

Modification of Reduction Clearing Process of Polyester Blend Cotton Knitted Fabric Dyeing

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Abstract— Reduction clearing is a very well established process in case of polyester and polyester blend cotton fabric dyeing. Reduction clearing is done for the removal of unfixed dyes and auxiliaries from the fabric surface being a prerequisite of quality assurance and the ease of subsequent processes. Usually in case of two bath polyester blend cotton dyeing, prior to polyester part dyeing pretreatment (followed by scouring, bleaching and enzyme wash) is done first. Then polyester part is dyed followed by reduction clearing. Finally cotton part is dyed. But in this study few modifications of reduction clearing process have been scrutinized combining the scouring, bleaching and reduction clearing process simultaneously and incurring the sequential inter change between polyester part dyeing and pretreatment (scouring, bleaching, enzyme wash) with and without reduction clearing process separately. Accomplishing the experiments, the fabric samples were characterized by wash fastness, rubbing fastness, perspiration fastness, light fastness, surface smoothness and compared with aforementioned process. The modified process was also investigated in terms of water consumption, power consumption, steam consumption and total process time. The results revealed very good fastness properties and salient economic efficiency reducing all utility consumption and process time.

Index Terms— Modification, Reduction clearing, Polyester blend, Knitted fabric, Pre-treatment, HTHP, Color fastness

1 INTRODUCTION

Polyester blend cotton fabric is one of the prodigiously consumed fabric combinations for its multi-dimensional uses and aesthetic attributes. This blend is popular for comprising a large variety of lucrative characteristics such as breathability, tear resistance and formability of being fashioned to be abrasion resistant fabric like canvas. Notably, in spite of having these worthwhile features polyester blend cotton tends to cost less than comparable clothing made of 100% cotton and provides much comfort. Among various blend ratio of poly cotton, 65/35 cotton/polyester is the most largely consumed combination particularly for reasonable price, durability and wide variety of color choice.

The solid coloration process and mélange effect of poly cotton comprises pretreatment, polyester part dyeing, reduction clearing and cotton part dyeing. Although lot of research works are going on for developing efficient blend dyeing method but still two bath process is being used mostly for polyester blend cotton dyeing. Cotton part is mostly dyed by reactive dyes by exhaustion method at 60°C. On the other hand, polyester part is extensively dyed by high temperature high pressure (HTHP) method. It is well known that polyester part is comprehensively dyed exclusively with disperse dyes.

Disperse dyes are kind of nonionic dyes with trivial water solubility. As polyester is comparatively hydrophobic in nature, disperse dyes are applied to polyester at HTHP method at around 130°C. Because of lower water solubility

and dispersion to aggregate during dyeing, some disperse dyes remain adhered on the fabric surface after polyester part dyeing [1]. These unfixed dyes may adversely affect the color fastness properties of fabric and cause inevitable unevenness of subsequent processes. To avoid these mentioned problems reduction clearing is traditionally done after polyester part dyeing [2].

Reduction clearing process can be demarcated as a wash-off treatment after polyester part dyeing which removes the unfixed dyes and auxiliaries from the surface of the fabric. NaOH and Na₂S₂O₄ are commonly used as the reduction clearing agent industrially at 60-80°C for 20-30 minutes [3]. It is very well granted that reduction clearing plays significant role in case of fabric's brightness and color fastness properties required to maintain the quality parameters imposed by buyers or consumers. But the reducing agents used for reduction clearing process have adverse environmental effect in addition to its expense due to the presence of aromatic amines in case of azo disperse dyes [3].

In conventional process reduction clearing process is done separately after polyester part dyeing which consumes substantial volume of water, chemicals, process time thus requiring expanded production cost. Now-a-days dyers and producers and remarkably well concerned regarding the ecofriendly and efficient technological processes due to increased pressure and demand claimed by the buyers and end users. As the adequate water resources are gradually diminishing alarmingly, all manufacturing plants including textile wet processing industries are trying to best use the water by imparting process modifications due to environmental and commercial concerns as well. Accordingly, in this study few alternative thoughts have been devised instead of earlier method of reduction

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clearing focusing on reduction of water consumption, utility consumption, process time keeping all the parameters as required. Unlike traditional process polyester blend cotton dyeing process has been modified in this study by the dyeing the polyester part firstly followed by scouring, bleaching, enzyme wash and reduction clearing together and separately. Furthermore, we tested the dyed fabric processed by scouring, bleaching, enzyme wash and cotton part dyeing eliminating the reduction clearing diametrically after polyester part dyeing and comparative analysis has been depicted.

2 LITERATURE REVIEW

2.1 General interpretation

It is well known that reduction clearing process is a vital part of polyester blend dyeing especially for medium to dark colors. In case of polyester blend cotton dyeing the entire solid dyeing process comprehends the sequence e.g. pretreatment (scouring, bleaching, enzyme wash), polyester part dyeing, reduction clearing and finally cotton part dyeing.

2.2 Pretreatment (Scouring, bleaching, enzyme wash)

Cotton is a naturally grown cellulosic fiber and comprises natural yellowish color in raw fiber. It is very common knowhow that certain whiteness is required for levelness of textile coloration. That is why bleaching is done traditionally for whitening the cotton fiber. H_2O_2 is widely used bleaching chemical in textile industries. On the other hand, cotton and cotton blend grey fabric may have some oil, wax and other impurities due to weaving and other related process during fabrication which may also cause unevenness of dyeing process. That is why scouring is done to avoid these aforesaid constraints. NaOH in this regard plays the main role as scouring agent by doing saponification reaction with cellulose thus removing the impurities and enhancing the absorbency of the fabric which is very important for the penetration of dyestuffs into fiber molecules. In this study scouring and bleaching are done simultaneously at 110°C for 20 minutes. Along with aforementioned processes enzyme wash is also required for making the cotton fiber ready for dyeing. There are various methods and purpose of enzyme wash for cotton [4] [5] [6] but the main motto of enzyme wash is to reduce the hairiness and protruding fiber that may cause barrier for level dyeing. As polyester is synthetic and does not require these pretreatment processes for coloration that is why this pretreatment step has been moved after polyester part dyeing with a view to reducing the utility consumption and process time by the simple modification of reduction clearing process as depicted in figure 1(b)- trial 1 and 1(c)- trial 2 process.

2.3 Polyester part dyeing

Polyester blend dyeing is exclusively done by high temperature high pressure (HTHP) method [7]. Disperse dyeing is the usual choice of polyester dyeing. Dyeing of polyester with disperse dyes is carried out in acid medium keeping pH 4-4.5. The range of dyeing temperature of polyester dyeing is $130-135^\circ\text{C}$.

2.4 Reduction clearing

Reduction clearing is done after polyester part dyeing to remove the unfixed dyes and auxiliaries from the fabric surface required for the quality assurance. For medium to dark shade, reduction clearing is done using commercially available reducing agent in 2 gm/ltr at 80°C for 30 minutes typically. In case of dark to extra dark shade reduction clearing may need to be done twice. Hence reduction clearing process takes 1-2 hrs. approximately. NaOH and $\text{Na}_2\text{S}_2\text{O}_4$ are also extensively used as reducing agent after polyester part dyeing. As mentioned earlier that NaOH and H_2O_2 are used as scouring and bleaching agent respectively can play the role of reduction clearing as well if the pretreatment process is done after polyester part dyeing keeping all quality parameters maintained which have been illustrated in results of this study.

2.5 Cotton part dyeing

Cotton is extensively dyed by reactive exhaust dyeing method [8]. In this study cotton part dyeing has been done by mentioned method also. In this process cotton is dyed in $60-80^\circ\text{C}$ at alkaline medium keeping pH 10-11. While wet processing, dyestuff mixture is generally dosed linearly whereas other chemicals and auxiliaries are dispensed progressively or by injection method as recommended in their application manual.

3 METHODOLOGY

3.1 Materials

65/35 cotton/polyester blend fleece knitted fabric, yarn count 34's, fabric weight 180 GSM was taken in consideration for investigation. As aforesaid, in case of traditional polyester blend cotton fabric dyeing as shown in figure 1(a), firstly pretreatment (scouring, bleaching, enzyme wash) is done, then polyester part is dyed followed by reduction clearing. Finally cotton part is dyed. But in this study we trialed few modifications of reduction clearing unlike traditional process with a view to shortening the process and reduce production cost. Accordingly, in 1st trial as shown figure 1(b), polyester part of mentioned fabric was dyed in black color followed by pretreatment (scouring, bleaching) and reduction clearing together. In this case polyester part was dyed by the

HTHP method and reduction clearing was done simultaneously with scouring bleaching at 110°C for 20 minutes. Novaux Reduction RCA was used as reduction clearing agent in 2 gm/l. Finally cotton part was dyed in black color by the reactive exhaustion method. In 2nd trial as depicted in figure 1(c), the same fabric was processed without any reduction clearing process and any extra wash off chemicals. All the remaining processes and parameters of trial 1 and 2 were kept unchanged alike traditional process. Notably, the enzyme wash process was identical in

all processes and was done at 80°C while cooling after scouring and bleaching. The dyestuffs used for polyester part were Taicron RED SP-2RT, Taicron Black SP-GT and for cotton part Remazol D Black RGB, Remazol Navy Blue GG were used. The total shade percentage for cotton and polyester part was 3% each being 6% in total. The shade%, dye stuffs and other auxiliary chemicals were kept same for both trials. The dyeing machine used for the experiments was HT sample winch dyeing machine of brand Thies, Germany.

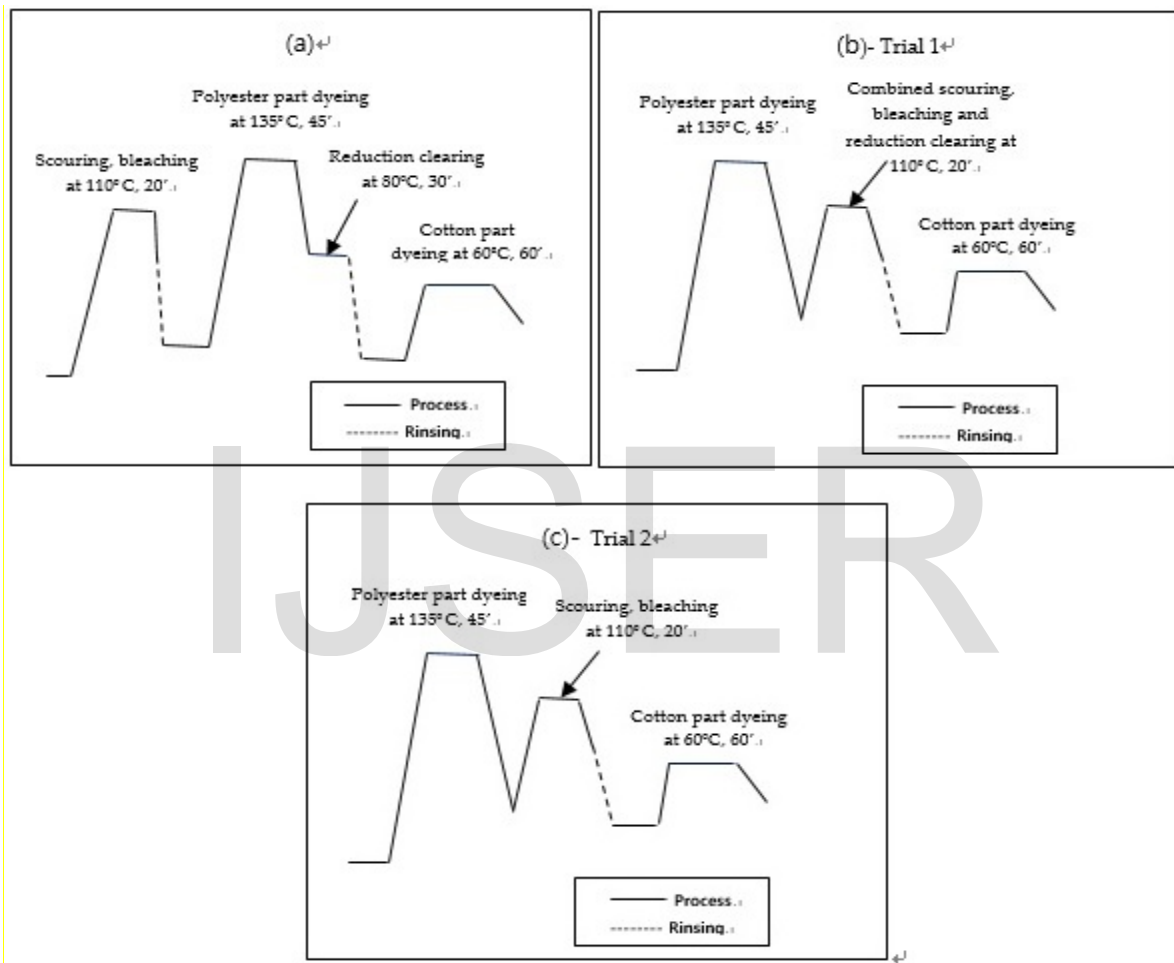


Figure 1: Dyeing curve of polyester blend cotton (a) traditional process, (b) Combined scouring, bleaching and reduction clearing (Trial 1), (c) Eliminating reduction clearing (Trial 2)

3.2 Color Fastness to Wash

After accomplishing the experiments successfully, the fabric samples were characterized by color fastness to wash as shown in table 1. Fabric samples undergone through the process as shown in figure 1(b) and 1(c) were tested and compared with the sample previously dyed by the traditional process as depicted in figure 1(a). The test of color fastness to wash was carried out by ISO 105-C06: A2S method.

3.3 Color Fastness to Rubbing

Both the dry and wet rubbing fastness properties of the trialed samples were investigated and compared with the sample processed by traditional method. The results are illustrated in table 2. The testing method in this regard was ISO 105-x12.

3.4 Color Fastness to Perspiration

The color fastness properties to perspiration of trialed fabric samples were also investigated as represented in table 3.

The fastness properties in both acid and alkali perspiration were analyzed. Perspiration fastness test was performed following ISO 105-E04 method.

3.5 Color Fastness to Light

The light fastness properties of the trialed samples were checked by ISO 105-B02 method.

4 RESULT AND DISCUSSION

4.1 Fabric surface properties

Surface smoothness is one of the important qualities and requirements imposed by the consumer. As clothing remains next to human skin it is very sensitive issue to ensure this quality properly. The surface smoothness of the trialed fabric samples was scrutinized manually. Comparing the both trialed samples with the traditionally

processed sample, the surface of the trialed samples was found satisfactorily fine with no mentionable change.

4.2 Color fastness to wash

The color fastness properties to wash of trialed fabric samples were tested and compared with the traditionally processed sample. No substantial difference in rating among traditional and trialed samples was observed. The rating of color staining to acetate, nylon, acrylic and wool was same for all samples being rated 4-5. On the other hand, unpredictably the color staining of trial 1 samples to cotton and nylon became rated 5. This might be the reason of using reducing agent at the time of scouring and bleaching done simultaneously at 110°C for 20 minutes. Analyzing the color fastness to wash results, it could be claimed that the trialed modifications are well compatible for application compared to old process.

TABLE 1
Rating of color fastness to wash properties

Fastness to	Staining to	Rating (Traditional Process)	Rating (Trial 1)	Rating (Trial 2)
Washing	Acetate	4-5	4-5	4-5
	Cotton	4-5	5	4-5
	Nylon	4-5	4-5	4-5
	Polyester	4-5	5	4-5
	Acrylic	4-5	4-5	4-5
	Wool	4-5	4-5	4-5

4.3 Color fastness to rubbing

The trialed fabric samples were characterized by both dry and wet rubbing test. The ratings of color staining in this

regard were interestingly exactly same for all trialed samples along with the traditional one being rated 4-5 and 2-3 in case of dry and wet rubbing respectively. So the results depict the exploitability of trialed process in bulk production.

TABLE 2
Rating of color fastness to dry and wet rubbing

Fastness to	Staining to	Rating (Traditional Process)	Rating (Trial 1)	Rating (Trial 2)
Dry rubbing	Standard rubbing cloth	4-5	4-5	4-5
Wet rubbing	Standard rubbing cloth	2-3	2-3	2-3

4.4 Color fastness to perspiration

Alike color fastness properties to wash and rubbing, the ratings of color fastness properties to both acid and alkali perspiration showed satisfactory result. In humid weather and due to metabolic process human body tends to sweat.

Uneven dyeing may lead to serious discoloration incurred by sweating. That is why color fastness test to perspiration comprises great importance for quality issue. As demonstrated in table 3 the fastness ratings in this regard for all samples were identical being 4-5 except the rating of

color staining to nylon although this rating was same in case of all traditional and trialed samples. Generally, 3-4 as

rating of color fastness to perspiration is accepted.

TABLE 3
Color fastness to acid and alkali perspiration

Fastness to	Staining to	Rating in acid perspiration (Traditional Process)	Rating in acid perspiration (Trial 1)	Rating in acid perspiration (Trial 2)	Rating in alkali perspiration (Traditional Process)	Rating in alkali perspiration (Trial 1)	Rating in alkali perspiration (Trial 2)
Perspiration	Acetate	4-5	4-5	4-5	4-5	4-5	4-5
	Cotton	4-5	4-5	4-5	4-5	4-5	4-5
	Nylon	4	4	4	4-5	4-5	4-5
	Polyester	4-5	5	4-5	4-5	4-5	4-5
	Acrylic	4-5	4-5	4-5	4-5	4-5	4-5
	Wool	4-5	4-5	4-5	4-5	4-5	4-5

4.5 Color fastness to light

Color of dyed fabric may fade for being exposed to different kind of heat, sunlight and other light energy sources. That is why color fastness to light is measured to determine how much the color fades during the expose to a known source of light. It is also a significant test to be done for the

assurance of fabric quality as garments may undergo through various kind of light exposure while outside job especially at day time. The color fastness to light of the trialed samples was rated 3-4 which also resembled the sample processed traditionally. In case of light fastness, no change in rating has been observed as displayed in table 4 ensuring the aptness of trialed processes replacing the traditional one.

TABLE 4
Color fastness to light

Fastness to	Rating (Traditional Process)	Rating (Trial 1)	Rating (Trial 2)
Light	3-4	3-4	3-4

4.6 Comparative analysis between traditional and trail 2 process

As aforesaid that in traditional process reduction clearing is separately done after polyester part dyeing and pretreatment (scouring, bleaching and enzyme wash) is done prior to polyester part dyeing in case of polyester blend cotton fabric dyeing. To compare the economic concerns of bulk dyeing, 600 kg (same fabric as trial) was dyed by trial 2 process with same particulars as mentioned in experimental section and compared with the traditional process. The dyeing machine used in this regard was SCLAVOS Athena for both old and experimental process. The comparative results showed outstanding efficiency in case of utility consumption, process time and total dyeing production cost as mentioned in table 5. The reason behind this efficiency is nothing but eliminating the reduction clearing process diametrically and using no extra wash off chemicals. In trial 2 process the pretreatment was done after

polyester part dyeing unlike traditional process. As per our trial and observations, the scouring and bleaching process can do the function of reduction clearing as well. The reason for it could be that NaOH used as main scouring agent can do surface cleaning [9] and H₂O₂ used for bleaching can perform as a discoloration agent [10] thus removing the unfixed dyes and auxiliaries from the fabric surface fulfilling the purpose the reduction clearing process without using any extra wash off chemicals. Although lot of research works are being performed for the development of efficient wet processing of blend fabric [11] [12] [13], we believe that the mentioned trial 2 process could play beneficial role if adopted by the textile dyeing industries. As represented in table 5 by applying trial 2 process the water consumption, steam consumption, power consumption, process time and total batch cost could be reduced by 25.82%, 3.62%, 15.3%, 15.43% and 8.01% respectively.

TABLE 5
Comparison of 65/35 cotton/polyester dyeing by traditional and trial 2 process

Comparison points	65/35 C/P dyeing with traditional process	65/35 C/P dyeing without reduction clearing (trial 2)	Beneficial reduction in %
Water consumption(L)	80704	59864	25.82
Steam consumption (Kg)	3196.2	3080.4	3.62
Power consumption (kWh)	254.9	215.9	15.30
Processing time (Min)	927	784	15.43
Total batch cost (BDT)	78158	71896	8.01

This paper provided the experimental data regarding traditional solid color dyeing process of 65/35 cotton/polyester along with two trials having some modifications of reduction clearing unlike traditional one. The fastness tests were done multiple times for getting precise data. Although both trials showed well accordance comparing with traditional process, trial 2 process has been more exploitable than trial 1 process as neither reduction clearing process was involved nor any extra wash off chemical was used. Moreover, all the fastness ratings of trial 2 process were explicitly satisfactory confirming the rightness for application in bulk production.

5 CONCLUSION

It can be concluded that two trial processes replacing the traditional process of 65/35 cotton/polyester blend knitted fabric dyeing have been well devised by simple modification of reduction clearing process. Every important color fastness property e.g. color fastness to wash, rubbing, perspiration and light showed almost same results as old process with trivial changes. Fabric surface and hand feel were also perfectly fine. All experiments were done with 65/35 cotton/polyester fleece knitted fabric. As cotton is a cellulosic fiber, the trialed processes could be applied to other cellulosic fiber blend with polyester. So analyzing the experimental results and discussion it is evident that trialed processes would be beneficial for the industries to adopt in bulk production whereas trial 2 process would patently be more advantageous.

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