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Nano silica loaded cotton fabric; Characterization and Mechanical testing

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Abstract

In-house synthesized silica nano particles were applied to cotton fabrics by exhaust technique. The nano treated fabrics were characterized by SEM and FTIR analysis ensured uniform distribution and presence of silica nano particles on substrates. The treatment enhanced the mechanical properties such as tensile strength, tearing strength and crease recovery angle of treated substrates. The water absorbency and wicking behaviour of treaded fabrics is reduced, but the overall improvement in water repellency does not show any significant change due to the treatment with nano silica particles.

Keywords: Absorbency, Exhaust technique, Cotton, Mechanical properties, Silica nano.

Introduction

The mechanical properties of textile fibers can be enhanced by incorporation of nanoparticles in fiber. Such properties include increased tensile strength, tearing strength, wrinkle recovery and stiffness of textiles. Researchers all over the world has reported that these properties can lead to the production of high performance fiber with enhanced strength, wrinkle recovery and increased wear and tear resistance of a fabric[1-4].

Recently, it has been reported in literature that the mechanical properties of textiles can be improved by integration of carbon nano tubes through nanoengineering[5-7]. Furthermore reports the possibility to increase the abrasion stability of polyester by treating the finished fabric with a SiO_2 coating. The coating is produced through a sol-gel process which involves the production of SiO_2 nanoparticles dispersion[8, 9].

In our earlier study we have reported application of TiO_2, Ag, Cu and Zn nano-particles to textile fabrics[10-17]. in the present work, an attempt has been made to apply in-house synthesized nano SiO_2 particles to cotton textiles by exhaust and pad-dry cure techniques. The treated fabric was morphologically observed by scanning electron microscope, IR Characterization absorption peak of normal and treated cotton fabric was recorded on FTIR Spectrometer. Effect of nano silica particles on various properties of fabric, like tensile, crease recovery, absorbency, water and air permeability were also examined by standard methods.

Materials and Methods

Materials Fabric Mill scoured and bleached cotton fabric with specifications given in Table 1 were procured from local market and used for the study. The procured fabric was further thoroughly washed, neutralised and air dried.

Chemicals: In-house synthesized nano SiO_2 nanoparticles and polyacrylamide ($CH_2CHCO\ NH_2$, M_w 71.08) of analytical grade purity was procured from SuLab reagents.

Experimental methods: Treatment of cotton with silica nano-particles: The coating solutions containing nano silica particle were prepared using 1gpl, 2.5 gpl, and 5 gpl concentration, i.e. for 1 gpl solution; in 100 ml of water, 0.1 gm nano particles were added with 5 gm Lissapol L surfactant and 10gm polyacrylamide binder. The mixture was then stirred using magnetic stirrer at 250 rpm for 30 minutes at 60°C temperature. Likewise all concentration solutions were prepared. The padding liquor was applied to the cotton fabric samples (size : 40 cm X 30 cm) by dipping them in the dispersion for 10 min and then padded on an automatic padding mangle machine, which was running at a speed of 15 rpm with a pressure of 1.75 Kg/cm^2 using 2-dip-2-nip padding sequence at 70% expression. The padded substrates were air dried and finally cured at 120˚C for 20 min in a preheated curing oven.

Table-1
Cotton fabric specification

Sample	Warp count (Ne)	Weft count (Ne)	Ends/inch	Pick/inch	Weave	Weight in gm/sq.m.	Thickness (mm)
Cotton	35s	31s	116	88	Plain	118.1	0.23

Testing and Analysis: Fabric characterization techniques: The surface morphology of the nano silica loaded cotton fabric was observed on scanning electron microscope (SEM) instrument (Model JSM5610LV, version 1.0, Jeol, Japan) and the presence of silica in composite fabric was confirmed by FTIR Spectroscopy (Nicolet is10 FTIR Spectrometer, Thermo Scientific, Japan).

Determination of physical properties of cotton fabric: Before physical testing the samples were dried and conditioned at 65± 2 % RH and 27 ± 2°C temperature.

Determination of Tensile strength: 2 cm x 8 cm fabric samples were tested at 100 mm/min traversing speed for the determination of breaking load, breaking elongation, stress and strain. The test was performed as per B.S. 2576:1959.

Determination of tearing strength: The tearing strength of treated and untreated cotton fabric samples were measured on pendulum type (Elmendorf) tearing strength tester. The test was carried out in standard atmospheric condition using ASTM-D-1424-1996 method.

Determination of crease recovery angle: The test specimen was folded and compressed under controlled condition of defined force to create a folded angle, the specimen was suspended in an instrument for a controlled recovery and the recovery angle was measured. The test was performed as per AATCC test method 66-2003.

Determination of absorbency by drop test: Nano silica treated and untreated cotton sample were tested for comparing the effect of silica nano finish on absorbency. The test was conducted in a standard atmospheric condition as per the AATCC Test Method 79-2000.

Evaluation of water permeability: These test methods provide procedure for determining the hydraulic conductivity (water permeability) of textile materials in terms of permittivity under standard testing condition in uncompressed state. The test was conducted using ASTM D 4491 (Constant Head Method) water permeability test method.

Evaluation of air permeability: The air permeability of treated and untreated cotton fabric samples were measured on Metefem air permeability tester as per ASTM D 737 test method. The result of the test is reported in $m^3/ m^2/hr$.

Results and Discussion

Surface morphology of nano silica loaded cotton fabric: The surface morphology of treated cotton fabric is shown in Figure 1 a and b. The nano scale silica particles can be clearly seen well distributed on the surface of cotton fabric. The particle size plays a primary role in determining their adhesion to the fibre. It is reasonable to expect that the largest particle agglomerates will be easily removed from the fibre surface, while the smaller particle will penetrate deeper and adhere strongly into the fabric matrix.

Infrared spectral analysis of nano silica/cotton composite fabric: The intermolecular changes in cotton fabric before and after silica nano treatment are illustrated in IR spectra figures 2 and 3. The absorption in the region of 3600-3100 cm^{-1} was due to the stretching of –OH group and at 3000 to 2800 cm^{-1} to the CH stretching, the increase of these contents after treatment indicate that silica nano attach with methyl and methylene of cellulose by hydrogen bonding. The band at 1642 cm^{-1} across from the H-O-H bending of the absorbed water. The symmetric C-H bending occurred at 1425 cm^{-1}. The band was assigned at 1315 cm^{-1} to C-C and C-O skeletal vibrations. The main characteristic peaks of Si-O-Si bonds a vibration mode was detected around 1086 cm^{-1}, which are attributed Si-O-Si asymmetric stretching vibration band in treated cotton fabric, so its indicated that the silica nano particle present in cellulosic polymer matrix.

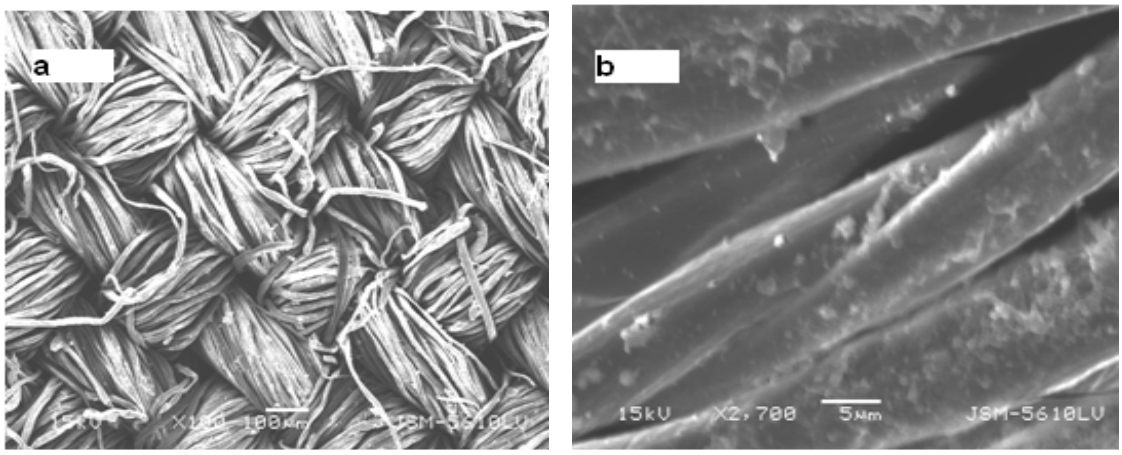

Figure-1
SEM microphotographs of cotton fabric treated with silica nano particle

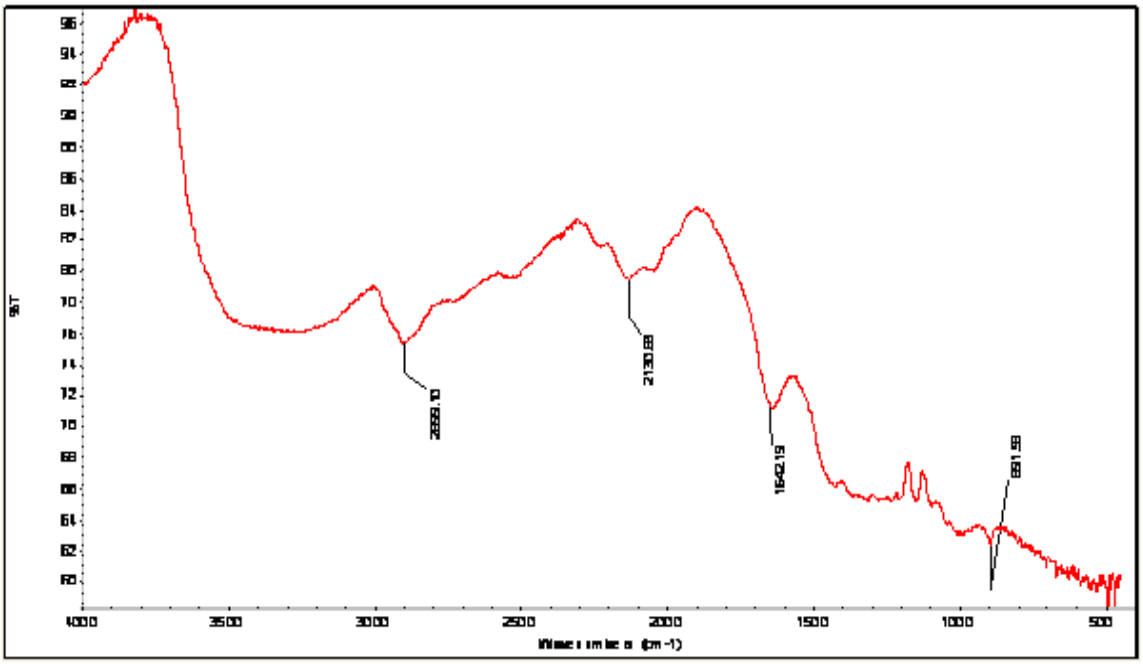

Figure-2
IR Characterization absorption peak of normal cotton fabric

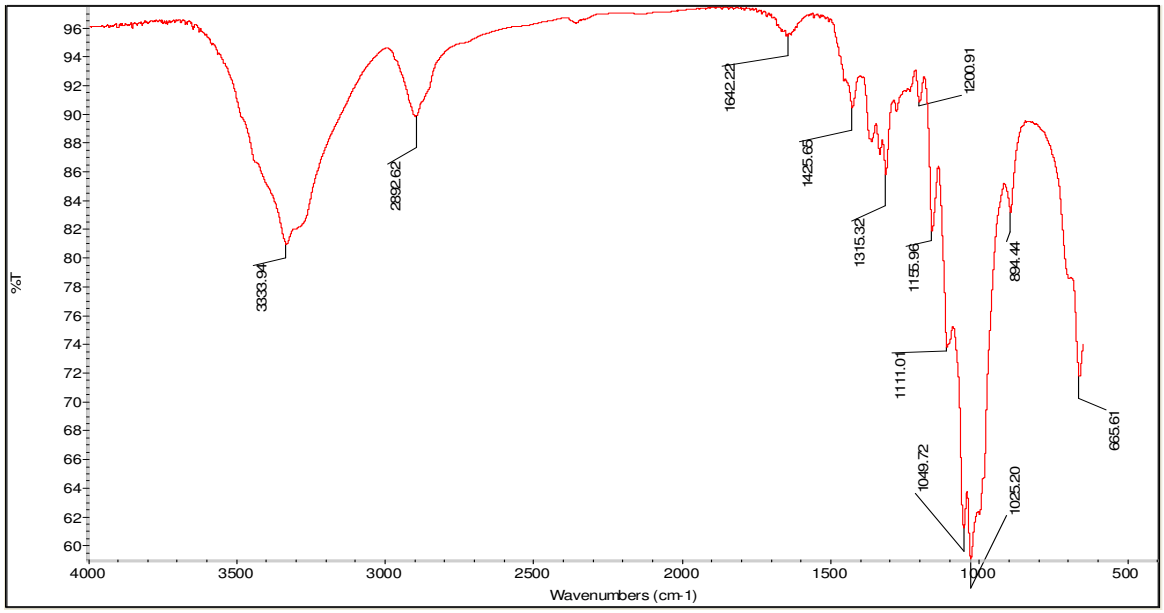

Figure-3
IR Characterization absorption peak of treated cotton fabric

Effect of nano silica on physical properties of cotton fabric: Changes in physical properties of nano silica loaded cotton fabric was evaluated in terms of tensile strength, tearing strength, crease recovery angle and bending length and compared with the untreated cotton fabric.

Tensile strength: The results given in Table 2 shows that the introduction of silica nano particles into the structure of the fibre cause an improvement in the load bearing capacity of the fibre, irrespective of method used for application. However, exhaust method performed better in terms of tensile strength compare to the pad-dry- cure method.

Table-2
Tensile strength of pure and nano silica treated cotton fabric

Concentration of silica (gpl)	Tensile Strength (kgf)			
	Warp way		Weft way	
Exhaust method	**Bre.load(kgf)**	**Extension(mm)**	**Bre.load(kgf)**	**Extention(mm)**
Nil	53.95	20.71	37.63	23.68
1	54.54	21.43	38.05	26.11
2.5	56.68	24.64	39.97	37.53
5	59.09	25.17	42.13	40.78
Pad-dry-cure method				
Nil	53.98	20.71	37.62	23.68
1	54.19	21.13	38.10	26.10
2.5	55.78	23.88	39.16	33.16
5	58.11	24.79	41.21	38.13

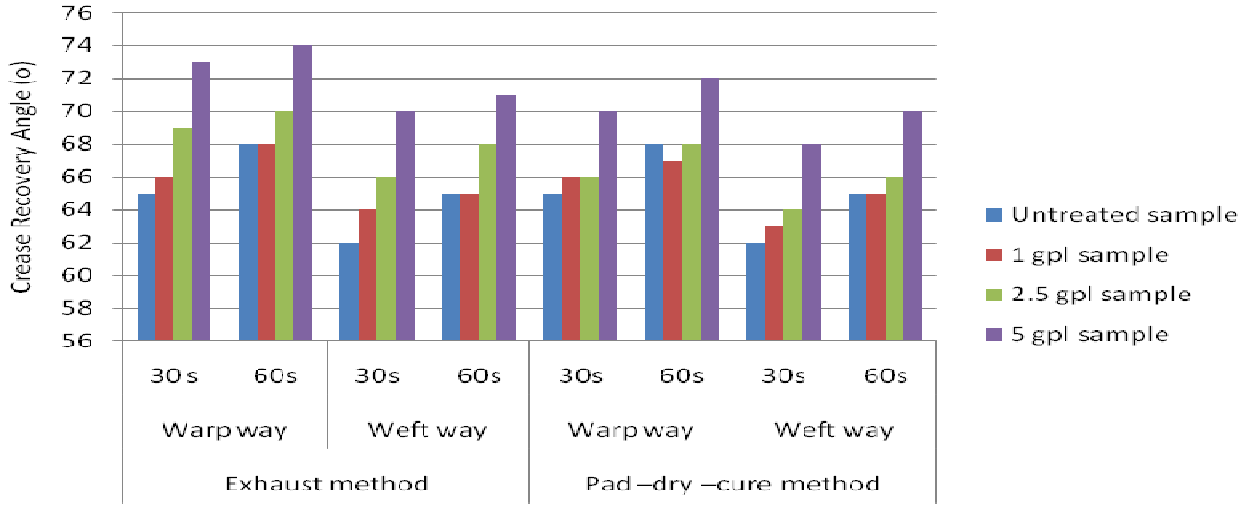

Figure-4
Crease recovery angle of nano silica treated and untreated cotton fabric

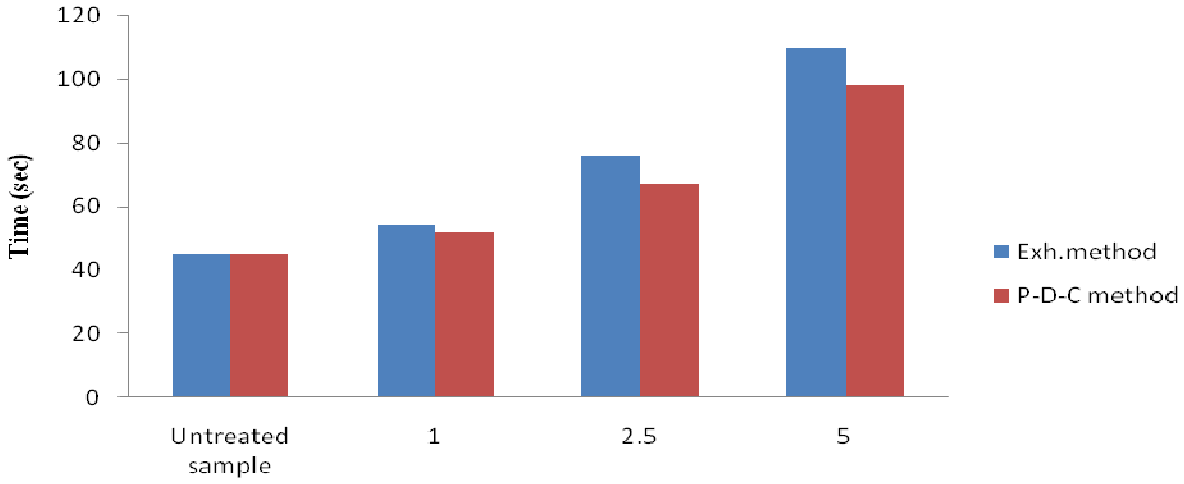

Figure-5
Effect of nano silica on water absorbency of cotton fabric

Tearing strength: The composite cotton/nano silica fabric shows minor improvement in tearing strength compare to pure cotton fabric as seen from Table 3. The increase in concentration of silica nano particle gives better result in exhaust method compared to pad-dry-cure method. This may be attributed due to the small size of silica nano particles; it can enter in between the polymer molecules and perhaps act as filler or cross linking agent which also contributes to the load sharing phenomenon during load application to the material.

Effect of nano silica on crease recovery angle of fabric: There was little improvement in the crease recovery angle which proves that the particle penetrated in between the polymer chain molecules, do not interfere much to the polymer flexibility. Results given in Figure 4 indicates that the crease recover properties of fabric improves with increase in the concentration of silica nano particle and was found better in exhaust method compare to pad-dry-cure method. From the results it can also be seen that the incorporation of nano silica particle improves crease recovery angle without imparting rigidity to the fabric.

Effect of nano silica on water absorbency of cotton fabric: Figure 5 shows the time required for the absorption of water into fabric sample evaluated by drop test. It can be seen from the figure that the absorbency of cotton/ nano silica nano composite fabric was reduced compare to the pure cotton fabric. The absorbency was further reduced with the increase in the concentration of nano silica in cotton fabric. The exhaust method of application of nano silica to cotton fabric shows the lower absorbency as compare to pad-dry-cure method.

Effect of nano silica on water permeability of cotton fabric: Water permeability of nano silica loaded cotton fabric and pure cotton fabric is given in Table 4. The results show that the water permeability of nano silica loaded cotton was found less compared to the pure cotton fabric. The reduction in water permeability in nano silica loaded fabric may be attributed due to the presence of nano silica particles in polymer matrix which resists the flow of water through the fabric. Further, increase in the concentration of nano particles in polymer matrix, decrease the permeability of water. Out of two methods used for the loading of nano silica particles to cotton fabric, the exhaust method has reduced the water permeability to greater extent compare to the pad-dry-cure method.

Effect of nano silica on air permeability of cotton fabric: Air permeability of cotton loaded with nano silica and pure cotton is shown in Table 5. From the results it can be seen that the air permeability of nano loaded cotton was found lesser than the pure cotton sample. This may be due to the penetration of silica nano particles into the amorphous region of cotton fabric, obstructing the air flow.

Table-3
Tearing strength of pure and nano silica loaded cotton fabric

Concentration of silica (gpl)	Tearing Strength (gf)			
	Exhaust method		Pad-dry-cure method	
	Warp way	Weft way	Warp way	Weft way
Nil	1472	1122	1472	1122
1	1475	1156	1470	1124
2.5	1488	1162	1478	1150
5	1510	1178	1496	1180

Table-4
Water permeability of cotton fabric

Concentration of nano silica (gpl)	Ψ-Water Permeability (S^{-1})	
	Exhaust method	P-D-C method
Nil	0.3579	0.3579
1	0.3405	0.3411
2.5	0.3102	0.3208
5	0.2870	0.3010

Table-5
Air permeability of cotton fabric

Samples	Air permeability ($m^3/h/m^2$)	
	Exhaust method	P-D-C method
Pure cotton	671.66	671.66
Cotton/(1 gpl) nano silica	601.17	623.14
Cotton/(2.5 gpl) nano silica	556.79	587.79
Cotton/(5 gpl) nano silica	505.89	560.70

Conclusions

In-house synthesized nano silica powder was successfully applied to cotton fabric by both exhaust and pad-dry-cure method. The exhaust technique performs better than the pad-dry-cure technique which was further confirmed from SEM micro photographs of treated cotton samples. The presence of silica is confirmed by the FTIR spectrum of treated cotton fabric. The tensile strength, tearing strength and crease recovery angle was found improved in nano silica loaded cotton fabric compare to the pure cotton fabric. The absorbency, water permeability and air permeability of nano silica loaded cotton fabric was reduced with increase in the concentration of nano silica in cotton fabric.

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