Study on Dyeing Properties of Wool Fabric under Low Temperature

Fengrong Xia, Junying Tian

School of Textile, Tianjin Polytechnic University, Tianjin 300160, China

Email: xiafengrong123@163.com, tjy6818@163.com

Abstract: Wool fibers are usually dyed under high temperature for long time because of the dense scale structure and hydrophobic lipid layer covered on the surface of wool fibers. It not only wastes resources but also makes the wool yellow and strength decrease. In order to save energy and improve the quality of wool, dyeing temperature should be as low as possible and retain the original style to the best. This research work involves the dyeing of wool with reactive dye in low temperature using low temperature auxiliary; at the same time, soaping fastness and crocking of wool fabric dyed with reactive dye are measured and evaluated; finally, dyeing thermodynamics and dyeing kinetics of reactive dye with low auxiliary are measured, calculated and analyzed to determine the optimal wool fabric dyeing process.

Keywords: wool; low temperature dyeing; dyeing kinetics; dyeing thermodynamics

1. Introduction

Wool is one of the most important fibers in textile industry and is commonly used for producing top-grade garments due to its special properties in fullness, elasticity handle, warmth retention and comfortability. [1]As we all know, a number of processes involving dyeing have been extensively investigated. The traditional dyeing of wool fabric is strict controlled by boiling temperature for long time, this can adversely affect the mechanical properties which affect the carding, combing, spinning and weaving operations. This paper reports on dyeing of wool with reactive dyes at low temperature using low auxiliary for enhancing the hydrophilicity and prompting the expansion [2]. It is believed that this would lead to an economic, non-polluting and energy saving method without any adverse effect on the colourfastness.[4]

2. Experimental

2.1. Materials

Pure wool knitted fabric(26tex) was supplied by Neimenggu Erduosi Group,China.
Active Yellow 4G supplied by Huntsman.

2.2. Dyeing process

2.2.1 Normal temperature dyeing prescription:

Active Yellow 4G 2% (owf), ammonium sulphate 2% (owf), the acidity of the bath was adjusted to pH 4-4.5 by acetic acid, the liquor ratio 1:50, Figure 1 gives the profile of high temperature dyeing (100°C) of wool with reactive dye.

2.2.2 Low temperature dyeing prescription:

Active Yellow 4G 2% (owf), O BaiGe SET 1%, ammonium sulphate 2% (owf), the acidity of the bath was adjusted to pH 4-4.5 by acetic acid, the liquor ratio 1:50, Figure 2 gives the profile of low temperature dyeing of wool with reactive dye.

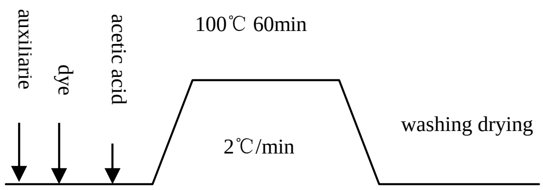

Figure 1. dyeing process of wool

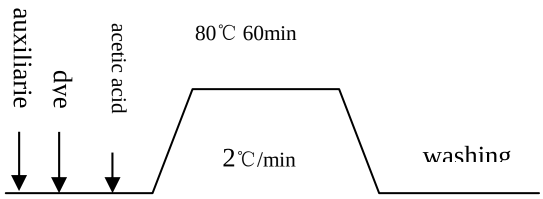

Figure 2. dyeing process of wool under low tmperayure

2.3. Dyeing kinetics research

The weight of wool is 0.2g, the liquor ratio 1000:1, preparing 14 dye bath(1#~14#), take 2.5ml standardized 0.4g/l dye solution, join dyeing auxiliaries, add the distilled water to 200ml. The dyeing time (1#~14#) is 1,3,5,7,10,12,15,20,30,45,60,75,90,120min respectively. The temperature of the dyebath is 80°C and 100°C respectively. Finally, test the absorbency, draw the rate curve and calculate the diffusion coefficient.

2.4. Dyeing thermodynamics research

Taking the standards of after-chroming(0.4g/l) is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10ml, put them into cups respectively. The dye solution was added to the dyebath and the temperature was raised to 60°C, the temperature was respectively increased at a rate of 2 deg/minute reach 70°C and 90°C. Then, the dyed wool sample was taken from the dyebath and washed thoroughly with warm and cold water, squeezed and dried at ambient temperature. Finally, test the absorbency, draw the adsorption curve, calculate the dyeing affinity and dyeing entropy.

3. Results and Discussion

3.1. Dyeing kinetics research

3.1.1 Draw the standard curve

Preparation for the dyebath of 0.4g/l, remove 1ml, 2ml, 3ml, 4ml, 5ml, 6ml, 7ml, 8ml, transfer them to another 8 cups. Scale the capacity with distilled water line, shake up evenly. In the largest wavelengths, test the absorbency respectively. The standard curve is showed in Fig.3.

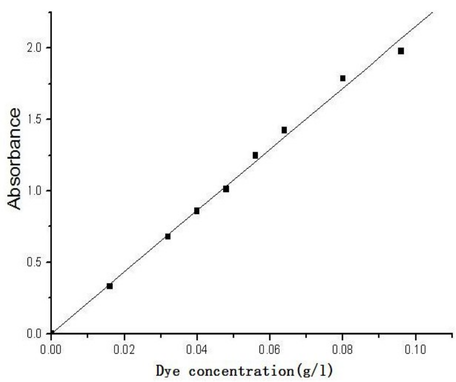

Figure 3. Standard curve of Active Yellow 4G

3.1.2 Draw the dyeing rate curve

To determine the effects of dye exhaustion on wool samples, the two different temperatures were applied on wool at 80°C and 100°C. The dye exhaustion obtained during dyeing with different temperatures is shown in Fig.3. It can be observed from Fig. 4 that in the former 10 minutes the dye exhaustion is very quickly, then achieve steady. The final dye exhaustion at 80°C was lower than 100°C, however, the initial dyeing rate at 80°C was better than 100°C. So, the low temperature is also advisable.

3.1.3 Equilibrium of dyeing percentage and half dyeing time

As it can be seen from Table 1, the time required reach equilibrium is always shorter at higher dyeing temperature. Notice that, at higher temperature, the fiber contains more dye in the early stages but less dye in the latter stages of dyeing. thus, the half dyeing time at 100°C is shorter than 80°C. This means that the shorter time of dyeing, the less time to reach equilibrium.

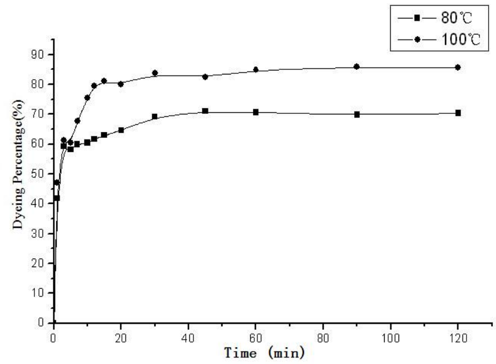

Figure 4. Dyeing rate curve of Active Yellow 4G

Table 1. equilibrium of dyeing percentage and half dyeing time under high and low temperature

Temp. (°C)	Equilibrium of dyeing percentage (%)	Half dyeing time (min)
80°C	77.1	1.1536
100°C	84.4	0.6794

3.1.3 Diffusion coefficient curve

As it can be seen from Figs. 5, it could be suggested that the diffusion coefficient at 80°C is as good as at 100°C, the basic trend of diffusion coefficient change is reduced accompanied by time and decreases tremendously in the former 10 minutes, it is explained that the dye process is mainly concentrated in the former 10 minutes.

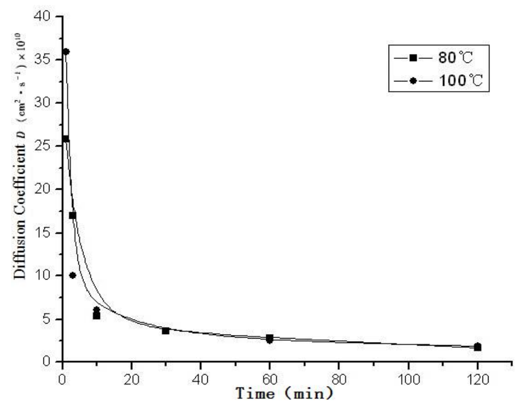

Figure 5. Diffusion coefficient curve of Active Yellow 4G

3.2. Dyeing thermodynamics research

3.2.1 The equal adsorption curve

As Figs. 6 shows, the equal adsorption of wool treated

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with 90°C better than 70°C, the wool fibers have strong adsorption at high temperature. Because of scale structure, an increase in dyeing temperature causes an increase in the rate of dyeing.

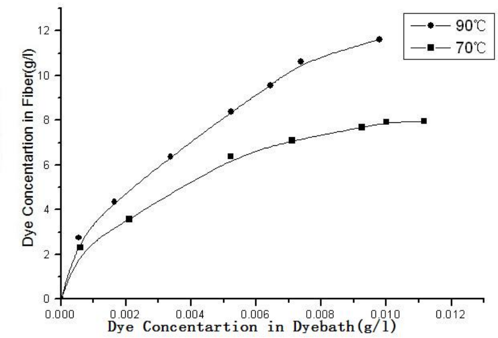

Figure 6. Rate of dyeing isotherms of Active Yellow 4G

3.2.2 Calculate of standard affinity,dyeing heat and dyeing entropy

Data in Table 2 show the parameters of dyeing thermodynamics in dye and wool fibers. The dye has affinity for both the fiber and the dyebath, actually, the greater of the affinity, the driving force become more quickly from dyebath to fiber, when the temperature rises, the affinity will decline. With the increasing of the dyeing entropy, the dyeing orientation will become higher, while, the possibility of fiber adsorption get smaller, coupled with the decreasing of affinity, otherwise, the increasing of the affinity.

Table 2. Parameter calculation results of dyeing thermodynamics

Dye	Standard affinity kJ/mol		Dyeing heat kJ/mol	Dyeing entropy kJ/mol·°C
	70°C	90°C		
Active Yellow 4G	71.277	50.674	-143863	-1.030

3.2.3 Fastness properties

It was observed from Table 3 that there are no obvious differences between normal temperature and low temperature. Considering of the environmental issues and the deterioration of the tensile strength of wool in the boil, the low dyeing temperature is more benefit for us. [5]

Table 3. Fastness properties of wool dyed with Active Yellow 4G

Temp. (°C)	crocking fastness		soaping fastness		
	dry	wet	cotton staining	wool staining	color fading
80°C	4	4	4～5	3	2
100°C	4	4～5	4～5	3～4	2

4. Conclusion

It is found from the study that dyeing kinetics and dyeing thermodynamics can be successfully used for uptaking rate of fibers and distribution trend in dyebath and fiber by using low auxiliary. After evaluating the properties of the dyed samples it was observed that low temperature was fair to fairly good, fastness to washing and rubbing in both dry and wet conditions was good to excellent, without causing any adverse effects on the dyeing properties.[6] This may lead to saving energy and preventing wool damage. Also, this impetus makes us to employ better ways to deal with wool fabrics.

5. Acknowledgment

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