Improvement of Colour Fastness for Deep Blue Shade of Cotton Fabric

Lina Lin[1, a], Md. Ziaur Rahman[2, b], Shu Wen[2, c], Rahul Navik [2, d], Ping Zhang[3, e]*, Yingjie Cai[1, 2]

[1] Hubei Key Laboratory of Biomass Fibers and Eco-dyeing & Finishing, Wuhan Textile University, Wuhan, 430073, China

[2] School of Chemistry and Chemical Engineering, Wuhan Textile University, Wuhan, 430073, China

[3] Engineering Research Centre for Clean Production of Textile Dyeing & Printing, Ministry of Education, Wuhan Textile University, Wuhan, 430073, China

[a]email: linalin@wtu.edu.cn, [b]email: Ziaurmmm@yahoo.com, [c]email: 869882975@qq.com,

[d]email: rahul.navik2012@gmail.com, [f]email: Yingjiecai@wtu.edu.dn

*Corresponding author, [e]E-mail: zp@wtu.edu.cn

Keywords: Cotton; Deep Shade; Reactive Dye; Wash Fastness; Rubbing Fastness

Abstract. Cotton fabric was dyed by exhaust method with C.I. Reactive Blue 19 with various dye concentrations, followed by the treatments of soaping, dye fixing, and wet rubbing improving. The dye exhaustion, wash fastness, rubbing fastness, and colour difference of dyed cotton fabric were examined. The consequences demonstrate that the entire utilized textile auxiliaries did not cause a yellowness problem. After application of the dye fixative and wet rubbing improver, to the deep blue shade cotton (15% dye o.m.f), the wash fastnesses were all at grade 5, and at grade 5 and 4 of dry and wet of rubbing fastness respectively. The wet rubbing improver contributed to deep blue shade and promoted half grade in wet rubbing for all dye o.m.f.

Introduction

Reactive dyes are usually applied for dyeing of cellulosic fibers because of their low cost, easy to apply, excellent wet colour fastness, and bright colour [1-5]. High popularity of reactive dyes is based on producing brilliant hues with a wide variety of shades using various environmentally pleasant methods. Reactive dyes stand out from other dyes by their capability of making covalent bonds between dye and cellulose [6]. Many methods of improving wash fastness and wet rubbing fastness properties of reactive dyes on cotton have previously been reported [7, 8]. During reactive dyeing process, the reactive dyes always have a tendency to be hydrolyzed [9, 10]. After dyeing, the unfixed reactive dyes (hydrolyzed and unreacted reactive dye) exist in the interior and on the surface of fiber, especially in deep shade dyeing. Without actual dye removal, it results a poor colour fastness; thus an actual washing, such as soaping treatment, is applied to assist in washing off the unfixed dyes [11, 12]. However, it is very difficult to achieve a brilliant colour fastness since 0.003% dyes on the mass of fabric (o.m.f) will produce a stain same as to a grey scale rating of 4. In industry there are numerous reasons in affecting the colour fastness, such as dye structures, slack colour, dye bath pH, water quality, fabric structure and stitch density of the fabric, as well as post treatment [13]. In the traditional method of acquiring high colour fastness, after reactive dyeing the dyed substance is neutralization washed and soaped to remove the unfixed dyes as much as possible, subsequently dye fixing treatment is conducted to prevent the unfixed dyes from staining [14-16]. The perfect colour and colour fastness have been achieved on appropriate selection of dyes and precise of dyeing process [17].

This paper aims to organize a deep blue shade cotton fabric with high colour fastness, consequently the textile auxiliaries from two companies, i.e. Dymatic Company and Transfar Company in China are selected, and their performances in soaping, fixing and wet rubbing improving on deep blue shade cotton fabric are investigated in the promotion of the wash fastness and rubbing fastness.

Experimental

Materials.

A desized, scoured, bleached and unmercerized woven cotton fabric (100%) was dyed with C. I. Reactive Blue 19 (Shanghai Jiaying Chemical Company) without purification. The textile auxiliaries of DM1578 (soaping agent), DM1518 (dye fixative), and DM2588X (wet rubbing fastness improver) are from Dymatic Chemical Company; TF231A (soaping agent) and TF234FK (dye fixative) are from Zhejiang Transfar Company. Dimethylformamide (DMF, Sinopharm Chemical Reagent Company, 99.5%) was used in reflux. Other chemicals were general laboratory grade.

Dyeing.

Cotton fabric was dyed in a rotary infrared laboratory dyeing machine with C.I. Reactive Blue 19 in different dye amount on the mass of fabric (o.m.f) in 3%, 5%, 8%, 10%, 12%, and 15% at a liquor ratio of 1:20 with 80 g L^{-1} of NaCl, 20 g L^{-1} of Na_2CO_3 for 60 min at 60°C. After dyeing, the dyed fabric was neutralization washed at room temperature, and then rinsed thoroughly in tap water. The dyeing process is described in Fig. 1.

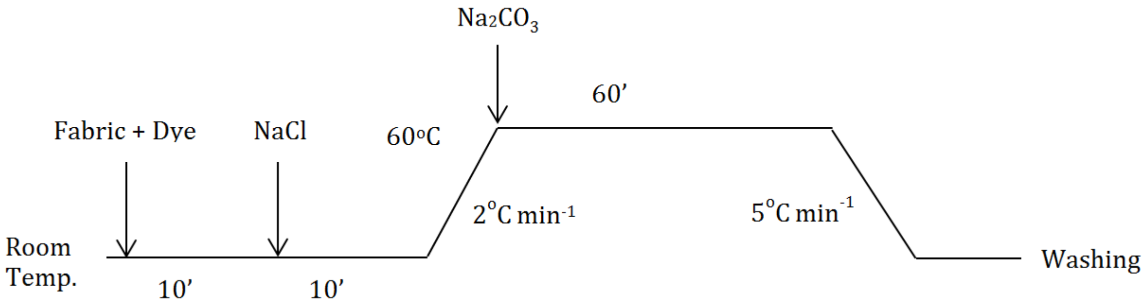

Fig. 1. Dyeing process

Soaping.

The dyed cotton was soaped at a liquor ratio of 1:30 and 2 g L^{-1} of soaping agent at 100°C for 30 min, and then rinsed in tap water, and air dried.

Reflux.

The dyed cotton was refluxed with 50% aqueous DMF solution at a liquor ratio of 1:40 for 20 min, and repeated it until all the unfixed dye was completely removed [16].

Dye Fixing Treatment.

After soaping, the dyed cotton was treated using 2% o.m.f of the dye fixative at a liquor ratio of 1:30 at 55°C for 15 min, and then rinsed in tap water, and air dried.

Wet Rubbing Improvement.

After dye fixing treatment, the dyed cotton was immersed in the wet rubbing improver solution (40 g L^{-1}), padded with 80% wet pick-up, dried at 100°C for 5 min and cured at 150°C for 2 min, rinsed in tap water, and air dried.

Dye Exhaustion.

The absorbance of the dye solution was measured at λ_{max} (594 nm) before and after dyeing solution by using UV 8000S Spectrophotometer (Yuan Xi, Shanghai, China). The exhaustion of dye solution was calculated followed by Eq. 1.

$$\%E=\frac{A_0-A_1}{A_0}\times 100 \quad (1)$$

Where A_0 and A_1 are dye solution absorbance before and after dyeing process, respectively.

Dye Mass Absorbed on Unit Weight.

Dye exhaustion percentage is just the ratio of dye absorbed on fibre in the initial dye mass used, but cannot show the dye quantity on unit weight of substance. The exact dye mass of unit weight (q, mg g^{-1}) is normally used to discover the sorption capacity of substance, and was calculated by Eq. 2.

$$q=\frac{\%E \times \%\ o.m.f}{10} \quad (2)$$

Where %E and % o.m.f are the dye exhaustion and dye mass of fabric percentage respectively.

Dye removal rate.

Dye removal rate (R) is the value to determine the soaping efficiency of detergent, and is worked out based on the K/S values using Eq. 3. The K/S value is the average of 20 values (datacolor 110, US) measuring on random position at maximum absorption values.

$$\%R=\frac{(K/S)_0-(K/S)_1}{(K/S)_0}\times 100 \quad (3)$$

where $(K/S)_0$ and $(K/S)_1$ are the colour strength value of samples before and after treatment respectively.

Colour Difference.

The colour difference (Δ (K/S)) is an absolute value and to inspect the colour distinction between samples using Eq. 4.

$$\Delta(K/S) = \left|(K/S)_0 - (K/S)_1\right| \quad (4)$$

where $(K/S)_0$ and $(K/S)_1$ are the colour strength value of samples before and after treatment respectively.

Colour Fastness.

Wash fastness and rubbing fastness (dry and wet) of dye cotton were measured as per the ISO 105-C06 and ISO 105-X12 respectively.

Results and Discussion

Dye exhaustion.

The absorbed dye mass (q) and dye exhaustion (E) in different dye o.m.f dyeing conditions are showed in Fig. 2. In q values, the dye mass absorbed on cotton (mg g^{-1}) increases with an increase of dye o.m.f, and emerges a linear relationship with regression coefficient R^2 of 0.9762. While the dye exhaustion percentages are stable at 80% from 3% to 8% dye o.m.f, but gradually reduce at 64% in 15% dye o.m.f, which can be explained by the excessive dye mass in 10% and more dye o.m.f. A comparatively low affinity between the dyestuff and cotton fiber occurs when the cotton fibre absorbs dyestaff [18].

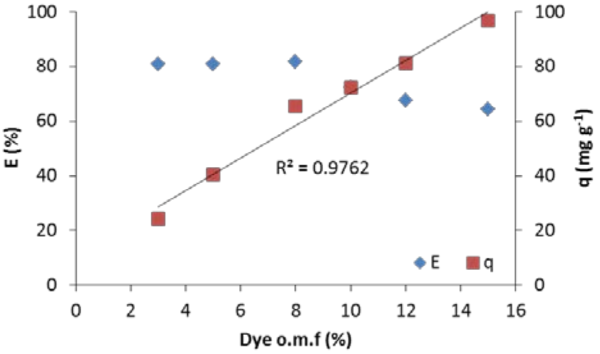

Fig. 2. Dye exhaustion and absorbed dye mass

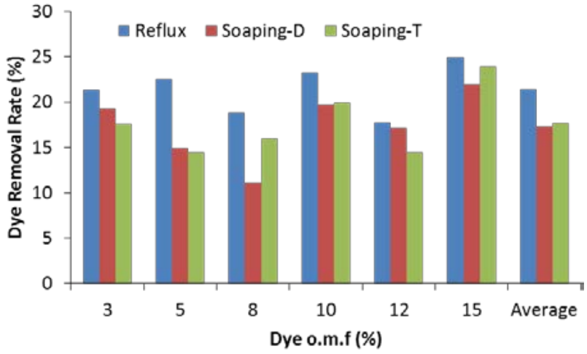

Fig.3. Dye removal rate in soaping and reflux

Soaping and Reflux.

In the end of dyeing, the unfixed dyes mainly existed in the interior and surface of cotton fibre via Van Der Waals force between dye and fibre, and/or between dye and dye. The both soaping and reflux treatments are able to remove the unfixed dyes, but the latter is more effective. Fig. 3 shows the dye removal performance of reflux and soaping treatments on dyed cotton fabric with various dye o.m.f. The Soaping-D and Soaping-T refers the dyed samples soaped off with DM1578 and TF231A respectively. It is apparent that the reflux exhibits its glorious dye removal ability, since the dyes removal rates of all dye o.m.f conditions are higher in contrast to soaping treatments. It indicates that under the reflux, the unfixed dye in the interior can be removed to the reflux mix solution. The soaping agents of DM1578 and TF231A express a good and similar performance on washing off unfixed dye. Despite the dye removal rates of the both soaping agents seesaw up and down, the average dye removal rates of all dye o.m.f conditions for both soaping agents are same, which are 17.4% and 17.7% for soaping-D and soaping-T respectively. The worse dye removal efficiency of soaping treatment compared to reflux since soaping agent with major surfactant content has a good property in removing dust, but has not ability to completely remove the unfixed dye, especially the unfixed dye in the interior of fibre.

The dye removal efficiency also can be characterized by colour fastness, such as wash fastness and rubbing fastness since the unfixed dyes without effective remove will result in a pale colour fastness. The wash fastnesses staining on bleached cotton fibre of multi fabric of all samples are excellent, which are at 5 grade, but different in polyamide fibre. Table 1 lists the wash fastness (staining on polyamide fibre of multi fabric), and rubbing fastness (dry and wet) of dyed fabrics with different colour shade. The wash fastnesses of dyed cotton treated by soaping with detergents are similar and gradually decrease from grade 5 to grade 4-5 with an increase of colour shade. In contrast to reflux, the wash fastness is slightly worse, which are all at grade 5 due to its outstanding dye elimination property.

In the rubbing fastness, the dyed samples are at grade 5 and 4-5 in dry, and at grade 4 and 3-4 in wet. The dyed sample treated with reflux always demonstrates its superior performance in rubbing fastness, which are all at grade 5 in dry and grade 4-5 in wet. It is very difficult to gain grade 5 of wet rubbing fastness because during wet rubbing process, slight dyed hairiness fibre is rubbed out from the dyed fabric and stained on the wet white test cotton fabric. Furthermore, with the exception of reflux, the rubbing fastness decreases by half grade with increasing of dye shade, which correspondingly exists in the wash fastness.

Table 1. Wash fastness and rubbing fastness after reflux and soaping treatments

Treatment		Reflux						Soaping-D						Soaping-T					
Dye o.m.f (%)		3	5	8	10	12	15	3	5	8	10	12	15	3	5	8	10	12	15
Wash Fastness		5	5	5	5	5	5	5	5	5	4-5	4-5	4-5	5	5	5	4-5	4-5	4-5
Rubbing	Dry	5	5	5	5	5	5	5	4-5	4-5	4-5	4-5	4-5	5	4-5	4-5	4-5	4-5	4-5
	Wet	4-5	4-5	4-5	4-5	4-5	4-5	4	4	4	3-4	3-4	3-4	4	4	4	3-4	3-4	3-4

Table 2. Wash fastness, rubbing fastness and colour difference of dyed cotton fabrics

Fixing Treatment	Dye o.m.f (%)	Wash Fastness	Rubbing Fastness		Δ (K/S)	Wet Rubbing Improving Treatment	Dye o.m.f (%)	Wash Fastness	Rubbing Fastness		Δ (K/S)
			Dry	Wet					Dry	Wet	
Fixing-D	3	5	5	4	0.286	Rubbing-D-D	3	5	5	4	0.354
	5	5	5	4	0.549		5	5	5	4	0.146
	8	5	5	4	0.455		8	5	5	4	0.078
	10	5	5	4	0.533		10	5	5	4	0.481
	12	5	5	3-4	0.229		12	5	5	4	0.162
	15	5	4-5	3-4	0.000		15	5	5	4	0.298
Fixing-T	3	5	5	4	0.097	Rubbing-T-D	3	5	5	4	0.299
	5	5	5	4	0.038		5	5	5	4	0.616
	8	5	5	4	0.214		8	5	5	4	0.231
	10	5	5	4	0.376		10	5	5	4	0.388
	12	5	5	3-4	0.046		12	5	5	4	0.395
	15	5	4-5	3-4	0.421		15	5	5	4	0.550

Dye Fixing Treatment.

After soaping, as the wash and rubbing fastnesses are unsatisfactory, a dye fixative is applied to fix the unfixed dyes via ionic bond for example, and thereby improves the fastness. The DM2518 and TF234FK fixatives are applied on the dyed cottons soaped with DM1578 and TF231A respectively, which are correspondingly named Fixing-D and Fixing-T; their wash and rubbing fastnesses are displayed in Table 2, as well as the colour difference (Δ (K/S)). The results state that after dye fixing treatment, the wash fastnesses were improved, which were all at grade 5. It hints that both dye fixatives can promote wash fastness of dyed samples at least half grade.

Rubbing fastness is an alternative significant directory to evaluate the performance of dye fixing treatment. After treatment, both dye fixing agents display an enhancement of dry and wet rubbing fastness, which were elevated to grade 5 from grade 4-5 at dye for o.m.f 15% in dry; meanwhile the grade was 4 for o.m.f (3%, 5%,8%, and 12%) and 3-4 for o.m.f (12% and 15%) dyes shades in wet.

This result demonstrates that both dye fixatives can improve half grade of dry and wet rubbing fastness.

In textile industry, yellowness problem is rigorously avoided after post treatment. The Δ (K/S) values of Fixing-D and Fixing-T in Table 2 are less than 1, which means that the colour of dyed samples was not changed by the dye fixing application, i.e. no yellowness appearance.

Wet Rubbing Improving Treatment.

The wet rubbing improver DM2588X was applied on the dyed cotton previously treated by the fixative (Fixing-D and Fixing-T), and the wet rubbing improving treated cotton fabric are named Rubbing-D-D and Rubbing-T-D respectively. The wash fastness, rubbing fastness and colour difference are listed in Table 2. It represents outstanding wash fastness of Rubbing-D-D and Rubbing-T-D substance since all values are at grade 5. The dry rubbing fastness and wet rubbing fastness are at grade 5 and grade 4 respectively. It hints that under the treatment circumstances, the wet rubbing improver agent can contribute the enhancement of wet rubbing fastness when the dye shades are in the range of 12% to 15% dye o.m.f. It is hard to obtain a wet rubbing fastness at grade 5, because during wet rubbing process, the unfixed dyes always tend to leave from the dry dyed fabric and transfer on the wet crock cotton fabric, resulting in a poor staining problem. The wet rubbing improver is to cover off the anionic groups of the unfixed dye, like as sulfo groups, to prevent the unfixed dye moving on the wet rubbing crock fabric. Addition, the Δ (K/S) values of Rubbing-D-D and Rubbing-T-D are smaller than 1, which suggests that the colour of dyed samples did not change when treated with wet rubbing improver (DM2588X), i.e. no yellowness appearance.

Conclusion

After treatments of soaping, dye fixing, and wet rubbing improving, the colour fastnesses of dyed cotton fabric with different dye o.m.f were improved without doubt. The optimum colour fastnesses of the dyed cotton fabrics with these treatments were all at grade 5 in wash fastness, all at grade 5 in dry rubbing fastness, and at grade 4 in wet rubbing fastness. The soaping agents and dye fixatives showed the similar performances, and the dye fixatives promoted half grade of wash fastness and wet rubbing fastness. The auxiliaries did not cause any yellow problem.

Acknowledgments

This work was sponsored by the Hubei Key Laboratory of Biomass Fibers and Eco-dyeing & Finishing, Wuhan Textile University (Project No. 2014STRZ003), China National Textile & Apparel Council (Project No. 2015061), and Collaborative Innovation Plan of Hubei Province for Key Technology of Eco-Ramie Industry (E JIAO KE HAN 2014 No.8)

References

[1] L. Hao, R. Wang, K. Fang, et al., The synchronized wash-off of reactive-dyed cotton fabrics and decolorization of resultant wastewater using titanium dioxide nano-fibers [J]. Carbohydrate polymers, 2015, 125: 367-375.

[2] L. Fang, X. Zhang, D. Sun, Chemical modification of cotton fabrics for improving utilization of reactive dyes [J]. Carbohydrate polymers, 2013, 91 (1): 363-369.

[3] S. Burkinshaw, G. Salihu, The wash-off of dyeings using interstitial water. Part 4: Disperse and reactive dyes on polyester/cotton fabric [J]. Dyes and pigments, 2013, 99 (3): 548-560.

[4] M. Shahidullah, R. Islam, M. Alamgir Sayeed, et al., Improvement of light fastness properties of dyed jute fabrics through pretreatment [J]. Journal of applied sciences, 2007, 7: 3791-3795.

[5] J. Shore. Cellulosics dyeing, Bradford: Society of Dyers and Colourists, 1995.

[6] K.Y. Tam, E.R. Smith, J. Booth, et al., Kinetics and mechanism of dyeing processes: the dyeing of cotton fabrics with a procion blue dichlorotriazinyl reactive dye [J]. Journal of colloid and interface science, 1997, 186 (2): 387-398.

[7] K. Xie, A. Hou, Y. Zhang, New polymer materials based on silicone-crylic copolymer to improve fastness properties of reactive dyes on cotton fabrics [J]. Journal of applied polymer science, 2006, 100 (1): 720-725.

[8] X. Lei, D. Lewis, Y. Wang, The production of level fast dyeings on wool with nucleophilic dyes and a crosslinking agent [J]. Journal of the society of dyers and colourists, 1992, 108 (9): 383-387.

[9] M. Gorenšek, Dye–fibre bond stabilities of some reactive dyes on cotton [J]. Dyes and pigments, 1999, 40 (2): 225-233.

[10] I. Holme, New developments in the chemical finishing of textiles [J]. Journal of the textile institute, 1993, 84 (4): 520-533.

[11] K. Venkataraman. The chemistry of synthetic dyes, New York: Elsevier, 2012.

[12] E.R. Trotman. Dyeing and chemical technology of textile fibres, London: Charles Griffin, 1975.

[13] L. Li, Measures for color fastness to wet crocking of cotton fabric dyed with reactive dyes [J]. Dyeing and finishing, 2004, 7: 23-25.

[14] W.D. Schindler, P.J. Hauser. Chemical finishing of textiles, New York: The textile institute, 2004.

[15] M. Akalin, N. Merdan, D. Kocak, et al., Effects of ultrasonic energy on the wash fastness of reactive dyes [J]. Ultrasonics, 2004, 42 (1): 161-164.

[16] R.M. El-Shishtawy, Y. Youssef, N.S. Ahmed, et al., The use of sodium edate in dyeing: II. Union dyeing of cotton/wool blend with hetero bi-functional reactive dyes [J]. Dyes and pigments, 2007, 72 (1): 57-65.

[17] H.-r. Cui, Color fastness improvement (II) [J]. Dyeing and finishing, 2004, 22: 15-20.

[18] Y. Cai, S. David, M. Pailthorpe, Dyeing of jute and jute/cotton blend fabrics with 2: 1 pre-metallised dyes [J]. Dyes and pigments, 2000, 45 (2): 161-168.