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Discussion on Avoidance of Staining Problem in Cotton/CDPET Dyeing

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Abstract. In this research, a novel approach has been proposed to remove stain problem from blended fabrics as an alternative option with traditional reduction clearing process. For this purpose, cationic dyeable polyester and cotton blended fabrics were dyed as traditional technique based on formulations approach and the colour strength (K/S), dye uptake (%) and the whiteness index properties were evaluated. The results of color strength indicated that dye was more uniformly absorbed by the blended fabric compared to the untreated fabric. In addition, when untreated fabric was dyed in the presence of a leveling agent (Lyogen DFTN), the K/S and levelness of dye uptake (%) values were enhanced. Finally, very less staining was observed that proved by CIE Whiteness Index values and indicates that formulation (F-IV) has more beneficial to reduce staining from Cotton/CDPET blended fabric (65/35).

1 Introduction

Consumers have greatly hailed the chemical and natural fibres' blended products due to the fact of the wearing and wrinkle resistance nature of chemical fibres and the moisture absorption and high permeability on the part of natural fibres [1]. There is an ascendant marketplace percentage for polyester/cotton (P/C) blends in the textile industry of 58.45% share in worldwide marketplace as a result of their cost of aesthetic and affable achievement of the consumer [2]. Nonetheless, when disperse dyes under dyeing conditions' conventional high-temperature polyester, such as 130 ºC and pH 4–5, are used in the dyeing of blends, the result is a poor wet fastness such as washing and perspiration. The hydrophobic polyester fibre can easily be accessed by disperse dyes since polyester fibre has glass transition temperature (Tg) that is relatively low compared to cotton. Thus, there is heavy staining of the polyester component, resulting in the blend having wet fastness properties that are very low [3]. Contrary to conventional polyester (PET) fibres, cationic dyes can be used in dyeing cationic dyeable polyester (CDP) with a lot of ideal characteristics exhibited. Cationic dyeable polyester (CDP) can be described as a distinct polyester fibre which underwent transformation during the process of polymerisation. The fabrication of this was attained through the adding of dimethyl ester sodium salt of 5-sulfoisophthalic acid (DMS salt), in order that anionic sites, not possessed by normal polyester fibres, could be generated by imparting PET cationic dyeability for the solution of dull colour problem [4]. Figure 1 shows the structure of cationic dyeable polyester. There is much less number of sections containing anionic sites compared to the number of normal ester sections.

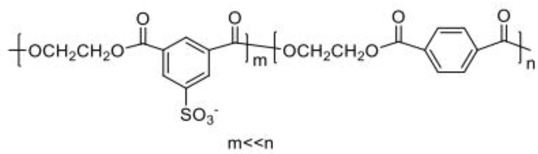

Figure 1. Structure of cationic dyeable polyester.

Identical properties that have normal PET fibres are possessed by modified polyester. Cationic dyes can be used to dye anionic groups. Again, the development of this fibre was made for the lowering of polymer's glass transition temperature, which usually lowered by 10% compared to normal polyesters, so that additional segmental mobility and open polymer structure could be obtained [5], leading to lower temperature dyeing. Again, the hydrolysing of this modified polymer takes place more readily as it is highly sensitive to heat setting. A comprehensive research has been undertaken on CDP [6-8] as a result of the brilliant colour that the dyed fabric displayed and higher colour yield, as well as better wet and sublimation fastnesses and the rest. The application of cationic dyes has been successfully performed at

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100ºC and normal pressure on easy cationic dyeable polyester (ECDP) while the dyeing of blends made up of comprising ECDP and cellulosic or protein fibres could be accomplished without damaging the fibres [9]. Abolishing of disperse dye on the PET surface and making adjustment to achieve the proper wetness fastness levels are important as well. There is a general acceptance of the technical importance of reduction clearing in order that the accuracy of the colour and the fastness properties could be enhanced, specifically to wet treatments [10].

A new approach has been undertaken in this research to see to it that the staining of the dyes at the time of dyeing behaviour is overcome with the use of levelling agent. This is followed by reduction clearing when subjected to whiteness index as response limitation on pilot scale experiment.

2 Experimental

2.1 Materials

Cotton/cationic dyeable polyester (CT/CDPET) blended woven fabric was collected from local textile mill. The commercial dyes of Cationic Red 4G and Reactive Red HE8B were purchased from DyStar Group, India. Lyogen DFTN (levelling agent), Ladiquest DWA (soaping agent) and Ekaline F (washing off agent) were purchased from Clariant, India.

2.2 Method

The bleaching solution was prepared by adding 1 gL^{-1} of wetting agent, 1 gL^{-1} of peroxide stabiliser, 6 gL^{-1} of hydrogen peroxide (30%), and 2 gL^{-1} of NaOH. The blended fabric was immersed in the bleaching solution at a liquor-to-goods ratio of 20:1 at 98ºC for 60 minutes, and then the bleached fabric was washed with hot water and rinsed thoroughly with cold water and dried under ambient conditions. Briefly, Cotton/CDPET blended fabrics (20/80, 35/65, 65/35, 80/20) were placed in a Cationic Red 4G dyebath at a liquor-to-goods ratio of 20:1 and pH 4–5 at room temperature. The cationic dyed fabrics were then put into a Reactive Red HE8B dyebath at a liquor-to-goods ratio of 20:1 at room temperature, 50 gL^{-1} sodium sulphate and 15 gL^{-1} soda ash were used for exhaustion and fixation of the reactive dyebath. After fixation, the dyed fabrics were then rinsed at 35°C and the wash liquor pH was measured, followed by neutralisation with 1% of acetic acid at room temperature for 10 minutes and washed with 1 gL^{-1} of detergent at a liquor-to-goods ratio of 50:1 at 80°C for 10 minutes. Finally, the fabrics were rinsed thoroughly with cold water and air dried. The dyed fabrics were firstly rinsed with warm water and then a reduction clearing process was applied. The fabrics were treated at 70ºC for 20 minutes using at a liquor-to-goods ratio of 20:1. The reduction clearing bath comprised 3 gL^{-1} sodium hydrosulphite ($Na_2S_2O_4$) and 3 gL^{-1} sodium hydroxide (NaOH). Reduction cleared samples were then rinsed with water and dried at room temperature. According to Table 1, the experimental process was followed throughout the whole study.

Table 1. Experimental process formulations.

Formulation I	Formulation II	Formulation III	Formulation IV	Formulation V
Bleaching ↓ Dyeing ↓ Reduction clearing ↓ Hot wash ↓ Washing off ↓ Dry	Bleaching ↓ Dyeing ↓ Reduction clearing (Reduced 50% concentration) ↓ Hot wash ↓ Washing off ↓ Dry	Bleaching ↓ Dyeing + Lyogen DFTN (1% o.m.f.) ↓ Reduction clearing ↓ Hot wash ↓ Dry	Bleaching ↓ Dyeing + Lyogen DFTN (3% o.m.f.) ↓ Reduction clearing ↓ Hot wash ↓ Dry	Bleaching ↓ Dyeing + Lyogen DFTN (5% o.m.f.) ↓ Reduction clearing ↓ Hot wash ↓ Dry

2.3 Measurements and standards

Color strength (K/S) and fastness values were determined according to our previous work [11]. The dye uptake percentage (D) of fabrics was calculated using [12] and the whiteness index (WI), denoted as CIE units, was measured for fabrics as per AATCC standard test method using international data colour.

3 Results and discussion

3.1 Colour Strength and Dye uptake

It is well-known that the colour strength parameter (K/S) has been widely used for colour measurement of dyed substrates [13]. Colour strength values (K/S) of dyed blended fabrics were shown in Figure 2. It is clear that the colour strength was found to be higher in the formulation (F-IV) range with 65/35 fabric and then decreased thereafter, and it should be noted that a very small amount of dye might have been lost from the blended (65/35) fabric surface. The colour strength (K/S) was better while the reflectance on the wavelength of maximum absorption (λ_{max}) decreased and suggested a greater uniform dye distribution [14, 15]. The high K/S values obtained from the fabrics with (65/35, 80/20) blended in formulation (F-III, F-IV) suggest that the reflectance's of these fabrics were lower than the others (20/80, 35/65) blended in formulation (F-I, F-II and F-V). This must be a result of different light absorption characteristics. The levelling agent decreases the initial dyeing rate in the dyeing process to ensure level dyeing. The effect of the levelling agent amount on the colour

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yield of formulations (F-III, F-IV and F-V) was given higher with an increased amount of levelling agent, as shown in Figure 2, which was attributed to the interaction between the dye and the levelling agent. Lyogen DFTN, the levelling agent used in this study, was non-ionic aliphatic polyglycol ether and shows high affinity to dyes. The colour strength was very low when a large amount of levelling agent was added. It seems that the pressure of the levelling agent with dye was so sturdy that it became difficult for the dye molecule to be separated from the levelling agent and migrate into the fibre when there is an excessive amount of levelling agent present. Therefore, a minimum amount of levelling agent ought to be used for suitable colour strength as long as uniform dyeing may be obtained. The colour strength of the 65/35 blended fabric was higher in formulation (F-IV) cases, indicating that it was easier for the dye to migrate into the less compact 65/35 fabric than others.

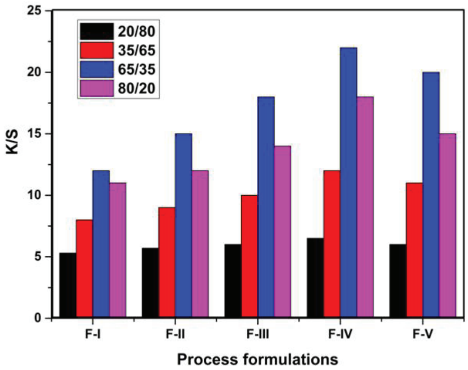

Figure 2. Color strength values**.**

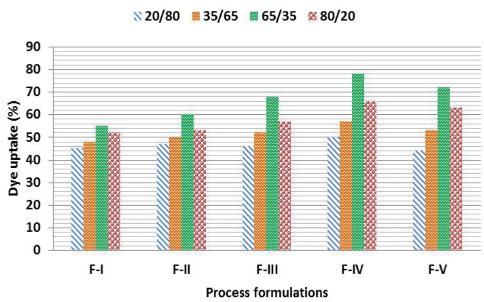

Figure 3. Dye uptake (%) of blended fabrics.

The dye uptake (%) of blended fabrics was shown in Figure 3. It has been shown that the dye uptake (%) was found to be higher in the formulation (F-IV) range with 65/35 blended fabric among all the samples. This result was attributed to the hydroxyl group of the cellulose carrying a slight negative charge, which is undesirable for dye fibre interaction because of the anionic nature of reactive dye used in this study. In addition, by using electrolyte in a dyeing bath, slight positive charge was acquired on the fabric surface. This will promote more dye fibre interaction and resulted in more dye uptake percentage [16-18]. Levelling agents have been evolved with reactive dyes to overcome the skitteriness of the fibre. Lyogen DFTN considerably enhanced the rate and extent of the dye uptake percentage. The glass transition temperature (Tg) of polyester material increases the chain mobility and leads to an extra shape ultimately being opened that can also enhance the uptake percentage by less penetration of the dye molecule [19].

Table 2 and 3 show the wash and rubbing fastness properties of the blended fabrics. The results indicate that the levelling agent involved in dyeing has slightly improved the fastness properties of the dyed blended fabrics. It was attributed to the interaction between the dye and levelling agent [20]. The attraction force of the levelling agent with the dye was so strong that it was difficult for the dye molecule to be separated from the levelling agent and migrate into the fibre in the case of high concentration of levelling agent. Therefore, the minimum amount of levelling agent should be used for good colour fastness yield as long as level dyeing can be obtained.

Table 2. Wash fastness values.

Process Formulations	20/80	35/65	65/35	80/20
F-I	3-4	3-4	4	3-4
F-II	3-4	3-4	4	3-4
F-III	4	4	4-5	3-4
F-IV	4-5	4	4-5	4
F-V	4	3-4	4	4

Table 3. Dry rubbing fastness values.

Process Formulations	20/80	35/65	65/35	80/20
F-I	4-5	4	4-5	3-4
F-II	4-5	4-5	4	4
F-III	4	4-5	4-5	3-4
F-IV	4	4	4	3-4
F-V	4	4	4	4

3.2 Whiteness index

Fabric whiteness maintenance is one of the most important cleaning performance indications in the textile industry. Whiteness can be defined as a facet of colour corresponding to a high luminosity and a lack of hue and greyness. In order to evaluate whiteness quantitatively, the CIE (Commission International de l'Eclairage) advocated a whiteness index based solely on studies by using Ganz [20]. This formula is used to calculate whiteness, W, and is based on illuminant D65 and 10º standard observer. It must be mentioned that the CIE Whiteness Index is not generally a valid assessment of whiteness for values below 40 [21]. Figure 4 shows the effects of various process formulations on CIE whiteness change in blended, bleached and dyed fabric. It is evident that the degree of change in whiteness is subject to the type of formulations. Although bleaching conditions were standardised, they were not representative of factory practice. The higher values of whiteness were obtained in the case of formulation (F-IV) with 65/35 fabric among all samples after bleaching conditions. It is apparent that the mentioned formulations' (F-I, F-II, F-III and F-V) results were not satisfactory, and there is a noticeable difference in the whiteness index of dyed fabric in comparison with bleached fabric, and washing off agent was not able to remove stains completely from the blended fabric. Therefore, these formulations failed to reduce the staining of fabric and were not found to be more effective in erasing staining of blended fabric. The concentration of the reduction clearing treatment was then reduced to 50% and the fabric was subjected to washing off agents in order to remove the slight tint from the fabric. However, the fabric became more stained. This result predicts that the tinting of the fabric may be due to the washing off agents. It can be observed that in formulation (F-IV), there is a very slight difference in the whiteness index of dyed fabric compared to bleached fabric, i.e. much less staining was observed, which was proved by the CIE Whiteness Index and indicates that formulation (F-IV) is beneficial for reducing staining from Cotton/ CDPET blended fabric (65/35).

Less staining observed may be due to the Lyogen acting as a levelling agent along with diffusion acceleration, ensuring that maximum exhaustion of dye goes into the fibre rather than remaining in the bath. However, there could also be unfixed dye that has been removed to a greater extent by reduction cleaning. This indicates that the industrial problem can be solved by using Lyogen DFTN as a levelling agent in the dyeing bath, followed by reduction clearing. The dye has been fixed instead of remaining on surface.

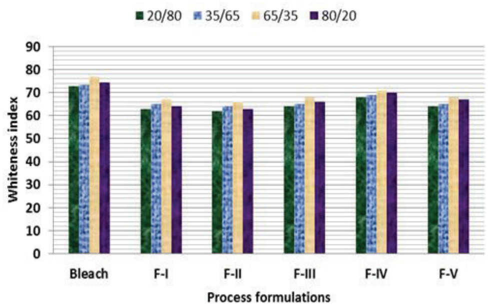

Figure 4. Whiteness index of blended fabrics.

4 Conclusion

In this study, various attempts have been made to overcome the staining of the cotton/CDPET blended fabric based on different formulations and desired result obtained in case of dyeing performed with a leveling agent (commercial name: Lyogen DFTN) followed by reduction clearing. Specifically, the results were found to be the best of the formulation (F-IV) for 65/35 blended fabric, among all the formulations performed. In addition, the obtained results confirmed that the Reactive dye do not contribute in staining problem. Our results are consistent with the proposal that both the reduction cleaning and addition of Lyogen DFTN to the dyebath enhance the absorption of dyes in a similar manner by modifying the surface of the blended fabric and played a role to avoid staining problem.

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