Study on the application of darkening agent Y-6473 on cotton fabric

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Abstract. This paper explored the effect of new darkening agent depth-adding to promote active dyes in fabric dyeing process. Contrast the depth effect after treated, the pure cotton woven fabric dyed with reactive black dye KN-B were treated by Y-6473. The results showed that the apparent color difference and light of the fabric increased significantly, the color fastness increased and hand feeling improved to a certain extent after processing. The production and environmental requirements were considered, the optimal dosage of the extender Y-6473 was 25g.L-1, baking temperature & time were 160-170 ℃ and 90-120s respectively. High washing stability and mass concentration can be adjusted according to the requirements.

1. Introduction
Energy saving and consumption reduction had been the main problems faced by textile & garment dyeing and finishing industry in recent years. Although many enterprises can effectively reduce the discharge of wastewater by reducing the amount of various dyes, the color depth on the surface of textile fabrics was difficult to achieved the desired effect, especially in the dyeing of dark fabrics. With the increasing of dye price and customers' demand for dyeing depth, the use of darkening agent can be promoted without increasing the amount of dye. There are two principles of darkening: fabric dyeing and finishing after dyeing. The darkening agent researched and developed in this project belongs to the darkening after dyeing reactive dyes. This principle of agent is to use low refractive index silicone resin to cover the surface, reduce the reflectivity of light and increase the absorption of incident light. The main components of the deepening agent were epoxy-based quaternary ammonium polymer cationic compounds. When it reacts with the negative charge of cellulose fiber, the surface of the fabric dyed with reactive dyes was cationic, which facilitates the dyeing of anion reactive dyes and improves the dyeing rate.

Therefore, this paper using Y-6473, which was developed by Foshan Youxing Spin Material Science Co.,Ltd , to conduct the deepening finishing of pure cotton woven fabric dyed with reactive black dye, in order to achieve the maximum effect of deepening, and the color fastness to the hand is stable and indirectly reduce the environmental problem of sewage discharge[1-3].
2. Experimental section

2.1 Materials
All-cotton woven twill; Activity depth-enhancing agent Y-6473; Reactive black dye KN-B, soap powder; Sodium chloride and sodium carbonate were A.R. grade. The above materials were provided by Foshan Youxing Spin Material Science Co.,Ltd.(China)

2.2 Main instruments
CS-280 spectrophotometer; R-3 the Dryer; Electronic fabric strength machine; Laboratory mangle.

2.3 Processing
2.3.1 Dyeing process flow and conditions: Use one bath pad dyeing: Fabric of pure cotton→ dip Dyeing liquid (Reactive black KN-B (o.w.f 7%) dye, at room temperature, one dip & one roll, rolling residual rate of 70%) → drying → baking (140-150℃, 2-2.5min) → washing → soap washing (soap powder 3g/L, bath ratio 1:30, temperature above 95℃ for 3min) → washing → drying .Leave blank sample were tested.

2.3.2 Darkening process One-bath one-step process was adopted: Y-6473 (Dosage:Xg.L⁻¹) of Reactive deepening agent was placed in the small rolling groove. The dyed samples were soaked at room temperature for about 20 seconds, put into the sample setting machine to dry, take out the fabric, return the moisture and keep the sample for testing.

2.4 Data testing
2.4.1 DE The surface overlapping layers of the dyed blank sample and the fabric after deepening were measured (according to the thickness of the fabric, until the increase of the overlapping layers no longer results in the change of the radiation value was appropriate), Multiple and multi-point measurements were used to take the average value. The DE of the sample after processed was mainly read from the spectrophotometer. Where \( \Delta L \) is brightness difference, positive values mean brighter; \( \Delta a \) is color difference of red and green light, positive value represents reddish light; \( \Delta b \) is yellow and blue light difference, positive value represents yellowish light.

2.4.2 Strength test The tensile performance test of the warp and weft direction of the fabric before and after the strip method was adopted based on the standard GB/T 39231-2013.

2.4.3 Handle and soaping stability Assess by touch method: invited the master who has been engaged in fabric dyeing and finishing for many years to ranking. The soft feel of unfinished fabric was defined as level 5. The lower the level, the better the feel be.

3. Results and Discussion
3.1 Effect of darkening agent on color light
Table.1 showed the effect of different dosage of darkening agent on color light before and after treatment of dyed fabric. It can be seen that different concentrations of Y-6473 have a greater impact on the color of the treated fabric. There had significant changes in \( \Delta L \), \( \Delta a \) and \( \Delta b \). Compared with the blank sample, the negative values of the three elevated with the increase of mass concentration for darkening agent, which indicated that the brightness was gradually darker, the sample tended to be green and bluer, which was consistent with the trend of black darkening. However, when the dosage was increased to a certain extent (after 25g.L⁻¹), the positive value of \( \Delta L \) gradually increased, the
positive value of $\Delta a$ gradually became smaller, and the negative value of $\Delta b$ gradually decreased. It showed that the fabric presented with tendency of “back dyeing” towards red and yellow after treated. It was likely that the pits on the surface of fabric were gradually filled with the darkening agent and the excess dye molecules began to saturate.

**Table 1.** Effect of darkening agent Y-6473 on the DE of fabric after treated

| Darkening agent | Dosage/(g.L$^{-1}$) | $\Delta L$ | $\Delta a$ | $\Delta b$ |
|-----------------|---------------------|-----------|-----------|-----------|
| 0               | 16.67               | 0.46      | -1.16     |           |
| 10              | -11.20              | -0.21     | -0.98     |           |
| 20              | -13.70              | -0.38     | -1.26     |           |
| 25              | -14.20              | -0.56     | -1.32     |           |
| 30              | 11.25               | 0.23      | -0.95     |           |
| 40              | 14.98               | 0.17      | -1.03     |           |

3.2 Effect dosage of darkening agent on DE (Delta-E)

Fig. 1 showed effect of different mass concentrations Y-6473 on DE for fabric. As can be seen from the figure, Y-6473 had a particularly effect on fabric deepening, the color degree was significantly improved. DE values was read from the instrument and the $\Delta E$ was calculated both showed a trend of rising first and then falling. With the rise of deepening agent, DE values in reading and calculation gradually increased, but after 25g.L$^{-1}$, the increase gradually slowed down. The reason was that Y-6473 covered the surface of fabric dyed black with an uneven low refractive index film to increase the diffuse reflection condition, enhanced the absorption and decreased the amount of reflected light. However, after the mass concentration of agent increased to a certain extent (30g.L$^{-1}$), the adsorption capacity of the fabric to the resin was limited. After the critical value was exceeded, the apparent darkening degree reached saturation. As the darkening agent of the thin film, it will reduced the condition of diffuse reflection and caused the DE to increased slowly or even decrease. Simultaneously, the dosage that agent was overmuch, bring about the fabric to be able to produced “cracks” [4-6]. Considering the production cost and the required deepening effect, the mass concentration of Y-6473 product 25g.L$^{-1}$ was more suitable. The mass concentration of 25g.L$^{-1}$ was used in the subsequent experiments.

3.3 Effect of baking temperature on DE
Fig. 2 showed the effect of Y-6473 baking temperature on DE of fabric at the mass concentration of 25g.L⁻¹. It can be seen that with the increase of baking temperature, the darkening effect on dyed fabrics tends to decrease. It was consistent with previous studied reports by scholars [7]. The reason was that at low temperature, the disperse dyes in the reactive black dyes swimming and moving, covering the fabric surface and the silicon resin film of the darkening agent, making the color deepen. However, when the temperature increased gradually, the dispersed reactive dyes sublimated, making the color gradually become lighter. Considering the low temperature baking, the film forming degree of the darkening agent will be poor, resulting in poor stability and presenting sticky feel, and the DE of fabric will change greatly. It was advisable to determine the baking temperature of 160-170°C.

3.4 Effect of baking time on DE

Fig. 3 showed the effect of Y-6473 on darkening effect of different baking times on the fabric at the mass concentration of 25g.L⁻¹ and the baking temperature of 160°C. With the extension of baking time, darkening effect showed a trend of increasing first and then decreasing and the DE value did not change significantly. It takes a certain amount of time of film forming reaction, and too short baking time will lead to the instability. When the time reached a certain value (120s), the resin film formation and the deepening effects were stable. However, too long baking time can lead to sublimation of reactive dyes, denaturation of the darkening agent, damaged to the resin film, which may affect the feel of the fabric. Therefore, comprehensive consideration should be given to the baking time of 90-120s in actual production.

3.5 Effect of fabric tensile properties after processing
Tab. 2 showed the data of the tensile properties of the fabric after processing with different dosages of Y-6473 at the baking temperature of 160℃ and time of 120s. It was found that the breaking strength of the fabric in both warp and weft showed downward trend after processing of Y-6473 with different dosage. It had been reported that with the increase of deepening agent, the feel of the fabric became soft, the tissue structure loosened and the tensile breaking strength decreased. At the dosage of 25g.L⁻¹, the warp and weft reduction rate were lower, and the loss value was respectively (2.82% and 3.53%), which was controllable. Therefore, the development of products to pay attention to the strong loss rate. In this sense, the demand of customers and production should be taken into account comprehensively when using the deepening agent. Orthogonal experiments should be carried out to optimize all the indexes to achieved the desired effect of deepening and strength loss.

3.6 Effect of deepening agent on hand

Tab. 3 showed the influence of different dosage of Y-6473 on the handle and soaping stability of fabric when the baking temperature and time was 160℃, 120s, respectively. It can be seen that compared with the blank, the handle of fabric had been greatly improved, which can reach 2-3 grades. With the increased of the mass concentration of the darkening agent, the hand feel became softer and softer. However, after a certain dosage (25-30g.L⁻¹) was reached, the change was not significant, and the color fastness was relatively stable after soap washing. This indicated that the product had the effect of increasing the “softness”. The reason is that the silicone resin in the darkening agent had excellent crosslinking performance and low viscosity, which made the fabric have good softness and color fastness. To some extent, this can reduce the use of softeners and dyes to achieved energy conservation and environmental protection.

| Dosage/(g.L⁻¹) | Rate of warp strength loss(%) | Rate of weft strength loss(%) |
|----------------|-------------------------------|-------------------------------|
| 10             | 6.2                           | 2.1                           |
| 20             | 6.74                          | 5.7                           |
| 25             | 2.82                          | 3.53                          |
| 30             | 3.87                          | 3.59                          |
| 40             | 6.75                          | 4.37                          |

| Darkening agent | Dosage/(g.L⁻¹) | Feel (grade) | Soaping stability |
|-----------------|----------------|--------------|-------------------|
| 0               | 5              |              |                   |
| 10              | 4              |              | stable            |
| 20              | 3              |              | stable            |
| 25              | 3              |              | stable            |
| 30              | 2              |              | stable            |
| 40              | 2              |              | stable            |

Table 2. Effect of different dosage of Y-6473 on the tensile properties after processing

Table 3. Effect of Y-6473 on handle and washing stability after processing
3.7 Photos after processing

Fig. 4 showed a, b and c were the pictures of Y-6473 at the baking temperature and time was 160℃, 120s with mass concentration of 20g.L⁻¹, 25g.L⁻¹ and 40g.L⁻¹, respectively. It can be seen that the fabric deepening effect were more obvious after different dosage treated. From the perspective of environmental protection and economic cost, the desired softness and deepening effect can be achieved by using 25g.L⁻¹, but the larger the dosage, the smoother the feel. Therefore, pay attention to the optimization of various index factors in actual production.

4. Conclusions

The product deepening agent Y-6473, which was independently developed, had an obvious deepening effect on fabric dyed with reactive black dye. Thus, different mass concentrations can be adjusted to meet the actual production, customer needs, hand feel and other requirements. Considering environmental protection and production requirements, the optimal dosage of Y-6473 is 25g.L⁻¹, and the baking temperature and time are within 160-170℃ and 90-120s respectively, which can achieve the required effect, in line with the sustainable economic development model.

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