Effects of repeated home launderings and non-durable press on the colour properties of plain woven polyester fabric

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The colour values and colour differences occurred in dyed polyester fabrics after repeated home launderings and non-durable pressings (hot-pressing) have been assessed. Two disperse dyes with different chemical structures (azo and anthraquinone) were applied to the polyester fabric separately at different dyeing concentrations and the domestic ironing was simulated by using international hot-pressing standards. The K/S value, lightness (L*), chroma (C*) and colour differences (DE*) were measured for the repeated experiment cycles. It is observed that the K/S values slightly decrease and L* values gradually increase, indicating the loss of some dyes from the fibres and decreasing depth. C* values increase as the experiment cycles increase. Colour differences are found to depend on the chemical class and concentration of the disperse dyes used, and colour measurement time. Dyeing at low dye concentrations is affected more from the repeated experimental procedure.

Keywords: Colour difference, Disperse dyes, Home laundering, Non-durable press, Polyester fabric, Thermomigration

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1 Introduction
The wear life of garments is an important property for the consumers as they do not want the garments to change their properties, like colour and dimension during their usage. The wear life of garments depends on their ability to serve the consumer without changing their properties during their usage in daily life and can be assessed by garments’ properties and by their response to the effects that they encounter during usage. From the viewpoint of textile testing and analysis, the wear life of garments is also assessed by their fastness properties to daily usage. Fastness tests which simulate the effects of daily usage on the properties (such as colour, washing, and dimension) of the garments are very important because of their ability to test the garments according to real consumer needs.

Wear life of cotton textiles has been discussed from a number of viewpoints, including home laundering practices, colour fastness, durable press, etc. Alpay and coworkers studied the possible wear life of fabrics woven from different fibre materials from the viewpoint of abrasion, fabric reflectances and colour differences.

Polyester fibre became the most important synthetic fibre over the past half century and reached the status of the highest volume of production among the other synthetic fibres. Disperse dyes being the most suitable dye class for the polyester fibres also became one of the highly consumed dyes.

Wet fastness of the dyed fabrics is of paramount importance at almost every dye-fibre system. Wet fastness can be considered as an umbrella term that encompasses performance in a variety of tests, such as wash fastness, water fastness, wet rubbing and perspiration fastness. Wash fastness has particular importance within the apparel industry. But the wet fastness properties cannot be considered separate from the some other fastness properties, such as fastness to heat and light fastness. Dyed fabrics must show the possible longest wear life without changing their colours and the multiple effects will determine the total wear life of garments. In the case of polyester fabrics dyed with disperse dyes, the response of the dye in the fibre to the consumer uses
depends on both the usage conditions of the garment in daily life and on the situation of the dye in the fibre after laundering and heat application, such as domestic ironing, which is mostly dependent on dye molecular structure. Affinity of the disperse dye and its thermomigration capability as a result of the heat application determine the results of wet fastness. Consumers will wash and later iron the goods (although ironing is made at moderate temperatures) resulting in a possible thermomigration and low wash fastness.

After the dyeing process is completed, polyester fabrics are subjected to reduction clearing to remove the unfixed dye from the fibre surface and to heat treatments after the application of finishing agents to the fabrics. Unfixed dye on the surface of the fibre at the end of the dyeing process reduces wet fastness. Even though the unfixed dye can be completely removed from the fibre surface by the reduction clearing treatment, problems may occur with subsequent finishing treatments, including heat applications. The finishing agents form a thin film around the fibres which acts as a dissolving medium for the unfixed dye on the fibre surface or for the dye that thermomigrates because of the heat treatment.

The term ‘thermomigration’ of dyes is currently used to describe the phenomenon in which movement of disperse dyes out of synthetic fibres or their blends during application of different finishes at high temperatures or during storage takes place. Such dye migration results in change in shade, water-spotting, inferior fastness of dyed and finished fabrics, mark-off of prints and staining adjacent garments made from synthetic fabrics during simultaneous washing in washing machines. In case of polyester fabrics, several factors, viz. type of fibre, chemical constitution of disperse dye, dye content of the substrate, method of dyeing employed, type and concentration of the finishing agent, and conditions of application, play a vital role for the extent of thermomigration.

Practically all disperse dyes tend to migrate to the surface of the fibre during any heat treatment of polyester material subsequent to dyeing. The extent to which they migrate depends on the depth of dyeing, the temperature of treatment and the individual properties of the dye. This migration is not necessarily associated with sublimation although as a rule the least volatile dyes show the least tendency to produce surface deposits. Surface deposits are usually removed by the first laundering treatment received by the made-up articles.

Sublimation fastness is one of the most important fastness properties of dyed polyester materials. The migration properties of the dye and therefore the fastness to washing of the dyed fibre are, in most cases, broadly related to its sublimation fastness. Fastness to heat treatment is required, so that the dyed fibre may withstand the conditions encountered in ironing or pressing during the making-up of garments or other articles, as well as in pleating and in heat-setting. Consequently, it is necessary to take great care in the selection of dyes for end-uses, to ensure that the fastness of the dyed yarns or fibres is adequate. Care must also be taken to ensure that the heat treatment applied is perfectly uniform in its effect.

Phillips et al. studied the usage of proposed new test methods with activated oxygen bleach containing detergents on fabrics. The effects of laundering followed by domestic ironing on colour values have not been widely discussed till now.

The present study is aimed at investigating the effects of repeated home laundering and non-durable press practices on the colour of plain woven polyester fabric having no finish. The possible wear life of the fabrics in terms of colour values, colour differences and simulated domestic ironing considering the application of the international standards of hot-pressing has been discussed.

2 Materials and Methods

2.1 Fabrics and Dyes

100% plain polyester fabric (120 g/m²), woven from 170 denier (36 filaments) warp and 180 denier (36 filaments) weft yarns and having 40 and 22 warp and filling densities respectively, was used. The fabric was specially woven under controlled mill conditions. After weaving, the woven fabric was desized, pre-treated, heat-set at 180°C for 1 min under mill conditions and used for dyeing.

Disperse dyes of two different classes (azo and anthraquinone) were used at different dye concentrations (% owf). Details of the dyes and dyeing concentrations are given in Table 1. Auxiliaries of commercial purity were used according to the instructions of the dye manufacturer (Colorinda Chemtra PT). The dyes were used as obtained commercially without any purification.
2.2 Dyeing
The dyeing of the polyester woven fabrics (3 g sample) was made under laboratory conditions in a laboratory type sample dyeing machine (Mathis CH-8156), using liquor-to-material ratio of 50:1. The details of the dyes used and dyeing concentrations are given in Table 1. The dyeing experiments were carried out according to the dyeing procedure as provided by the dyestuff manufacturer. Dyeing was carried out at 50°C in dyebath containing x % (owf) dyestuff, 1.0 g/L ammonium sulphate, 1 g/L levelling agent, 0.6 g/L sequestering agent, 1 g/L crease inhibitor, and 1 mL/L acetic acid at pH 4.5-5. The temperature was raised to 130°C by 1.5°C/min and the dyeing continued at this temperature for 60 min. The temperature was then decreased to 80°C by 2°C/min. Later the samples were taken out from the dyeing tubes and post treated at 100:1 liquor-to-material ratio. The samples were washed with cold and hot water, and a reductive clearing with 3.0 mL/L sodium hydroxide (36 °Be) and 1.0 g/L hydrosulphite (sodium dithionite) was performed at 70°C for 25 min, neutralized, hot and cold rinsed and left to dry under laboratory conditions. No finishing agents or chemicals were applied to the dyed samples.

2.3 Laundering and Colour Measurement
The dyed samples were cut into four equal pieces for repeated home laundering and hot-pressing experiments. Two of the samples were used for hot-pressing I (as two replicas) and the remaining two of the samples were used for hot-pressing II (as two replicas). The laundering (washing) and hot-pressing experiments were performed in duplicate. Two samples were separately home laundered and hot pressed and reflectance measurements were performed on these samples. Four reflectance measurements were made on each sample, rotating the samples at 90° before each measurement. The average of the measurements of the two samples was recorded as reflectance values and used in calculating the colour values and colour differences.

The sequence of the experimental procedure (one experiment cycle) is as follows: conditioning at standard atmospheric conditions → washing (home type laundering) → drying in a place without the direct sun light → hot-pressing (hot-pressing I or hot-pressing II) (non-durable pressing) → colour measurement [immediate measurement; (Imm)] → conditioning for 4h at standard atmospheric conditions → colour measurement (measurement after 4h).

The above sequence (experiment cycle) is repeated from 1 to 20 cycles and the results are given in the Figs 1-4.

Washing (laundering) experiments were performed according to BS 1006:1997 C06 B1M (colour fastness to domestic and commercial laundering) in a washing solution of 150 mL at 50°C for 45 min with 4 g/L ECE detergent (without optical brightener) and 50 stainless steel balls (6mm diameter each). Hot-pressing I experiments were performed according to BS 1006:1996 X11 standards (colour fastness to hot-pressing). Hot-pressing II was also performed according to the same standards but the method was modified to simulate domestic ironing. Hot-pressings I and II were performed with an iron equipped according to the standard (4 kPa ± 1 kPa) at 180°C for 15s. The home-type iron equipped and calibrated according to the standard was moved back and forward on the fabric samples for 14 times to simulate the domestic ironing (hot-pressing II).

The colour coordinates of control (dyed, post-treated but not subjected to any laundering or non-durable pressing) and laundered and hot-pressed samples were measured on a Macbeth reflectance spectrophotometer (MS 2020+) coupled to a PC between 400-700 nm under D65/10° illuminant. The per cent reflectance values at the wavelength of maximum absorption were recorded. The control fabric was taken as the standard and the laundered and hot-pressed fabrics were taken as the samples when calculating the colour differences. Colour differences according to CIELAB (1976) equation were obtained from the colour measuring software.

The results are reported as K/S (colour strength) (Kubelka-Munk value), L* (lightness), C* (chroma) and DE* (CIELAB 1976) colour differences (Figs 1 – 4).

3 Results and Discussion
The effects of dye chemical classes (azo and anthraquinone), dye concentrations (low, medium and high), the time when the colour measurements were

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<th>Table 1 — Dyes and dyeing concentrations</th>
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made (immediately and 4 h later) and different non-
durable press (hot-pressing) applications [hot-pressing
I (standard application) and hot-pressing II (simulated
domestic ironing)] on the colour values are presented
in Figs 1 – 4.

3.1 K/S Values
K/S (colour strength) values of the samples after
repeated washing (home laundering) and hot-pressing
(experiment cycles 1 - 20) are shown in Fig. 1 for
dyes I and II. The K/S values decrease very slightly as
the number of experiment cycles increases. The
decrease in K/S values can be hardly recognized.
Almost the same K/S values were obtained for hot-
pressing I and hot-pressing II, indicating that the
simulated domestic non-durable pressing results in
similar manner with the standard procedure (hot-
pressing I). The K/S values measured immediately
and after 4 h are found to be almost the same, except
at 2% and 4% (owf) dye concentrations for dyes I and
II respectively. These two concentrations are the
highest ones applied in the experimental part and
differences in K/S values in measurement time can be
directly related to the dye concentration on the fabric.

3.2 L* Values
L* values of the samples after repeated washing
(home laundering) and hot-pressing (experiment
cycles 1 - 20) are shown in Fig. 2 for both the dyes.
The L* values increase very slightly as the number of
cycles increases. The gradual slight increase in the L*
values indicates that the colour of the samples
changes as the number of experiment cycles increases
and the sample surfaces become lighter because of the
loss in some amount of dye; similar to the results of
K/S values. The dye may have lost because of the
increasing cycles of hot-pressing and washing. L*
values are almost the same for immediate
measurement and for the measurement made 4 h later
for both the dyes. The change in L* values as the
experiment cycles increase is almost the same for all
the dyes and their concentrations.

3.3 C* Values
C* values of the samples after repeated washing
(home laundering) and hot-pressing (experiment
cycles 1 - 20) are presented in Fig. 3 for both the
dyes. The changes in C* values are different for Dye I
and Dye II as the number of experiment cycles
Fig. 2 — $L^*$ values of fabric samples according to cycle number for both the dyes [Dye I: –◊– 0.1% (1 mm), –○– 0.5% (1 mm), –△– 2% (1 mm), –■– 0.1% (4h), –▲– 0.5% (4h), –♦– 2% (4h); Dye II: –◊– 0.2% (1 mm), –○– 1% (1 mm), –△– 4% (1 mm), –■– 0.2% (4h), –▲– 1% (4h), –♦– 4% (4h)]

Fig. 3 — $C^*$ values of fabric samples according to cycle number for both the dyes [Dye I: –◊– 0.1% (1 mm), –○– 0.5% (1 mm), –△– 2% (1 mm), –■– 0.1% (4h), –▲– 0.5% (4h), –♦– 2% (4h); Dye II: –◊– 0.2% (1 mm), –○– 1% (1 mm), –△– 4% (1 mm), –■– 0.2% (4h), –▲– 1% (4h), –♦– 4% (4h)]
In case of Dye I, the $C^*$ values slightly increase and at 2% (owf) dye concentration the value remains almost constant while at 0.1% and 0.5% (owf) dye conc. the $C^*$ values gradually increase as the experiment cycles increase. The biggest changes are obtained in the first cycle which shows that some unfixed dyes are removed from the fibre surfaces. It is observed from the figures that the amount of dye (Dye I) in the fibres (or on the fibres) affects the $C^*$ values according to the cycle, and the post treatments performed after the dyeings (reduction clearing and rinsing to remove the unfixed dye) might have also influenced the values obtained. The $C^*$ values for 0.5% (owf) dye conc. are found to be the highest, indicating a different colouring property of Dye I. In case of Dye II, the $C^*$ values rapidly increase in the first cycle. It is observed that the amount of dye (Dye II) in the fibres (or on the fibres) affects the $C^*$ values according to the cycle, and the post-treatments performed after the dyeings (reduction clearing and rinsing to remove the unfixed dye) might have also influenced the values obtained as in case of Dye I. The sudden increase in $C^*$ values between the control and the first cycle at 0.2%, 1% and 2% (owf) dye conc. indicates that the post treatment is insufficient for the removal of unfixed dyes, especially as the dye concentration increases, and a considerable amount of dye from the fibre surfaces is removed. The $C^*$ values for 1% (owf) dye conc. is found to be the highest, indicating a different colouring property of Dye II.

The $C^*$ values obtained for low dye concentrations (0.1% for Dye I and 0.2% for Dye II) show steeper increase than those for the medium (0.5% for Dye I and 1% for Dye II) and high (2% for Dye I and 4% for Dye II) dye concentrations in the first cycle. The values are found to be almost the same for immediate measurement and for the measurement made 4h later for both the dyes (Fig. 3). Also, the two hot-pressing applications do not show the significant difference.

The colouring properties of the two chemical classes are found to be much different from each other with respect to the dyeing concentration and experimental procedure.

### 3.4 $DE^*$ Colour Difference Values

$DE^*$ colour difference values of the samples after repeated washing (home laundering) and hot-pressing (experiment cycles 1 - 20) are shown in Fig. 4 for both the dyes. Dye I shows lower $DE^*$ values than Dye II on increasing experiment cycles. In case of
Dye I, the $DE^*$ values differ very much from each other for measurement times. The measurement time is observed as the main cause of the variation in $DE^*$ values. The 0.1% dye conc. shows the highest and the 2% (owf) dye conc. shows the lowest $DE^*$ values. The greatest increase in $DE^*$ values is observed up to the 8th experiment cycles for 0.1% and 0.5% (owf) dye conc.. The $DE^*$ values for 2.0% (owf) dye conc. remain almost constant after the first cycle. The values slightly decrease after the 15th experiment cycles at 0.1% and 0.5% (owf) dye conc. but slightly increase at 2% (owf) dye conc.. $DE^*$ values are almost the same at 0.5% and 2% (owf) dye conc. for hot-pressings I and II. The $DE^*$ values for 0.1% (owf) dye conc. are found to be higher for at hot-pressing I than that for hot-pressing II. Also, the initial colour difference at first cycle is higher for hot-pressing I than that for hot-pressing II for the three dye concentrations.

In case of Dye II, the $DE^*$ values change more gradually than that in case of Dye I. Opposite to the $DE^*$ results of Dye I, the variations in the values are not observed according to the measurement times. $DE^*$ values regularly increase up to the 8th cycle and then remain almost the same. The highest increase in colour differences is observed at the lowest dye concentration (0.2% owf) and at the first cycle similar to the results of Dye I. Although the higher colour differences are obtained for Dye II than for Dye I, it dose not change its colouring property according to measurement times.

It is stated in BS 1006:1997 C06 B1M that in some cases the results of one “M” (multiple) test may be approximated by the results of up to 5 domestic or commercial launderings at temperatures not exceeding 70°C. According to this statement and to the results of this experimental procedure, the customers will recognize visible colour differences ($DE^* > 1$ or 1.2) in the garments after about 10 - 30 domestic launderings followed by non-durable pressings in which the results will vary according to the chemical class, dyeing concentration and thermomigration capability of the disperse dye applied to the fibres.

4 Conclusions

All the samples lose some dye from the surface of the fibres because of the increase in application cycles (laundering and hot-pressing) and show a considerable change in colour depth. Although regular changes in $K/S$, $L^*$ and $C^*$ values are observed at increasing experiment cycles for the independent variables, the colour differences show great variations according to measurement times and dye chemical classes. The results differ from each other for these independent variables. Colour values of fabrics dyed with the anthraquinone dye are affected more from the experimental procedure and found to be higher than that of the fabrics dyed with azo dye. Colour differences of the fabrics dyed with azo dye are found to be very sensitive to measurement times. The sudden increase in chroma and colour difference values especially for the samples dyed with the low dye concentrations might be related to the thermomigration property of the different chemical classes of the dyes and/or to the efficiency of the post-treatments, where the unfixed dye is removed from the fibre surface. The post-treatment conditions must be well arranged for different dyeing concentrations because the repeated home launderings and hot-pressings change the colour of the fabric in relation with the dye amount in the fibres. No significant differences are observed between the colour values of standard non-durable press (hot-pressing I) and simulated domestic ironing (hot pressing II) and thus it is concluded that the standard non-durable press application meets the needs of the procedure. But in terms of colour difference, the situation must be studied more. The chemical class of the disperse dye which is responsible for its migration capability and bonding property to the fibre is observed as the main point of colour differences associated with the applied dye concentration and hot-pressing method. Domestic ironing (hot-pressing II) after laundering does not cause higher colour differences as compared to the standard method (hot-pressing I) at the experimental procedure. Customers will recognize a change in colour of the garments after about 10 - 30 domestic launderings followed by non-durable hot-pressings; the colour change will be closely related to the chemical structure and thermomigration capability of the disperse dye applied and the dyeing concentration.

References