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RESEARCH ARTICLE

APPLICATION OF SILICONE BASED FINISH ON COTTON FABRIC AND ITS EFFECT ON WATER ABSORBENCY AND ANTIBACTERIAL ACTIVITY

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ABSTRACT

Cotton fabric was finished with lab prepared silicone finish (F1). It was developed and applied on cotton fabric by pad-dry-cure method for enhancing water absorbency and antibacterial activity. Untreated (F0) and treated (F1) cotton fabric samples were tested for water absorbency using water drop put on the fabrics and recorded the absorption time, by standard test method AATCC Test Method 79-2007 and the antibacterial activity against *staphylococcus aureus* by AATCC test method 90-2011. Physical properties: stiffness, crease recovery angle and tensile strength were also evaluated. FTIR spectroscopy was also analyzed which interpreted the chemical structure of the substance consequently identification of its functional group. Result showed that the FTIR was ensure the presence of silicones on the lab prepared silicone finished (F1) fabrics and the water absorbency and antibacterial efficacy of the lab prepared silicone finish (F1) on cotton was more than unfinished (F0) fabric. Thus, silicone provides higher functionality to cotton fabric.

INTRODUCTION

Cotton, as a natural cellulosic fiber, has a lot of characteristics, such as comfortable, good strength, color retention, drapes well, easy to handle and also it is cheaper one. But it does not possess any special function on its own nature (Pechimuthu*et al.,* 2013).To impart the required functional properties to the fiber or fabric, it is customary to subject the material to different types of physical and chemical treatments. Finishing is the final processing of the cloth and its purpose is to make the fabric suitable for its intended end use. Textile finishes and finishing are classified in several ways. Usually categorized as aesthetic and functional finishes (Kapolph and Langford, 1998). These days due to specific use and requirements of consumers special purpose finishes are gaining importance of these water absorbency and antibacterial finishes are one of them. The clothing should take up the moisture from the skin as well as transmit it to the atmosphere. Higher hydrophilicity of a material is known for good absorption (Das *et al.,* 2009). Fabric structure can also influence hydrophilic properties due to mechanisms of moisture transport between fabrics. Moisture can remain in the fiber cross-sections, on the surface of the fibers, in the voids formed within a yarn by a plurality of fiber channels and in the voids caused by yarn crossovers in woven and knitted fabrics (Freddi*et al.,* 2003).

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Natural fibers are easy objects for microbial attack because they retain water readily and microbial enzymes can readily hydrolyze their polymer linkages. Cotton, wool, jute and flex are reported to be most susceptible to microbial attack (Gupta and Bhaumik, 2007).Textile goods, especially those made from natural fibers, provide an excellent environment for microorganisms to grow, because of their large surface area and ability to retain moisture. Organo modified silicones are structurally derived from poly-dimethyl siloxanes in which the methyl groups are partly substituted by liphophilic or hydrophilic non-ionic or ionic moieties. The unique properties of organo modified silicones are due to their lyophobic silicone part. Depending upon their structure, they are surface active not only in water but also in organic media. This unique property makes it a versatile product for various applications and industries. Viz. effective wetting agents in paints and agro chemicals, as emulsifiers, anti-foams, textile softeners and wrinkle resistant, as conditioners in hair care products and as emollients in skin care formulations (Shivaramakrishnan, 2009).Silicones are mainly used in the textile industry as softener.They also find use as lubricants in spinning and winding of yarns and sewing lubricants. In pretreatment, dying and washing off bath silicones are used as an anti-foaming agent (Periyasamy andKhanna, 2007; Menezes andKorde, 2001). Surface and bulk characteristics of fabrics such as softness (surface or inner), bounciness, dry feel, wet feel, hydrophilicity and several other fabric properties can be enhanced significantly by modifying silicones for desired transport and interfacial properties. These silicones are applied to the fabric surface through micro or macro emulsions.

In the actual process, micro or macro droplets of silicone are adsorbed onto the fabric surface leading to its surface modification (Purohit*et al.,* 2006). Islam M., *et al.,* (2015) conclude that the silicone softener plays a very significant role in textile finishing. It has wide spread applications in textile dyeing and finishing. Combination of silicone softener and chitosan with citric acid was studied by Karolia and Mendapara (2007) to impart antimicrobial and fragrance finish on cotton fabric. It is observed that the finish provides better functionality to the fabrics as it shows good performance and improved crease recovery. The finish shows good washing as well as perspiration fastness, and the use of carboxylic acid also improves the affinity of chitosan for cellulose. In the present study silicone based finish was prepared in laboratory, and applied on cotton fabric using pad-dry-cure method. The prepared finishes were evaluated against a water absorbency and anti-bacterial activity.Effect of finishes on wear properties of the fabrics were also evaluated to study their influence on stiffness (bending length), crease recovery angle and tensile strength of fabrics.

MATERIALS AND METHODS

Materials

100 % Cotton plain weave fabric shown in table-1 was used for the study. Fabric was procured from Mafatlal family shop of Anand.

Methods

- The procured cotton fabric was thoroughly scoured, using standard method and air dried.
- Identification (AATCC test method 20-2007):
- Confirmation of the fiber type was done through microscopic analysis, burning test and chemical solubility test.
- Determination of preliminary data:

Preliminary data including fabric structure (weave), fabric count (the number of yarns/inch) helped to describe the tightness of the weave, weight per unit area, thickness were determined using standard methods (Booth, 1996) and are given in table-1.

Table 1. Preliminary data of fabrics

Fabric	Weave	Yarn count (inch)		Weight per Unit area (gms/sq.mtr)	Thickness (mm)
		Warp	Weft		
Cotton	plain	134	68	138.4	0.26

Preparation and application of finish

Silicone finish (F1) was prepared in the laboratory under controlled conditions using laboratory grade reagents. The finish (50g/l) was prepared as per recipe given in table no- 2. Cotton fabric was finished by pad (2min)-dry (10 min) (4 times) iron-cure, (3 minutes at 110°C temperature) sequence.
The finish was applied on cotton fabric with the help of padding mangle. The finish was applied with 4 dips and 4 nips (2 minutes dip). The fabrics were then dried at room temperature for 10 minutes and then cured at 130° C temperature for 3 minutes.

Table 2. Recipe for lab prepared silicone finish (F1)

Epoxide (with known molecular weight)	Optimum quantity (Total volume 50 gpl, padding)
Tri Methyl Silyl Chloride	
Cetyl Tri-methyl Ammonium Bromide	
Tri Ethyl Amine	
Solubilising agents: (Poly Ethylene Glycol, Benzene, Methanol, Water)	

FTIR analysis

Fourier transform infrared spectra (FTIR) analysis are the best way to interpreted the chemical structure of the substance consequently identification of its functional group.
IR spectra of untreated (F0) and treated (F1) cotton was obtained by using ABB FTIR spectrometer model number MB 3000 in the range of 4000-400 cm^{-1} at reflectance mode for identification of functional group presented in fabric and was compared with reference IR spectra given in research papers.

DSC analysis

Thermal property of the finish (Fl) was analyzed by using Perkin Elmer (Model - Pyris-1DSC) Differential Scanning Calorimeter. The measurement was done under N_2 atmosphere in a temperature range of 0.00°C to 210.00°C with 10°C/ minute heating rate.

Testing of water absorbency

The water absorbency was evaluated by standard test method (AATCC Test Method 79-2007) of fabrics. In this test the time taken for the absorption of water drop completely in the fabric was used to analyze the hydrophilic nature of fabric. The specimen was clamped circularly and held taught and allow one drop of distilled water to fall on the cloth and the stop watch was started immediately. When the diffused reflection from the liquid vanishes and the liquid is no longer visible, the timing is stopped and recorded.

Determination of Antibacterial property

The antibacterial properties of sample was evaluated qualitative by measuring the width of clear zone of inhibition around the samples by (AATCC test method 90-2011) antibacterial activity assessment of textile materials: agar plate method. In order to evaluate the antibacterial properties, specimens of the test material including corresponding untreated controls of the same material were placed in intimate contact with the agar which had been previously seeded with an inoculamns of a test bacterium. After incubation a clear zone of interrupted growth underneath and /or adjacent to the test material indicates antimicrobial activity of the specimen. A standard stain of *S.aureus*Gram positive bacteria was used.

The average width of a zone of inhibition on either side of the specimen may be calculated using the following equation.

$$W = (T-D) / 2$$

Where, W is width of clear zone of inhibition in mm

T is total diameter of test specimen and clear zone in mm

D is diameter of the test specimen in mm

The durability of finish was also evaluated by giving one wash and ten washes and then observing antibacterial property of the fabric samples.

Effect of finish on physical properties of the fabric

Evaluation of Stiffness

The samples were evaluated for stiffness using standard test method (Booth, 1996). Eureka stiffness tester was used, five warp and five weft specimens of size 6 x 1 inches were placed on the instrument and the scale was slided till the edge of the sample was in line with the line in the reflection mirror. The reading on scale was taken and average was recorded.

Evaluation of crease recovery angle

To determine crease recovery by AATCC test method 66-1975. Eureka make crease recovery tester was used. Five warp and five weft specimen of 50 x 25 mm size were cut and placed in a loading device one at a time for five minutes under a pressure of 5oo gms after being folded in half. The folded sample was then placed in a crease recovery tester which allowed the fabric to unfold, the recovery of fabric after five minutes was noted, and average has been recorded.

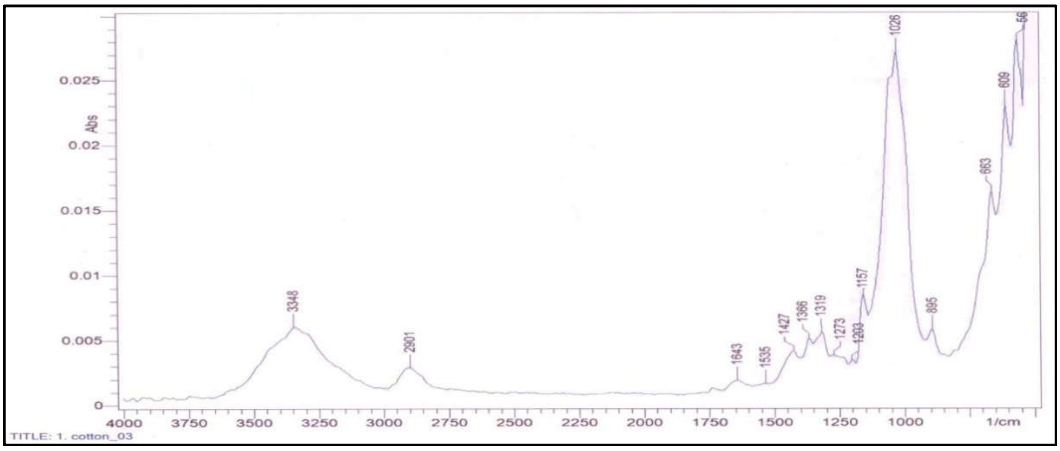
Evaluation of tensile strength

The strength of the samples was determined using elongation at break and breaking load using standard test method (Booth,1996). Fully computerized Lloyd LRX was used. Five warp and five weft samples of size 15 x 1 cm were cut and loaded on the instrument. The instrument was run and direct readings were obtained.

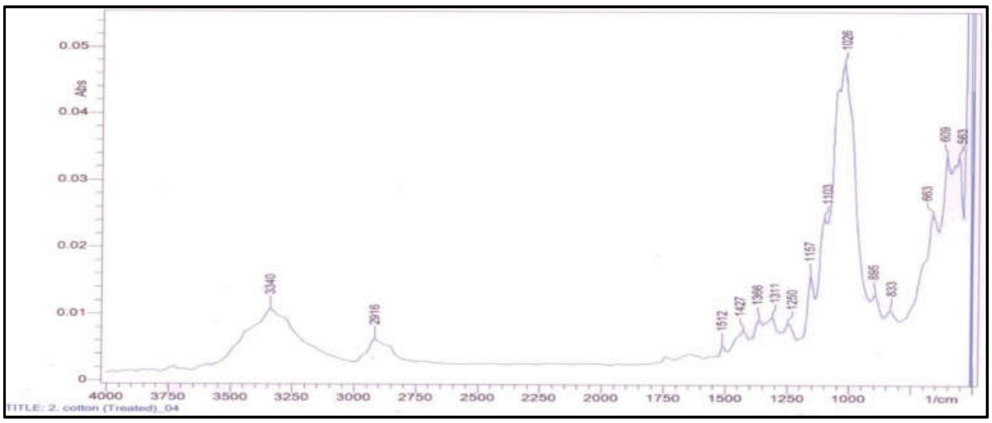
RESULTS AND DISCUSSION

FTIR analysis of fabrics

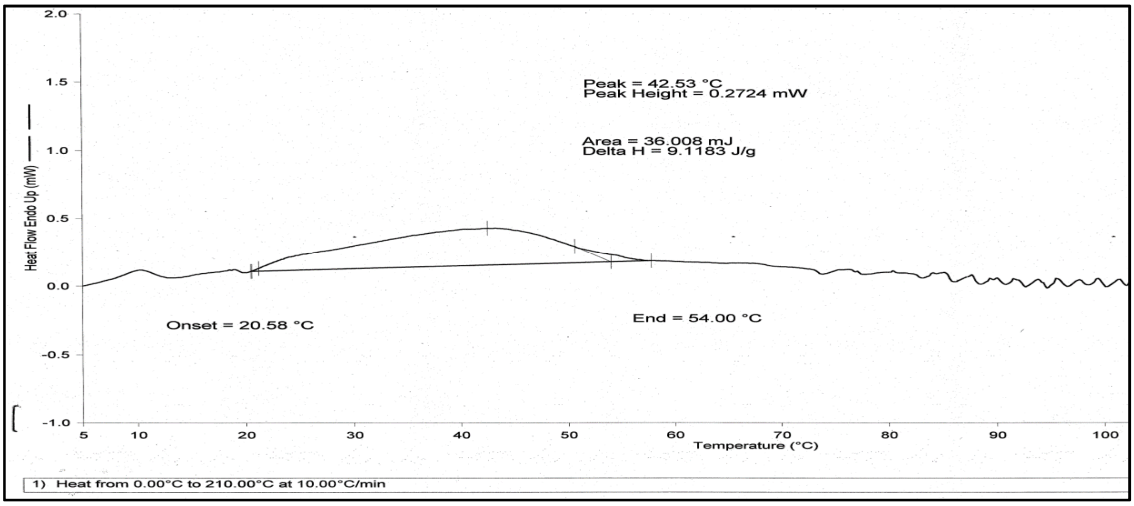
Infrared spectra (IR) of untreated (F0) and treated with (Fl) cotton fabrics are presented in Graph 1-2. Absorbency peak was compared with reference IR spectra of cotton given in Chung, Lee and Choe, (2004) and Chen and Jakes, (2002), it was concluded that fabric taken for finishing was 100% cotton. Fourier Transform Infrared spectroscopy (FTIR) was used to ensure the presence of silicones on the lab prepared epoxy based silicone finished (Fl) fabrics. Comparing the FTIR spectra of untreated cotton (Graph-1) with the treated cotton fabric (Graph-2). It was observed that the some new picks shown in treated fabric, thus the additional functional groups modified in a specific way by treatment with finishes. There are new peaks observed at the absorption peak of 1512 cm^{-1} and 1250 cm^{-1} consist of a main absorption peak –Si $(CH_3)_2$-groups and Si-CH_3.



Graph-1 FTIR of untreated (F0) cotton



Graph 2. FTIR of treated (F1) cotton



Graph 3. DSC thermogram of (F1) finish

The Si-CH_3 groups are easily recognized by medium, sharp band at about 1250 cm^{-1} together with one or more bands (833 cm^{-1}) in the range 865-750 cm^{-1} (Launer, 1987). Also additional peak was observed at 1103 cm^{-1} attributed to Si-O-CH_3 stretching. These results are in agreement by which was reported Robati, (2007).

DSC analysis

The DSC measurement was observed in the thermogram of F1 finish run at a heating rate of 10°C/minute, as depicted in Graph-3. Finish F1 did not show a melting point instead a melting range was obtained, because F1 finish contains mixtures of compounds, so, melting temperature was recorded in range. The onset temperature was 20.58°C and end set decomposing temperature was 54.00°C, i.e. F1 finish has a melting range from 20.58°C to 54.00°C and the maximum melting temperature was 42.53°C.

Effect of water absorbency on fabrics

Absorbency of fabrics was evaluated by the water drop absorbency of the fabrics which is given in table-3 and Graph-4. Decrease in time revealed increase in water absorbency of fabrics. Overall it was observed that the lab prepared silicone finish (F1) improved the water absorbency of cotton fabric because the time taken to absorb water molecules by treated samples is comparatively less with respect to the untreated samples.

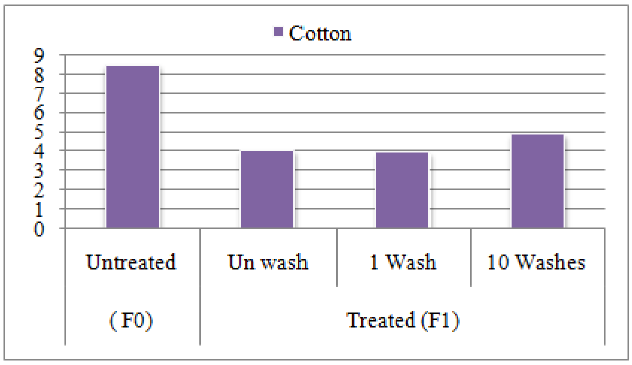
Table 3. Water absorbency (wetting time) of untreated fabrics (F0) and fabrics treated with (F1) finish

Fabric	Water Absorbency (Wetting time in second)			
	Untreated (F0)	Treated (F1)		
		Un wash (sec)	1 Wash (sec)	10 Washes (sec)
Cotton	8.45	4.03	3.91	4.87

Antibacterial effect on the fabric

S. aureus (gram positive) bacteria were used for antibacterial testing as it is the main cause of skin disease and body odour.Antibacterial activity was evaluated by observing the clear zone.

The observations are given in table-4 and Graph 5. Cotton fabric treated with the lab prepared silicone finish (F1) shows 8.85 mm clear zone, i.e. the bacterial growth was seen 8.85 mm away from the sample.Over all it was observed that the lab prepared silicone finish (F1) improved the antibacterial properties of the cotton fabrics used in the study. The durability of all finish was also evaluated, it was found to be good as washing has not influenced the effectiveness of finish, moreover, after washing antibacterial property of lab prepared finish (F1) improved further after one wash and after ten washes also. This could be attributed to the influence of soap present in the wash liquor.



Graph 4. Water absorbency (wetting time) of untreated fabrics (F0) and fabrics treated with (F1) finish

Table 4. Antibacterial properties (width of clear zone) of untreated fabrics (F0) and treated fabric with (F1) finish

Fabric	Treatments	w (width of clear zone of inhibition in mm)		
		Unwash	1 Wash	10 Washes
Cotton	Untreated(F0)	0	0	0
	Treated (Fl)	8.85	10.85	14.65

Physical properties of the fabric

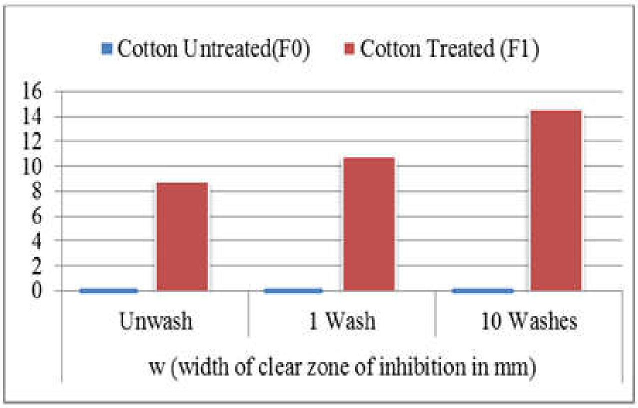
Finishes were evaluated to study their influence on stiffness (bending length), crease recoveryand tensile strength properties.

Table 5. Physical properties of untreated and treated fabrics

Fabric	Treat -ments	Stiffness (cm)				Crease Recovery (Degrees)				Tensile Strength (Elongation at break)			
		Warp		Weft		Warp		Weft		Warp		Weft	
		Face	Back	Face	Back	Face	Back	Face	Back	Load (kg)	Elongation mm)	Load (kg)	Elongation (mm)
Cotton	Untreated (F0)	2.60	2.60	2.10	2.10	46.66	44.50	47.00	45.33	18.56	15.10	9.17	16.45
	Treated (Fl)	2.80	2.80	2.20	2.20	51.66	52.33	52.00	51.33	17.30	14.24	8.33	14.36

Effect on stiffness

Details of stiffness are presented in table-5 shows that all the treated fabrics generally had marginally higher bending length meaning that the treated fabrics were slightly stiffer when compared to the untreated fabric.



Graph 5. Antibacterial properties (width of clear zone) of untreated fabrics (F0) and treated fabric with (F1) finish

Effect on crease recovery angle

The crease recovery readings of all the samples are presented in table 5. There has been significant improvement in crease recovery of all lab prepared silicone finished (F1) fabric. This could may have been due to the finishing agent molecules present on the fabric surfaces, resulting in increased crease recovery.

Effect on tensile strength

The influence of tensile strength, load at break and elongation of warp and weft has been presented in table 5. On comparing the readings of untreated and treated samples, it is observed that the warp and weft side load and elongation of cotton fabric slightly decrease from (warp/weft load-18.56, 9.17, warp/weft elongation-15.10, 16.45) of untreated to (warp/weft load-17.30, 8.33, warp/weft elongation-14.24, 14.36) of treated. The changes have been very minor so it can be said that the finish does not have any adverse effect on the tensile strength of cotton fabric.

Conclusion

In case of lab prepared silicone (F1) finish, comparing the FTIR spectra of untreated (F0) fabrics with the treated (F1) fabrics. It was observed that some new peaks were seen in treated fabrics, thus the additional functional groups modified in a specific way by treatment with finishes.By analyzing DSC thermogram of F1 finish, it was observed that, because (F1) finish contains mixtures of compounds, so, melting temperature was recorded in range.

The water absorbency of (F1) finished fabric was found to be better than the (F0) unfinished fabrics. A property like improved absorption is important for the comfort and also plays a big role in manufacturing process because good absorption gave a good and even dyeing, this can reduce the wetting agents, therefore good absorption can save a lot of time during the whole manufacturing process.The antibacterial efficacy of the (F1) finish on cotton fabric was more in comparison to untreated (F0). So, application of silicone finish provides higher functionality and better performance to cotton fabricfor multi-functional effects like water absorbency and antibacterial activity without any drastic change in wear properties.

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