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Research Article

An Innovative Solution Approach for Carpet Pile Pull out Problem

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Abstract: In this study, an alternative solution was presented for the pile pull out problem of carpets. Composite weft yarn samples were produced by wrapping jute yarns with low-melt polymer. The weft yarn samples were produced as 1, 2 and 4 plies. The carpet samples with high density were produced by using the composite weft yarns without latex application and by using standard jute yarn with latex application. The carpet samples were applied pile withdrawal force and compression-recovery tests. It was analyzed that the performances values of both test for carpets with composite yarns are higher than that of standard latex applied samples.

Key Words: *Compression-recovery, Low-melt polyester, Pile withdrawal, Ply yarn, Wilton carpet.*

Halılarda İlmek Çıkma Sorunu İçin Yenilikçi Bir Çözüm Yaklaşımı

Özet: Bu çalışmada, halılarda ilmek çıkma problemi için alternatif bir çözüm sunulmuştur. Kompozit atkı ipliği numuneleri, düşük erime sıcaklığına sahip polimer ile jüt iplikleri sarılarak üretilmiştir. Atkı ipliği numuneleri 1, 2 ve 4 kat olarak üretilmiştir. Lateks uygulaması olmayan kompozit atkı iplikleri kullanılarak ve lateks uygulaması ile standart jüt ipliği kullanılarak yüksek yoğunluklu halı örnekleri üretilmiştir. Halı numunelerine ilmek çekme kuvveti ve sıkıştırma geri kazanma testleri uygulanmıştır. Her iki testte kompozit iplikli halılar için performans değerlerinin standart lateks uygulamalı numunelere göre daha yüksek olduğu analiz edilmiştir.

Anahtar Kelimeler: *Sıkıştırma geri kazanımı, Düşük erime sıcaklığına sahip polimer, hav çekme, Katlı ipliği, Wilton halı.*

1. Introduction

In the current technology, carpet finishing process involves applying a binding solution through rollers to hold pile yarns which can easily remove from the carpet structure with a low withdrawing force during rubbing, cleaning, walking traffic and etc. After the carpet weaving process has been achieved, some finishing operations; mending, anti-shading, back-coating, final inspection and warehousing are performed. Carpet back-coating removes all creases and folds from the carpet. It improves pile bind and prevents the removal of loose pile yarns from the carpet structure. Back-coating process provides also a good dimensional stability and prevents broadloom carpets from fraying when they are cut for installation [1-3].

The carpet back latex coating process is achieved by means of a specially designed machine. The carpet is fed to the machine with a uniform tension and the back of the carpet is coated with an adhesive film called as latex. Because of the structure of the carpet, the latex solution cannot migrate inside the carpet background structure and so some of the pile yarns cannot get the adequate amount of latex material. So, these pile yarns may be easily removed from the carpet structure with a low withdrawing force during daily use actions such as rubbing, cleaning, walking traffic and etc. This is an important manufacturing problem of carpet weavers. The descried event restricts the high pile density production conditions and necessities higher attention and experience. The latex solution concentration must be adjusted properly and adequate viscosity must be obtained. Finding the optimum process parameters need many experimental trials and cause higher cost.

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Some studies have been conducted on carpet performance in literature. Generally, the studies are focused on the effect of pile yarn material and carpet physical properties such as pile height, pile density and weave type on carpet compressibility and resilience performance [4-15]. Any study on pile yarn pull out problem has not been encountered. There are very limited studies about the effect of latex application process parameters on carpet mechanical performance. Carr et al. [16] investigated the effect of latex drying conditions on tufted carpet mechanical properties. Latex-backed tufted carpet samples were dried at four different oven temperatures (52°C, 79°C, 107°C, and 135°C) using heated atmospheric air. The oven temperature influenced the moisture content of the latex adhesive. The mechanical properties of tufted carpet samples; tuft pull out force and delamination strength were tested. It was concluded that there is a clear correlation between mechanical properties and the lowest moisture content. The highest mechanical properties were achieved at the highest latex temperature. Watzl [17] introduced a new tufted carpet back-coating method. In this study, polyethylene powder was proposed instead of latex solution. The polyethylene fiber powders melted and provided binding of pile yarns to secondary backing. It was stated that it application provided better ecologically friendly process.

In this study, an innovative alternative to traditional new carpet back-coating method was developed for Wilton type acrylic woven carpet production. In this method, the standard jute yarn used as weft yarn in acrylic carpet weaving process was plied with low melt polymer monofilament yarn. Then, the carpet samples were exposed to heat. Thus, the filament yarns melted and migrated between warp, weft and pile yarns and carried out the binding process. For this aim, composite weft yarns were prepared by ply-twisting 0.2 mm diameter mono-filaments with jute in 1, 2 and 4 folding. The carpet samples with 132 wefts/10 cm density were produced by using the produced composite weft yarns without latex application and by using standard jute yarn with latex application. The carpet samples were applied pile withdrawal force and compression-recovery tests.

2. Materials and Method

All carpet samples were produced at the same manufacturing condition such as warp yarn, pile yarn, weave type, pile height and pile density, only the weft yarns were changed. The weft yarn and carpet sample properties are given in Table 1 and Table 2 respectively. Polyester mono-filamet melting at 80°C temperature was used as ply yarn component. The composite weft yarns were produced at twist value of 40 turns/meter with different ply numbers (1, 2 and 4 plies).

Table 1. Weft yarn properties.

Weft Yarn Samples	**Components**		**Mono-Filament Diameter (mm)**	**Jute Linear Density (L)**	**Ply Number**	**Pile Yarn**	**Stuffer Warp**	**Chain Warp**
	1. Component	**2. Component**						
A1	Polyester Mono-Filament	jute	0.2	18/1	1	100% Acrylic, Nm 15/3	Polyester, 1100 Denier	Polyester, 800 Denier
A2	Polyester Mono-Filament	jute	0.2	18/1	2			
A3	Polyester Mono-Filament	jute	0.2	18/1	4			
A4	-	jute		18/1	-			

Table 2. Carpet sample properties.

Carpet Samples	**Weft Yarn Samples**	**Weave Type**	**Weft Sett (Jute/10cm)**	**Pile Height (mm)**	**Latex Application**
C1	A1	1/1	132	12	Not Applied
C2	A2	1/1	132	12	Not Applied
C3	A3	1/1	132	12	Not Applied
C4	A4	1/1	140	12	Applied

The carpet samples without latex application will be applied heat treatment after weaving operation so that mono-filament polyester melts and migrate between weft yarns and pile yarns. To provide the required binding performance, the polyester mono-filament must be completely molten. Since, melting of higher diameter polyester is more difficult and takes longer time, lower diameter and higher ply number application was preferred instead of using higher diameter mono-filament. By using each weft yarn sample four cut-pile Wilton carpet samples were manufactured using a Van de Wiele Wilton type face-to-face carpet weaving machine in Gaziantep University Naci Topçuoğlu Vocational School. In order to compare the performance properties of the carpet samples with and without latex application, pile withdrawal force and compression-recovery tests in accordance with ISO 4919:2012 and BS 4098:1975 standards respectively were performed. Carpet samples were conditioned at standard atmospheric conditions according to ISO 139:2005 (65±4% relative humidity and 20±2°C temperature) for 24 h before the tests were conducted.

Pile withdrawal test was applied by using a Wira Tuft Withdrawal Tensometer (Fig.1). Carpet specimens were prepared by cutting to size 15 mm × 15 mm. One end of the one tuft was selected and attached with tuft grip. The carpet sample was held down firmly by a steel plate. One end of the pile yarn to be tested was attached to tuft grip and it was placed to the upper jaw. Tensile force was applied to the pile yarn with Constant Rate of Extension (CRE) principle. The tuft grip was raised at steady state. The tension on the pile yarn was increased and the maximum force needed to withdraw the pile yarn and remove from carpet structure was recorded. This procedure was repeated for 10 tufts from each sample. It was assured that there is at least 25 mm distance between the previously drawn tuft and the next one.

Figure 1. Pile withdrawal test device.

The compression recovery test was applied to determine the compressibility and recovery capacity of the carpet sample. This test was performed to evaluate the resilience performance of the carpet sample under effect of foot traffic. The tests were performed using an SDL K94 Atlas Digital Thickness Gauge machine according to BS 4098:1975. From different parts of the carpet sample, five specimens with a size of 75 × 75 mm were prepared for each carpet sample. The initial thickness of the carpet sample was measured under 2 kPa pressure. The pressure under presser foot was increased to 200 kPa without removing the carpet sample by sequentially placing extra weights; A: 5kPa, B: 10kPa, C: 20 kPa, D: 50kPa, E: 100 kPa, F: 150 kPa, G: 200 kPa. The carpet thickness was recorded after each weight placed. After the last weight (G: 200kPa) was added, the extra weights were removed one by one at 30 s intervals. The previous process is called as loading and the latter is called as unloading. When all loading and unloading thicknesses were measured, a thickness versus pressure curve was created. By using the measured thickness values four compressibility parameters; compression recovery, work compression, work recovery and the percentage work recovery were calculated by means of corresponding equations given in BS 4098:1975 standard.

The percentage of compression recovery after loading and unloading processes was calculated with following equation (1).

$$Compression\ recovery\ (\%) = \left[\frac{t_r - t_{200}}{t_2 - t_{200}}\right] * 100 \quad (1)$$

where;

t_2; is the thickness under 2 kPa pressure at the beginning of the loading process,

t_r; is the thickness at 2 kPa pressure after unloading all weights

t_{200}; is the thickness at 200 kPa pressure.

The work of compression in j/m^2 was determined by calculating the area under loading curve between t_2 and t_{200} thickness values.

$$Work\ compression\ \left({}^{j}/_{m^2}\right) = 1.5t_2 + 4t_5 + 7.5t_{10} + 20t_{20} + 40t_{50} + 50t_{100} + 150t_{150} + 173t_{200} \quad (2)$$

The work of recovery was calculated in j/m^2 as an area under unloading curve between t_r and t_{200} thickness values.

$$Work\ recovery\ \left({}^{j}/_{m^2}\right) = -173t_{200} + 150t_{150} + 50t_{100} + 40t_{50} + 20t_{20} + 7.5t_{10} + 4t_5 + 1.5t_2 \quad (3)$$

The percentage work recovery is calculated with the equation below

$$Percentage\ work\ recovery(\%) = \left(\frac{work\ recovery}{work\ compression}\right) * 100 \quad (4)$$

3. Result and Discussion

The pile withdrawal force results are given in Fig. 2. It can be clearly seen that the pile withdrawal force of the all carpet samples produced with composite weft yarns are higher than that of conventional latex applied carpet sample. From these results, it can be deduced that the jute yarn plied with low-melt polyester provides stronger binding of the pile yarn to the carpet structure. Among the carpet samples woven with jute-polyester plied weft yarn, the lowest pile withdrawal forces are obtained with samples with 1 ply and 2 ply weft yarns (C1 and C2). The pile withdrawal force of C1 and C2 samples are close to each other. So, it can be said that there is no considerable difference between 1 ply polyester and 2 ply polyester usages in the weft yarn. On the other hand, the highest pile withdrawal force is obtained with C3 sample that is woven with 4 ply jute-polyester weft yarn. It can be revealed that 4 ply polyester mono filament usage in weft yarn composite has important contribution to pile withdrawal force performance of the carpet sample.

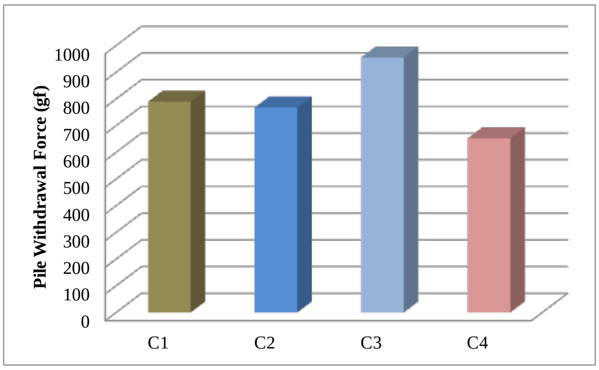

Figure 2. Pile withdrawal force values of the carpet samples.

The resilience and compressibility performances of the carpet samples are evaluated in accordance with the compression recovery (Fig. 3) and work recovery (Fig. 4) percentage values respectively. As it can be followed from Fig.3, the carpet samples woven with polyester plied jute yarn (C1, C2 and C3) have better resilience performance than latex applied carpet sample (C4).

The compression recovery values of the carpet samples produced with composite weft yarn; C1, C2 and C3 are very close to each other. So, it can be concluded that the number of polyester monofilament ply has not considerable effect on carpet resilience performance.

The compressibility performance of the carpet samples can be evaluated from percentage work recovery values of the samples (Fig. 4). The lowest work recovery is obtained with C2 sample that is produced with 2 ply polyester monofilament. The higher work recovery is obtained with C3 sample produced with 4 ply polyester monofilament. Except the sample C3, other two carpet samples produced with new composite weft yarns have higher recovery work than that of latex applied sample C4. It can said that compressibility of the carpet samples with composite weft yarns are higher than latex applied carpet. According to these analyses, it can be revealed that composite weft yarn usage instead of latex application provides less pile bending rigidity and so higher pile softness.

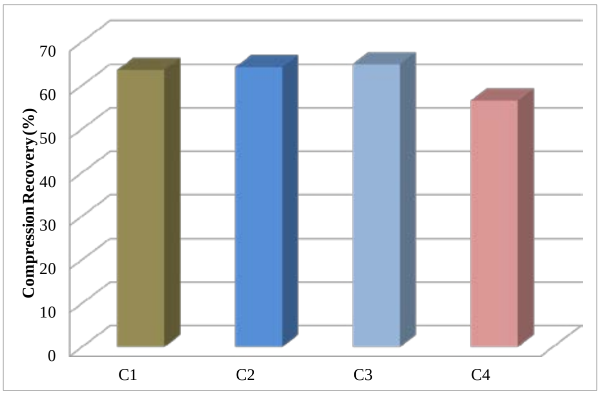

Figure 3. Compression recovery values of the carpet samples.

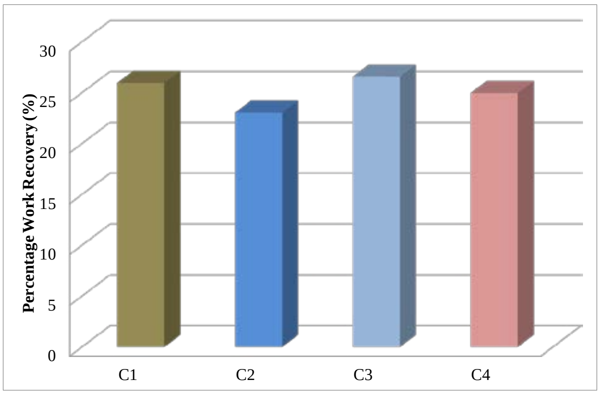

Figure 4. Percentage of work recovery values of the carpet samples.

4. Conclusion

In the content of this study, an alternative approach was developed to bind the pile yarns to the carpet structure. In the traditional carpet manufacturing method, the carpet back is coated with a latex solution to provide both dimensional stability and pile binding to the carpet structure. The performance of the carpet samples produced with the proposed new approach that is based on the composite weft yarn usage and with latex application were compared in terms of pile withdrawal force and compression-recovery.

As a result of the applied test method, it was determined that the pile withdrawal force of the carpet samples with composite weft yarn were higher than that of conventional latex applied carpet. So, it was decided that the developed new approach can be applied as a solution to carpet pile removing problem at especially 1/1 dense woven carpets. On the other hand, the resilience performance of the carpet samples that is one of the most important performance properties of the carpets was compared by analyzing the compression recovery and work recovery values. It was obtained that the resilience performance of the carpet samples with developed composite weft yarns were higher than that of latex applied carpet sample. As a conclusion, it can be evinced that the developed composite weft yarn that is produced by plying the low-melt polyester monofilament and jute can be used as an alternative to latex application. Only observed difficulty of the developed method is melting of polyester mono-filament. Optimum heat treatment condition must be determined to ensure that all mono-filaments were completely molten. The proposed method will both energy saving and chemical raw material saving. According to cost analysis performed for both latex and novel developed method, it was revealed that the developed method provides at least 20% production cost saving.

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