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COMPARATIVE ANALYSIS OF THE DIGITAL PRINT FASTNESS OF KNITTED FABRICS WITH DIFFERENT TEXTURES PRODUCED FROM RECYCLED FILAMENT YARNS

Muhammed Feyruz Caner[1*], Kenan Yıldırım[2*]

[1]MSC Student at Biocomposite Engineering Postgraduate Education Institute, Bursa Technical University, Bursa, Turkey
[2]Department of Polymer Materials Engineering/ Faculty of Engineering and Natural Sciences, Bursa Technical University, Bursa, Turkey

Abstract – The depletion of natural resources and increasing environmental pollution necessitate recycling to reduce resource consumption and pollution. This study, conducted at Kadifeteks Mensucat A.Ş., compares the fastness performance of fabrics made from recycled polyester yarns to those made from cationic polyester yarns using digital printing at three resolutions (600 DPI, 1200 DPI, 2400 DPI) and two production methods (direct fabric printing and paper transfer printing). Fastness tests included dry and wet rubbing, light, weather, washing, Martindale abrasion, and perspiration fastness. Findings showed that recycled fabrics performed better in dry and wet rubbing and perspiration tests, while cationic fabrics excelled in light fastness on the Reggiani machine, and recycled fabrics on the Saitu machine. Abrasion tests generally favored cationic fabrics, except for certain warp-knitted recycled fabrics, and washing fastness showed no difference between the two yarn types. Overall, the study demonstrates the superior performance of recycled yarn fabrics, supporting recycling's environmental and resource conservation benefit.

Keywords – Digital Printing, Fastness, Warp Knitting, Weft Knitting, Sublimation Ink

I. INTRODUCTION

In today's conditions, our natural resources are on the verge of depletion. Environmental pollution has increased, resulting in air, water, and soil pollution. Air pollution has significantly increased due to carbon emissions from industries. The portion of our forests used for industrial purposes has increased considerably, and our forests are decreasing due to the demand for cellulose. To minimize this situation, recycling should be encouraged and implemented [1].

Thanks to recycling, the rate of depletion of our natural resources will slow down, and economic savings will be achieved. The search for raw materials for new products will decrease to reduce environmental pollution. The pollution caused by petroleum and chemicals will decrease. In developed countries, recycling is encouraged to achieve recovery. As a result of implementing this, environmental pollution, raw material consumption, costs, and carbon emissions have decreased.

In our research topic, we will examine the fastness performance of fabrics obtained from recycled polyester yarns compared to cationic polyester yarns. In this way, we will prove that the performance of recycled yarns is not inferior. As a result, [2] we aim to minimize the use of ethylene glycol and terephthalic acid used in the production of polyester. This will reduce the use of petrochemical raw materials.

II. MATERIALS AND METHOD

We completed our research on digital printing, a branch of textiles, in the laboratories of Kadifeteks Mensucat A.Ş. In our research, cationic polyester yarn and recycled polyester yarn were used, and the fabrics obtained from these yarns have different textures. Printing was done at three different resolutions, [3] and two different production methods were tested. The resolutions of these prints are 600 DPI, 1200 DPI, and 2400 DPI [4]. As a production method, direct fabric printing and paper transfer printing were used. In these processes, sublimation disperse ink was used to print on ecru unbleached fabrics. Fixing processes were carried out on a 10-chamber Monforts stenter machine.

Warp knitting and weft knitting techniques were used for the fabrics in our research. Warp-knitted fabrics were produced on a 4-bar knitting machine, with one yarn for the surface and the other three for the ground. Other weft-knitted fabrics include one quilted and one plush fabric [5].

The fastness tests we conducted in our laboratory studies are as follows:

- Dry and wet rubbing fastness test
- Light fastness test
- Weather fastness test
- Washing fastness test
- Martindale abrasion test
- Perspiration fastness

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The fixation of the printed fabrics was done according to the type of fabric on the 10-chamber Monforts stenter machine.

- Warp-knitted recycled (E fabric) and cationic (F fabric) fabrics were processed at 220°C at a speed of 20 m/min.
- Quilted recycled (C fabric) and cationic (D fabric) fabrics were processed at 160°C at a speed of 25 m/min.

- Plush recycled (A fabric) and cationic (B fabric) fabrics were processed at 180°C at a speed of 30 m/min.

Photos in TIFF format was preferred for printing quality in our research. The number of colours used in digital printing is 256^3 in Adobe Photoshop, meaning the RGB gamut is used. Each colour has 256 shades, and these colours are formed by the combination of red, green, and blue. The 16 million colours used on panels and screens are reduced to 1 million colours during digital printing. This colour gamut is the number of colours used in the printing process and dyehouses. This gamut, consisting of cyan, magenta, yellow, and key (black) colours, is used to create the colours of inks, dyes, and materials being coloured. This gamut is called the CMYK gamut. In the CMYK gamut, there are 100^3 colours, and each colour is accepted to have 100 shades with the help of black according to the gamut and spectrophotometer [6].

The print heads we used in digital printing processes within the scope of this research are:

- Japanese-made Kyocera KJ4B print head for direct printing.
- Japanese-made Epson I3200 print head for paper transfer printing.

There are quite different features among these print heads. In the use of Kyocera print heads, each print head works with one colour, and at least 4 print heads are needed for the smallest prototype machine. This is because there are 4 colours that make up the CMYK gamut [7]. Unless auxiliary colours are needed, we can create 1 million colours according to the CMYK gamut with 4 print heads [4].

In the paper transfer digital printing machine, the Epson I3200 print heads in the machine each receive every colour of the CMYK gamut, and the print colour is formed in the print heads. Cyan, magenta, yellow, and key (black) colours can create 1 million colours in the print heads. [15]

Two different methods were used to create digital printing processes, and these processes are:

- Direct fabric digital printing
- Paper transfer digital printing process.

In the direct fabric printing process, fabrics printed with the Kyocera print heads on the Reggiani brand Renoir Pro 180 model machine were fixed in a natural gas fixative/dryer oven at temperatures activating the inks at 100°C and above [8] [12]. This temperature can be increased according to customer fastness requirements. In our studies, digitally printed fabrics were fixed at 210°C [10].

In the paper transfer digital printing process, printed papers were transferred in a paper transfer machine like a calendar machine at 230°C and a speed of 35 m/min [11].

No pre-treatment was needed outside of fabric fixation for digitally printed fabrics since sublimation disperse ink was used. Digitally printed fabrics were taken to the laboratory for fastness tests after the printing process.

Yarns and Fabrics Used in Our Research [13]

Types of Yarns:

• Recycled Yarn: 150 denier, 144 filament, China-origin, Jangsu Reborn brand.

• Cationic Yarn: 150 denier, 144 filament, China-origin, Gouwang brand.

• Warp Knitting Fabric Ground Yarn: 50 denier, 24 filament FDY PET yarn.

• Plush Knitting Yarn: 150 denier, 96 filament, textured, Turkey-origin, Peker Tekstil brand PET yarn.

• Quilted Knitting Filling Yarn: 600 denier, 144 filament, textured, Turkey-origin, Peker Tekstil brand PET yarn.

Fabric Structures:

• Fabric A: Technique: Circular knitting – single yarn knitting Ground Yarn: Recycled yarn Plush Yarn: Textured yarn

• Fabric B: Technique: Circular knitting – single yarn knitting Ground Yarn: Cationic yarn Plush Yarn: Textured yarn

• Fabric C: Technique: Circular knitting – single yarn padded knitting Ground Yarn: Recycled yarn Filling Yarn: Textured yarn Type: Quilted knitting

• Fabric D: Technique: Circular knitting – single yarn padded knitting Ground Yarn: Cationic yarn Filling Yarn: Textured yarn Type: Quilted knitting

• Fabric E: Technique: Warp knitting – 4-bar knitting Effect Yarn: Recycled yarn Ground Yarn: FDY yarn

• Fabric F: Technique: Warp knitting – 4-bar knitting Effect Yarn: Cationic yarn Ground Yarn: FDY yarn

Production Techniques and Machines Used:

Three different production techniques were used to produce three types of fabrics, and two different types of yarns were used. One of the yarns is recycled, and the other is cationic yarn.

Karl Mayer Warp Knitting Machine:

Model: HKS 4EL (2017) Features: 4 yarn laying beams, 6100 needles, 40 beams Operation: 30 beams for ground yarns, 10 beams for effect yarns Capacity: 1500 rpm, 42 meters/hour

Monarch Circular Knitting Machine (For Fabrics C and D):

Gauge: 20 Width: 38 inches System Count: 84 Needles: 4832 needles Yarn Specifications: 150 denier, 144 filament; filling yarn 600 denier, 144 filament Width of Fabric: 240 cm Material: Polyester filling Hongji Circular Knitting Machine (For Fabrics A and B): System Count: 60 Yarn Specifications: 150 denier, 144 filament; plush yarn 150 denier, 96 filament, textured Fabric Weight: 200 g/m²

Warp Knitting Fabric Production Machine: Model: Karl Mayer HKS 4EL (2017) Features: 4 yarn laying beams, 6100 needles, 40 beams (30 for ground, 10 for effect yarns)

Capacity: 1500 rpm, 42 meters/hour

Plush Fabric Production Machine: Origin: China System Count: 60 Needles: 20 needles/inch, 30 inches long, 2386 needles Capacity: 86 meters/hour Quilted Fabric Production Machine: Partnership: British-Japanese Needles: 20 needles/inch, 38 inches long, 84 systems, 4832 needles (2416 front, 2416 back)

III. RESULTS

Within the scope of the research, 2 different digital printing production methods were applied at three different resolutions to fabrics with three different textures obtained from recycled yarn and cationic yarn [9].

Fastness tests such as dry and wet rubbing fastness test, light fastness test, weather fastness test, washing fastness test, Martindale abrasion test, and perspiration fastness were applied to 6 different fabrics in the studies. [14]

Studies were conducted with two different types of machines, Saitu and Reggiani. These machines include paper transfer digital printing and direct digital printing methods. These methods allow for different printing processes with

different temperatures and inks on the fabric. Therefore, the two different inks used form two different experimental data.

The fastness values of digitally printed fabrics on Saitu and Reggiani machines were different. This is due to the different chemical structures of the Sun Chemical and Papijet sublimation disperse inks used in the experiments and their different recommended fixation temperatures.

Different texture structures also resulted in different outcomes in constant experiments despite the same production conditions in some experiments. For example, E and F fabrics showed higher performance values in abrasion dry rubbing and wet rubbing fastness tests compared to other fabrics. This is because their structure has a smoother surface and is less affected by the conditions in these tests.

IV. DISCUSSION

In terms of resolution, it was observed that fabrics printed at 2400 DPI resolution had lower performance in dry and wet rubbing fastness tests. However, it was observed that recycled fabrics performed higher in dry and wet rubbing fastness tests.

In abrasion tests, it was generally observed that fabrics obtained from recycled yarns had lower performance compared to fabrics obtained from cationic yarns. However, it can be said that E and F fabrics produced by warp knitting had higher performance in abrasion tests compared to other fabrics.

In acidic and alkaline perspiration fastness tests, the performance of fabrics A, B, C, and D obtained from recycled yarns was higher in digitally printed fabrics on the Reggiani digital printing machine. The same performance was observed for E and F fabrics. There is no performance difference in perspiration fastness tests in the Saitu digital printing machine.

In light fastness tests, higher performance values were observed in cationic fabrics in digitally printed fabrics on the Reggiani digital printing machine. This can be attributed to the fact that cationic yarns can be dyed at lower temperatures. In digitally printed fabrics on the Saitu digital printing machine, the performance of fabrics obtained from recycled yarns was higher. This may be because different inks were used. In other words, the light fastness values of Papijet inks are higher than those of Sun Chemical inks.

V. CONCLUSION

Different situations emerged in colour fastness tests against weather conditions. In digitally printed fabrics on the Reggiani digital printing machine, the performance of recycled fabrics was higher in C and D fabrics. The performance of cationic fabrics was higher in E and F fabrics. There is no difference in A and B fabrics. In digitally printed fabrics on the Saitu digital printing machine, the performance of fabrics obtained from recycled yarns was higher in A and B fabrics. The performance of cationic yarns stands out in C and D fabrics. There is no difference in E and F fabrics.

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