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Shereen O.Bahloul, Eman A. Bydoon, Hanaa A. Saad. Effect of Water Repellent Finishes on Woven Egyptian Cotton Fabrics. International journal of advanced Science and Engineering, 2020, 06 (03), pp.1449-1455. <10.29294/IJASE.6.3.2020.1449-1455>. <hal-03141218>

HAL Id: hal-03141218

<https://hal.science/hal-03141218v1>

Submitted on 15 Feb 2021

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Effect of Water Repellent Finishes on Woven Egyptian Cotton Fabrics

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RESEARCH ARTICLE

ABSTRACT: This study investigates the effects of fluorinated or non-fluorinated water-repelling finishes on woven cotton fabric properties of ring and compact plain cotton fabrics made from Egyptian cotton variety (Giza 92). Spray rating test, stiffness, flexural rigidity, tensile strength and Elongation were done to assess the effect of water-repellent finishes on treated cotton fabric properties. The relationships between cotton fabric spinning type and fabric stiffness were measured. The results showed that the water repellent finishing has a great influence on fabric properties according to the cotton fabric spinning type and finishing concentration, The fabric stiffness (Flexural Rigidity) is increased by increasing of water repellent concentrations, as well as the weight of fabric increases in all finished fabrics at all concentrations, all treated fabrics showed a high level of water repellency.

KEYWORDS: Water repellent finishing, Woven fabrics, ring spinning, compact spinning, Egyptian cotton, Fluorocarbons

<https://doi.org/10.29294/IJASE.6.3.2020.1449-1455>

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1. INTRODUCTION

Yarns produced using various spinning technologies not only differ from one to another due to the yarn structure, but also in their physical, mechanical and surface properties, thus fabrics properties produced from such yarns are affected by yarn spinning technique [1]. Compact spinning system is a modified spinning technology used to produce a new cotton yarn structure in which the cotton fibers are uniformly oriented to improve the compact-spun yarns properties, such as yarn hairiness, strength, and elongation properties compared with the properties of the conventional ring-spun yarns. Moreover, compact-spun yarns have better quality and properties such as higher air permeability and wicking behavior which improve textile processing and increase their production. [2-4]. Kampen [5] compared the characteristics of compact-spun yarn with ring-spun yarn. The strength, and elongation of compact yarn were improved by approximately 20% and hairiness was lowered by as much as 50%. Nowadays, the compact-spun yarns are becoming more required due to their special yarn characteristics. Water repellency became one of the major points of interest for protective clothing such as apparel, home, and technical textiles [6].

Water repellency is defined by the ability of a fabric to resist wetting. This repellency can be carried out by implementing a layer of water repellent finishing on the textile surface which can be done by modification of the textiles surface energy [7, 8]. Applying the

water repellent chemical on cotton fiber allows monomers of the water repellent to be absorbed onto the cotton fibers forming polymeric chains which change the cotton fabric structure resulting in water repellent cotton fabric.

It has been reported that various types of fluorochemicals that are used for textile finishing, mainly used to impart water repellency along with oil repellency particularly to impart water repellency to cotton fibers [3-12]. There are some conflicting reports as to the most effective fluorochemical (FC) based water repellent consisting of per-fluorinated carbon backbone chains including perfluoro groups. Some existing fluorochemicals are made with C8 carbon backbone chains, Hence C6 based fluorocarbons were used but their repellency performance was considered inferior to C8 based ones [13,14].

A new FC compound was inspired by nature and therefore called bionic water repellent finishing where fluorocarbon polymers are applied with dendrimers which are highly branched oligomers, where the fluorocarbon chains are absorbed on the textile surface and crystallize with the dendrimers [15].

Repellent finishes reduce the free energy of the fiber surfaces. Fabric surfaces which exhibit low interactions with liquids have low energy surfaces. This can be explained by the adhesive interactions between a fiber and a drop of liquid placed on the fiber surface. If the internal cohesive interactions

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Received: 10.01.2020

Accepted: 25.02.2020

Published on: 27.02.2020

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within the liquid were greater the drop will spread and vice versa [15].

There are many ways for decreasing the energy surfaces of textiles; one is by applying the water-repellent finishing on the fabric surface, which penetrates in the space between the fibers such as paraffin emulsions. Another way is by a chemical reaction between repellent finishing agent and the cotton fiber such as fatty acid resins. Also, formation of a repellent film on the fiber surface is another technique of water repellency [16]. Most of water repellent chemicals are available as water emulsions and are applied to fabric by the pad-dry-cure method with a curing temperature around 170°C for a few minutes [10,11]. The finishing polymer spreads to cover the fabric surface during the drying/curing of the treated fabric. The fluoroalkyl chains are oriented perpendicular to the fabric surface resulting in reducing fabric surface energy. Therefore, water or oil can't spread out but slide off the fabric. Fluorinated compounds are the most widely used finishes for textile applications that can be applied to both natural and synthetic fibers and their blends [17].

Studies which compare the effect of spinning system on the wet finishing process are lacking. For the present research study, the cotton yarn of 80s Ne count was selected from two spinning systems namely ring spinning and compact spinning systems. The purpose of this study was to compare the effect of fluorinated and non-fluorinated water-repelling finishes and to evaluate their performance using different concentrations on woven cotton fabric properties after.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Fabrics

100% cotton woven fabrics samples pad 1 \ 1 from the ring and compact spinning yarn, of Egyptian cotton variety (Giza 92) was done at the factory in Bejamm - Shubra Al Khaimah, Egypt, with Shuttle loom.

Cotton Fabric Specification:

- Picks (1/cm) 28, Reed (1/cm) 40, Reed - Width 100cm, Dents 20, Denting 2ends / dent, Yarn Count 80/2 warp - 80/2 weft
- Weight per square meter of the ring-spun fabrics is (98 gm.), and the weight of the compact-spun fabrics is (81 gm.).

2.1.2. Chemicals Used

Triton X, NaOH, (10 g/l, 25 g/l and 50 g/l) fluorinated and non-fluorinated water-repelling finishes, namely; A; water repellent WR_3A (non-fluorinated) B; C6 water repellent WR_1 (fluorinated) supplied by Zuzhou Yuanna chemical technology Co., Ltd China,

2.2. Methods

Fabrics were scoured using 3% NaOH and then treated with different water repellent using three different concentrations (10 g/L, 25 g/L and 50 g/L). The process parameters were adopted as recommended by the supplier [18].

Padding 80% pick up; drying 110°C for 3 min; curing temperature 170: 180°C; curing time 2 min

2.3. Evaluation and Testing

Each sample was tested in the standard atmosphere, 25±2°C temperature and 65% RH after conditioning 24 hrs. All the fabric specimens were subjected to various tests, before and after treatment to assess the results according to the standard test procedure as following:

2.3.1. Weight change evaluation

The weight change evaluation was calculated by the following formula

$$\text{Percentage of weight change} = \frac{W_0 - W_1}{W_0} \times 100$$

Where, W₀= weight of fabric before treatment and W₁= weight of fabric after treatment

2.3.2. Spray rating test (ISO 4920-2012 (E))

The test method is used to evaluate the water repellency of the fabric. Spray Test one of the water repellent evaluation method which measures resistance of fabric to surface wetting under mild water impact. The fabric surface is visually rated. This method is widely used because of it is considered as a quick, easy, inexpensive screening test. Spray rating tests were done by Spray Tester at National Research centre NRC, Egypt.

2.3.3. Tensile strength and Elongation test

It was done for woven fabric according to Strip method ASTM D 5035 on fabric tensile strength tester.

2.3.4. Stiffness test (Flexural rigidity)

To measure the fabric stiffness in warp and weft directions of fabric, the flexural rigidity (gm.cm) of a fabric is given by [27], $G = wc^3$ where w is the fabric weight per unit area and c is the half of the fabric bending length. The fabric Flexural rigidity was measured by using stiffness tester according to the method given in ASTM, D 1388-08.

3. RESULTS AND DISCUSSIONS

3.1. The weight change

Data presented in Table (1) showed that the weight of fabric increases in all finished fabrics at all concentrations for both water repellent finishing; non-fluorinated and fluorinated water-repelling finishes (A&B, respectively) which means that finishing increasing the treated fabric weight. This result may be due to the formation of a repellent film on the cotton fiber surface.

3.2. The Tensile Strength

The results of tensile behavior of finishing fabrics (warp & weft) samples are reported in the Table 2.

The test results show a marginal difference between the rings-spun fabrics and the compact-spun fabrics and between the fluorinated and non-fluorinated water-repelling finishes, it has been noted that compact spun fabrics had the highest mean value of tenacity (37.5 kg/f) was reached by the warp direction of the concentration (50% Finishing A) sample. In contrast, the lowest mean value of weft

tenacity for ring-spun fabrics (24.53 kg/f) was obtained from the concentration (10% Finishing B) sample.

Finished fabrics have the highest value of tensile strength this may-be due to rough yarn surface which gives high friction value of yarn warp way tensile strength is always higher than the weft way strength [19].

Table 1. The weight change % of treated Ring and Compact spun cotton fabric

Finishing conc.	The weight change (%)	
	Ring-spun fabrics	Compact-spun fabrics
10% Finishing A*	15.39	12.35
25% Finishing A	34.62	25.2
50% Finishing A	56.25	43.75
10% Finishing B**	9.77	8.35
25% Finishing B	18.22	10.42
50% Finishing B	34.6	29.17

*A; water repellent WR_3A (non- fluorinated)

**B; C6 water repellent WR_1 (fluorinated)

Table 2. The Tensile Strength (kg/f) on warp and weft directions of treated Ring and Compact spun cotton fabric

Tensile Strength (kg/f) Finishing conc.	Compact-spun fabrics		Ring-spun fabrics	
	weft direction	warp direction	weft direction	warp direction
Control	26.5	28	21.85	24
10% Finishing A	27	30.25	25.3	27.35
25% Finishing A	28.33	32	26.62	28.92
50% Finishing A	35.5	37.5	32.25	33.75
10% Finishing B	27	28.25	24.53	27.35
25% Finishing B	27.35	31	25.82	28.92
50% Finishing B	31.5	32.5	28.33	31.5

*A; water repellent WR_3A (non- fluorinated)

**B; C6 water repellent WR_1 (fluorinated)

Table 3. Elongation % on warp and weft directions of treated Ring and Compact spun cotton fabric

Elongation (%) finishing conc.	Compact-spun fabrics		Ring-spun fabrics	
	warp direction	weft direction	warp direction	weft direction
Control	18	22	24	26
10% Finishing A	24	22.5	25.3	22
25% Finishing A	28	26.33	26.2	24
50% Finishing A	24.5	23.13	25	23
10% Finishing B	30	28.5	30.5	30.55
25% Finishing B	28	27.5	29.25	30
50% Finishing B	27	26	30	24.6

*A; water repellent WR_3A (non- fluorinated)

**B; C6 water repellent WR_1 (fluorinated)

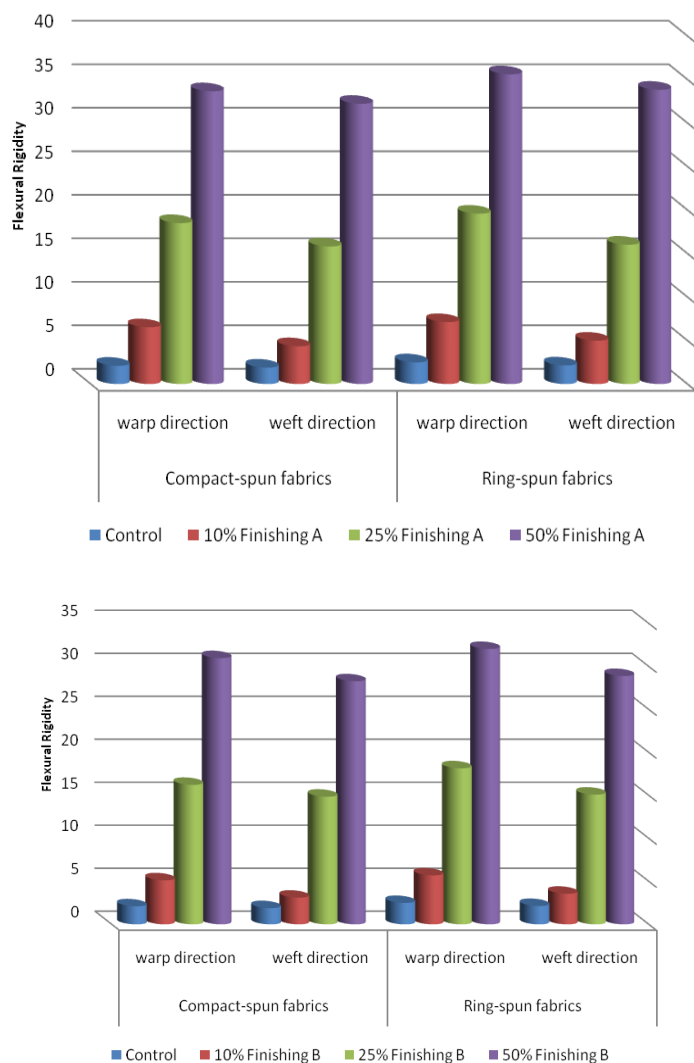


Figure 1. The flexural rigidity (gm.cm) of ring and compact spun cotton fabric treated with A; water repellent WR_3A (non- fluorinated), B; C6 water repellent WR_1 (fluorinated)

Table 4 Water Repellency of treated Ring and Compact spun cotton fabric

Water Repellent (%) Finishing conc.	Ring-spun fabrics		Compact-spun fabrics	
	Finishing A	Finishing B	Finishing A	Finishing B
Control	0	0	0	0
10% Finishing	80	80	80	80
25% Finishing	100	100	100	100
50% Finishing	100	100	100	100

*A; water repellent WR_3A (non- fluorinated)

**B; C6 water repellent WR_1 (fluorinated)

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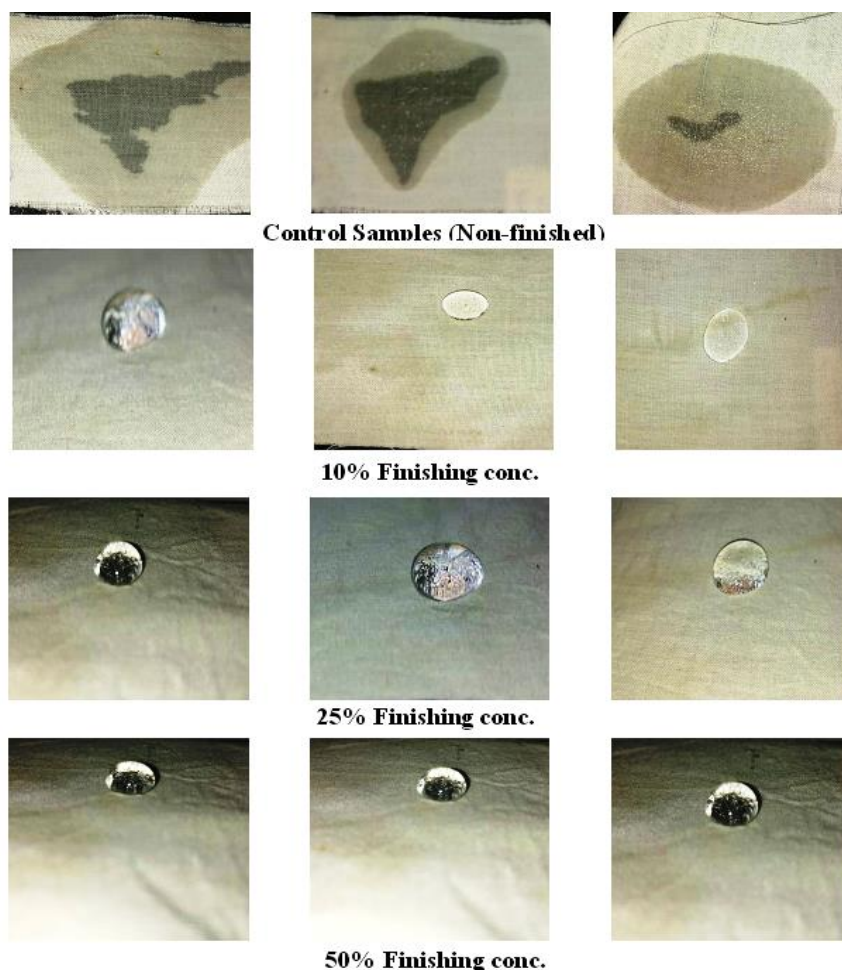


Figure 2 Images of water repellency

3.3. The Elongation

Elongation % of all the fabric samples were measured in both warp and weft direction and is given in Table 3. It is found that after the treatment, elongation % changes in both warp and weft direction had a marginal difference among the spinning system.

3.4. Flexural Rigidity

The stiffness increased for all types of water repellent finishes. The fabric stiffness is increased by increasing of water repellent chemical conc. Stiffness test has been increased after water repellent finishing due to that resin cross-links in amorphous region of cellulose leading to lower flexibility and harsh hand feel. For that reason, fabric stiffness is increased after finishing. As shown, a similar effect was noted between the concentration of finishing A and B, and the fabric stiffness, as the Finishing concentration increased the fabric Flexural Rigidity is increased which means more stiffness.

It should be noted that the Flexural Rigidity of the samples were measured in the warp and weft directions. Compact Spinning fabric showed less

stiffness compared to ring spinning fabric. Stiffness of compact and ring fabrics differs related to the yarn properties as well as the woven fabric structure [20,21]. Flexural rigidity of a fabric can be judged in terms of stiffness of a fabric, which determines the stiffness using combination of bending length and weight per unit area [26,27].

The effect of two types of finishing agent and their concentration on the flexural rigidity of finished fabrics was determined and the results presented in Figure 1. The results of flexural rigidity results in that the rate of stiffness was higher at using high finishing agent concentration. Cotton fabric treated with finishing A showed high flexural rigidity than fabric treated with finishing B, and Ring-spun fabrics more stiffness than Compact-spun fabrics.

3.5. Water Repellency

All treated fabrics show a high level of water repellency as shown in Table 4 and Figure 2. It is clear from the pictures reported in Figure 2, that finishing treatment doesn't allow water droplets to penetrate the fabric but just roll on the surface of the fabric.

Fluorinated chemistry works by binding and fixing the fluorinated polymer to the fiber surface in such a way that it remains fixed even after washing [22, 23].

4. CONCLUSION

The information acquired in this study showed that the water repellent types and their concentration ranges have a great influence on the woven cotton fabric repellence. The highest water repellence values were obtained when fluorocarbon-based repellent was used. Increasing the repellent concentration made the fabrics more water resistant regardless of repellent type. Cotton fabric treated with finishing A showed higher Flexural Rigidity than fabric treated with Finishing B, and Ring-spun fabrics showed more stiffness than Compact-spun fabrics. Environmental friendly fluorocarbon-free water repellent chemicals could be a good alternative to fluorocarbon-based water-repellent chemicals.

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