Electrochemical Dyeing of Cotton Fiber for Environmental Protection

Wei XIONG a,1, Yuxin YANG a, Yinyan HOU a, Guinian HUANG a, He Li a and Gang GAN b

aHubei Key Laboratory of Biomass Fiber and Eco-dyeing & Finishing, College of Chemistry and Chemical Engineering, Wuhan Textile University, Wuhan, China
bHubei Key Laboratory of Biomass Fiber and Eco-dyeing & Finishing, College of Physical Culture, Wuhan Textile University, Wuhan, China

Abstract. For environment-friendly dyeing, electrochemical dyeing method was researched. The low consumption of additives during dyeing is beneficial to environmental protection, and the electric field of electrochemical dyeing reduces the salt. Moreover, the K/S value of the fabric increases significantly at the same dye concentration. The alkaline electrolyte in the electrolytic cell may enhance the self-corrosion of the electrode during the electrochemical dyeing process. The results show that the electrochemical dyeing can reduce the amount of additives during the dyeing process.

Keywords. Electrochemical dyeing, environment-friendly dyeing, dyes, electrochemical treatment

1. Introduction

In order to solve the problems of water consumption, energy consumption, high chroma and pollution of reactive dyeing of cotton fabric, it is necessary to carry out energy-saving innovative design for reactive dye dyeing of cotton fabric. The realization of low alkali dyeing and the reduction of wastewater discharge and pollution are the key issues concerned by textile printing and dyeing workers at home and abroad. In recent years, salt free / low salt dyeing of reactive dyes has become a hot spot in dyeing and finishing industry.

The key of traditional salt free dyeing is how to eliminate the electrostatic repulsion between dye and fiber, and realize the efficient covalent combination between dye and fiber. It mainly includes the following ways [1]: converting the electrostatic repulsion between the fiber and the dye into electrostatic attraction; synthesizing cationic reactive dyes; using a medium that can make the fiber and / or dye charged [2-10].

However, due to the complex operation process, poor levelness, high cost and other shortcomings, these technologies can only be explored in the laboratory, but far from the large-scale use of industrialization. The electrochemical salt free dyeing
technology has many advantages, such as easy control, mild reaction conditions, little
damage to fiber, energy saving and emission reduction, simple operation, excellent
dyeing effect and environment-friendly [11-20].

The principle of electrochemical salt free dyeing with reactive dyes is that positive
charges are generated in the anode region under the electric field system, which can
eliminate the repulsion of negative charges on the surface of cotton fabrics to the anion
groups of reactive dyes, and promote the enrichment of dye anions in the anode region.
This method is conducive to the full contact between the dye and the fabric in the
anode area, so as to improve the dye uptake rate, abandon the use of salt and reduce
environmental pollution. As seen in Fig. 1, electrochemical methods can effectively
control the dyeing process and effect [21-28].

![Figure 1. Principle of indirect electrochemical reduction system.](image)

In recent years, some domestic dyeing workers are also engaged in the research of
electrochemical reduction dyeing. Zang Guoqiang et al. Studied the electrochemical
dyeing process of kn type reactive dyes with different structures. The K/S value of the
dyed fabric was improved, the color fastness was basically the same, the breaking
strength of the fabric was improved, and the COD of the dye residue was significantly
reduced. Pan Jie et al. Studied the electrochemical dyeing process of K-type reactive
dyes with different structures. It was found that under the condition of electrochemical
salt free dyeing, the larger the proportion of sulfonic groups in reactive dyes, the higher
the K/S value after dyeing. Wang Haiying et al. Have studied the electrochemical salt
free dyeing of reactive dyes. The results show that the electrochemical salt free dyeing
can significantly increase the dye uptake when dyeing cotton fabric with reactive dyes
by dip dyeing. Cai Xinbin et al. Studied the electrochemical salt free dyeing process of
reactive brilliant blue B-RV and obtained good results. But up to now, most of the
researches are still on the dyeing process, and the follow-up more in-depth research is
less.

Reactive dyeing technology has developed rapidly, and has made a lot of
contributions to the development of salt free dyeing technology at home and abroad.
Compared with the traditional salt dyeing, salt free dyeing is undoubtedly one of the
requirements of sustainable development, but also brings substantial benefits to the
people, which is also the direction of future printing and dyeing workers.

However, the disadvantages can not be ignored. The levelness and color fastness
of cotton fabrics need to be strengthened, and the breaking strength of cotton fabrics
should be further strengthened. In order to better promote the dyeing of reactive dyes,
the structure of reactive dyes should be designed, and at the same time, the
environmental protection oriented dyeing technology should be inclined, and the
matching dyeing auxiliaries should be developed. More clean, efficient, environmental
protection, more comfortable, better quality reactive dyeing process will be improved.
This experiment focuses on the possibility of application. The application of electrochemical salt free dyeing in reactive dyeing was studied. In order to further explore the feasibility of this process, the dyeing performance by different additive reagent in dyeing process was studied.

2. Experimental

Dyeing was carried out in an electrolytic cell. The cotton was placed in the anode area and applied with different voltage. In addition, the electrochemical performance of the system was tested in the electrochemical workstation.

2.1. Results and Discussion

2.1.1. Additives

Since the electric field can replace the salt in traditional dyeing, the amount of salt can be greatly reduced by electrochemical dyeing. By providing an electric field to the dye liquor, the dye anions migrate to the anode in the dyeing bath. The cotton fabric to be dyed is connected with the positive electrode, which increases the dye anion concentration near the fabric, promotes the dye adsorption and improves the dye uptake.

In addition, the external electric field can increase the chemical sites of dyes in the dyeing solution and decrease the chemical sites in the fibers, which will promote the transfer of dyes from liquid phase to solid phase, increase the diffusion coefficient of dyes, and increase the K/S value. The cotton with electrochemical dyeing method shows better performance.

2.1.2. K/S

Compared with the traditional dyeing method, the K/S value of the electrochemical dyeing method is significantly increased. However, when the applied current is too high, on the one hand, the rate of water electrolysis increases at the same time; on the other hand, with the increase of the current density of the whole electric field, the amount of dye in the anode area increases, and the hydrophobic part of some dyes molecules passes through hydrogen bonds and The effect of van der Waals force makes the concentration of dyes decrease in the whole dyeing bath. Therefore, if the electric field intensity is too large, the K/S value will also decrease.

The K/S value of the fabric increases significantly at the same dye concentration. As shown in figure 2 and figure 3, the cotton with electrochemical dyeing method shows good performance of dyeing.

The cotton with electrochemical dyeing has more uniform staining than that with traditional dyeing. The red and blue samples with electrochemical dyeing have deeper color than hat with traditional dyeing. Moreover, the amount of dyestuff required by electrochemical dyeing method may be reduced for fabrics with the same dyeing effect.
2.1.3. Reduction of Dyeing

The dye uptake rate is equivalent to the desorption rate because the dye and fiber gradually form an adsorption equilibrium. On the other hand, the dye anion concentration in the dye solution decreases continuously, and the dye anion adsorbed on the fabric surface has a reverse movement under the influence of anode region.

As a result, the concentration of dye anions on the fabric surface is reduced. The electric field of electrochemical dyeing can increase the dye uptake rate, so it can reduce the dyeing time.

At the same time, the fixation effect is better and the fixation time is shorter. On the one hand, the addition of alkali agent improves the pH value of dyeing solution, which makes the hydroxyl groups of cellulose more easily dissociate into anions, breaks the adsorption equilibrium between dyes and fibers, and slows the desorption rate on the fibers; on the other hand, under the electrochemical action, sodium carbonate as a strong electrolyte greatly improves the electric field strength. Traction is also greatly improved. However, with the prolongation of fixation time, the increase of K/S value of electrochemical salt free dyeing fabric decreases.

2.1.4. Microstructure.

The microstructure of electrode after dyeing in the electrolytic cell may have serious corrosion because of the alkaline electrolyte.

3. Conclusion

The electrochemical dyeing method can reduce the amount of additives during the dyeing process. Meanwhile, the external electric field can increase the chemical sites of dyes in the dyeing solution and decrease the chemical sites in the fibers. The addition of alkali agent improves the pH value of dyeing solution.
Acknowledgments

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