Effect of Water Repellent Finish on Reactive Dyed Cotton Fabric

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Abstract:
Reactive dyed cotton fabrics are extensively utilized in a wide range of textile applications owing to their excellent color strength, shade versatility, and wearer comfort. Despite these advantages, the inherently hydrophilic nature of cotton restricts its suitability for applications where resistance to water penetration is required. In response to this limitation, the present study focuses on investigating the effect of a water-repellent finishing treatment applied to reactive dyed cotton fabrics and its influence on overall functional performance and durability. Cotton fabric was initially dyed using reactive dyes through a conventional exhaust dyeing process to ensure effective dye fixation and uniform shade development. Subsequently, a water-repellent finish was applied using a pad–dry–cure technique, which is widely adopted in industrial textile processing due to its efficiency and scalability.
The performance of the treated fabrics was primarily assessed in terms of water repellence using standardized spray rating methods. The durability of the applied finish was further examined through repeated laundering cycles to evaluate the retention of water-repellent properties under simulated end-use conditions. The results reveal a substantial enhancement in water repellence after the application of the finishing treatment, demonstrating the effectiveness of the finishing process in imparting hydrophobic characteristics to reactive dyed cotton fabrics. Importantly, the water-repellent treatment exhibited good compatibility with reactive dyes, as no adverse interaction affecting dye fixation or shade appearance was observed.
The study further highlights the practical feasibility of integrating water-repellent finishing with reactive dyed cotton fabrics for value-added textile applications. The developed process offers a promising approach for producing functional cotton textiles suitable for protective clothing, outdoor apparel, and home textile products where water resistance is a desirable attribute. Overall, this work confirms that water-repellent finishing is an effective and durable method for enhancing the performance characteristics of reactive dyed cotton fabrics without compromising their inherent advantages, thereby broadening their scope of application in advanced and functional textile products.

Keywords: Cotton, Reactive Dye, water repellent finish, spray test, Absorbency test.

Introduction

Cotton is one of the most extensively used natural fibers in the textile industry owing to its comfort, breathability, biodegradability, and wide availability. Its favorable characteristics make it suitable for diverse applications including apparel, home textiles, and technical textiles. To meet consumer demand for vibrant colors and durable performance, cotton fabrics are commonly dyed using reactive dyes, which are capable of forming covalent bonds with the hydroxyl groups of cellulose. This chemical bonding results in excellent color strength, high wash fastness, and good shade reproducibility, making reactive dyes the preferred choice for cotton dyeing applications [1,2].

Despite these advantages, cotton fibers are inherently hydrophilic in nature due to the presence of numerous hydroxyl groups in their molecular structure. This characteristic leads to rapid wetting and moisture absorption, limiting the use of cotton fabrics in applications where resistance to water penetration is required, such as outdoor garments, protective clothing, upholstery, and functional home textiles [3]. To overcome this limitation, water-repellent finishing treatments are commonly applied to cotton fabrics to impart hydrophobic properties while preserving their inherent comfort.

Water-repellent finishes function by reducing the surface energy of textile substrates, thereby preventing water droplets from spreading and penetrating the fabric surface. Among the various water-repellent agents, fluorocarbon-based finishes have been widely adopted due to their excellent water repellency, durability, and commercial viability [4,5]. Traditionally, these finishes are applied as a post-dyeing process using pad–dry–cure techniques, which are well established in industrial practice. However, the addition of separate finishing steps increases processing time, energy consumption, water usage, and chemical input, contributing to higher production costs and environmental concerns [6].

In recent years, increasing emphasis on sustainable and resource-efficient textile processing has encouraged the development of integrated manufacturing approaches. Combining dyeing and functional finishing processes offers significant potential to reduce energy, water, labor, and chemical consumption while maintaining fabric performance [7]. In this context, the present study focuses on investigating the application of a water-repellent finish on reactive dyed cotton fabrics and evaluating its effectiveness in enhancing water resistance. The findings of this study aim to contribute toward the development of value-added, functional cotton textiles using efficient and industry-relevant processing techniques.

Materials And Experimental Method

Materials

Specification of the Cotton Fabric

Ready to dyeing 100% cotton fabric was used in the present study. The specification as shown in table 1.

Table: 1 Specification of Cotton Fabric

Sr. No.	Parameter	Specification of Cotton Fabric
1	Ends per inch (EPI)	80
2	Picks per inch (PPI)	70
3	Weight (in grams/meter^2) GSM	129
4	Warp Count	38^s
5	Weft Count	37^s
6	Thickness (in mm)	0.23

Specification of Reactive Dye

Reactive dyes used for the experimental work are Hot brand reactive dye.

1) Jekofix Brilliant Red HER3B

Specification of Water Repellent Finish

Fluorocarbon (FC) water repellent chemicals were used in this experiment.

Experimental Methods

Exhaust Dyeing

Exhaust dyeing was conducted in an electronic water-heating bath preheated to 80 °C for 10 min. The fabric was dyed with a reactive dye solution under neutral conditions at 80 °C for 15 min. Glauber's salt was added in three installments at 15, 30, and 45 min to promote dye exhaustion. Soda ash was added in two portions at 30 and 45 min, followed by dyeing for 15 min. The dyed fabric was soaped with a non-ionic detergent at boil for 10–15 min and rinsed with cold water to improve wash fastness.

Table: 2 Recipe for Exhaust dyeing of Reactive Dye

Ingredients	Concentration
% Shade	1% & 2%
M: L: R	1:25
Glauber's Salt	60 g/l
Soda Ash	20 g/l
Temperature	80°C
Time	1 hr

Finishing with Water Repellent Finish

Cotton fabrics were treated with Fluorocarbon (FC) water repellent chemicals at two different concentrations (03 g/l & 06 g/l) from a separate bath with the similar bath condition. Pad-Mangle machine was used for padding with 2.5 m/min fabric speed and 2.8 kg/cm2 padding pressure.

Table: 3 Recipe for Finishing with Water Repellent Finish

Finishing Bath Set Up		**Fluorocarbon (FC)**
Name Of Chemicals	Finish	03 & 06 g/l
	Acetic Acid	1 ml/l as required for pH 3.5
Application Parameter	Padding	80% Pick up
	Drying	110°C for 3 Min.
	Curing Temperature	150°C
	Curing time	3 Min.
	Padder Prs.	2.8 Kg/cm^2

The fabric is immersed in above solution at room temperature for few minutes. Afterwards, the fabric is passed through the padding mangle between two squeezing bowl and is given 2 dip 2 nip treatment. The padded goods are then dried at 110°C for 3 Minutes. Further, the dried fabric is cured in a hot air oven at 150°C for 3 minutes.

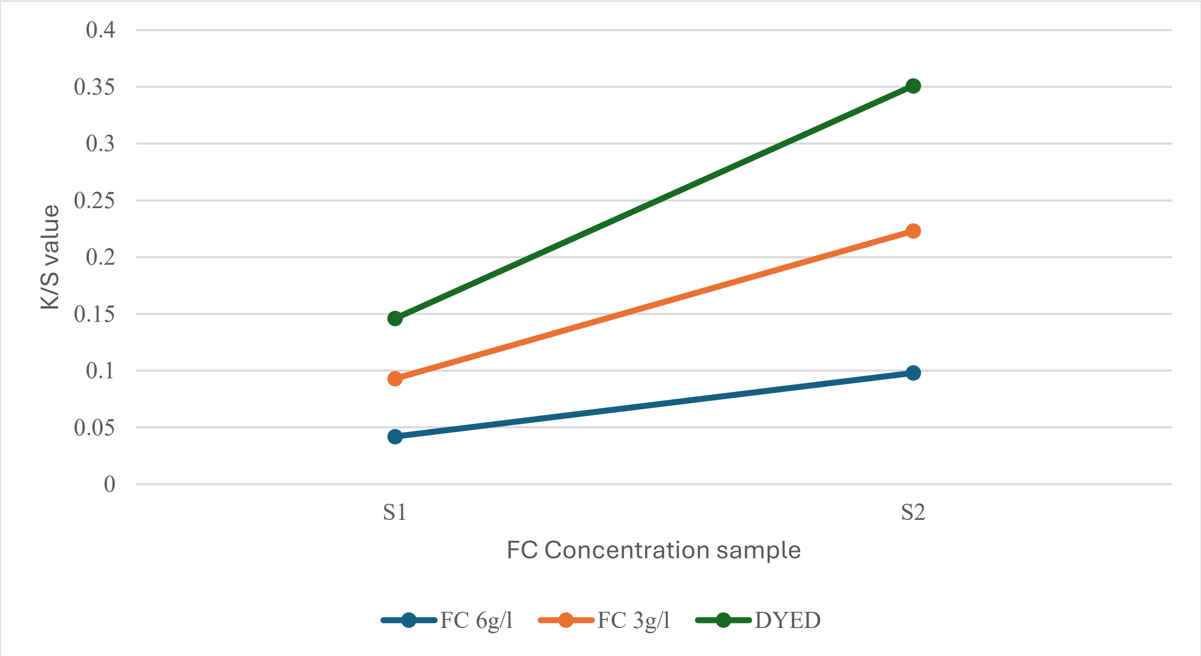
Result And Discussion

Effect of Color Strength on Water Repellent Finished Fabric

In this method first cotton fabric can be dyed with Reactive dye by exhaust method. After dyeing fabric wash thoroughly with water and dried. And then finished with Water repellent finish by pad-dry-cure method.

Table: 4 Color strength (K/S Values) of Water Repellent Finished Specimen

Sr. No.	Sample code	Dyed with conc.	Dyed Sample K/S	FC Finished Sample K/S with 3g/l conc.	FC Finished Sample K/S With 6g/l conc.
1.	S1	1%	0.053	0.051	0.042
2.	S2	2%	0.128	0.125	0.098
Note: S1 RED1% Dye Conc. With 3 g/l Pad liquor Conc., **S2** RED2% Dye Conc. With 6 g/l Pad liquor Conc.,					



Graph:1 FC Concentration v/s K/S

The decrease in colour strength (K/S values) observed after the application of finishing treatments can be attributed to modifications in the surface and optical characteristics of the dyed fabric. The formation of a thin film of finishing agents on the fibre surface partially masks the dye molecules, thereby reducing light absorption[1]. In addition, the smoother surface generated by finishing enhances light reflectance, leading to a reduction in colour strength. According to the Kubelka–Munk Theory, an increase in reflectance results in a decrease in K/S values[2]. This behaviour is consistent with the experimental results obtained in the present study, where a progressive decrease in K/S values was observed with increasing finishing concentration.

Water-Repellent Finish Absorbency Test (Drop Test)

The absorbency behaviour of the fabric samples was evaluated using the drop test method according to AATCC Test Method 79. In this test, a small drop of distilled water was placed carefully on the fabric surface using a dropper. The time required for the water droplet to be completely absorbed by the fabric was recorded as an indicator of fabric wettability. A longer absorption time indicates lower wettability and better water-repellent performance, whereas rapid absorption suggests higher wettability of the fabric surface[8].

Table: 5 Drop Test of Water Repellent Finished Specimen

Sr. No.	Sample Code	Absorb Time for FC with 3 g/l Finished Sample (Min)	Absorb Time for FC with 6 g/l Finished Sample (Min)
1	S1	6.47	10.00
2	S2	12.00	16.23
Note: S1 RED1% Dye Conc. With 3 g/l Pad liquor Conc., **S2** RED2% Dye Conc. With 6 g/l Pad liquor Conc.,			

Spray Test for Water Repellence

The water-repellent performance of the fabric samples was evaluated using the spray test method according to AATCC Test Method 22. In this test, the fabric specimen was mounted on a test frame at a specified angle, and a controlled amount of distilled water was sprayed onto the surface from a standard nozzle. After spraying, the fabric surface was visually examined and compared with the AATCC spray rating chart to determine the degree of surface wetting. A higher spray rating indicates better water-repellent performance, while lower ratings indicate greater wetting of the fabric surface[9].

Table: 6 Spray Test of Finished Specimen

Sr. No.	Sample Code	Finish with Conc.	FC Finished Sample Spray Rating
1	S1	3 g/l	80
2	S2	6 g/l	80
Note: S1 RED1% Dye Conc. With 3 g/l Pad liquor Conc., **S2** RED2% Dye Conc. With 6 g/l Pad liquor Conc.,			

Conclusion

The present study demonstrates that the application of water-repellent finishes using the pad–dry–cure method significantly enhances the surface hydrophobicity of cotton fabrics dyed with reactive dye, while largely preserving the original colour strength. Analysis of K/S values, based on the Kubelka–Munk Theory, revealed that the finished samples exhibited only a slight reduction in colour intensity compared to the untreated fabric, indicating good compatibility between the dyeing and finishing processes without adversely affecting fabric appearance.

A gradual decrease in K/S values was observed with increasing concentration of finishing agent, which can be attributed to surface film formation and increased light reflectance. Evaluation of water repellency using the drop test (AATCC TM79) showed prolonged absorption time for treated samples, confirming reduced wettability. Similarly, spray test results (AATCC TM22) indicated improved spray ratings, demonstrating effective surface repellency after finishing treatment.

Overall, the results suggest that the application of water-repellent finish on reactive dyed cotton fabric is effective in imparting functional properties while maintaining acceptable colour characteristics, making it suitable for potential use in protective and performance textile applications.

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