A NOVEL APPROACH IN DYEING OF COTTON FABRIC WITHOUT SALT

M. Senthilkumar
Department of Textile Technology, PSG College of Technology, Coimbatore – 641004, Tamilnadu, India
Email: mskumar77@gmail.com

Abstract

Textile dyeing is a complicated process involving the addition of a large number of dyes and auxiliaries to achieve the exact shade. The wastes generated in this process are huge and polluting to the land and the surrounding environment. The main cause of this effluent problem happens to be the addition of salt in reactive dyeing. Hence rather than finding a method to dispose these hazardous waste generated it would be better to devise a safer system of dyeing. Salt is inevitable in the conventional method because it masks the zeta potential developed by cotton fabric when immersed in water. This masking of the zeta potential facilitates the negatively charged dye to get attracted to the fabric. But the same effect can be produced with the help of electric current by passing positive charges to the fabric. The quality parameters, such as K/S value, fastness and uniformity, of fabric dyed with help of electrical current is also similar to that of fabric dyed using conventional method. By doing this the TDS content of the effluent is greatly reduced and reduces sludge formation. This also poses a chance for reuse of dye liquor which will minimize the consumption of dyes and reduce cost. It also has an ease of implementation in all dyeing units by slight modification of the present working style.

Keywords: salt-free dyeing, electrochemical, zeta potential, TDS, reactive dye

1. Introduction

Textile dyeing is a complicated process involving the addition of a large number of dyes and auxiliaries to achieve the exact required shade. The wastes generated in this process are huge and polluting to the land and the surrounding environment. It is very toxic and greatly affects the water bodies if diverted into it. This has led to the closure of a number of textile processing industries in and around the state. The main cause of this effluent problem happens to be the addition of salt in reactive dyeing. Hence rather than finding a method to dispose these hazardous waste generated it would be better to devise a safer system of dyeing which happens to be the objective of this work. Salt is added in reactive dyeing as a source of positive charges to the dye bath which is inevitable in the normal dyeing method. But the positive charges can be created both chemically and electrically. The intention of the research is to replace the chemical method by electrical method. Electric current of a particular voltage is passed through the dye bath to aid in the transfer of dye molecules from the dye bath to the fabric. With this new method a number of trials were conducted to match the shade with standard shade. The various problems encountered during the process were rectified and a perfect shade match has been achieved. This has a good scope of implementation in all industries by slight modification of the present working style. This also poses a chance for reuse of dye liquor which will minimize the consumption of dyes and reduce cost. This when implemented in the industries serves a dual purpose of reducing cost and minimizing effluents thus aiding in a green dyeing process.

2. Materials and Methods

2.1 Materials

2.1.1 Cotton Fabric

Bleached cotton fabric was used for this work. Cotton was chosen since it was most widely used. The particulars of the fabric are given in Table 1

Table 1 Particulars of cotton fabric

S No	Particulars	Value
1	EPI	92
2	PPI	88
3	Warp Count	2/80s
4	Weft Count	60
5	Cover Factor	22
6	GSM	150

2.1.2 Dyes and Auxillaries

Reactive dye was used for dyeing since cotton was best dyed with it. Two types of reactive dyes were used for the project. They are the cold brand reactive dye and the hot brand reactive dye. Cold brand reactive dyes are dyed with cotton fabric at room temperature. Hot brand dyes have only one reactive functional group and are dyed at an increased temperature. The dyes used for the research are given in Table 2

Table 2 CI Names of dyes

S.No.	Colour	Name	CI Name
1	Red	Red HE 3B	Reactive Red 20 A
2	Yellow	Yellow HE 4G	Reactive Yellow 21
3	Blue	Blue HRL	Reactive Blue 19

Common salt (sodium chloride) was added in appropriate amounts to aid in the exhaustion stage of dyeing in the conventional method. An alkali (Sodium Carbonate) was used for fixation of the dye molecules onto the fabric in both conventional and developed methods. Distilled water was used as a dyeing medium in both the cases. Soap was used to finally wash off the surface molecules.

2.2 Methods

2.2.1 Production of Standard Sample

Cotton fabric was first dyed with reactive dyes using conventional method. This acted as the standard sample with which the samples from the electrical method were compared. Samples were prepared separately using cold brand and hot brand reactive dyes.

2.2.2 Dyeing with cold brand reactive dye

The recipe shown in Table 3 was followed for dyeing of cotton fabric with cold brand reactive dyes.

Table 3 Particulars of dyeing with cold brand reactive dye

Particulars	
Dye	5%
Sodium Chloride	40 gpl
Sodium Carbonate	25 gpl
Temperature	Room temperature
Time	60 mins + 30 mins

First a sample of pure cotton fabric was taken and weighed accurately. A dye bath was prepared taking the appropriate quantity of liquor as per the recipe. The dye was quantitatively weighed and added and then salt was added for exhaustion to take place. The material was wetted and then entered and worked thoroughly to obtain uniform dyeing. This was continued for a period of time and then sodium carbonate was added for fixation.

2.2.3 Dyeing with Hot Brand Reactive Dyes

The recipe shown in Table 4 was followed for dyeing cotton fabric with hot brand reactive dyes.

Table 4Particulars of dyeing with hot brand reactive dyes

Particulars	
Dye	1%, 3%, 5%
Sodium Chloride	20, 30, 40 gpl
Sodium Carbonate	15, 20, 25 gpl
Temperature	80^{O}C
Time	60 mins + 30 mins

First a sample of pure cotton fabric was taken and weighed accurately. A dye bath was prepared taking the appropriate quantity of liquor as per the recipe. It was then placed in a bath and heated to 80^{O}C. This temperature was maintained throughout the process. The dye was quantitatively weighed and added and then salt was added for exhaustion to take place. The material was wetted and then entered and worked thoroughly to obtain uniform dyeing. This was continued for a fixed period of time and then sodium carbonate was added for fixation. The dyeing cycle is shown in the figure 1.

After the dying was completed, washing must be done to the material to remove the extra unfixed dye molecules from the surface. This was done by means of cold wash, hot wash and soap wash. The sample was then dried thoroughly.

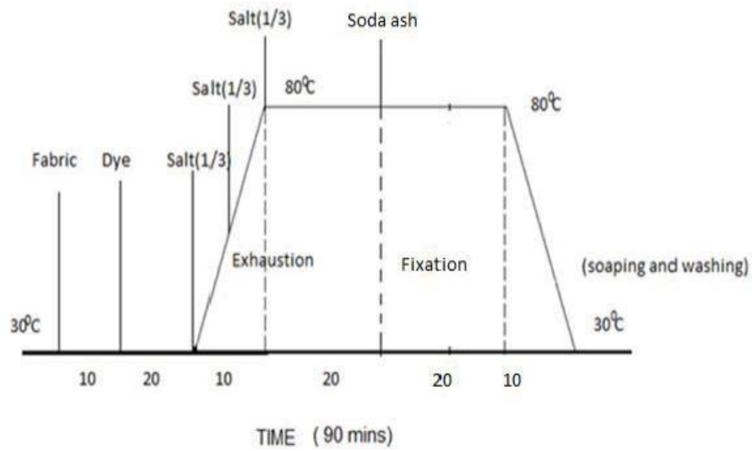

Figure 1 Dyeing cycle of reactive dye

2.2.4 Dyeing of Cotton Fabric using Developed Method

In this proposed method, salt was completely eliminated and electric current was used as a source of charges. The positive charge provided by the electric current on the fabric attracts the negatively charged dye molecules towards it. The following procedure was followed for dyeing.

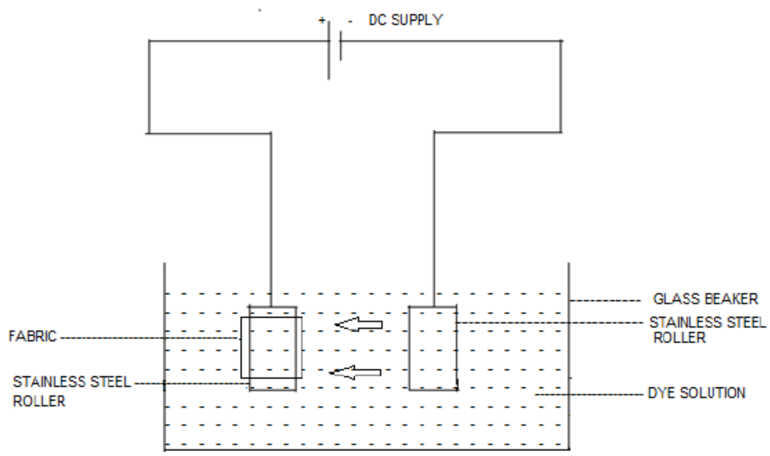

Figure 2 Schematic representation of the developed method

1.1 Dyeing with cold brand reactive dye

The fabric sample made of pure cotton was taken and weighed accurately. A glass beaker was taken and appropriate quantity of water was added to make up the dye bath. Dye was then quantitatively added as per the recipe. This was maintained at room temperature. Two rollers made of pure stainless steel metal were designed to act as electrodes. These rollers were connected to the positive and negative terminal of the DC supply. The fabric sample was wetted and wound over the positive roller. Both the rollers were then immersed into the dye bath. Care was taken to see that the rollers did not touch each other or the walls of the container to avoid short circuit. Power was switched on and the set-up was left intact for a fixed period of time (Figure 2). Then the fabric was unwound from the roller and fixation was done by adding alkali into the dye bath. After fixation, the sample was washed and dried.

1.2 Dyeing with hot brand reactive dye

The pure cotton fabric was taken and weighed accurately. The dye bath was prepared with water heated to 80^{O}C initially. Dye was then quantitatively added and the steel rollers were immersed into it. Fabric was wound on the positive roller. Electric current helped to maintain the temperature throughout the process. The same precautions as mentioned previously were followed and dyeing was carried out. After exhaustion with the current, fixation and washing off were done. The particulars in dyeing using the developed method are shown in the Table 5

2.2.5 Testing

Once the samples were produced from both the methods, their colour was quantitatively evaluated. It was done by using visible spectrophotometer. All the fabric samples were measured using SS5100A Spectrophotometer, Premier Colour Scan, at a wavelength range of 400 to 700 nm.

ISBN:

Table 5 Particulars of dyeing in developed method

Particulars	
Voltage	10 Volt
Current	0.5 – 0.8 Amp
Electrode	Roller Form
Metal used	Stainless Steel
Dye Bath	Glass Beaker

1.3 Determination of K/S Value

The values of the Kubelka Munk function (K/S) of the fabrics is calculated using the below given formula.

$K/S = (1-R)^2/2R$

Where

R – Reflectance value, K – Absorption coefficient, S – Scattering coefficient

Reflectance value (R) of the dyed sample was measured by the Spectrophotometer.

1.4 Determination of Colour Difference Value

The values which were used to quantify a colour were the L, a, b values. L denotes the lightness or darkness value on a scale of 0 to 100. The value a denotes the greenness or redness value. A negative value denotes greener shade and a positive value denotes a reddish shade. The value b denotes blue or yellowness values. A negative value indicates a bluer shade and a positive value indicates yellow shade.

The colour difference ΔE value of the fabric was calculated using the formula given below. $\Delta E = \sqrt{[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]}$

Where

$\Delta L = L_{sample} - L_{standard}$, $\Delta a = a_{sample} - a_{standard}$, $\Delta b = b_{sample} - b_{standard}$

1.5 Measurement of Total Dissolved Solids Content

The toxicity of textile effluents was assessed by a number of parameters like BOD, COD, TDS, TSS etc. The TDS content is especially very harmful because it cannot be removed by any means. But a salt-free dyeing significantly reduces the TDS content. It was quantitatively measured of the effluent generated from the conventional method and the developed method with the help of an instrument. The instrument used for measuring the TDS content is the Multi Parameter Water Analyser, Eutech 3210.

3. Results and Discussion

3.1 Effect of Voltage on Dye Uptake of Fabric Dyed With Cold Brand Reactive Dye

The samples dyed in the proposed method needs to be compared with the samples dyed in the conventional method to ascertain that they are of the same shade. The sample dyed using the conventional method is treated as the standard against which the samples dyed using the developed method are compared with. This quantitative evaluation of the colour was done using the spectrophotometer and the results are given in table.6 and figure 3. Cold brand reactive dye can be dyed at room temperature without the application of external heat. Thus it was chosen for the initial trial works. Optimization of the process parameters was the main goal in the initial trial works while trying to achieve a perfect shade match. Voltage required for the process was varied in the range of 60 V to 10 V and the optimum voltage was found.

Table 6 Effect of voltage on colour difference values of fabrics dyed in conventional and developed method

Sample Number	**Dye**	**Voltage (V)**	**ΔE Values**
1	Cold Reactive Yellow	60	15.173
2		50	10.55
3		40	9.289
4		30	7.712
5		20	4.624
6		10	2.324

Salt, in conventional dyeing, plays the role of masking the zeta potential by providing positive charges. In the proposed method, current performs this role. The effect of current on the exhaustion properties is evident from the colour achieved on the fabric. In this way, on comparing the samples dyed, it is ascertained that the exhaustion property of current is the same as that through the conventional method. Also, uniform results are achieved irrespective of the shade of the dye.

ISBN:

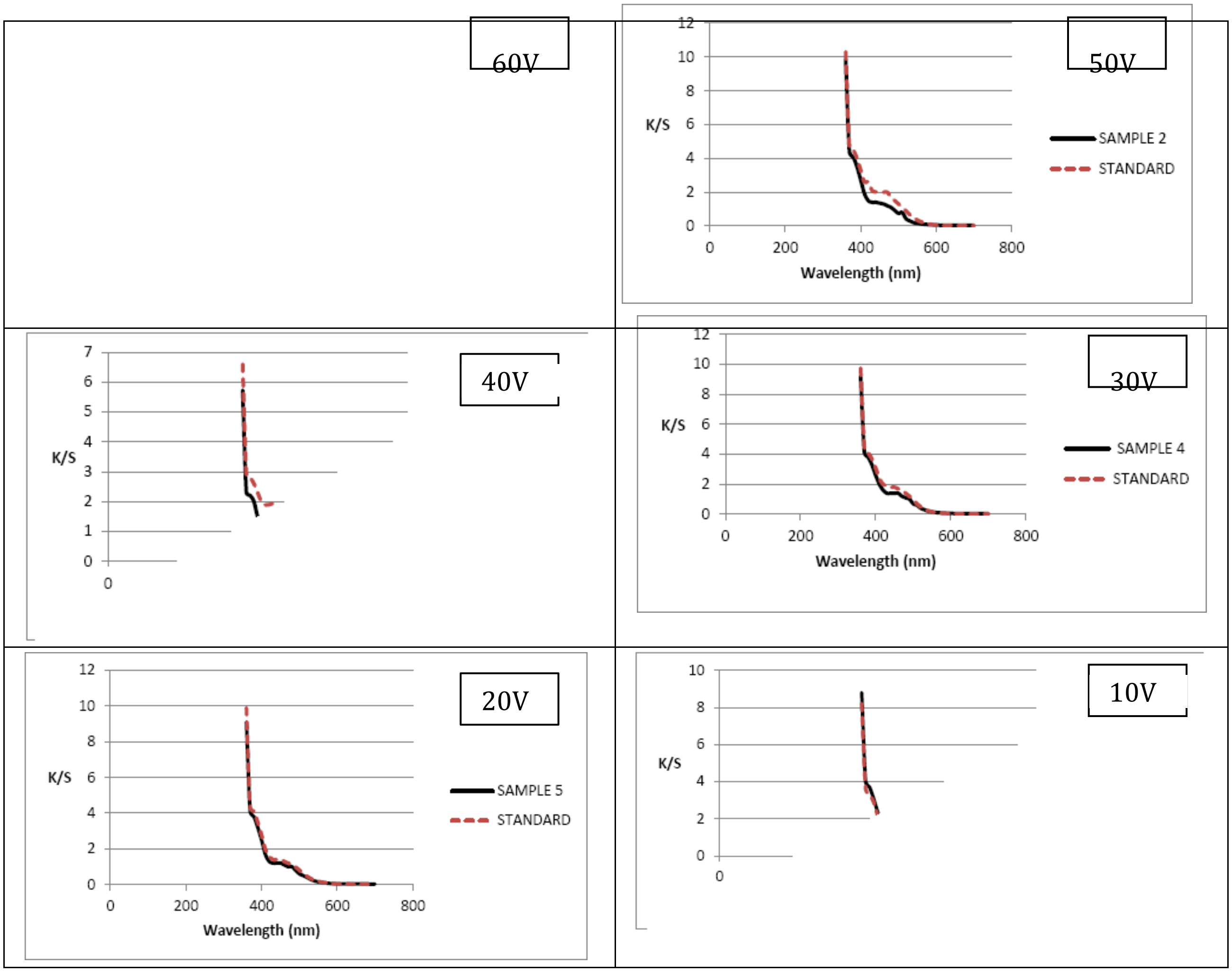

Figure 3 Effect of current density (60 V- 10V) on K/S value of fabrics dyed in conventional and developed method

3.2 Effect of Current on Dye Uptake of Fabric Dyed with Hot Brand Reactive Dye

A reactive dye by name - Red HE 3B and CI name - Reactive Red 20 was used for trial works with hot brand reactive dye. Hot brand dyes posed an additional problem. Heat had to be provided throughout the process. But since electric current gives rise to heat, a solution was adopted. Water initially heated to 80^{O}C was used for dyeing and the current helped to maintain that heat throughout the process. After the process was perfected, a number of samples were dyed in the same way in the same shade to check the reproducibility of the methodology. The graphs obtained between the standard samples and the ones dyed using the developed method are shown in the figure 4.

3.3 Measurement of Total Dissolved Solids Content

The TDS content is majorly contributed by the salt and it makes the effluent generated very harmful. The TDS is measured with the help of a portable TDS tester. It has probes which when inserted into the effluent solution gives a measure of the TDS directly. The TDS values obtained from both the methods are shown in the Table 7. From the values given above, it is evident that the TDS values have been reduced to half in the proposed method. This reduces the harmfulness of the effluent.

4. CONCLUSION

The ideas pertaining to a new method of dyeing has been presented. Numerical values of the colour obtained through the two methods are compared and the results are shown.

- This elimination of salt can prove to a major breakthrough in the processing industry as it solves the age old problem of effluent generation.
- Rather than concentrating on costly equipments that would dispose the effluents, it would be more effective to modify the working method such that waste generation is minimum

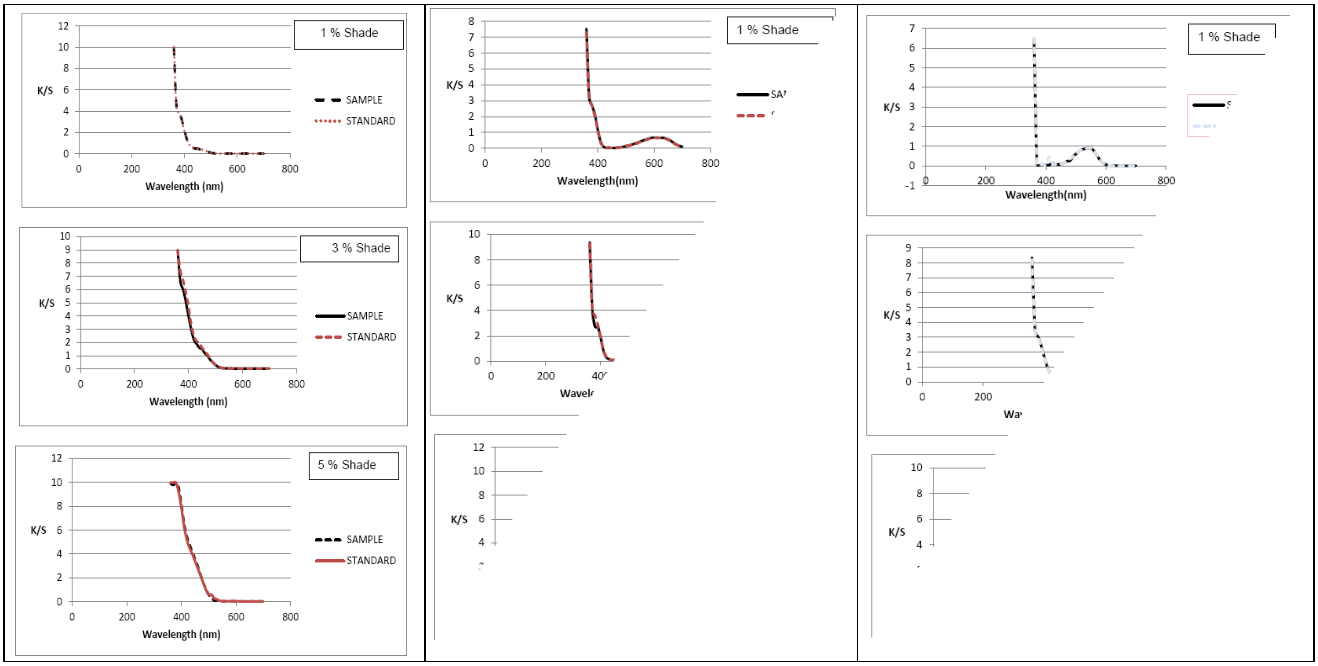

Figure 4 K/S values of fabrics dyed in conventional and developed method with hot brand reactive dye (Reactive yellow 21,Reactive blue 19 and Reactive red 20 A) at 1%, 3% and 5% shades

Table 7 Comparison of TDS values between conventional and developed method

Dye	**% Shade**	**TDS**	
		Conventional Method	**Developed Method**
Reactive Yellow 21	1	65.65	35.42
	3	68.56	37.66
	5	63.12	32.57
Reactive Blue 19	1	62.99	31.46
	3	58.32	28.72
	5	63.47	26.95
Reactive Red 20 A	1	61.46	24.11
	3	63.25	25.98
	5	64.77	27.32

1.6 References

1. Jason Mc Gregor, “Trade Waste Minimisation through Recycling and Substitution”, 69th Annual Water Industry Engineers and Operators’ Conference, Bendigo Exhibition Centre, 5 to 7 September, 2006.
2. Thomas A Yager, 2012, *Dyeing of Fibres using Supercritical Carbondioxide and Electrophoresis”,* Patent number-20120047665.
3. Ramesh Babu B., Parande A K., Raghu S and Prem Kumar T., “Cotton Textile Processing- Waste Generation and Effluent Treatment”, The Journal of Cotton Science, Vol. 11/ 2007, pp. 141–153.
4. Mireia Sala and Carmen Gutiérrez-Bouzán M., “Electrochemical Techniques in Textile Processes and Wastewater Treatment”, International Journal of Photoenergy Vol. 12/ 2012, Article ID 629103.
5. Chattopadhyay D.P., Chavan R.B., Sharma J.K., "Salt-free reactive dyeing of cotton", International Journal of Clothing Science and Technology, Vol. 19 Iss: 2/ 2007, pp.99 – 108.
6. Subramanian Senthil Kannan M., Gopalakrishnan M., Kumaravel S., Nithyanandan K J., “Influence of Cationisation of Cotton on Reactive Dyeing”, Journal of Textile and Apparel, Technology and Management, Vol 5. , Issue 2/2006.
7. Kunal Singha, Subhankar Maity and Mrinal Singha, “The Salt-Free Dyeing on Cotton: An Approach to Effluent Free Mechanism; Can Chitosan be a Potential Option?”, International Journal of Textile Science , Vol. 1 No. 5/2012, pp. 69–77
8. Hebeish A., Hashem M., EL-Hosamy and Abass S., “No-Salt Dyeing Behaviour of Cationized Linen Fabrics”, Research Journal of Textile and Apparel, Vol. 10 No. 2/2006

Corresponding Address
Dr.M.Senthilkumar Associate Professor

Department of Textile Technology
PSG College of Technology, Coimbatore – 641004 Mskumar77@gmail.com, msk.textile@psgtech.ac.in9443948513, 8610643346