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The Effects of Steaming Duration and Temperature on Pilling and Fastness Properties in Vigoureux Printing Technique

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ABSTRACT

This study examines the impact of steaming duration and temperature on pilling resistance and fastness properties in fabrics printed using the Vigoureux technique. The Vigoureux printing method, which dates back to the 1800s, involves printing patterns on fiber tops, blending these with unprinted fibers, and producing mélange-like yarns used in textile applications. In this study, polyamide and wool fibers printed with acid dyes were subjected to varying steaming durations (50–70 minutes) and temperatures (85–105°C). Subsequently, the yarns were processed into knitted fabrics and subjected to a series of tests to assess their pilling, rubbing, washing, and water fastness properties. Results indicated that increased steaming duration and temperature led to reduced pilling resistance but enhanced fastness properties, likely due to improved dye penetration. The study emphasizes the critical role of steaming parameters in optimizing textile performance, providing insights for enhancing the durability of Vigoureux-printed fabrics.

Vigore Baskı Tekniğinde Buharlama Süresi ve Sıcaklığının Boncuklanma ve Haslık Özelliklerine Etkileri

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Anahtar Kelimeler
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ÖZ

Bu çalışmada, vigore tekniği kullanılarak baskı yapılan kumaşlarda buharlama süresi ve sıcaklığının boncuklanma direnci ve haslık özellikleri üzerindeki etkisi incelenmektedir. 1800'lü yıllara dayanan Vigore baskı tekniği, elyafın üzerine desenler basmayı, bunları baskısız elyaflarla karıştırmayı ve tekstil uygulamalarında kullanılan melanj benzeri iplikler üretmeyi amaçlamaktadır. Bu çalışmada, asit boyalarla baskısı yapılan poliamid ve yün elyafları değişen buharlama sürelerine (50-70 dakika) ve sıcaklıklara (85-105 °C) tabi tutulmuştur. Baskılı elyaflar iplik haline getirilip örüldükten sonra boncuklanma, sürtünme, yıkama ve su haslığı özellikleri değerlendirilmiştir. Buharlama süresi ve sıcaklığının artması boncuklanma direncini azalttığını ancak muhtemelen iyileştirilmiş boya penetrasyonu nedeniyle haslık özelliklerini artırdığını göstermiştir. Bu çalışma vigore baskı tekniğinde buharlama parametresinin kritik rolünü önemini ortaya çıkararak vigore baskılı kumaşların kalitesini ve dayanıklılığını artırmak için öneriler sunmaktadır.

1. INTRODUCTION

One of the methods used to increase the value added in textile products is to create the visual effect techniques such as the surface appearance, colors, and patterns of the fabrics in clothing and home textiles. These techniques are of great interest in the industry [1]. Many methods are used to provide surface appearance effect on fabrics on fabrics, such as printing, dyeing, and mechanical finishing techniques like brushing or sanding, which help to alter the texture, color, and overall visual appeal of the fabric. In addition, different surface appearance effects are given to the fabrics by using many different printing methods in printing technologies. One of the methods that contains limited information in the literature and dates to 1800 years is the Vigoureux printing method. The Industrielle Vigoureux of St. Denis was granted patent rights in 1863, but the potential for extending the work was minimal since the patent reserved the exclusive right to utilize his privileges for the full length of the Grant [2,3]. In this method, the fiber tops are first printed with the desired patterns and colors, then the printed fiber tops are mixed with the white unprinted fiber tops and the yarns produced in ring spinning process have a similar effect mélange yarn and then evaluated in fabric production. Mélange yarns are the fancy yarns, which have fibers or filaments of different colors. They are usually made by mixing slivers of different colours or printed in stripes. The properties of the fibers that make up yarn are crucial for its functionality and appearance, and altering these fibers can enhance the overall quality of the yarn [4-9]. Vigoureux printing technique is used to obtain well blended colors in worsted spinning system. The traditional Vigoureux printing and continuous Vigoureux printing (Fleissner's system and Siro-print system) are the two prominent techniques in Vigoureux printing. [10,11]. This printing technique enhances the aesthetic value of yarn or fabric by generating a natural, vibrant, and multi-tonal pattern. It is widely utilized in the fashion, sportswear, and home textiles industries due to its ability to provide visual complexity while also concealing surface pilling, thus improving the overall durability and appearance of the fabric.

There are few studies on Vigoureux printing system in the literature. Kaimori et al. [12,13] studied on development of a new continuous dyeing and multi-color printing system for slivers to resolve some defects (color bleeding at blotch edge, and multi-color printing etc.) in the Vigoureux printing system. It was stated that the disadvantages in Vigoureux printing system were eliminated with the new system they developed, and multi-color printing, printing without gilling, and clear printed patterns were obtained. Additionally, a crucial assessment for the absorption of dye liquids by slivers was conducted using specially designed apparatus.

Studies were conducted on mélange or Vigoureux printing of wool by Delmenico in 1957. The study covered developing a method for increasing the rate of dye fixation in Vigoureux printing system. The duration for fixing dyes can be shortened from 1 or 2 hours under standard atmospheric conditions to mere minutes by employing the right solvents in the printing mixture and increasing the steam pressure. In experimental studies, the depth of color increased using suitable solvents were achieved with a given amount of dye [14].

Buxtorf and Wiazmitinow described the equipment, and the methods used in the Vigoureux printing process for wool, rayon staple, and polyamide fiber slubbing in their work published in 1953 [15]. Potter’s work [2] was on the printing of wool including the mélange or Vigoureux printing of other staple fibers. The mélange process is giving a more intimate blend of colored and uncolored fiber. There are claims that the product has a more pleasant handle, but the primary appeal of this printing style stems from the special effects it generates, which cannot be replicated by blending dyed and undyed wool fibers. Bell et al. [16] studied on the effect of solvents in wool printing. The advantages of using benzyl alcohol in print pastes were highlighted in their work on Vigoureux printing with wool slubbing and standard printing on wool textiles.

There are many steps involved in Vigoureux printings. Single or multi fiber tops printing in this process can be done as a rope shown in Figure 1. The printing process is done with pressure rollers on tops. Usually diagonal and diagonal striped patterns are printed. Printing can be done in the desired number of colors. However, printing in more than two colors is not common. After the printing process, the printed tops first go through the pre-drying unit, which is located on the Vigoureux printing machine, and then they are placed inside the steaming machine. Steaming is done in the machine for 90 or 105 min at 100, 105 ºC. After steaming, fiber tops are dried in a dryer, the fibers are transferred into tops again, yarn is obtained in the ring spinning system and fabric is produced by a flat knitting machine. Vigoureux printing process is mostly applied to wool, polyester and polyamide tops. Especially, it is more preferred in worsted wool tops [17].

Considering the critical role of the steaming stage in the Vigoureux printing process and the limited number of studies conducted on Vigoureux printing, this study aimed to investigate the impact of varying durations and temperature levels during the steaming stage on the pilling performance and some important fastness values of wool and polyamide fibers printed by acid dyes using the vigorous printing method.

2. MATERIAL AND METHOD

2.1. Material

In this study, 3.3 dtex 100% polyamide fiber and 26.5 micron 100% wool fiber were used in the tops form. The staple length of wool and polyamide are 54.3 ± 7 mm and 56.8 ± 4 mm, respectively. The C.I. Acid Red 414, C.I. Acid Yellow 116, and C.I. Acid Blue 193 were used in Vigoureux printing process for both fiber types.

2.2. Printing Process

The Vigoureux printing process was given in Figure 1.

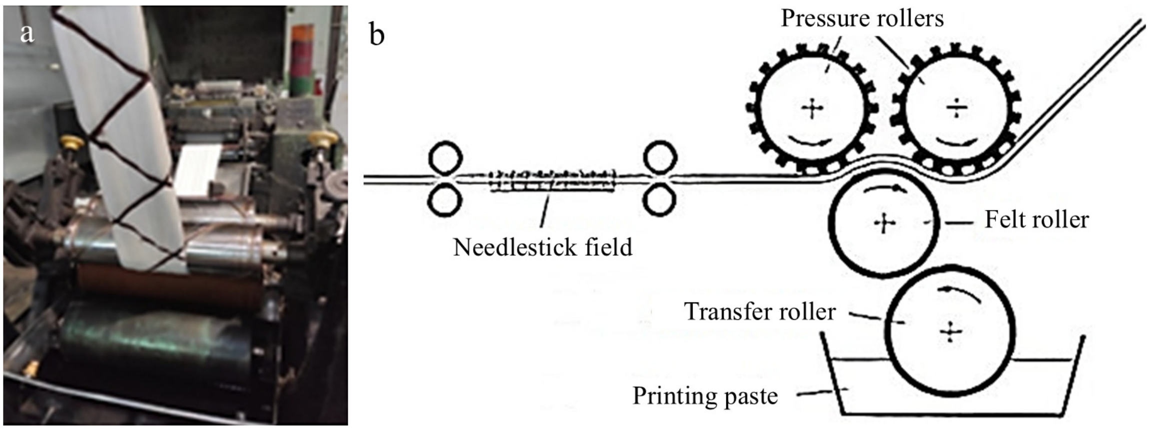

Figure 1. a) Vigoureux printing machine, and b) its components

After printing, the steaming process was applied to fiber samples via a HT batch steamer (Figure 2a). The fiber samples entered the steaming machine in bags (tulles) (Figure 2b). These bags were made of fine tulle and the total weight of the printed fiber was 4 kg. The reason for using tulles in steamers was to achieve complete dye penetration into the fiber by aiding the steaming process.

Figure 2. a) HT steamer, and b) tulles (bags) for printed fiber tops

In a steaming process, following the initial 3 minutes during which water is taken into the chamber, the temperature rises to 98 °C over the subsequent 10 minutes. The following 2 min are dedicated to the process of bluffing, which involves the removal of excess air from the chamber. Over the subsequent 5 min, the temperature is elevated to 105 °C for a period of 60 min. In this study, the duration and temperature at steaming step were varied. Applied temperature and duration values, and sample coding system were given in Table 1.

Table 1. Applied temperature and duration values, and sample coding system

Sample code	Fiber type	Temperature (°C)	Duration (min)
P85-50	Polyamide	85	50
P85-60			60
P85-70			70
P95-50		95	50
P95-60			60
P95-70			70
P105-50		105	50
P105-60			60
P105-70			70
W85-50	Wool	85	50
W85-60			60
W85-70			70
W95-50		95	50
W95-60			60
W95-70			70
W105-50		105	50
W105-60			60
W105-70			70

2.3. Knitted Fabric Production Process

Sample yarns with a yarn count of Nm 35/1 and a twist of 400 T/m were spun from printed polyamide and wool fiber tops using ring spinning machines with a feed speed of 24 m/min. The yarn parameters were selected in accordance with the fiber fineness and length to ensure optimal compatibility and performance. Yarn production parameters for polyamide and wool are total draft 28-31, twist 500-600 TPM, spindle speed 10,000 rpm and twist coefficient 134 αm. Then, the plain knit fabrics were produced on Brother KH-864 manual flat weft-knitting machine with 5E fineness for pilling and fastness tests.

2.4. Characterization

The printed samples in fabric form were subjected to pilling resistance, rubbing fastness, washing fastness, and water fastness tests according to TS EN ISO 12945-1, TS EN ISO 105-X12, TS EN ISO 105-C06 (A2S), TS EN ISO 105-E01, respectively. The multifiber strip fabric was utilized as an adjacent material during washing and water fastness tests. The gray scale was employed for staining.

The results were subjected to statistical analysis of variance (ANOVA) to evaluate the effects of steaming temperature and duration on pilling and selected fastness properties using Design Expert 13.0 package program. The results were statistically significant at $p \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1. Characterization

The pilling test results of the wool and the polyamide samples according to steaming temperature and duration are given in Figure 3.

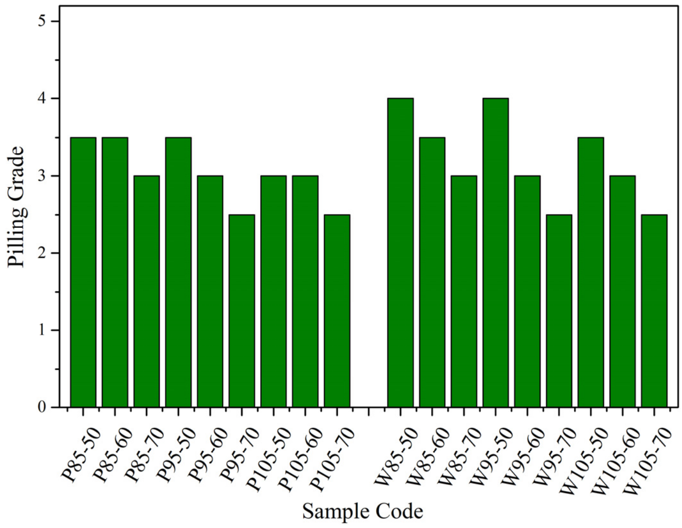

Figure 3. Pilling box test results

In pilling performance evaluation, a rating of 1 denotes a high degree of pilling, whereas a rating of 5 indicates the absence of any observable pilling on the fabric surface. The pilling performance was decreased with increasing of steaming duration for both wool and polyamide samples from 50 min to 70 min. The pilling performance was also decreased with increasing of steaming temperature for both wool and polyamide samples from 85 °C to 105 °C. This phenomenon can be attributed to the fact that elevated temperatures and extended periods of time result in greater damage to the fibers that comprise yarn structures. Because polyamide and wool fibers demonstrate distinct thermal and moisture sensitivities. Wool is prone to structural swelling and weakening under heat and humidity, while polyamide tends to undergo surface deformation due to softening at elevated temperatures. The effect of temperature ($p=0.0035$) and duration ($p<0.0001$) of the steaming process on the pilling performance were statistically significant.

3.2. Rubbing Fastness Test Results

Dry and wet rubbing fastness test results of the wool and the polyamide samples according to steaming temperature and duration are given in Table 2.

Table 2. Rubbing fastness test results

Sample code	Dry rubbing fastness	Wet rubbing fastness
P85-50	3-4	2-3
P85-60	4	3
P85-70	4	3-4
P95-50	4	3
P95-60	4	3
P95-70	4-5	3-4
P105-50	4	3-4
P105-60	4-5	4
P105-70	4-5	4
W85-50	4	3
W85-60	4-5	3-4
W85-70	4-5	3-4
W95-50	4	3-4
W95-60	4-5	4
W95-70	4-5	4
W105-50	4-5	4
W105-60	4-5	4-5
W105-70	4-5	4-5

The dry and wet rubbing fastness properties were generally increased with increasing of steaming duration for both wool and polyamide samples from 50 min to 70 min. Those properties were also increased with increasing of steaming temperature for both wool and polyamide samples from 85 °C to 105 °C. This may be related to the fact that raising the temperature accelerates diffusion, especially into the fiber. Longer duration also enhanced this. The effect of temperature ($p=0.0427$) and duration ($p=0.0108$) of the steaming process on the dry rubbing were statistically significant. Also, the effect of temperature ($p<0.0001$) and duration ($p=0.0012$) of the steaming process on the wet rubbing were statistically significant.

3.3. Washing Fastness Test Results

Washing fastness staining test results of the wool and the polyamide samples according to steaming temperature and duration are given in Table 3.

Table 3. Washing fastness test results

Sample code	Staining					
	CA	CO	PA	PES	PAN	WO
P85-50	1-2	2	2	2	2	2
P85-60	1-2	3	2	3	3	2-3
P85-70	2	3-4	2-3	4	4	3
P95-50	4	4	4	4	4	4
P95-60	4-5	4-5	4	4-5	4-5	4
P95-70	4-5	4-5	4-5	4-5	4-5	4-5
P105-50	4	4	4	4	4	4
P105-60	4-5	4-5	4-5	4-5	4	4-5
P105-70	4-5	4-5	4-5	4-5	4-5	4-5
W85-50	2	2	2	2	2	2
W85-60	2-3	3-4	2-3	3-4	3-4	2
W85-70	2-3	3-4	2-3	4	4	3
W95-50	4-5	4	4	4	4	4-5
W95-60	4-5	4	4-5	4-5	4-5	4-5
W95-70	4-5	4-5	4-5	4	4-5	4-5
W105-50	4-5	4-5	4	4	4	4
W105-60	4-5	4-5	4-5	4-5	4-5	4-5
W105-70	4-5	4-5	4-5	4-5	4	4-5

CA: Cellulose Acetate, CO: Cotton, PA: Polyamide, PES: Polyester, PAN: Acrylic, and WO: Wool.

The washing fastness staining performance was generally increased with increasing of steaming duration for both wool and polyamide samples from 50 min to 70 min. It was also increased with increasing of steaming temperature for both wool and polyamide samples from 85 °C to 105 °C. Raising the temperature speeds up diffusion into fibers resulting in higher washing fastness values. The effect of temperature ($p<0.0001$) and duration ($p<0.0001$) of the steaming process on the dry rubbing were statistically significant.

3.4. Washing Fastness Test Results

Water fastness staining test results of the wool and the polyamide samples according to steaming temperature and duration are given in Table 4.

Table 4. Water fastness test results

Sample code	Staining					
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**
P85-50	1-2	1-2	2-3	3	1-2	2
P85-60	2	2	3	3-4	2	2-3
P85-70	2-3	2-3	3-4	4	3	3-4
P95-50	4	4	4	4	4	4
P95-60	4	4	4-5	4-5	4-5	4
P95-70	4-5	4-5	4	4-5	4-5	4-5
P105-50	4	4	4	4-5	4	4
P105-60	4-5	4-5	4-5	4-5	4-5	4-5
P105-70	4-5	4-5	4-5	4-5	4-5	4-5
W85-50	2-3	2	3	3-4	1-2	2
W85-60	2-3	2-3	3	4	2	2-3
W85-70	2-3	3	3-4	4	2-3	2-3
W95-50	4	4-5	4-5	4-5	4	4
W95-60	4-5	4	4-5	4-5	4-5	4-5
W95-70	4-5	4-5	4-5	4-5	4-5	4-5
W105-50	4-5	4-5	4	4-5	4-5	4-5
W105-60	4-5	4-5	4-5	4-5	4-5	4-5
W105-70	4-5	4-5	4-5	4-5	4-5	4-5

CA: Cellulose Acetate, CO: Cotton, PA: Polyamide, PES: Polyester, PAN: Acrylic, and WO: Wool.

The water fastness staining performance were increased with increasing of steaming duration for polyamide samples from 50 min to 70 min. It was also increased with increasing of steaming temperature for both wool and polyamide samples from 85 ℃ to 105 ℃. The increase in temperature accelerates the diffusion into the fibers and results in higher water fastness values. The effect of temperature ($p<0.0001$) and duration ($p=0.0023$) of the steaming process on the dry rubbing were statistically significant.

4. CONCLUSION

This study examined the impact of steaming duration and temperature on the pilling resistance and various fastness properties of polyamide and wool fibers printed using the Vigoureux method with acid dyes. The results demonstrated that increased steaming temperature and duration tend to reduce pilling resistance, attributed to the fiber damage induced by prolonged heat exposure. However, these conditions significantly improved rubbing, washing, and water fastness properties due to enhanced dye diffusion and fixation within the fibers. The findings reveal that optimizing steaming parameters is crucial for balancing durability and aesthetic qualities in Vigoureux-printed fabrics. While higher temperatures and longer steaming durations may be necessary to achieve desired fastness levels, these settings should be adjusted carefully to mitigate adverse effects on pilling resistance. Upon examination of the test results in general, it was observed that the test results obtained at 105 °C were similar to those obtained at 95 °C. Based on these findings and considering the energy consumption, it can be posited that steaming conditions could be selected as 95 °C and 60 minutes. This study contributes to a deeper understanding of the Vigoureux printing process, providing valuable insights for textile manufacturers aiming to improve the quality and longevity of printed fabrics through controlled steaming.

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