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Research Article

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Effect of Temperature on Dyeing Cotton Knitted Fabrics with Reactive Dyes

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Abstract The effect of dyeing temperature has been studied on the color strength and color fastness properties of single jersey cotton knitted fabrics dyed with Novacron Red S-B reactive dye (1%) using conventional exhaust dyeing method. Same bath scouring and bleaching are done and conventional exhaust dyeing method employed by IR laboratory sample dyeing machine. Various dyeing temperature such as 40, 50, 60, 70 and 80ºC are used and other parameters are kept fixed. The color strength (K/S), color fastness to washing and color fastness to rubbing are examined and evaluated. It is observed that the value of K/S increases with the increase in temperature from 40ºC to 60ºC and then up to 80ºC the value decreases. The overall color fastness properties to washing and rubbing for the dyed samples range from good to excellent.

Keywords Dyeing temperature, cotton fabrics, reactive dye, color strength, color fastness

1. Introduction

Cotton is a cellulose based natural fiber originated from the cotton plant which is extensively used for manufacturing textile goods of various types around the globe. Cotton has some advantageous properties such as good tensile strength, smoothness, wicking properties and availability [1-5]. On the other hand, reactive dye has gained huge popularity on dyeing cotton fabrics due to its exceptional color fastness properties, wide variety of color gamut and ease of applications [6-9]. The dyeing rate increases with an increase in temperature but the final exhaustion may increase or decrease depending upon the particular dyeing system. Initial dyeing rate increases with the increase of temperature. This is the usual effect of temperature on the rate of a dyeing process. Dyeing is usually an exothermic process i.e. heat releasing; the interaction between the dye and fiber molecules is stronger than between the dye and water molecules in solution. The dyeing equilibrium reacts to an increase in temperature by absorbing more heat energy. It therefore shifts in the endothermic direction i.e. heat absorbing, dye desorbing from the fibers so that the final exhaustion is less at the higher temperature. A dilute solution of a dye does not necessarily consist of a collection of individual dye molecules surrounded by water molecules. Many dyes, in solutions at lower temperatures or at high salt concentration, exist as micelles or aggregates containing many molecules. Their behavior is identical to that of surfactant molecules. Only individual dye molecules, however, are able to diffuse into the fibers. A rapid equilibrium exists between single molecules and aggregates in solution. Aggregation is slightly exothermic. As the dyeing temperature increases, the aggregates gradually break up (heat absorbing) so that more individual molecules are available for penetration into the fibers. The exhaustion thus increases with increasing temperature. Eventually, if the dyeing temperature increases further, and aggregation is no longer significant, the final exhaustion will begin to decrease with increasing temperature [1, 5, 8].

Many researchers have been studied the dyeing of cotton fabrics with reactive dyes [9-17]. The effect of dye concentration, electrolyte concentration, dyeing time and temperature on dyeing performance of cotton fabric dyed with reactive dyes (Reactive Red 6B and Reactive Yellow RL) has been experimented and it is found that dye absorption increases with the increase in electrolyte concentration, dyeing time and dyeing temperature but decreases with the increase in dye concentration. The Reactive Yellow RL imparts better physico-chemical properties than Reactive Red 6B in most cases [9]. Haque reported the effect of dyeing parameters on dyeing of cotton fabrics with fluorochloro pyrimidine reactive dyes [10]. Effect of different dyeing parameters on color strength and fastness properties of Cotton-Elastane (CE) and Lyocell-Elastane (LE) knit fabric has been studied by Shahid et al. [11]. Different dyeing parameters such as temperature, pH and time were optimized using irradiated dye and irradiated cotton. Colorfastness properties show that UV radiation of both cotton and dye powder has improved the grading of fastness from fair to good [12]. By fixing other parameters and changing alkali concentrations from 6g/l to 10 g/l, cotton knitted fabrics are dyed with 1% reactive dye, and found that color strength increases with the increasing concentrations of alkali up to 8 g/l, then it declines. Fastness properties are also found satisfactory level [13]. A. D. Broadbent et al. have investigated the continuous dyeing of cotton with reactive dyes using infrared heat [14]. Mohsin et al. are reviewed on developments in dyeing cotton fabrics with reactive dyes for minimizing effluent pollution [15]. Cotton is modified with hydrolysedsericin 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 given optimum results with respect to exhaustion and fixation of reactive dyes having chlorotriaznyle and vinyl sulphone reactive groups when dyeing is 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 [16]. The influence of salt, alkali and dye on dyeing cotton knitted fabric by reactive dyes and the rubbing, ironing and dry cleaning fastness properties are studied by Iftikhar et al. [17]. Blackburn et al. have reported the use of cationic fixing agents to cotton dyed with direct dyes under various alkaline conditions [18]. Tissera et al. are experimented the ultrasound energy to increase dye uptake and dye–fiber interaction of reactive dye on knitted cotton fabric at low temperatures [19].

The present study deals with the dyeing of single jersey cotton knitted fabric with reactive dye with temperature variations and other parameters are kept fixed. The aim of this study is to examine the effects of dyeing temperature on the color strength and color fastness properties of the dyed fabrics. For this purpose, the color strength and color fastness to washing and colorfastness to rubbing are tested and evaluated.

2. Materials and Methods

2.1 Materials

100% cotton knitted fabric (single jersey, 180 GSM) is collected from local textile mill. Reactive dye (Novacron Red S-B), leveling agent, sequestering agent, electrolyte as Glauber's salt ($Na_2SO_4.10H_2O$), 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 dyeing temperature throughout this study. The dyeing curve is shown in Figure 1.

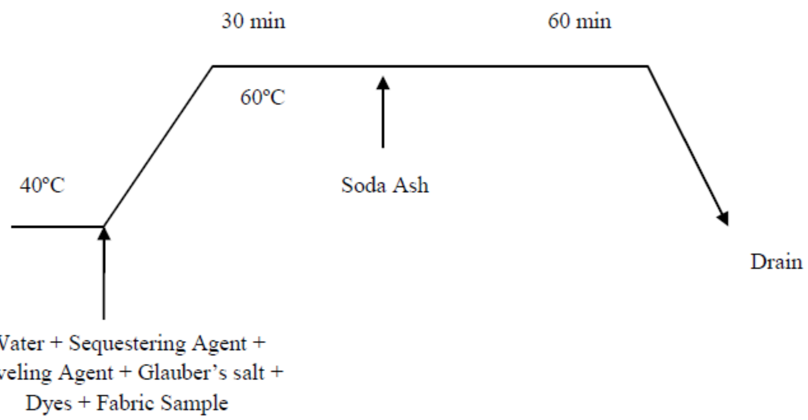

Figure 1: Conventional exhaust dyeing curve

Dyeing Process:

At first mark 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 up to 60ºC at 2º/minute

↓

After 30 minutes, add soda by dosing and run 60 minutes at 60ºC

↓

Cooling at 40ºC and drain

After Treatment:

After drain, fabric is rinsed at 50ºC temperature for 10 minutes

↓

Neutralized with 1 g/l acetic acid solution at 45ºC for 10 minutes

↓

Soaping with 2 g/l detergent at 90ºC for 10 minutes

↓

Rinse with normal water for 10 minutes

↓

Drying

Temperature Variation:

The depth of shade and the reactivity of dye decide the temperature of dyeing. With the increasing of temperature dye fixation increases until the dye bath reached at equilibrium. After that point if continue the temperature raises, the movement of dye molecules will increase. As a result, some of the dye molecules will come out from the fiber.

The variation of dyeing temperatures of40, 50, 60, 70 and 80 ºC 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
Soda ash	8 g/l
Sample weight	5 g

Liquor ratio	1:10
Time	60 min
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 400nm–700nm with 10nm intervals is found using Datacolor® Spectrophotometer. By using this reflectance value into the Kubelka Munk's equation [20] color strength (K/S) can be determined.

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 washing and color fastness to rubbing are 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 Effect of Temperature on Color Strength (K/S)

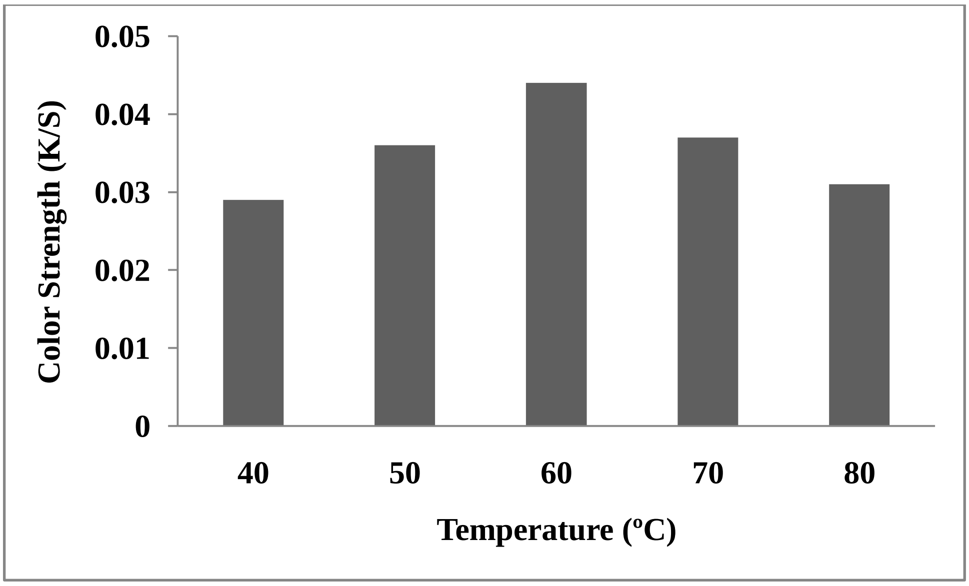

Figure 2: Color strength (K/S) against 690 nm for different temperature variation

Figure 2 exhibits the effect of dyeing temperature on the color strength of cotton fabrics dyed with 1% Nocacron Red S-B reactive dye. For dyeing temperature 40, 50, 60, 70 and 80 ºC the K/S value are found to be 0.029, 0.036, 0.044, 0.037 and 0.031 respectively. The color strength increases up to 60ºC then the value declines up to 80ºC. The highest value of K/S is observed for dyed sample at 60ºC temperature and dyeing temperature of 80ºC shows the declining value of K/S for cotton fabrics which mean that this temperature has less impact at the values of dye uptake for fabrics. As the temperature increases, the molecular structure becomes open which facilitate the dye uptake and hence the higher K/S value is obtained. The results show that K/S value of dyed fabrics increased gradually with the increase of temperature from 40°C to 60°C. At 80°C the dye uptake results getting down which may be due to diffusion of dye from the core of the fiber. Hence, the optimum value of temperature used may be 60°C, which helps in saving water, salt and alkali. However, the effect of temperature on dye uptake is also affected by other factors such as dye, salt and alkali concentration, and dyeing time etc.

3.2 Effect of temperature on color fastness to washing

Table 1: Color fastness to washing for different temperature variation

Temperature (ºC)	Change in color	Color staining on multi fiber					
		Wool	**Acrylic**	**Polyester**	**Polyamide**	**Cotton**	**Acetate**
40	3-4	5	5	4	5	4-5	3-4
50	3-4	5	5	4	5	4	3-4
60	4	5	5	4	5	4-5	5
70	4-5	5	5	5	5	4-5	5
80	3-4	5	5	4	5	4	3-4

Table 1 presents the color fastness to washing for 40, 50, 60, 70 and 80 ºC of dyeing temperature of all the dyed samples. The overall results of color fastness to washing of samples are good to excellent. Fabric dyed at 60ºC temperature displays excellent grade in color change and staining.

3.3 Color Fastness to Rubbing for temperature variation

Table 2: Color fastness to rubbing for different temperature variation

Temperature (ºC)	Staining on cotton	
	Dry condition	**Wet condition**
40	5	4.5
50	4.5	3.5
60	4.5	4
70	5	4.5
80	4.5	4

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 fabrics. 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 at 60ºC exhibits good wet rubbing and excellent dry properties.

As the temperature increases, the depth of shade also increases. As a result, when the dyed samples are rubbed against an object, more dye molecules come out from the fabric surface hence the value becomes less which means rubbing fastness property is not good. In some cases, the rubbing fastness value increases with temperature which may be due to good fixation of the dye molecules at that temperature to these particular fiber. However, the effects of temperature on washing fastness properties of the dye molecules are not as visible as in case of rubbing fastness.

4. Conclusion

The single jersey cotton knitted fabrics are dyed with 1% Novacron Red S-B reactive dye using same bath conventional exhaustion dyeing method by IR laboratory sample dyeing machine. All the parameters are kept fixed except dyeing temperature and the temperature varies from 40ºC to 80ºCfor dyeing different samples. The better color strength finds for 60ºC dyeing temperature and the color fastness to washing and rubbing for the dyed fabrics are found to be good to excellent. Hence, the optimum value of dyeing temperature uses may be 60ºC, which helps in saving water, salt and alkali for dyeing the cotton fabrics with reactive dyes.

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