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Activated bleaching with sodium perborate and potassium persulphate

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Attempts have been made to use sodium perborate as a bleaching agent with potassium per sulphate as an activator at lower temperature in combined pre-treatment of cotton fabric. Experimental trials have been designed by using taguchi technique. The results obtained by using this modified bleaching process are compared with the conventional combined pre-treatment process. The findings indicate conservation of energy by 50% and that of water and process time by 30%. The whiteness index is also found to be higher than conventional combined pre-treatment process. Thus, the modified process fulfils the requirements of ecofriendly concept.

Keywords: Cotton fabric, Combined pre-treatment, Potassium persulphate, Sodium perborate, Whiteness index

The objective of bleaching is to produce white fabrics by decomposing the colouring matter with the help of bleaching agents with minimum degradation of the fibre[1]. The colour producing agents in natural fibres are often organic compounds containing conjugated double bonds. Decolouration can occur by breaking up the chromophore, most likely destroying one or more of the double bonds within the conjugated system[2]. There are two types of bleaching agents – reducing and oxidizing. Due to the concern for ecofriendliness, oxidative bleaching using hydrogen peroxide is practised on large scale commercially.

In conventional processing, every pretreatment such as desizing, scouring, bleaching is performed separately. Each pretreatment has to be followed by thorough washing to remove the impurities of the process and the extraneous chemicals causing large consumption of water and energy in addition to the time required to obtain bleached fabric. Conventional hydrogen peroxide bleaching is carried out at 85-90°C for 4 h at alkaline *p*H between 10 and 11 using sodium silicate as a stabilizer. Sodium silicate is non-ecofriendly and it gives harsh feel to the bleached cotton material. The consumption of water is about 40 L/kg, which is considerably high. The requirement of energy in the form of steam is also more (2.5 kg/kg of fabric)[3]. Due to rapid increase in cost of energy, the research is focussed on low temperature applications or combining the pretreatment processes.

Combined scouring and bleaching process is now more common for cotton and cotton blends. But whiteness may be little inferior than sequential scouring and bleaching process. Time required for combined process is nearly 4-6 h in batch process.

Sodium perborate is a white, odourless, water-soluble powder. The monohydrate and tetrahydrate are the commercially important forms, of which the former dissolves better and has higher heat stability. Sodium perborate undergoes hydrolysis in contact with water, producing hydrogen peroxide and borate[4].

In this study, potassium persulphate (PPS) has been used as an activator in bleaching with sodium perborate. The effect of temperature, time and concentrations of sodium perborate, PPS and NaOH on whiteness of treated fabrics is studied by using taguchi analysis. The quality of bleached fabric is assessed by evaluating whiteness index, strength loss, carboxyl group content and copper number of the treated cotton and the results are compared with conventional combined pre-treatment process.

Experimental

Materials

The 62 × 60 plain woven greige 100% cotton fabric having 156 g/m^2 was used for the experiments. Both warp and weft yarns were of 20s count. The specifications of cotton fabric used are given below:

Parameter	Value
Tensile strength	
Warp wise	:45.57 kgf
Weft wise	:36.89 kgf
Tearing strength	
Warp wise	:1344.15 gmf
Weft wise	:1545.66 gmf
Whiteness index (CIE)	:14.75

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Laboratory grade reagents sodium perborate and potassium per sulphate obtained from Loba Chemicals were used as bleaching agents and activator respectively. Sodium hydroxide (LR), procured from Fisher Cheimicals, was used as alkali for the study. Besides, magnesium sulphate (LR) procured from Merk (I) Ltd was used to maintain water hardness.

Methods

Low temperature combined scouring and bleaching was carried out on mill grey cotton fabric (amount of fabric 10 g) in the laboratory using ' Mathis Labomat'(high temperature high pressure beaker machine), keeping material-to-liquor ratio 1:20. After this treatment, fabric samples were rinsed with fresh water and dried in air. Similar experiment using conventional process was also conducted for comparison. Both the processes are explained below:

(i) Conventional Process

Processing steps are given below:

Mill grey fabric ⟶ Conventional scouring & bleaching ⟶ Hot wash ⟶ Cold wash ⟶ Cold wash

The conventional recipe comprises 3 vol. hydrogen peroxide, 2.5 % (owf) sodium hydroxide, 0.5 % (owf) emulsifier, 0.5% (owf) soap, 3g/L stabiliser- sodium silicate, 90°C temperature and 4 h time.

(ii) Modified Process

Mill grey fabric ⟶ Modified scouring & bleaching ⟶ Hot wash ⟶ Cold wash ⟶Cold wash

The parameters used for quality assurances are given in Table 1. To find out optimum combination for best results, Taguchi analysis was carried out using Minitab 13 statistical data software. Twenty-five different recipe formulations were selected. The details of the recipes are shown in Table 2.

Testing and Analysis

Sodium perborate undergoes hydrolysis in the presence of water, producing hydrogen peroxide and borate as indicated in the following reaction[5] :

$$\underset{\text{(Sodium perborate tetrahydrate)}}{NaBO_3.4H_2O} \rightarrow \underset{\text{(Sodium metaborate)}}{NaBO_2} + \underset{\text{(Hydrogen Peroxide)}}{H_2O_2} + 3H_2O \quad \ldots(1)$$

The molecular weight of sodium perborate is 154. As per Eq. (1), 154 parts of sodium perborate are equivalent to 34 parts of hydrogen peroxide. Residual sodium perborate content in the bleach bath was calculated by potassium permanganate titration method using the following formula:

$$H_2O_2\left(\frac{g}{L}\right) = \frac{0.0017 \times A \times 1000}{V}$$

where A is the burette reading of 0.1N $KMnO_4$; and V, the volume (mL) of the sample taken. Similar

Table 1 – Parameters for quality assurance

Parameter	Value
Sodium perborate , g/L	5, 10, 15, 20, 25
Sodium hydroxide, g/L	5, 10, 15, 20, 25
Potassium per sulphate (activator), g/L	0.5, 1.0, 1.5, 2.0, 2.5
Temperature, °C	80, 90, 100, 110, 120
Time, h	1, 2, 3, 4, 5

Table 2 — Taguchi analysis chart

Recipe No.	Sodium perborate g/L	Potassium persulphate g/L	NaOH g/L	Temp. °C	Time h
R 1	5	0.5	5	80	1
R 2	5	1	10	90	2
R 3	5	1.5	15	100	3
R 4	5	2	20	110	4
R 5	5	2.5	25	120	5
R 6	10	0.5	20	90	3
R 7	10	1	25	100	4
R 8	10	1.5	5	110	5
R 9	10	2	10	120	1
R 10	10	2.5	15	80	2
R 11	15	0.5	10	100	5
R 12	15	1	15	110	1
R 13	15	1.5	20	120	2
R 14	15	2	25	80	3
R 15	15	2.5	5	90	4
R 16	20	0.5	25	110	2
R 17	20	1	5	120	3
R 18	20	1.5	10	80	4
R 19	20	2	15	90	5
R 20	20	2.5	20	100	1
R 21	25	0.5	15	120	4
R 22	25	1	20	80	5
R 23	25	1.5	25	90	1
R 24	25	2	5	100	2
R 25	25	2.5	10	110	3

method was used for estimating residual hydrogen peroxide content in bleach bath. Whiteness indices of bleached samples were measured on Konica Minolta 3600d spectrophotometer by using CIE formula, D-65 light source and 10° observer.

Tensile strength of greige as well as bleached fabric samples was measured both in warp and weft directions by using ASTM-D- 5035 (1995) method on Instron tensile tester (Model No. 5565). Tearing strength of greige as well as bleached fabric was measured both in warp and weft way by using IS - 6489 (1971) method on Instron tensile tester (Model No. 5565).

Carboxylic group content of the samples was determined by IS: 1560 – 1974 (Reaffirmed 1999). Copper number of the cotton fabric bleached by modified and conventional process was determined by IS: 200: 1989 method. Wettability of bleached fabrics was measured by IS: 2349: 1963 standard method.

Results and Discussion

Taguchi analysis is a systematic and efficient approach for determination of optimum experimental configuration of design parameters for performance, quality, and cost[6]. Experiments were carried out on greige cotton fabrics by exhaust method in the laboratory using recipes as given in Table 2. The effect of parameters like temperature, time and concentrations of NaOH, PPS and perborate on weight loss, whiteness index, tensile strength, tearing strength, carboxylic group content and copper number is shown in Figs 1 and 2.

From the general linear model analysis of weight loss percentage, it is observed that the concentrations of sodium perborate, PPS and time have no significant effect on weight loss. In case of temperature, as the temperature increases up to 100°C, the weight loss decreases. However, with further increase in temperature up to 120°C, the weight loss increases. The weight loss of modified pre-treatment process is, however, found to be the same as for conventional combined pre-treatment process.

Up to 20 g/L concentration of sodium perborate, the whiteness index increases, which decreases slightly thereafter. Thus, the concentration of sodium perborate has significant effect on whiteness. Samples bleached with recipes from R 7 to R 25 show higher whiteness as compared to conventional combined pretreatment process. This can be attributed to alkaline treatment of samples for more time.

It is observed that 12% loss in tensile strength occurs in warp way and 24% loss in weft way direction. Warp tensile strength initially decreases for 2 h time of treatment, after which it is increased with an increase in time. There is no significant effect of NaOH and sodium perborate concentrations on weft way strength. Warp and weft tensile strength loss of modified process is observed to be nearly same as that for conventional pre-treatment. Tensile strength (warp way) after conventional treatment is found to be 40.19 kgf and that of weft way is 28.12 kgf.

Also, 17% loss in warp way and 15% loss in weft way tearing strength is observed. As the concentrations of NaOH and PPS are increased, the warp tearing strength is increased. Warp tearing strength decreases with increase in concentrations of sodium perborate and time. As the concentrations of NaOH and sodium perborate increase, the weft tearing strength is decreased. Warp and weft tearing strength loss is observed to be lower than conventional bleaching process. Tearing strength (warp way) after conventional treatment is found 1115.70 gmf and that of weft way is 1313.94 gmf.

The carboxylic group content is increased up to 15, 1.5, 15 g/L concentrations of NaOH, PPS and sodium perborate respectively and 100°C temperature. The carboxylic group content decreases with increasing time upto 3 h and it is found to be marginally higher than that of conventional bleaching process; carboxylic group content of conventional treated sample is found 4.7.

Copper number increases with increase in concentrations of NaOH and PPS. With increase in time, copper number is constant upto 4 h and then it decreases. Increase in concentration of sodium perborate from 5 g/L to 10 g/L decreases the copper number, which remains constant thereafter. Copper number of modified process bleached samples is found to be lower as compared to conventional bleaching process; copper number of conventional treated sample is 0.004.

Residual content of sodium perborate, as decomposed into peroxide in bleach bath, decreases with increase in concentration of sodium perborate and treatment temperature. It is marginally lower as compared to peroxide bleaching. Wettability of bleached samples is found identical (1.3 s) both in modified and conventional combined process.

Trial is also done by using recipe R 10 where instead of perborate, hydrogen peroxide is taken

as bleaching agent keeping all other parameters constant and it is observed that CIE whiteness index of perborate bleached sample is better than in peroxide bleaching. Peroxide treated sample shows 64 CIE whiteness, whereas 67 is shown by perborate treated sample. This may be due to rapid decomposition of peroxide in bleach bath wherein stabilizer is not used.

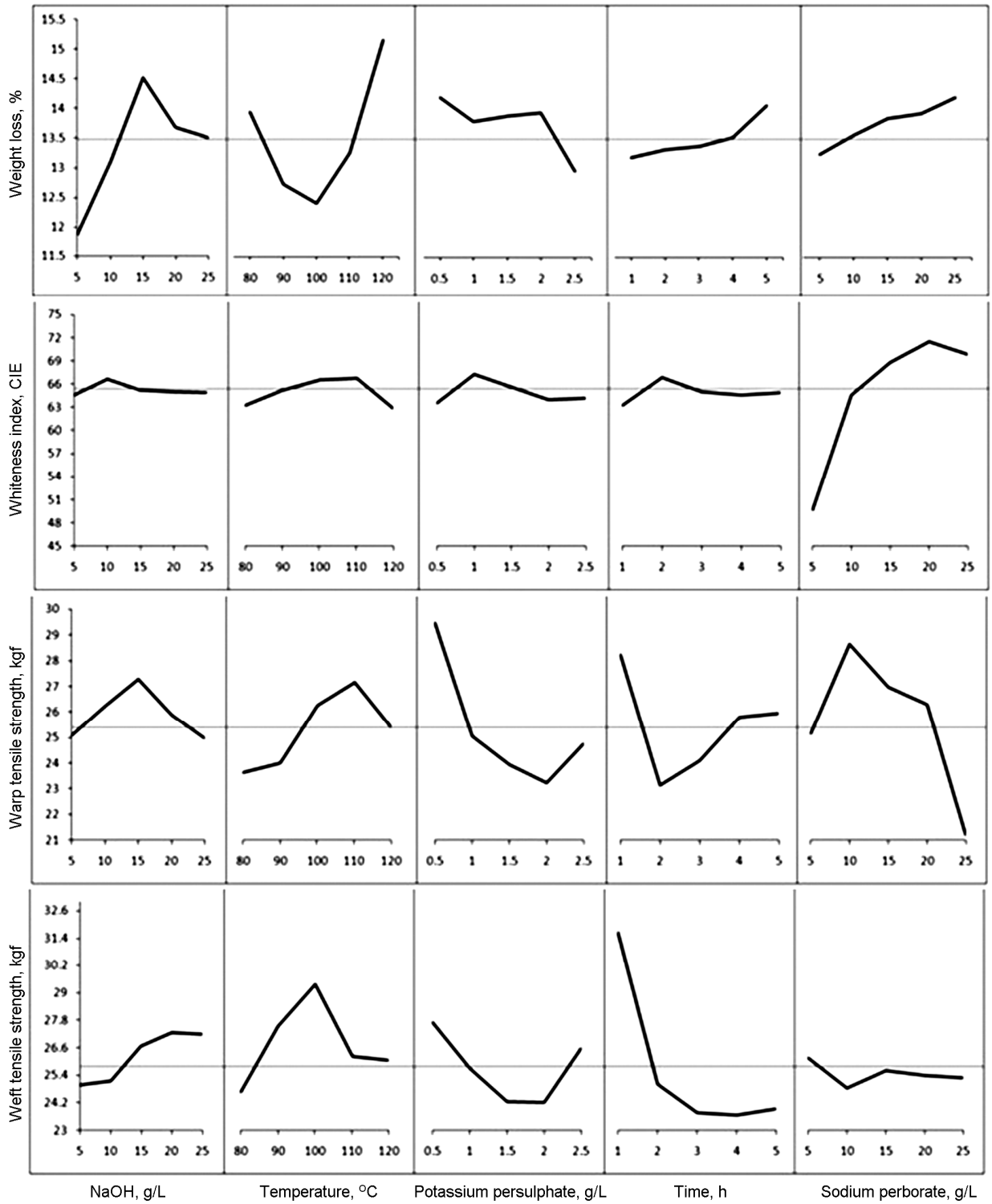

Fig. 1 —Effect of treatment conditions on tensile strength, whiteness index, and weight loss of fabric (Main effect plots data mean values)

The modified combined pre-treatment process using PPS as an activator along with sodium perborate as an oxidizing gent has proved to be efficient in giving results at par with the conventionally combined pre-treatment process, wherein peroxide is used as bleaching agent. Modified process can conserve 50% energy and time as well as 30% saving of water. Also, the

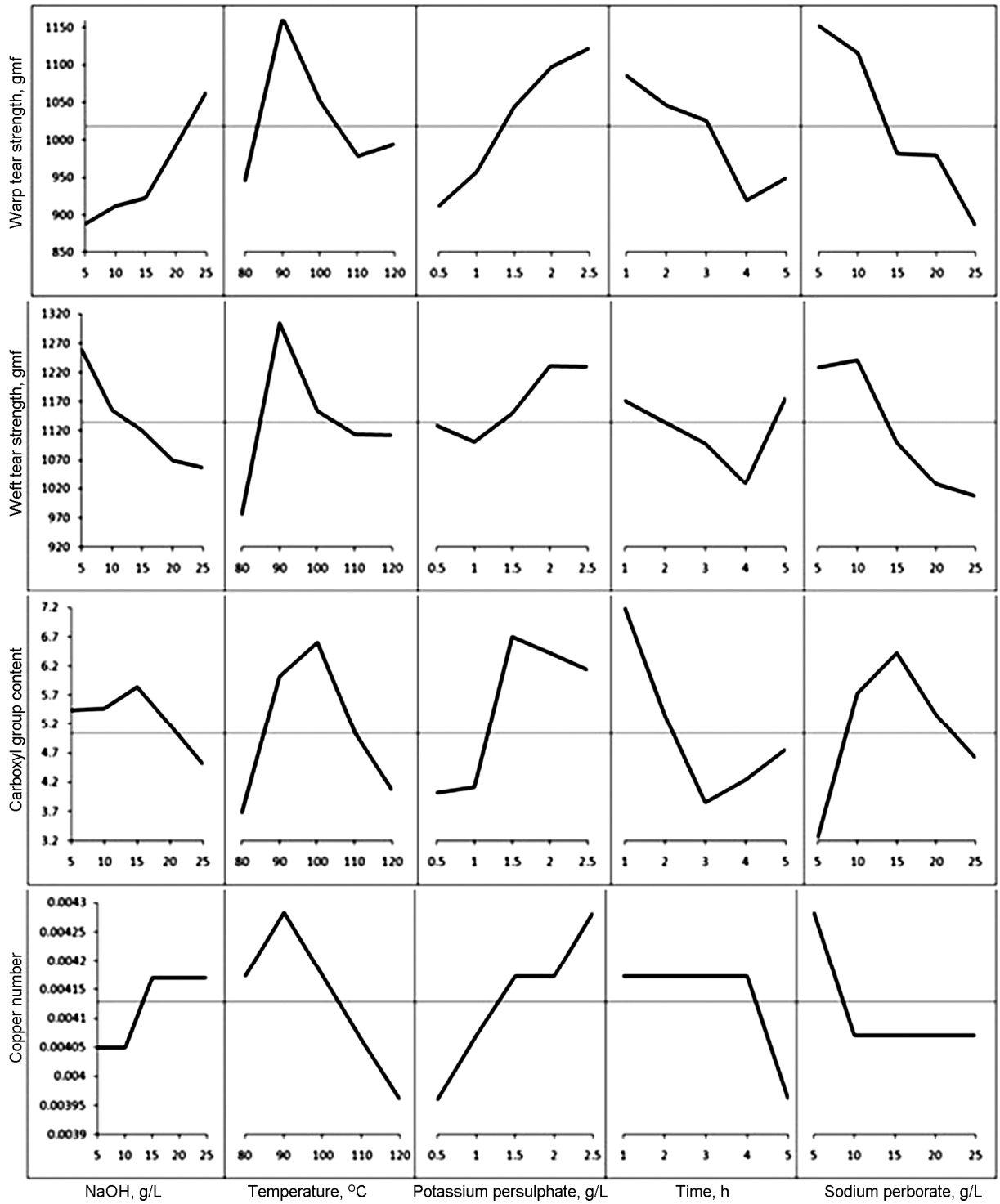

Fig. 2 — Effect of treatment conditions on copper number,carboxyl group content and tear strength of fabric (Main effect plots data mean values)

effluent load is reduced as compared to conventional combined bleaching process. It can be concluded that in the modified process, the utilization of active species that are responsible for bleaching action is better as compared to conventional peroxide bleaching.

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