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A Study on the Effect of Reducing Agents on Reduction Potential of Vat Dyeing on Cotton Fabric

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ABSTRACT

Vat dyes are one of the most popular dyes used on textiles particularly on cotton textile materials. However, Vat dye is insoluble in water, hence, powerful reducing agent like sodium hydrosulphite (hydrose) in presence of strong alkali is required for its solubilisation (vatting). An attempt has been made to see the effect of hydrose and its combination with ferrous sulphate, hydrose and its combination with zinc as reducing agent. The results of these reducing agents were compared with those of the conventional vat dyeing with hydrose, in terms of reduction potential of vat dye bath. Based on the results arrived, the reducing agent, ferrous sulphate1.0% owm + hydrose 1.0% owm combination is best suited for vat dye dissolution in alkaline medium and dyeing on cotton fabric. This enhances quality of the fabric needed for the vat dyed textile products and textile industries.

KEYWORDS Vat dye, reducing agent, reduction potential, cotton fabric.

1.0 Introduction

Among the cellulose polymeric variety, cotton is considered as one of the important textile fibers. Cotton can be dyed with many natural colours extracted from natural sources and synthetic dyes such as direct dye, reactive dye, sulphur dye, vat dye, etc [1]. In the colouration of cellulose fibers, vat dyes (including indigo) still represent a relatively large part of the dyestuff market; among them about 120 000 tons of vat dyes are being used annually [2]. Vat dyes are practically insoluble in water, but can be converted into water soluble form called leuco dye by reduction with a strong reducing agent like hydrose and solubilising agent sodium hydroxide. The reduced dyestuff penetrates into the fiber and it is reoxidised on the fiber back to the insoluble form, which remains fixed in the fabric [3]. The use of sodium hydrosulphite (hydrose) is being criticized for the formation of non-environment friendly decomposition products such as sulphite, sulphate, thiosulphate and toxic sulphur [4]. Therefore many attempts are being made to create alternate for the sodium hydrosulphite that cause less pollution.

1.1 Vat process using reducing agents other than hydrose

Many previous investigations were carried out to focus on the replacement of sodium hydrosulphite by other reducing agents like organic reducing agent α-hydroxy ketone [5], Sodium borohydride [6], hydroxy alkyl sulphonate, thiourea [7], complex ferrous hydroxide with tartaric acid gluconic acid, citric acid [8], glucose and dextranil [9], natural ingredients namely fenugreek, jaggery, lime and soda ash [10] and glucose [11].

Other alternate reduction technolologies like, reduction using ultrasonic reactor [12], catalytic hydrogenation using raney nickel [13], catalytic hydrogenation using Pd catalyst [14], electrolytic method [15], electrochemical techniques [16], like direct electrochemical reduction [17, 18] and indirect electrochemical reduction [19, 20] were also studied.

After several decades of research and development there is still no commercial reducing technology, including electrochemical processes available today that can replace sodium hydrosulphite in all areas of vat dye application.

The present study is carried out to see the effect of hydrose and its combination with ferrous sulphate, hydrose and its combination with zinc as reducing agent on textile material. The results of dyeing using hydrose and its combination with zinc such as hydrose (1.5% owm) + zinc (0.5% owm), hydrose (1.0% owm) + zinc (1.0% owm), hydrose (0.5% owm) + zinc (1.5% owm), and hydrose with ferrous sulphate such as hydrose (1.5% owm) + ferrous sulphate (0.5% owm), hydrose (1.0% owm) + ferrous sulphate (1.0% owm), hydrose (0.5% owm) + ferrous sulphate (1.5% owm) as reducing agent have been compared with those of the conventional dyeing with hydrose (2.0% owm), in terms reduction potential of vat dye bath.

2.0 Experimental

2.1.0 Materials

2.1.1 Textile fabric

100% cotton poplin fabric was used with following particulars:

Ends/Inch : 132, Picks/Inch: 70,

Warp Count: 37s, Weft Count : 41s

2.1.2. Chemicals, auxiliaries and dye

Sodium hydrosulphite (AR), zinc (AR), ferrous sulphate (AR) and their combinations with hydrose were used as reducing agents. Sodium hydroxide (AR), turkey red oil (AR), sodium carbonate (AR), hydrogen peroxide (AR) and soap powder were used as other main chemicals and auxiliaries. The dye selected was commercial Navinon Jade green FFBU/C commonly called as Jade green XBN (Vat Green 1, C.I.59825).

2.2.0 Methods

2.2.1 Pretreatment given to the fabric

The grey cotton fabric was initially pretreated by standard scouring treatment using sodium hydroxide and bleaching treatment using hydrogen peroxide as per the standard method [21].

2.2.2 Dyeing of pretreated cotton fabric using vat dyes

Conventional vat dyeing was carried out on pretreated cotton fabric using hydrose as a reducing agent [12]. Similar procedure was followed for the combination of reducing agents such as hydrose with zinc and hydrose with ferrous sulphate using Vat dye (Jade green XBN) along with suitable ingredients.

2.2.3 Evaluation of reduction potential of vat dye bath

The reduction potential of vat dye bath with various reducing agents such as hydrose and its combination with zinc, hydrose and its combination with ferrous sulphate, and conventional reducing agent (hydrose) were determined by using digital potentiometer (DP001, Pico make) at different time intervals [22, 9].

3.0 Results and Discussions

2.1 Reduction potential of vat dye bath using different reducing agents

The mean Reduction Potentials of vat dye bath using hydrose and its combination such as Hydrose 2.0% owm, Hydrose 1.5% owm + Zinc 0.5% owm, Hydrose 1.0% owm + Zinc 1.0% owm, Hydrose 0.5% owm + Zinc 1.5% owm, Hydrose 1.5% owm + $FeSO_4$ 0.5% owm, Hydrose 1.0% owm + $FeSO_4$ 1.0% owm, and Hydrose 0.5% owm + $FeSO_4$ 1.5% owm have been shown in Table 1 and Figure 1.

Reducing agents used during vat dyeing on cotton fabric ↓	Reduction Potential (Volts)↓						
Time (min)→	0	5	10	15	20	25	30
Hydrose 2.0 % owm	-0.835	-0.824	-0.805	-0.778	-0.723	-0.542	-0.357
Hydrose 1.5 % owm+ Zinc 0.5 % owm	-0.411	-0.156	-0.250	-0.214	-0.155	-0.199	-0.148
Hydrose 1.0 % owm+ Zinc 1.0 % owm	-0.200	-0.300	-0.330	-0.277	-0.250	-0.223	-0.203
Hydrose 0.5 % owm+ Zinc 1.5 % owm	-0.174	-0.262	-0.288	-0.232	-0.260	-0.291	-0.316
Hydrose 1.5 % owm+ $FeSO_4$ 0.5 % owm	-0.395	-0.387	-0.355	-0.330	-0.303	-0.298	-0.288
Hydrose 1.0 % owm+ $FeSO_4$ 1.0 % owm	-0.693	-0.638	-0.619	-0.598	-0.541	-0.531	-0.521
Hydrose 0.5 % owm+ $FeSO_4$ 1.5 % owm	-0.439	-0.290	-0.281	-0.242	-0.221	-0.215	-0.209

Table 1 Reduction potential of vat dye bath using hydrose and its combination as reducing agent

The reduction potential is very high in the vat dye bath using hydrose 2.0% owm as reducing agent compared with its other combination with zinc and ferrous sulphate. As the time increases, the reduction potential in vat dye bath using Hydrose 2.0% owm, Hydrose 1.5% owm + $FeSO_4$ 0.5% owm, Hydrose 1.0% owm + $FeSO_4$ 1.0% owm, and Hydrose 0.5% owm + $FeSO_4$ 1.5% owm steadily decreases, whereas in vat dye bath using hydrose combination with zinc (Hydrose 1.5% owm + Zinc 0.5% owm, Hydrose 1.0% owm + Zinc1.0% owm, and Hydrose 0.5% owm + Zinc1.5% owm), the reduction potential is invariably non-uniform from the initial period (0 minutes) till the completion of dyeing (30 minutes).

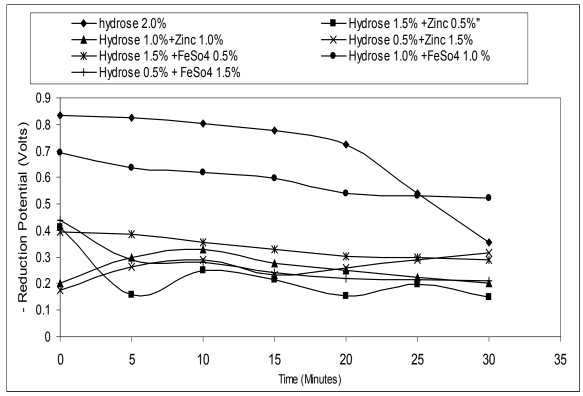

Figure 1 Reduction potential of vat dye bath using hydrose and its combination as reducing agent

4.0 Conclusions

The reduction potential of the reducing agents used for the dissolution of vat dye is good for ferrous sulphate with hydrose combination. However, ferrous sulphate 1.0% owm + hydrose 1.0% owm combination as reducing agent gives uniform reduction potential, and this is changed evenly throughout the dyeing period. Because of this, there is a good dyeing effect on the cotton fabric.

Among the different reducing agents, the ferrous sulphate and hydrose combination such as $FeSO_4$ 1.0% owm + hydrose 1.0% owm, give very good dyeing effect on the vat dyed cotton fabric with anticipated uniformity on the vat dyed cotton fabric.

The good dyeing effect on vat dyed cotton fabric due to ferrous sulphate and hydrose combinations is based on the good reducing efficiency of ferrous sulphate as well as hydrose on the vat dye, leads the good dyeing on cotton fabric.

The commercial cost of ferrous sulphate is similar to that of hydrose, and hence the process cost could be affordable to the textile industries. Since, the effluent parameters are within the limit of environmental aspect, the process is not only useful for the textile wet processing industry, but also to the society in general.

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