Use of Foam for Paper Printing and Pretreatment of Cotton and Polyester/Cotton Blends with Modified Crosslinking Agent for Sublimation Transfer Printing

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The use of foam for printing paper with disperse dyes and for pretreatment of cotton and PET/cotton blends with synthesized crosslinking agent for their sublimation transfer printing is discussed. The incorporation of a foaming agent in carboxymethyl cellulose thickener for paper printing considerably improved the dye transfer. A simple method of hand screen printing using foam of printable viscosity and crosslinking agent is suggested for fabric pretreatment. The results of dye transfer on foam pretreated fabrics and those pretreated with conventional pad-dry method were comparable. The use of synthesized crosslinking agent is also suggested for conventional printing with disperse dyes and wash and wear finishing of cotton and PET/cotton blends.

Keywords: Cotton fabric, Crosslinking agent, Foaming agent, Paper printing, Polyester/cotton blend, Sublimation transfer printing

1 Introduction

The sublimation transfer printing process which involves the transfer of disperse dye from paper to the fabric is particularly popular for printing of 100% polyester. This process is not suitable for cotton and PET/cotton blend, because of the lack of affinity of disperse dye for cotton. Various pretreatments are recommended for modification of cotton to make it suitable for sublimation transfer printing with disperse dyes. Some of the important modifications recommended are chemical modification, grafting and in situ polymerization. However, these require relatively stronger conditions and it is difficult to ensure uniformity and economy on commercial scale.

Pretreatment of cotton and PET/cotton with crosslinking agents seems to be a commercially viable proposition. Vellinsobserved that the resin pretreated cotton fabric gave solid shade on transfer printing with selected disperse dyes as compared to untreated fabric. He also revealed that there was some form of chemical reaction between certain groups in the dye molecule and the resin.

Blanchard and coworkers mentioned that melamine formaldehyde resin is useful for modifying cellulose fabric for transfer printing with disperse dyes. The resin was most effective when high boiling point glycols were included in the formulation.

Padhye and Gupta suggested the pretreatment of cotton with diethylene glycol monoethyl ether for sublimation transfer printing of cotton. With the help of microphotographs they revealed that the fabric showed pronounced swelling after treatment both in wet and dry conditions, the fibres then collapsed to their original diameter on thermal treatment during transfer printing and thus retaining the transferred dye into collapsed fibre structure.

It has been established that during transfer printing the dye vaporises and diffuses across the small air gap between dye on the paper and fibre before being absorbed on the fibre surface followed by diffusion into the interior of the fabric.

Hawkyard studied the release of disperse dye from three different thickeners. He carried out the initial printing on PET film and the dye was transferred at 200°C for 30 s. This operation was considered to be similar to transfer printing on polyester where the air gap between the dye on the paper and fabric was reduced to zero. The differences in dye transfer were explained on the basis of the structure and the dye distribution in the thicker film. He observed that the incorporation of hydrocarbon modified the thickener film to cellular structure which allowed the dye vapour to escape more readily than from unmodified sodium alginate.

Biedermann and Ischi studied the conventional printing of polyester fabric with disperse dyes using sodium alginate thickener and observed that the dye fixation was low in presence of only sodium alginate. The incorporation of fixation accelerants disturbed the continuity of thickener film and facilitated the dye transfer.
Chavan and Hanif Langer established that the structure of thickener film governs the dye transfer. They observed that foaming agent as an auxiliary thickener in the print paste composition gives the disrupted heterogeneous film formation on the surface of the paper, resulting in better dye release and thus giving higher dye transfer.

In the present study, attempts have been made to use foaming agent as a print paste auxiliary in order to facilitate the paper printing. The effect of addition of foam to the carboxymethyl cellulose (CMC) thickener was also investigated in terms of change in the structure of the thickener film and its effect on the dye release from the paper. The use of foam of printable viscosity is also suggested for (a) pretreatment of cotton and PET/cotton fabric with synthesized crosslinking agent to make it suitable for sublimation transfer printing with disperse dyes and also to impart wash and wear finish to the fabric, (b) direct printing of cotton and PET/cotton fabric with disperse dyes.

2 Materials and Methods

2.1 Materials

2.1.1 Cotton Fabric
Commercially scoured, bleached and mercerized, but unfinished, cotton fabric with following specification was used: ends, 90/cm; picks, 63/cm; and weight, 122 g/m².

2.1.2 PET/Cotton Fabric
Unfinished polyester/cotton shirting fabric with blend composition of 67/33 was used.

2.1.3 Paper
Bleached writing paper of 60 g/m² was used.

2.1.4 Dyes
The following five commercially available disperse dyes were used: Cibacan Orange 2R (C.I. Disperse Orange 3), Dispersol Red B-2B (C.I. Disperse Red 60), Navilene Violet 6R (C.I. Disperse Red 11), Cibacan Violet 2R1 (C.I. Disperse Violet 1), and Resoline Blue I-FBL (C.I. Disperse Blue 56).

2.1.5 Thickeners
The following thickeners were used:
(i) Carboxymethyl cellulose (CMC).
(ii) The foaming agent containing the stabilizer (supplied by Hico Products Ltd, Bombay, under the trade name of product FMPW). This product was used to get the foam of printable viscosity.

2.1.6 Polyvinyl Acetate (PVAc)
Aqueous emulsion supplied by Pidilite Industries Ltd, Bombay, under the trade name of Fevicol SH was used.

2.1.7 Resins
Commercial melamine formaldehyde resin Pidifix 303 (Parekh Dye Chem. Ltd, Bombay) and synthesized resin, i.e. the condensation product of melamine, paraformaldehyde and PEG 200 in molar ratio of 1 : 1 : 3, were used.

2.1.8 Catalyst
MgCl₂ .6H₂O catalyst (laboratory grade) was used.

2.2 Methods

2.2.1 Preparation of Foam Thickener
Commercially available foaming agent product FMPW was soaked in cold water (3% w/w) for 12 h or in warm water for 2-3 h. It was then stirred vigorously with the help of mechanical stirrer for about 30-40 min. To get a more stable foam paste of printable viscosity it was again stirred after few hours.

2.2.2 Preparation of Print Paste for Paper Printing
The recipe for the print paste containing disperse dye was as follows: Disperse dye, 5 parts; water, 5 parts; polyvinyl acetate (PVAc), 10 parts; foam/CMC thickener (50/50), to make 100 parts.

The paper was screen printed manually through the blank screen using two squeegee strokes and dried at 70-80°C for 2-3 min. Transfer printing of resin-treated fabric was performed at 200°C for one min using a manual heat transfer printing press supplied by M/S Adkins & Sons Ltd, UK.

2.2.3 Fabric Pretreatment by Foam Printing
The foaming agent (product FMPW) 3% w/w was soaked in water with the appropriate amounts of the resin and the catalyst for 12 h and then the required volume of foam paste was obtained by adding water and other ingredients. The foam paste was then stirred with high speed mechanical stirrer for about 30-40 min; after a few hours, second stirring was required to get suitable viscosity for printing on the fabric. Cotton and PET/cotton fabrics were screen printed using two squeegee strokes. The printed samples were then dried at 90-100°C for 5 min and then used for transfer printing.

2.2.4 Direct Printing with Disperse Dye
Cotton and PET/cotton fabrics were screen printed with disperse dye along with the resin in the foam paste using two squeegee strokes. The printed samples were then dried at 80-100°C for 5 min and...
cured at a specified temperature for a specified time. The half of the samples were washed in running tap water followed by soap washing at 60°C for 30 min.

2.2.5 Wash Fastness Test

The printed samples were subjected to ISO-3 wash-fastness test.

2.2.6 Method for Resin Synthesis

The method for the resin synthesis has been reported earlier. The resin was the condensation product of melamine, paraformaldehyde and polyethylene glycol 200 in the mole proportion 1:1:3.

2.2.7 Physical Properties of Fabric

Crease recovery angles were determined on Shirley crease recovery tester. Tensile strength was measured on Instron using 20 cm gauge length and 2.5 cm width. Bending length was measured on Eureka bending length tester.

Flex abrasion resistance of the transfer printed samples was measured on universal wear tester with a tension load of 2.73 kg and head load 0.68 kg. The sample width was 2.5 cm. In all physical tests the average of at least five measurements was taken.

3 Results and Discussion

3.1.1 Use of Foaming Agent for Paper Printing

The normal aqueous printing ink used for printing the paper by sublimation transfer printing consists of a suitable disperse dye, a vehicle like water, a thickener, and a thermoplastic polymer.

The suitable thickeners are sodium alginate, carboxymethyl cellulose, gum indalca, etc. The most suitable thermoplastic polymer is polyvinyl acetate. The function of this is to provide the tack and thus to maintain the intimate contact between paper and fabric during transfer printing. The effect of print paste composition on dye transfer has been reported in detail elsewhere. The release of dye is governed by the structure of thickener film. If the thickener gives a continuous film, imbidding the dye during transfer printing, the dye vapours get less opportunity to overcome the barrier effect of thickener film, resulting in poor dye transfer. Any auxiliary which breaks the continuity of thickener film should provide better opportunity for the dye vapours to escape from the paper and thus giving higher dye transfer. We investigated the effect of print paste composition on the dye transfer, the paper was printed with the following print paste compositions:

(1) CMC alone; (2) CMC/PVAc (90/10); (3) CMC/emulsion thickener (50/50); (4) Foam/CMC (50/50); and (5) Foam/CMC/PVAc (50/50/10).

The results of the dye transfer (Table 1) show that the dye transfer from print paste composition containing CMC alone was much lower than that from the print paste composition containing CMC and other auxiliaries. The difference was most striking for Navilene Violet 6R and Resoline Blue I-FBL in particular. The print paste composition containing foam/CMC/PVAc produced the highest transfer. The effect of incorporation of foaming agent in CMC in enhancing the dye transfer was explained on the basis of the disruption of continuity of CMC film and formation of cellular structure from which the dye vapours could readily escape. This is clearly revealed by SEM microphotographs (Figs 1-3).

In addition to the increased dye transfer the incorporation of foaming agent in CMC thickener showed following advantages: (1) The volume of print paste increased and therefore from the same weight of the print paste, it was possible to print more length of the paper as compared to that from the print paste composition containing CMC alone, and (2) The print paste became much more smoother and creamy and therefore ease of printing.

3.2 Foam Pretreatment of Fabric

To get the satisfactory sublimation transfer printing of cotton and PET/cotton blends, it was necessary to modify the cotton component by suitable pretreatment. Some of the pretreatments recommended are:

(1) Chemical modification of cotton such as acetylation, cyanethylation and benzoylation.

<table>
<thead>
<tr>
<th>Dye</th>
<th>Print paste composition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CMC</td>
</tr>
<tr>
<td>Cibacet Orange 2R</td>
<td>47</td>
</tr>
<tr>
<td>Dispersol Red B-2B</td>
<td>34</td>
</tr>
<tr>
<td>Navilene Violet 6R</td>
<td>19</td>
</tr>
<tr>
<td>Cibacet Violet 2RI</td>
<td>42</td>
</tr>
<tr>
<td>Resoline Blue I-FBL</td>
<td>17</td>
</tr>
</tbody>
</table>
(2) In situ polymer deposition.
(3) Pretreatment with self-crosslinking acrylates.
(4) Pretreatment with crosslinking agents such as melamine formaldehyde, DMEU, DMDHEU, etc. along with high boiling point glycols.

Among these the last approach is practically the most feasible and it has the advantage of getting simultaneous transfer printing and wash and wear finishing. We investigated this approach in detail and the results have been reported elsewhere \(^{13,14}\).

A modified melamine formaldehyde resin based on the condensation product of melamine, paraformaldehyde and PEG 200 in the mole proportions of 1:1:3 was synthesized and the fabric was pretreated with synthesized resin by conventional pad-dry technique and transfer printed. The pad liquor recipe consisted of 200-300 g/l of synthesized resin and 7-10 g/l MgCl\(_2\cdot6\)H\(_2\)O. In the absence of a suitable padding mangle, which is normally the case with the cottage industry, we applied the synthesized crosslinking agent through foam of printable viscosity by using hand screen printing technique. The product FMPW gives printable viscosity at suitable concentration (3%). Although the composition of this product is not known it is reasonable to assume that the crosslinking agent will not react with the foaming agent and, therefore, after the transfer printing application if present on the fabric, it will not hamper the feel of the fabric. The synthesized resin was incorporated along with the catalyst in the foaming agent and then it was foamed to get the printable viscosity. The recipe was as follows:

- Foaming agent, 30 g/kg
- Resin conc., 200-300 g/kg
- MgCl\(_2\cdot6\)H\(_2\)O, 7-10 g/kg
- Polyethylene emulsion, 30 g/kg

The method of preparing the foam print paste containing synthesized resin is given in experimental section. The fabric was screen printed using two squeegee strokes and then dried and transfer printed at 200°C for 1 min. The results of dye transfer on cotton and PET/cotton fabrics, which were pretreated by conventional pad-dry application and by foam through screen printing operation, are given in Table 2. The results show that the dye transfer and wash fastness of disperse dye on both cotton and PET/cotton blend by the two methods are almost equal.
Table 2—Dye Transfer and Wash Fastness of Foam Pretreated and Pad-dry Treated Cotton and PET/Cotton

<table>
<thead>
<tr>
<th>Dye</th>
<th>Pretreated by foam</th>
<th>Pretreated by padding</th>
<th>Pretreated by foam</th>
<th>Pretreated by padding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Dye transfer</td>
<td>% Dye fastness</td>
<td>% Dye transfer</td>
<td>% Dye fastness</td>
</tr>
<tr>
<td>Cibacet Orange 2R</td>
<td>86</td>
<td>5</td>
<td>86</td>
<td>5</td>
</tr>
<tr>
<td>Dispersol Red B-2B</td>
<td>86</td>
<td>4-5</td>
<td>87</td>
<td>4-5</td>
</tr>
<tr>
<td>Navilene Violet 6R</td>
<td>85</td>
<td>4-5</td>
<td>85</td>
<td>4-5</td>
</tr>
<tr>
<td>Cibacet Violet 2R1</td>
<td>86</td>
<td>5</td>
<td>82</td>
<td>5</td>
</tr>
<tr>
<td>Resoline Blue I-FBL</td>
<td>72</td>
<td>4-5</td>
<td>72</td>
<td>4-5</td>
</tr>
</tbody>
</table>

identical. Therefore, the method of fabric pretreatment by foam application through manual screen printing can be used as an alternative for conventional pad-dry application of the crosslinking agent. This modified method totally eliminates the use of padding mangle and, therefore, it will be ideal for small processors where screen printing is the most common. It also has the advantage that the paper printing and fabric printing can be carried out at the same place by small processors. However, the use of imported transfer printing equipment will be necessary for carrying out the transfer printing.

3.3 Direct Printing of Polyester/Cotton Blends with Disperse Dyes

After establishing that the modified resin pretreated PET/cotton can be successfully transfer printed with selected disperse dyes, the PET/cotton blends were printed with disperse dyes by the conventional method. In this method, the use of the conventional thickener for making the print paste was not possible because of the possibility of its reaction with synthesized resin and thus getting insolubilized and fixing on to the fabric. The foam thickener was obviously the choice for the printing of PET/cotton blend. The following three approaches were considered for this purpose:

1. Incorporation of foaming agent in the dye, synthesized resin and catalyst and then foaming it to the printable viscosity followed by direct printing of PET/cotton fabric.
2. Pretreatment of the fabric by hand screen printing operation through the foam application of the synthesized resin followed by drying and printing with the foam thickener containing disperse dye only.
3. Pretreatment of the fabric with synthesized resin by pad-dry application followed by printing with the foam thickener containing disperse dye only.

When the approach (1) was used the prints obtained were dull and not comparable with the prints obtained with transfer printing. This may be due to the following two reasons:

(i) During direct printing, there was deep penetration of dye to an extent that the front and back portions of printed samples were almost identical.

(ii) The extent of reaction of dye with crosslinking agent was to a greater extent, as indicated by more bluish tone of samples printed with Navilene Violet 6R, and thus shifting the wavelength of maximum absorption.

In the case of approaches (2) and (3) the prints obtained were acceptable in terms of depth of shade and brightness although they were not identical to those obtained by transfer printing. This means that for direct printing of PET/cotton blend with disperse dyes, it is necessary to pretreat the fabric with synthesized resin along with catalyst by a suitable method followed by printing with disperse dyes using foam thickener; the fixation of the disperse dye and the crosslinking can be carried out simultaneously by heat treatment at 200°C for 1 min. The results of dye fixation obtained from the difference in K/S values, measured immediately after printing and curing and after washing, are shown in Table 3. The table shows that the three approaches of printing gave comparable dye fixation.

The approaches (2) and (3) have the advantages of not only getting satisfactory prints but they also impart wash and wear characteristics to the fabric. Thus, we feel that the methods of pretreatment of fabric with synthesized resin can be used satisfactorily for transfer printing or direct printing of PET/cotton blend with disperse dyes.

3.4 Foam Finishing

The synthesized resin is suitable not only for sublimation transfer printing of cotton and PET/cotton blend but it can also be used for the wash and wear finishing. We investigated this possibility by treating the fabric with synthesized crosslinking agent by conventional pad-dry application as well as by foam
application by hand screen printing technique. The recipe was as follows:

**Pad-dry application**
Resin conc., 200-300 g/l  
MgCl₂·6H₂O conc., 7-10 g/l  
Polyethylene emulsion, 30 g/l

**Foam application by hand screen printing**
Foaming agent (product FMPW), 30 g/kg
Resin conc., 200-300 g/kg  
MgCl₂·6H₂O conc., 7-10 g/kg  
Polyethylene emulsion, 30 g/kg

The above ingredients were foamed to printable viscosity as described in 2.2.3.
Cotton and PET/cotton fabrics were printed through a hand screen with two squeegee strokes. The printed samples were then dried at 90-100°C for 5 min and subjected to heat treatment at 200°C for 1 min. The results of %N and total formaldehyde for pad-dry and hand screen printed samples are given in Table 4. The results indicate that the foam application resulted in slightly lower add-on the fabrics. This may be due to increase in volume of the application chemicals on foaming. After curing the treated samples at 200°C for 1 min (these conditions were chosen to get simultaneous transfer printing, if desired), various physical properties were determined. The results (Tables 5 and 6) show that the synthesized resin showed much better performance in terms of improvement in dry and wet crease recovery angles with very good retention of the tensile strength and the feel of the fabric. On addition of polyethylene emulsion, the abrasion resistance of the PET/cotton fabric finished with commercial melamine formaldehyde and synthesized resin increased many-folds as compared to that of control. This may be attributed to the lubricating effect of polyethylene emulsion. The synthesized resin showed much higher abrasion resistance as compared to commercial melamine formaldehyde. It is worthwhile to point out that in the case of both foam finishing and conventional pad-dry finishing the improvement in wet crease recovery angle was much higher in the case of synthesized resin. This may be attributed to the formation of crosslinks with cellulose under swollen condition. This was quite possible because the synthesized resin contained substantial amount of PEG 200, which is a high boiling point solvent. After pad-dry application, it will retain the swollen state of the fibre even under curing.

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**Table 3—Dye Fixation on Cotton and PET/Cotton Fabrics**

<table>
<thead>
<tr>
<th>Dye</th>
<th>Cotton</th>
<th>Polyester/Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PP</td>
<td>PF</td>
</tr>
<tr>
<td>Cibacet Orange 2R</td>
<td>94.5</td>
<td>94</td>
</tr>
<tr>
<td>Dispersol Red B-2B</td>
<td>93.0</td>
<td>93</td>
</tr>
<tr>
<td>Navilene Violet 6R</td>
<td>93.5</td>
<td>93</td>
</tr>
<tr>
<td>Cibacet Violet 2R</td>
<td>95.0</td>
<td>95</td>
</tr>
<tr>
<td>Resoline Blue I-FBL</td>
<td>94.5</td>
<td>94</td>
</tr>
</tbody>
</table>

PP—Pretreated by padding; PF—Pretreated by foam; DP—Direct printed.

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**Table 4—Total Formaldehyde and Nitrogen Content of Resin-Treated Fabrics**

<table>
<thead>
<tr>
<th>Pad bath</th>
<th>Cotton</th>
<th>PET/Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N %</td>
<td>Total formaldehyde %</td>
</tr>
<tr>
<td>Commercial MF + polyethylene emulsion (pad-dry application)</td>
<td>4.05</td>
<td>7.63</td>
</tr>
<tr>
<td>Commercial MF + polyethylene emulsion (foam application)</td>
<td>2.52</td>
<td>4.73</td>
</tr>
<tr>
<td>Synthesized resin + polyethylene emulsion (pad-dry application)</td>
<td>1.84</td>
<td>2.55</td>
</tr>
<tr>
<td>Synthesized resin + polyethylene emulsion (foam application)</td>
<td>1.31</td>
<td>1.57</td>
</tr>
</tbody>
</table>
Table 5—Effect of Foam and Pad-dry Pretreatments on Physical Properties of Cotton

<table>
<thead>
<tr>
<th>Pad bath</th>
<th>Dry crease recovery angle</th>
<th>Wet crease recovery angle</th>
<th>Tensile strength retention %</th>
<th>Bending length cm</th>
<th>Abrasion resistance (cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control PET cotton</td>
<td>W+F 160</td>
<td>W+F 150</td>
<td>W+F 100</td>
<td>W+F 185</td>
<td>W+F 40</td>
</tr>
<tr>
<td>Commercial MF + polyethylene emulsion (pad-dry application)</td>
<td>254 206</td>
<td>41 63</td>
<td>3.40 2.02</td>
<td>18 28</td>
<td></td>
</tr>
<tr>
<td>Synthesized resin + polyethylene emulsion (pad-dry application)</td>
<td>292 280</td>
<td>70 77</td>
<td>1.86 1.78</td>
<td>35 46</td>
<td></td>
</tr>
<tr>
<td>Commercial MF + polyethylene emulsion (foam application)</td>
<td>245 197</td>
<td>33 65</td>
<td>3.05 1.90</td>
<td>20 30</td>
<td></td>
</tr>
<tr>
<td>Synthesized resin + polyethylene emulsion (foam application)</td>
<td>281 267</td>
<td>73 84</td>
<td>1.05 1.85</td>
<td>36 46</td>
<td></td>
</tr>
</tbody>
</table>

Table 6—Effect of Foam and Pad-dry Pretreatments on Physical Properties of PET/Cotton

<table>
<thead>
<tr>
<th>Pad bath</th>
<th>Dry crease recovery angle</th>
<th>Wet crease recovery angle</th>
<th>Tensile strength retention %</th>
<th>Bending length cm</th>
<th>Abrasion resistance (cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control PET/cotton</td>
<td>W+F 208</td>
<td>W+F 200</td>
<td>W+F 100</td>
<td>W+F 2.25</td>
<td>W+F 295</td>
</tr>
<tr>
<td>Commercial MF + polyethylene emulsion (pad-dry application)</td>
<td>236 215</td>
<td>94 88</td>
<td>3.90 3.70</td>
<td>1164 1148</td>
<td></td>
</tr>
<tr>
<td>Synthesized resin + polyethylene emulsion (pad-dry application)</td>
<td>273 250</td>
<td>100 99</td>
<td>2.35 1.95</td>
<td>2992 2500</td>
<td></td>
</tr>
<tr>
<td>Commercial MF + polyethylene emulsion (foam application)</td>
<td>224 209</td>
<td>96 90</td>
<td>3.85 3.65</td>
<td>1163 1140</td>
<td></td>
</tr>
<tr>
<td>Synthesized resin + polyethylene emulsion (foam application)</td>
<td>270 248</td>
<td>100 100</td>
<td>2.30 1.90</td>
<td>2990 2485</td>
<td></td>
</tr>
</tbody>
</table>

In addition to this, it might be possible that the melamine formaldehyde and PEG 200 condensed with each other before crosslinking with cotton with the formation of longer crosslinks.

4 Conclusions

4.1 The incorporation of foaming agent as an auxiliary along with CMC thickener in the printing paste improves the dye transfer.

4.2 The pretreatment of cotton and PET/cotton fabrics with synthesized resin by foam application through screen printing technique gives satisfactory results in terms of dye transfer, wash fastness and physical properties of the fabrics when compared with those of pad-dry pretreated fabrics.

4.3 Cotton and PET/cotton fabrics, pretreated with synthesized resin through foam and pad-dry applications, can be printed directly with disperse dyes.

4.4 The synthesized resin can be used for wash and wear finishing of cotton and PET/cotton blend.

Acknowledgement

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