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Effect of Alkali Concentration on Dyeing Cotton Knitted Fabrics with Reactive Dyes

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Abstract: The effect of alkali concentrations has been studied on the color strength (K/S) and color fastness properties of single jersey cotton knitted fabrics dyed with 1% Novacron Red S-B reactive dye. Same bath scouring and bleaching are performed and conventional exhaust dyeing method employed by IR laboratory sample dyeing machine. Various alkali concentrations such as 6, 7, 8, 9 and 10 g/L are employed and other parameters are kept fixed. The color strength (K/S) and color fastness to wash and rubbing are examined and evaluated. It is revealed that with the increase in alkali concentration from 6 g/L to 8 g/L the value of K/S increases and then up to 10 g/L the value decreases. The overall color fastness properties to washing and rubbing for the dyed samples range from good to excellent.

Key words: Alkali concentration, cotton fabrics, reactive dye, color strength, color fastness.

1. Introduction

Cotton is used as textile fiber from the beginning of our modern civilization and a wide range of apparels are produced from cotton fibers. Cotton is the most used textile fiber in the globe. The demand for cotton is increasing day by day due to its unique comfortablitiy, good strength, moisture absorption, wicking properties, beautifulness and availability around the world [1-3]. For dyeing of cotton goods reactive dyes are so much suitable and extensively used in the textile dyeing industries. They have good color fastness properties and a wide range of shade can be achieved by this dye. Generally, reactive dyes produce covalent bonds between carbon atoms of the dye reactive group and oxygen atoms of cotton hydroxyl groups under alkaline conditions. The most important parameters which can affect the exhaustion and fixation of reactive dyes are salt concentration, alkali concentration, liquor ratio and temperature [4-6]. Alkali must be required to the dye liquor for reaction between dye and fibre to perform. For some kind of reactive dyes this reaction with alkali can take place at room temperature. However, with most reactive dyes, the temperature of the dye liquor must be increased, in some cases to the boil, to affect the reaction between the dye molecule and the polymer system of the fiber. Reactive dyes have specific temperatures at which reaction between dye and fibre are optimum. In any case the formation of the covalent link requires the addition of an alkali [2, 7].

Many researchers have studied the dyeing of cotton fabrics with reactive dyes [8-14]. Compatibility analysis was done by exhaustion, fixation and adsorption isotherm upon three reactive dyes such as Remazol Red RR, Remazol Yellow RR and Remazol Blue RR. Dyeing concentrations of 0.5, 1, 2 and 3% were employed. Better exhaustion found for Blue RR but it was not attached with the fiber during fixation and Red RR found excellent in both exhaustion and

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fixation stages. It was also found that in deeper concentrations the compatibility among these three dyes would be low. But research data showed that introducing more electrolytes and reducing the temperature and the alkali amount can improve the compatibility of these dyes [8]. Khan et al. [9] studied the dyeing of cotton fabrics with reactive dyes and their physico-chemical properties. Broadbent et al. [10] investigated the continuous dyeing of cotton with reactive dyes using infrared heat. Mohsin et al. [11] reviewed on developments in dyeing cotton fabrics with reactive dyes for minimizing effluent pollution. Bhuiyan et al. [12] reported the influence of mixed alkali (soda ash & sodium hydroxide) on fixation of deep shades (8, 7.6 and 7.2%) of Novacron super black G and Cottonfix black B reactive dyes. The dyed fabrics showed very good to excellent fastness properties due to high exhaustion and fixation of dye molecule. It is found that the reactivity of reactive dyes was increased, 10% dyes were saved and the fastness of rubbing and washing were improved for each shade [12]. Cotton was modified with hydrolysed sericin fraction of silk in the addition of trisodium citrate as the esterification catalyst by a pad-dry-cure method. The treatment of cotton fabric with 5% hydrolysedsericin in the addition of 7.5% catalyst followed by drying at 95 °C for 5 minutes and curing at 140 °C for 5 minutes gave optimum results with respect to exhaustion and fixation of reactive dyes having chlorotriaznyle and vinyl sulphone reactive groups when dyeing was performed without salt. Color fastness to wash, light and rubbing of cotton for the use of reactive dyes remain unchanged for such prior modification with hydrolysedsericin [13]. The influence of salt, alkali and dye on dyeing cotton knitted fabric by reactive dyes and the rubbing, ironing and dry cleaning fastness properties were studied by Iftikhar et al. [14]. Effects of alkali proteases on dyeing characteristics of different proteinous materials with natural dyes were examined by Kumbasar et al. [15]. Ahmad et al. [16] studied the application of sodium edate in the dyeing of cotton with reactive dyes. Blackburn et al. [17] reported the use of cationic fixing agents to cotton dyed with direct dyes under various alkaline conditions. The effects of alkali (aqueous NaOH and KOH solutions) pre-treatment on dye exhaustion, color values, color fastness, tensile and surface properties of lyocell yarns were investigated. Dye exhaustion and color yield of lyocell yarns were improved by increasing alkali concentrations. The tensile strengths of lyocell yarns decreased with the increase of alkali concentrations because of the decrement of yarn diameter by weight loss of the open twist spirals, and the increased volume of lyocell yarns after alkali pre-treatment. The washing and perspiration fastness results of untreated lyocell yarns were better than alkali pre-treated lyocell yarns, while the light fastness results of untreated and alkali pre-treated samples were similar [18]. Goswami et al. [19] examined the sorption of dyes on cellulose II: effect of alkali treatment of fiber and dye structure. Blackburna et al. [20] investigated the alkali treatment of cellulose II fibres and effect on dye sorption. Tissera et al. [21] experimented the ultrasound energy to increase dye uptake and dye-fiber interaction of reactive dye on knitted cotton fabric at low temperatures. The present study deals with the dyeing of single jersey cotton knitted fabric with reactive dye with various alkali concentrations and other parameters are kept fixed. The aim of this study is to examine the effects of alkali concentration on the color strength and color fastness properties of the dyed fabrics. For this purpose, the color strength and color fastness to wash and colorfastness to rubbing are tested and evaluated.

2. Materials and Methods

2.1 Materials

One hundred percent cotton knitted fabric (single jersey, 180 GSM) is collected from local textile mill. Reactive dye (Novacron Red S-B), leveling agents, sequestering agent, electrolyte as Glauber’s salt

($Na_2SO_4 \cdot 10H_2O$), soaping agent (detergent) and acetic acid are used from the laboratory of the Department of Textile Engineering, MBSTU. All the chemicals are laboratory grade and used without any purification.

2.2 Method

2.2.1 Conventional Exhaust Dyeing

Same bath scoured and bleached sample is dyed with NOVACRON Red S-B reactive dye for 1% shade. IR laboratory dyeing machine is used for the variation of alkali concentration throughout this study. The dyeing curve is shown in Fig. 1:

Alkali Concentration Variation:

Alkali or soda is mainly used for pH control and dye fixation in dye bath. In case of reactive dye, soda is given by dosing after exhaustion of 30 minutes. If

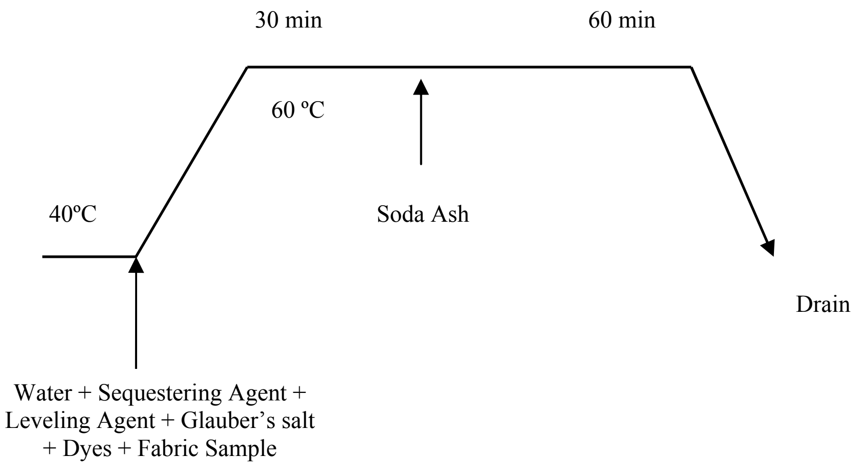

Fig. 1 Conventional exhaust dyeing curve.

Dyeing Process:

At first marked five dyeing pots for five samples
↓
Add required amount of water, sequestering agent, leveling agent, salt, dyes and fabric sample at room temperature
↓
Then raise the temperature at 60 ºC at 2 ºC/minute
↓
After 30 minutes, add soda by dosing and run 60 minutes at 60 ºC
↓
Cooling at 40 ºC and drain

After Treatment:

After drain, fabric is rinsed at 50 ºC temperature for 10 minutes
↓
Neutralized with 1 g/L acetic acid solution at 45 ºC for 10 minutes
↓
Soaping with 2 g/L detergent at 90 ºC for 10 minutes
↓
Rinse with normal water for 10 minutes
↓
Drying

soda is given at the initial stage and directly into the dye bath, uneven shade can be produced because there will be premature reaction.

The soda ash concentrations of 6, 7, 8, 9 and 10 g/L are taken and kept the other parameters fixed as below:

Novacron Red S-B	1%
Sequestering agent	1 g/L
Leveling agent	1 g/L
Glauber's salt	40 g/L
Liquor ratio	1:10
Sample weight	5 g
Time	60 minutes
Temperature	60 ºC
Acetic acid	1 g/L
Detergent	2 g/L

2.2.2 Measurement of Color Strength

The reflectance value of a specimen for the wave length of 400-700 nm with 10 nm intervals is found using Datacolor® Spectrophotometer. By using this reflectance value into the Kubelka Munk's equation [22] color strength (K/S) can be determined.

$$\text{Color Strength (K/S)} = \frac{(1-R)^2}{2R}$$

where, R = Reflectance of an incident light from the dyed material, K = Absorption, and S = Scattering coefficient of the dyed fabric.

2.2.3 Measurement of Color Fastness Properties

Color fastness properties of all dyed specimens are determined by using the crock meter (Brand: SDL, Origin: UK) and multi-fiber. Color fastness to wash and color fastness to rubbing is assessed by using grey scale of color change and staining according to ISO 105-C10:2006 and ISO 105-X12:1987 methods respectively.

3. Result and Discussion

3.1 Color Strength (K/S)

For the concentration of alkali 6, 7, 8, 9 and 10 g/L the K/S values are found to be 0.029, 0.032, 0.046, 0.035 and 0.028 respectively, as shown in Fig. 2, and it indicates that with the increased amount of alkali the dye uptake also increased and then decreased. The highest value of color strength (K/S) is observed with the amount of 8 g/L alkali concentration. The least value of alkali concentration i.e. 10 g/L shows the minimum K/S value for cotton fabrics, which means that this concentration has less impact on the values of dye uptake for fabrics. However, the effect of alkali concentration on dye uptake is also affected by other factors such as dye concentration, salt concentration, dyeing temperature and time etc.

3.2 Color Fastness to Washing

Table 1 presents the color fastness to washing for 6, 7, 8, 9 and 10 g/L salt concentration of all the dyed samples. The overall results of color fastness to wash of samples are good to excellent. Fabric dyed with 8 g/L alkali concentration displays excellent grade in color change and staining.

3.3 Color Fastness to Rubbing

Rubbing fastness is performed both in dry and wet conditions. The higher the ratings of crocking color fastness indicate the higher color depth and strength onto the fabric. The grade of color fastness to rubbing of the samples is evaluated and presented in the Table 2. The overall results of color fastness to rubbing of the samples are good to excellent. Wet rubbing properties are lower than dry rubbing. The minimum range for rubbing fastness is 3 and maximum range is 5. It is observed that the fabric sample dyed with 8 g/L alkali concentration exhibits good wet rubbing and excellent dry properties.

Inherently, both reactive dye and cotton release anion into water and repulse one another. But the addition of electrolyte in the dye bath makes the positive ring onto cellulose surface which leads to stronger covalent bond formation between cellulose and reactive vinyl sulphone (β sulfato ethyl sulfone) group of reactive dye molecules. The addition of alkali fixes the bonds between the fiber and dye

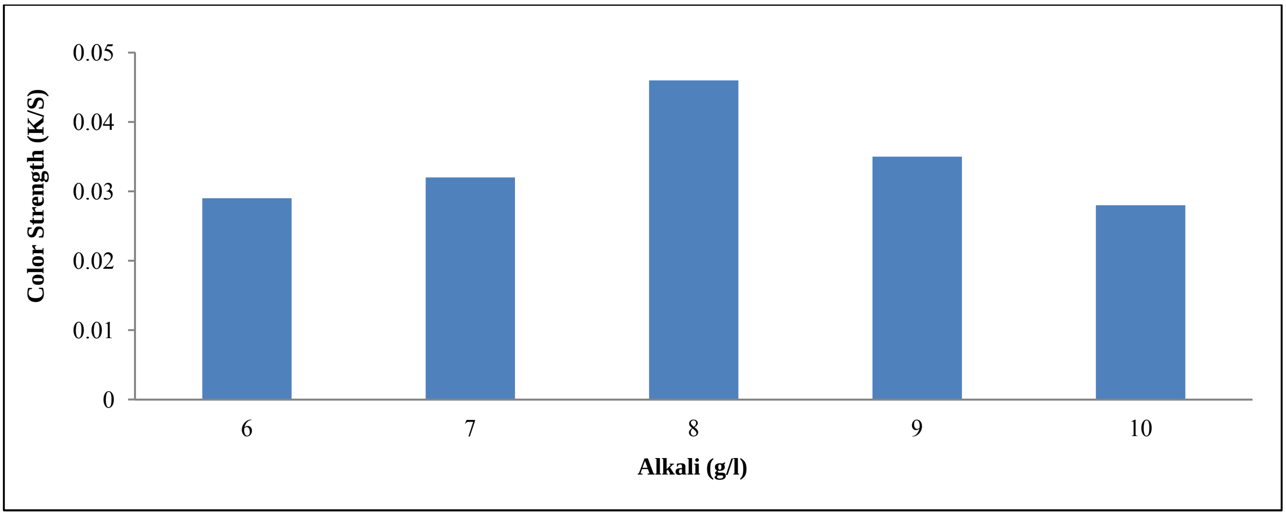

Fig. 2 Color strength (K/S) against 690 nm for different alkali concentration.

Table 1 Color fastness to washing for different alkali concentration.

Alkali (g/L)	Change in color	Color staining on multi fiber					
		Wool	Acrylic	Polyester	Polyamide	Cotton	Acetate
6	3-4	5	5	4	5	4-5	3-4
7	3-4	5	5	4	5	4	3-4
8	4	5	5	4	5	4-5	5
9	4-5	5	5	5	5	4-5	5
10	3-4	5	5	4	5	4	3-4

Table 2 Color fastness to rubbing for different alkali concentration.

Alkali (g/L)	Staining on cotton	
	Dry condition	Wet condition
6	4.5	3
7	5	4
8	5	4
9	5	4
10	5	4.5

particles. As a result, fabrics dyed with reactive dye exhibit excellent fastness grading due to the strong covalent bond between reactive dye molecules and fabric [23]. Excellent behavior assesses towards both dry and wet rubbing fastness (Table 2) in case of reactive dyed cotton. This observation also expresses that stronger binding ability between reactive dye and cellulose of cotton is favorable for excellent color durability to rub.

4. Conclusion

The single jersey cotton knitted fabrics are dyed with Novacron Red S-B (1%) reactive dye using same bath conventional exhaustion dyeing method by IR laboratory sample dyeing machine. All the parameters are kept fixed except alkali concentration and the concentration varies from 6 g/L to 10 g/L for dyeing different samples. The better color strength finds for 8 g/L alkali concentration and the color fastness to washing and rubbing for the dyed fabrics are found to be good to excellent. Hence, the optimum value of alkali concentration uses must be 8 g/L, which helps in saving water, salt and alkali for dyeing the cotton fabrics with reactive dyes.

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