Research Article

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Effect of copper sulphate on hydrogen peroxide bleaching with hydrolysis on p/c fabric mechanical properties

Abstract

Surface modification of polyester and Polyester/Cotton material is not a new concept to a processing man. Alkaline oxidation of P/C blends with copper sulphate, hydrogen peroxide and base hydrolysis has shown some interesting trends. The present work includes the investigation of effect of padding copper sulphate (3 levels) and bleaching with hydrogen peroxide followed by base hydrolysis (2% concentration) at 1:5 and 1:10 MLRs with treatment temperature selected at 110 and 120 degrees centigrade on fabric mechanical properties like tensile strength, bending length, crease recovery and compressibility. In general it is observed that following copper sulphate treatment the weight increases, and decreases after bleaching. Due to the action of caustic, substrate suffers from loss of weight due to removal of chains from surface by NaOH. With increase in bath ratio (w/v) and concentration of copper sulphate, an increase in weight after copper sulphate treatment is observed, followed by decrease in weight after bleaching and loss of weight following hydrolysis. The increase in weight with increase in copper sulphate concentration is mainly due to padding. The results clearly show a positive shift following alkaline oxidation and hydrolysis from gray level. Higher bath ratios with higher hydrolysis temperature have registered a positive shift by about 30%.Decrease in bending length following bleaching and base hydrolysis has indicated the softness of the substrate. At higher bath ratio and hydrolysis temperature, as copper sulphate concentration increases, nearly 20% positive shift is observed in stiffness values. Due to alkaline oxidation and base hydrolysis with higher copper sulphate concentration at higher bath ratio and temperature, nearly 20% negative shift increase recovery values have proved that fabric has become softer following finishing. An excellent compression behavior is observed in bleached, hydrolysed samples. With increase in copper sulphate concentration the compressibility has registered an increasing trend with hydrolysed samples.

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Introduction

The popularity of P/C blends at various levels in different fields is the main reason behind the surface modification of P/C blends. In the present day P/C blends are mainly used for dress materials. To modify the surface, oxidation deweighting process experiments were carried out on P/C blended fabric. The cotton fiber is accessible to damage and easy to degrade in certain conditions after being oxidized. The metal ions in the fabric may accelerate the decomposition of hydrogen peroxide and damage the cotton fiber. Among metal ions, copper ranks first in catalyzing such decomposition. On the other hand research studies have confirmed that iron ions may form brown rusty spots on the fabric. If the padded fabric is oxidized by hydrogen peroxide before finishing, the copper ions would drift away from the fabric to the hydrogen peroxide solution, causing effective decomposition of hydrogen peroxide which does not contact the fabric. In oxidation deweighting, the hydrogen peroxide should decompose on the fabric as much as possible and oxidize the cotton fiber. Therefore the fabric is padded with copper sulphate and dried before oxidizing.

Gao Ming & Dong Ying[2] has studied alkaline oxidation of P/C blended poplin fabric. In their study the relation between deweighting ratio with copper sulphate and hydrogen peroxide is reported. Process parameters like bath ratio, treatment times and concentration of NaOH on deweighting ratio are also reported. Although a considerable work has been reported on the effect of alkaline oxidation on deweighting ratio of P/C blends, work on the effect of alkaline oxidation followed by base hydrolysis on fabric mechanical properties like tensile strength, bending length etc. is scanty in literature. Hence the thrust of the present investigation is to investigate the effect of alkaline oxidation followed by base hydrolysis for a suiting fabric on mechanical properties.

Materials and methods

Materials

The geometrical parameters of 67/33 P/C suiting fabric are as follows Ends/inch=68, picks/inch=58, count of warp and weft=2/40s T/C×2/40s T/C. The fabric was woven on ruti-c loom with 59.5” reed space. The chemicals used were of laboratory grade and were not purified further.

Methods

Copper, sulphate padding with 10%, 20% and 30% was carried out in sealed beakers at room temperature using laboratory model HTHP beaker dyeing machine and dried in oven Zeronian.[1] The pad-dried fabric samples were then bleached using hydrogen peroxide (30% volume) at 60-80 degrees temperature. The procedure followed was recommended by Gao Ming & Dong Ying.[2] The bleached samples were then base hydrolysed using 2% NaOH with 1:5 and 1:10 bath ratios (w/v) at 110 and 120 degrees for 30minutes. The purpose of using low liquor ration is on the concept of low liquor dyeing using HTHP machine. Table 1 shows the coding of fabric samples with roman II for bleached samples and roman I for hydrolysed samples, indicated throughout the experiment. The samples were washed with tap water to remove excess alkali, followed by neutralization with 0.5% acetic acid and finally washed in deionised water and dried in oven.

Table 1 Sample coding

Code	Copper sulphate concentration	NAOH concentration	Liquor ratio	Temperature (for hydrolysis)
10 C1	10%	2%	1:05	110Degrees
20 C1	20%	2%	1:05	110Degrees
30C1	30%	2%	1:05	110Degrees
10C2	10%	2%	1:05	120Degrees
20C2	20%	2%	1:05	120Degrees
30C2	30%	2%	1:05	120Degrees
10C3	10%	2%	1:10	110Degrees
20C3	20%	2%	1:10	110Degrees
30C3	30%	2%	1:10	110Degrees
10C4	10%	2%	1:10	120Degrees
20C4	20%	2%	1:10	120Degrees
30C4	30%	2%	1:10	120Degrees

Conditioning and testing

The finished samples were conditioned at standard atmospheric conditions RH 65+-2% and temperature 27+-2 degrees as per IS 6359-1971.

Determination of geometrical properties

Measurement of yarn linear density: Yarn count was determined as per IS1315 and an average of 10 measurements is reported.

Measurement of yarn crimp

The crimp of yarns unravelled from the test fabric was measured on Shirley crimp as per IS: 3442-1966. Measurements were taken in both warp and weft ways. The average was given in percentage using following formula.

$$\%\ Crimp\ =\ \left(L_2 - L_1\ /\ L_1\right)*100 \quad (1)$$

Where L_1=length of yarn in the fabric, L_2= stretched length of the yarn.

Determination of fabric GSM

GSM of the fabric samples was measured as per IS: 1964-1970. Fabric GSM was determined and the value reported is an average of measurements.

Determination of fabric thickness (Compressibility)

Fabric thickness was measured using Shirley thickness gauge as per the standard test method IS: 7702-1975. The result shown is an average of at least 10 random measurements. EMC of control and treated fabric samples are was determined using in Table 2:

$$EMC\left(\%\right) = \left(T_o - T_m\right) / T_o \times 100 \quad (2)$$

T_o =Thickness at 0.5gf/cm² T_m =Thickness at maximum load

Table 2 Effect on Compressibility

Sample	50 g	100g	150g	200g	250g	300g
Control	4	6	8	11	12	14
10C1 II	4.3	6.8	10.34	11.2	12.06	12.93
20C1 II	3.27	4.9	8.19	9.8	10.65	11.47
30C1 II	1.6	5.6	6.45	8.8	9.6	11.29
10C2 II	3.38	5.08	9.32	10.16	11.86	12.71
20C2 II	1.66	4.16	5.83	7.5	10.83	12.5
30C2 II	1.61	4.83	7.25	8.87	11.29	12.9
10C3 II	3.33	5.83	7.5	9.16	10.83	12.5
20C3 II	2.27	4.54	6.63	8.18	9.09	10.9
30C3 II	3.5	5.26	7.01	8.77	10.52	11.4
10C4 II	4.16	5.8	8.3	10.83	15	16.66
20C4 II	1.78	4.46	8.92	10.71	12.5	14.28
30C4 II	3.33	5	6.66	8.33	9.16	12.5
Hydrolysed samples	**3**	**4**	**7**	**9**	**12**	**13**
10C1 I	2.04	5.01	7.14	9.18	11.22	12.24
20C1 I	1.74	4.31	6.03	7.75	9.48	12.06
30C1 I	2.67	4.46	7.14	8.9	11.6	13.39
10C2 I	1.78	7.14	9.82	8.95	14.28	16.07
20C2 I	1.75	3.5	6.14	7.89	10.52	12.28
30C2 I	2.7	4.6	6.48	9.25	11.11	12.96

Table Continued...

Hydrolysed samples	3	4	7	9	12	13
10C3 I	1.78	4.46	6.25	8.03	9.82	11.6
20C3 I	1.85	3.7	6.48	8.33	11.11	12.03
30C3 I	1.92	3.8	6.7	8.6	11.53	13.46
10C4 I	1.96	3.9	5.8	7.8	9.8	10.78
20C4 I	2.8	5.6	7.5	9.43	10.37	11.32

Determination of fabric set

Fabric set of the samples was determined as per IS: 1963-1969. This parameter defined the average distance between two consecutive threads in a fabric. Ends per inch and picks per inch are measured using Densimeter. The average of 10 observations selected randomly is reported as the final value which is later converted to threads per inch and was expressed in inches.

Testing of mechanical properties

Measurement of fabric tensile strength: Tensile strength of control and finished samples were measured as per IS1969-1968 using universal testing machine. Table 3 shows the tensile strength of control, bleached and hydrolysed samples.

Table 3 Effect on Tensile Strength

Sample	Warp way		Weft way	
	Strength	% Shift	Strength	% Shift
Control	45.75	-	44	-
10C1 II	44	3.8	42	0.54
20C1 II	43	6.01	41	6.81
30C1 II	40	12.56	39	11.36
10C2 II	43	6.01	42	4.54
20C2 II	37	19.12	37.2	15.45
30C2 II	44	3.8	43	2.27
10C3 II	43	6.01	40	9.09
20C3 II	42	8.19	41	6.81
30C3 II	38	16.93	37	15.9
10C4 II	41	10.38	38	13.63
20C4 II	38	16.93	36	18.18
30C4 II	40	12.56	37	
Hydrolysed samples				
10C1 I	41	10.38	40	9.09
20C1 I	40	12.56	37	15.09
30C1 I	36.4	20.43	40	9.09
10C2 I	-	-	-	-
20C2 I	-	-	-	-
30C2 I	36	21.31	29.6	29.52
10C3 I	35.4	22.62	35	16.66
20C3 I	38	16.93	40	4.76
30C3 I	-	-	-	-
10C4 I	38	16.93	36	14.28
20C4 I	36	21.31	34	19.04

Measurement of bending length: Shirley stiffness tester working on cantilever principle was used and the average of 10 replications is reported in Table 4 for control, beached and hydrolysed samples warp and weft way. The procedure followed is as per IS6490-1971.

Measurement of crease recovery: Shirley crease recovery tester was used to measure crease recovery angle of control bleached and finished angles as per IS4681-1968. The results reported as the average of 5 observations are shown in Table 5.

Table 4 Effect on bending length

Sample	Warp way		Weft way	
	Bending length (cm)	% Shift	Bending length (cm)	% Shift
Control	1.7	-	1.6	-
10C1 II	1.51	11.17	1.38	13.75
20C1 II	1.61	5.29	1.55	3.12
30C1 II	1.66	2.35	1.36	15
10C2 II	1.5	11.76	1.53	4.37
20C2 II	1.51	11.17	1.36	15
30C2 II	1.61	5.29	1.36	15
10C3 II	1.55	8.82	1.46	8.75
20C3 II	1.5	11.76	1.36	15
30C3 II	1.51	11.17	1.41	11.87
10C4 II	1.61	5.29	1.48	7.5
20C4 II	1.43	15.88	1.36	15
30C4 II	1.52	10.58	1.45	9.3
Hydrolysed samples				
10C1 II	1.3	23.52	1.26	21.25
20C1 II	1.45	14.7	1.46	8.75
30C1 II	1.5	11.76	1.36	15
10C2 II	1.35	20.58	1.28	20
20C2 II	1.38	18.82	1.3	18.75
30C2 II	1.41	17.05	1.35	15.62
10C3 II	1.35	20.58	1.28	20
20C3 II	1.43	15.88	1.34	16.25
30C3 II	1.46	14.11	1.36	15
10C4 II	1.41	17.05	1.35	15.62
20C4 II	1.41	17.05	1.3	18.75

Table 5 Effect on Crease Recovery

Sample	Warp way		Weft way	
	Crease recovery (Angle)	% Shift	Crease recovery (Angle)	% Shift
Control	99.5	-	115	-
10C1 II	109.5	10.05	126.5	12
20C1 II	110	10.5	127	12.88
30C1 II	113.5	14.07	128.5	13.77
10C2 II	115.25	15.82	129.5	15.11
20C2 II	117.5	18.09	131.75	17.11
30C2 II	114.5	15.07	125	11.11
10C3 II	112.5	13.06	124	10.22
20C3 II	112	12.56	119.5	6.2
30C3 II	111	11.55	122	8.4
10C4 II	111.5	12.06	123	9.3
20C4 II	119	19.59	126	12
30C4 II	108	8.54	119	5.7
Hydrolysed samples				
10C1 II	111.5	12.06	128	13.77
20C1 II	113	13.56	129.5	15.11
30C1 II	118	18.59	132	17.33
10C2 II	116	16.58	129	14.66
20C2 II	119.5	20.1	131.5	16.88
30C2 II	122.5	23.11	133.5	18.66
10C3 II	120.5	21.1	131.5	16.88
20C3 II	124	24.62	134	19.11
30C3 II	125	25.62	135.5	20
10C4 II	121	21.6	132	17.33
20C4 II	120	20.6	131	16.44

Table 6a Weight loss of samples after each chemical treatment

Sample	% Increase in weight after copper sulphate treatment	% Decrease in weight after bleaching	% Decrease in weight after hydrolysis
10C1 I	5.4	5.4	6.2
10C1 II	5.09	5.13	-
20C1 I	8.4	6.34	6.3
20C1 II	6.2	5.01	-
30C1 I	8.6	6.66	5.52
30C1 II	9.07	7.02	-
10C2 I	4.8	4.9	7.5
10C2 II	4.6	3.9	-
20C2 I	5.7	4.8	7.1
20C2 II	5.6	4.3	-
30C2 I	5.8	3.8	8.4
30C2 II	5.4	3.66	-
10C3 I	6.2	6.2	5.64
10C3 II	4.08	4.3	-
20C3 I	9.7	8.3	5.22
20C3 II	9.7	8.7	-
30C3 I	11.07	9.1	6.57
30C3 II	12.97	10.95	-
10C4 I	15.3	13.28	9.05
10C4 II	7.1	5.8	-
20C4 I	12.8	7.6	9.93
20C4 II	6.7	6.5	-
30C4 I	14.05	7.8	9.07
30C4 II	14.36	7.5	-

Results and discussion

Effect on weight following each chemical treatment

Table 6a shows the increase in weight after copper sulphate treatment and decrease in weight after bleaching and hydrolysis. It is clear that with the increase in copper sulphate concentration the increase in weight is due to padding. On the other hand the increase in weight loss after bleaching, as the copper sulphate concentration is increased, may be due to the removal impurities and the action of hydrogen peroxide on cotton. Similarly the weight loss after hydrolysis is due to the action of caustic on polyester. A height weight loss of 9% is observed with 30% copper sulphate concentration at 120 degrees temperature. Table 6b high lights the % shift in the weight following each chemical treatment at 1:5 and 1:10 bath ratios. The % shift (positive and negative) in weight increases with increase in copper sulphate concentration. Trend is similar for bleached and hydrolysed samples. This may be due to the facts as explained above. The results are in concomitant with several researcher investigations.

Effect on tensile strength

From the literature scan, it is observed that following base hydrolysis the fabric loses 5-10% fabric strength. (Table 7a) (Table 7b) addresses the positive shift for bleached and hydrolysed samples at 1:5 and 1:10 bath ratios with 3 levels of copper sulphate concentration. It is clear from the table that % shift increases in all cases with increase in copper sulphate concentration. This is due to loss in tensile strength following bleaching and hydrolysis. Reduction in tensile strength of bleached and hydrolysed samples may be due to gradual removal of molecular chains from the structure. The results are in agreement with findings by Zeronian & Collin.[1]

Effect on warp and weft way bending length

The positive % shift in bending length values of warp weft at 1:5 and 1:10 bath ratios with increase in copper sulphate concentration for bleached and hydrolysed (110 and 120 degrees temperature) samples is reported in (Table 8a) (Table 8b). A general trend observed is that % shift reduces with increase in copper sulphate concentration for warp but follows an irregular pattern for weft. The shift in bending length may be due to loss of weight following base hydrolysis. The fall in bending length values has clearly shown that fabric has imparted soft feeling.

Effect on crease recovery

Tables 9a & 9b shows the average % shift (negative) increase recovery angle for bleached and hydrolysed samples in different conditions. With the increase in copper sulphate concentration and treatment temperature, the hydrolysed samples have shown larger crease recovery angles. This may be due to the fact that following weight loss, the fabric has become soft.

Effect on compressibility

Table 2 reports the EMC values for bleached and hydrolysed samples. It is observed that with increase in copper sulphate concentration, compressibility decreases for bleached samples. A reverse trend is observed in the case of hydrolysed samples.

Table 6b Effect of Chemical treatment

Copper sulphate concentration	Average increase in weight after copper sulphate treatment	Average decrease in weight after bleaching	Average decrease in weight after hydrolysis at temperature	
			110 degrees	120 degrees
For 1:5 bath ratio:				
10%	4.89	4.83	6.2	7.5
20%	6.47	5.11	5.52	8.4
30%	7.21	5.28	5.52	8.4
For 1:10 bath ratio:				
10%	8.17	7.39	6.3	7.1
20%	9.725	7.75	5.22	9.93
30%	13.112	8.83	6.57	9.07

Table 7a Average % Shift for tensile strength of bleached samples

Copper sulphate concentration	Warp way shift	Weft way shift
For 1:5 bath ratio:		
10%	4.905	4.54
20%	12.56	11.17
30%	8.17	6.81
For 1:10 bath ratio:		
10%	8.195	11.36
20%	12.56	12.49
30%	14.74	15.9

Table 7b Average % shift for tensile strength of hydrolysed samples-Effect of Temperature

Copper sulphate concentration	Warp way shift		Weft way shift	
	110 degrees	120 degrees	110 degrees	120 degrees
For 1:5 bath ratio:				
10%	10.38	-	9.09	-
20%	12.56	-	15.9	-
30%	20.43	21.31	9.09	29.52
For 1:10 bath ratio:				
10%	22.62	16.93	16.66	14.28
20%	16.93	21.31	15.9	19.04
30%	-	21.31	-	30

Table 8a Average % Shift for bending strength of bleached sampleS

Copper sulphate concentration	Warp way shift	Weft way shift
For 1:5 bath ratio:		
10%	11.465	9.06
20%	8.23	9.06
30%	3.82	15
For 1:10 bath ratio:		
10%	7.05	8.125
20%	13.82	15
30%	10.87	10.58

Table 8b Average % shift for bending length of hydrolysed samples (Temperature)

Copper sulphate concentration	Warp way shift		Weft way shift	
	110 degrees	120 degrees	110 degrees	120 degrees
For 1:5 bath ratio:				
10%	23.52	20.58	21.25	20
20%	14.7	18.82	8.75	18.75
30%	11.76	17.05	15	15.62
For 1:10 bath ratio:				
10%	20.58	17.05	20	15.62
20%	15.88	17.05	16.25	18.75
30%	14.11	11.76	15	21.87

Table 9a Average % Shift for crease recovery of bleached samples

Copper sulphate concentration	Warp way shift	Weft way shift
For 1:5 bath ratio:		
10%	12.935	13.55
20%	14.29	14.99
30%	14.57	12.44
For 1:10 bath ratio:		
10%	12.56	9.77
20%	16.075	9.11
30%	10.045	7.1

Table 9b Average % shift for crease recovery of hydrolysed samples (Temperature)

Copper sulphate concentration	Warp way shift		Weft way shift	
	110 degrees	120 degrees	110 degrees	120 degrees
For 1:5 bath ratio:				
10%	12.06	16.58	13.77	14.66
20%	13.56	20.1	15.11	16.88
30%	8.59	23.11	17.33	18.66
For 1:10 bath ratio:				
10%	21.1	21.6	16.88	17.33
20%	24.62	20.6	19.11	16.44
30%	25.62	25.62	20	19.11

Conclusion

It is clear from the above discussions that P/C blended fabrics can be imparted a soft silk like feeling following weight reduction by alkaline oxidation and base hydrolysis and the fabric will exhibit the following features.

a. The fabric is very sensitive to chemical processing like effect of Copper sulpahate, Bleaching and alkaline hydrolysis.

b. Improved Compressibility following finishing.

c. Higher crease recovery and lower bending length.

d. Acceptable strength loss.

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None.

Conflict of interest

Author declares there is no conflict of interest in publishing the article.

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