk and strength of the resulting BCF yarn*, Iranian Polymer Journal, 12(5), 421-430.
8. Tavanai, H., Morshed, M., Zarebini, M. and Rezve, A. S. (2005), *A study of the nucleation effect of pigment dyes on the microstructure of mass dyed bulked continuous filament polypropylene*, Iranian Polymer Journal, 14(3), 267-276.
9. Bagheri, G., Tavanai, H., Ghiaci, M., Morshed, M. and Shamsabadi, A. S. (2020), *An investigation on the effect of pigments on the texture ability and mechanical properties of polypropylene BCF yarns*, The Journal of the Textile Institute, 111(9), 1308-1317
10. Sözcü, Ş. (2019), *The production of BCF yarn and machine carpet from recycled polypropylene pellets*, Gaziantep, Türkiye: MSc Thesis, Gaziantep University.
11. Yaz C. E, Güneşoğlu C. and Topalbekiroğlu M. (2021), *An investigation on some mechanical properties of the tuft carpets produced by homopolymer, copolymer and thermoplastic polyolefin mixed polypropylene bulked continuous filament yarns*, Tekstil ve Konfeksiyon, 31(3), 183-194.
12. Önder, E. and Berkalp, Ö. B. (2001), *Effects of different structural parameters on carpet physical properties*, Textile Research Journal, 71(6), 549-555.
13. Koç¸, E., Çelik, N. and Tekin, M. (2005), *An experimental study on thickness loss of wilton-type carpets produced with different pile materials after prolonged heavy static loading. Part-1: Characteristic parameters and carpet behaviour*, Fibres & Textiles in Eastern Europe, 13, 56-62.
14. Dayiary, M., Shaikhzadeh Najar, S. and Shamsi, M. (2009), *A new theoretical approach to cut-pile carpet compression based on elastic-stored bending energy*, The Journal of the Textile Institute, 100(8), 688-694.
15. Korkmaz, Y. and Koçer, S.D. (2010), *Polipropilen makine halısı üretim parametrelerinin halı performansına olan etkileri*, Electronic Journal of Textile Technologies, 4(1), 48-58.
16. Özdil, N., Bozdoğan, F., Kayseri, G. Ö. And Mengüç, G. S. (2012), *Compressibility and thickness recovery characteristics of carpets*, Textile and Apparel, 22, 203-211.
17. Fidan, G., Korkmaz, Y. and Çelik, H. İ. (2023), *Effects of fiber type and yarn production technique on pile yarn and carpet performances*, Journal of the Textile Institute, DOI: 10.1080/00405000.2023.2231191.
18. Erdoğan, Ü. H. (2012), *Effect of pile fiber cross section shape on compression properties of polypropylene carpets*, Journal of the Textile Institute, 103(12), 1369-1375.
19. Çelik, H. İ. (2017), *Effects of fiber linear density on acrylic carpet performance*, Journal of Engineered Fibers and Fabrics, 12(1), 1-11.
20. Fidan, G., Korkmaz, Y. and Çelik, H. İ. (2022), *Effects of filament fineness and disc type of drawn textured polyester yarns on carpet resilience and appearance retention performance*, Journal of Industrial Textiles, 52, 1-17.