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Original Article

Impact of single and mixed alkali for reactive black shade production

A. T. M. Gulam Moula[1]*, Md. Shafayet Arefin[1], Rijon Saha[2], Md. Ariful Islam[1], Asim Kumar Roy[1], Md. Reazus Salehin Bosunia[1], Md. Abdullah Al Mamun[1], Md. Abu Bakar Siddiquee[1]

[1]Department of Textile Engineering, Mawlana Bhashani Science and Technology University, Santosh, Tangail - 1902, Bangladesh, [2]Department of Textile Engineering, Uttara University, Dhaka, Bangladesh

ABSTRACT

The presence of alkali during dyeing of cotton fabric with reactive dyes is essential to maintain the dye-bath condition for the proper fixation of dye. The present work deals with the reactive dyeing for producing black deep shades for cotton knit fabric. In this study, the effects of using single alkali (soda ash) and mixed alkali (soda ash + sodium hydroxide) were compared in terms of lightness difference (DL*), fabric strength, color strength, and fixation% for 5, 7, 9, and 12% shade depth. Spectrophotometer analysis was conducted and lightness difference and fixation at different shade % were determined using computer color matching system. If mixed alkali is used instead of single alkali to upraise the pH of the dye bath then it increases the color strength, fixation% and forms darker shade. In additional mixed alkali reduces the fabric bursting strength to a little extent.

Keywords: Color strength, cotton dyeing, fixation percentage, lightness difference, soda ash, sodium hydroxide

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INTRODUCTION

Cotton is the most valued cash crops among the fiber arena due to its remarkable aesthetic properties and customized features to create new product variety due to its cellulosic purity of 95–98% and lower lignin %.[1] It is a very resourceful fiber and plant. Cotton can be used in many aspects of everyday life especially for garments making.[2] Textile dyeing is a complex process because sometimes it is difficult to match the quality parameters required by the buyers despite having modern colorimetry system.[3] According to a study, several attempts were made to apply dyes on cellulosic fibers. The dye ability of cellulosic fiber depends on the dielectric constant of nonpolar solvent.[4]

Reactive dyes are broadly used in textile industries to dye the cellulosic fibers. Reactive dyes are adsorbed on cellulose and then create bonding with the fibers.[5]

For dyeing of cotton fabric, reactive dyes are used very commonly by the textile industries. Their popularity in cotton dyeing results because of having good color fastness and a wide range of shade can be produced.[6]

As the demand for reactive dyes have grown rapidly, different technical problems has been emerged regarding reproducibility of shades. To obtain the best conditions for reactive dyeing of cotton fiber, it is required to find the connections between the dyes and the auxiliaries that are used in dyeing.[7] For example, dyeing of dark shades requires a higher amount of alkali. Researches show that the required amount of sodium carbonate to be added can be as high as 10–20 g/l. Usually, there is a practice of adding any alkali to the dye bath in solution form for mixing in the dye bath in a uniform manner.[8] Researches have been done on reactive black shade previously, where the dyeing process was conducted and the properties like color build-up was evaluated by value of the color strength (K/S value) and dye fixation rate.[9]

Reactive dye bears reactive system which forms a covalent bond with the hydroxyl or amino group of the substrate.

Address for correspondence: A. T. M. Gulam Moula, Department of Textile Engineering, Mawlana Bhashani Science and Technology University, Santosh, Tangail - 1902, Bangladesh. E-mail: gulammoula35@yahoo.com

Table 1: Recipe for dyeing of fabric samples

Dyes and chemicals	For 5% shade	For 7% shade	For 9% shade	For 12% shade
Reactive dyes (% owf)	5	7	9	12
Wetting agent (g/l)	1	1	1	1
Leveling agent (g/l)	1	1	1	1
Anti-creasing agent (g/l)	1	1	1	1
Salt (NaCL) (g/l)	50	50	50	50
Single alkali (Soda ash) (g/l)	20	20	20	20
Mixed alkali (soda ash + caustic soda)	Mix 1: 5 g/l Na_2CO_3 and 1.5 g/l NaOH	Mix 1: 5 g/l Na_2CO_3 and 1.5 g/l NaOH	Mix 1: 5 g/l Na_2CO_3 and 1.5 g/l NaOH	Mix 1: 5 g/l Na_2CO_3 and 1.5 g/l NaOH
	Mix 2: 5 g/l Na_2CO_3 and 2 g/l NaOH	Mix 2: 5 g/l Na_2CO_3 and 2 g/l NaOH	Mix 2: 5 g/l Na_2CO_3 and 2 g/l NaOH	Mix 2: 5 g/l Na_2CO_3 and 2 g/l NaOH
	Mix 3: 2.5 g/l Na_2CO_3 and 1.75 g/l NaOH	Mix 3: 2.5 g/l Na_2CO_3 and 1.75 g/l NaOH	Mix 3: 2.5 g/l Na_2CO_3 and 1.75 g/l NaOH	Mix 3: 2.5 g/l Na_2CO_3 and 1.75 g/l NaOH
Time (min)	60	60	60	60
Temperature (°C)	60	60	60	60

This reactive group enhances the fixation in elevated P^H condition and cellulosate ion (Cell-O^-) is the reaction initiator between cellulose and dye by nucleophilic addition reaction. Practically it is found that dyeing temperature and P^H value increase with the reactivity of the reactive group and vice–versa.[10] Naturally dyeing belongs in three ages. First one is dissolution, second one is adsorption and finally penetration and diffusion.[11] Reactive dyes have a fixation rate of 60–90% in a regular dyeing process and large amount of water is needed for dyeing and wash off.[12] 45% of cellulosic fibers are dyed with reactive dyes.[13] Reactive dyes react with the cellulosic fibers in the presence of alkali to form a strong covalent chemical bond between a carbon atom of the dye molecule and an oxygen atom of the hydroxyl group in the cellulose. Fixation levels for reactive dyes, when doing deep dyeing, can be as high as 70%. If the fixation% is increased, then the dyeing cost will be reduced. For reactive dye fixation the pH requirement would around 10.5–11.5.[14] In this study, pH of the dye bath after alkali dosing was measured. The reflectance value of individual specimen for the wave length of 400 nm–700 nm with 10 nm intervals was found. Using this reflectance value into the Kubelka Munk`s equation the color strength (K/S) value can be obtained.[15]

In this research work, impact of single alkali (soda ash) and mixed alkali (soda ash and caustic soda) are analyzed based on color strength, fabric strength, lightness difference and fixation % for 5%, 7%, 9%, and 12% reactive black shade. Here Darker black shade, better color fixation, improved color strength, and nominal reduction in bursting strength are observed as a result of using single alkali (soda ash) [Table 1].

MATERIALS AND METHODS

Materials

Fabric sample

About 100% cotton scoured and bleached, single jersey knitted fabric made from 24 Ne yarn with an areal density of 180 GSM was used in this research.

Dyes and chemicals

The mentioned chemicals such as: NOVACRON® Super Black R (dye), ALBATEX® DBC (levelling agent), Glauber's salt (Na_2SO_4.10 H_2O), soda ash (Na_2CO_3), caustic soda (NaOH), acetic acid, and ERIOPON®R LIQ (soaping agent) were used for this work.

Methods

This study deals with the fixation of reactive dyes in exhaust method using single alkali and mixed alkali. Soda ash was used as single alkali and soda ash + sodium hydroxide was used as mixed alkali.

Scoured and bleached fabric were dyed with only NOVACRON® Super Black R and the amount of using glauber's salt as electrolyte was taken from the technical data sheet of dye supplier. This study works with 5%, 7%, 9%, and 12% shade. At first 5% shade was produced using single alkali (the amount of soda ash was taken from the technical data sheet of dye supplier) and then three sample of 5% shade is produced using mixed alkali of its 3 volumetric combination. Mix_1 = 5g/l Na_2CO_3 and 1.5g/l NaOH, Mix_2 = 5 g/l Na_2CO_3 and 2g/l NaOH, and Mix_3 = 2.5 g/l Na_2CO_3 and 1.75 g/l NaOH. Then four dyed sample for 5% shade were gone for spectral analysis with spectrophotometer and SD is compared with M1, M2, and M3. Here, SD = Dyed sample where only soda ash is used to upraise the pH; M1 = Dyed sample where mixed alkali (Mix_1 = 5 g/l Na_2CO_3 and 1.5 g/l NaOH), M2 = Dyed sample where mixed alkali (Mix_2 = 5 g/l Na_2CO_3 and 2 g/l NaOH), and M3 = Dyed sample where mixed alkali (Mix_3 = 2.5 g/l Na_2CO_3 and 1.75 g/l NaOH). In the same way dyed samples are compared for 7%, 9%, and 12% shade in terms of dye fixation and the best-mixed alkali (among M1, M2, and M3) is chosen. Then SD is compared with chosen one (among M1, M2, and M3) in terms of color strength, fixation%, lightness value (measured using spectrophotometer), and bursting strength (Test method: ASTM D 3786, using hydraulic diaphragm bursting strength tester). To determine the fixation % the dyed fabric was cut into two pieces. After dyeing, one piece was left in open air and other pieces were neutralized with acetic acid, cold rinsed for 10 min, treated with 2 g/l ERIOPON®R LIQ (anionic surfactant agent; Huntsman, UK) at 98°C for 30 min' hot wash was done for 10 min and then dried in open air. The lightness difference, $DL^* = L^*_{trail} - L^*_{standard}$ was measured. In this study, SD of 5% shade was taken as standard and M1, M2, and M3 of same shade % were taken as trail to get DL*. Same process was followed for 7%, 9%, and 12% shade. All samples for this test have gone through the dyeing and after treatment process. DL* was measured directly with the Datacolor 600® spectrophotometer. Comparing among the three combinations in terms of lightness, one alkali combination was selected for comparison with single alkali. It can be noted that, the amount of soda ash or mixed alkali is not increased with the increasing shade percentage and the electrolyte was also same for 5%, 7%, 9%, and 12% shade. The recipe for dyeing of fabrics with various combinations of alkali along with other auxiliaries is given below.

RESULTS AND DISCUSSION

Lightness Difference (DL*) Analysis

In Figure 1, all the result of DL* is negative. It means M1, M2, and M3 are darker than SD. In case of black dyes, darker means more dyes were fixed with the fiber. In case of M1, it makes an arc and for 5% shade, it was much darker. In case of M2, the lightness difference (DL*) for 7%, 9%, and 12% shade was highest. It means it was darker than SD for 7%, 9%, and 12% shade. For M3, darkness gradually increased for 5%, 7%, and 9% shade, but for 12% shade it was slightly less. From this figure, in comparison among M1, M2, and M3 it could be said that M2 produce much darker shade than SD.

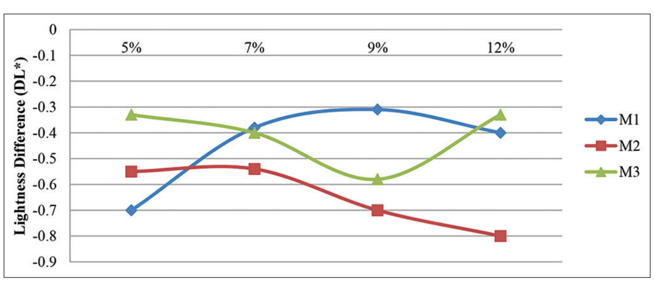

Figure 1: Lightness difference (DL*) of M1, M2, and M3 for 5%, 7%, 9%, and 12% shade. [SD was taken as standard for their respective shade % and D65 10 Deg was used as illuminant.]

Bursting Strength Result

Figure 2 shows that, the dyed sample had lower bursting strength than the undyed sample. Alkali has reduced the bursting strength of the sample. The bursting strength of SD was higher than M1, M2, and M3. It means mixed alkali had decreased the bursting strength more than the single alkali.

Color Strength (K/S) Analysis

Figure 3 shows color strength at λ_{max} =580nm for D65 10 Deg light source. Here color strength is measured for 5%, 7%, 9%, and 12% self-shade of NOVACRON® Super Black R. The color strength (K/S) of M2 is higher than SD for 5% and 12%. On the contrary, the color strength (K/S) of M2 is lower than SD for 7% and 9%.

Assessment of Fixation %

Table 2 shows the fixation % of SD and M2. The dye fixation of M2 was higher than SD. The dye bath P^H of SD was lower than M2. However, the fixation of SD was not bad. Hence, it can be said that in terms of dye fixation mixed alkali (soda ash + sodium hydroxide) method was better than single alkali (soda ash) method. In this fixation assessment, the reflectance of 410 nm wave length of D65 10 was used. These data only gave an

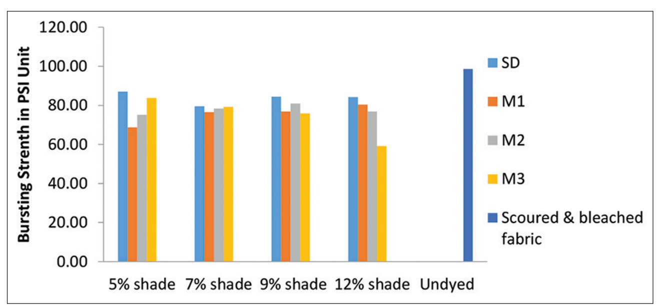

Figure 2: Bursting strength test result of SD, M1, M2, and M3 and undyed scoured bleached sample in psi (pound/square inch)

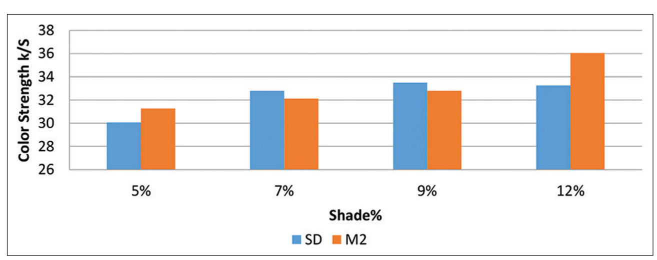

Figure 3: Color strength (K/S) test result of SD and M2 fabric sample for 5%, 7%, 9%, and 12% shade

Table 2: Fixation percentage of SD and M2 for different shade % at 410 nm wave length of the light source D65 10 Deg

Shade of the specimen (%)	Specimen name	Fixation (%)
5	SD	93.75987
5	M2	97.19824
7	SD	94.43112
7	M2	95.16666
9	SD	95.81720
9	M2	98.66956
12	SD	98.05342
12	M2	97.95356

approximate fixation value as there were hydrolyzed as well as unfixed dyes present in the fabric which could not be washed off.

CONCLUSION

In this comparative study, single alkali and mixed alkali method were justified in terms of lightness, fabric strength, color strength, and fixation%. Mixed alkali showed better result in all aspects. In conventional exhaust dyeing method for producing deep shade a large amount of soda ash (single alkali method) is used. In terms of fixation %, it exhibits better quality so the dye fixation with the fiber was better but it reduced the fabric strength to a certain extent.

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