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Vapour Phase Transfer Printing of Polyester Fabrics

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TRANSFER printing of polyester fabrics using disperse dye vapors is performed by contacting the un-dyed polyester fabrics (receptor) with other heavily dyed polyester fabrics (donor) under the influence of heat and pressure, a technique well known as heat transfer printing. The evolved disperse dye vapors will flow across the small air gap existing between the inner donor and receptor surfaces. Studies revealed that the dye uptake by the receptor fabrics is dependent on the original disperse dye content of the donor fabrics as well as, the transfer printing conditions, (temperature, time). Subsequently the released dye from the donor fabrics strongly depend on the amount of dye present originally. It was proved also that the dyed polyester donor fabrics could be used multiple times producing prints having similar color strength values to a certain extent. The possibility of application of the process as continuous process was also investigated. The color fastness and mechanical properties of the prints were assessed and found to be acceptable.

Keywords: Disperse dyes, Polyester, printing, Dyeing and fastness properties .

Introduction

It is known that synthetic fabrics could be transfer printed using sublimely disperse dyes. The technique is well-known and offers a quick, clean, effluent free, water and energy saving method. The mechanism involves coloration of synthetic fabrics, mainly polyester via transfer of disperse dye vapors form inert substrate mainly paper and was noted as vapour phase process [1]. The thermal migration of disperse dye vapors into synthetic fabrics has been previously investigated [2] .

A transfer way to dye un-dyed polyester fiber bits found as impurities in woolen blends in Milton fabrics was earlier employed [3]. The method used is of the vapor phase type, which employs deeply colored polyester fabrics which was brought into contact with the contaminated Milton fabric, the evolved dye vapors colored only the polyester white bits of the fabrics as the wool has no affinity for the disperse dye vapors. This technique has the advantages of avoiding subsequent washing and no solvents or carriers needed.

In this work, studies were carried out to assess the process and the possibilities of reusing the dyed donor fabrics several times and recharging it via replenishing of the used dyes. Studies were also carried out to assess the color strength, fastness as well as mechanical properties.

Experimental:

Materials

Fabrics:

Two types of bleached 100% polyester fabric (149 g\m^2 and 250g\m^2) were supplied by El-Mahalla El-Kobra Company. The fabrics were scoured in aqueous solution with a liquor ratio1:50 containing 2 g/l nonionic detergent solution (Hostapal, Clariant) and 2 g/l Na_2CO_3 at 50º C for 30 min to remove impurities, then rinsed thoroughly in cold tap water, and dried at room temperature.

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Dyes

Nano disperse blue 56 and nano disperse red 60 supplied by Dye star Company. Dispersing agent Matexil DA-N was supplied by ICI Company, for auxiliaries, acetone, dimethylformamide (DMF), sodium hydroxide, sodium hydrosulphate and acetic acid were laboratory reagent grade chemicals.

Dyeing Process for polyester donor fabrics.

10 g fabric samples were introduced in flasks containing 3, 5, 7, and 10% (w.o.f) for (polyester of 250 g /m^2) and 7% (w.o.f) for (polyester of 149/ m^2) dye with 1:20 liquor ratio at 130 ºC and pH 4.5. At the end of dyeing, the dyed samples were removed, rinsed in warm water and treated in a solution containing sodium hydrosulphite 2g/L, Sodium hydroxide (caustic soda) 2g/L for10 minutes at 60 ºC, liquor ratio 1:20, the reduction cleared samples were rinsed thoroughly in cold water, and neutralized with 1g/L Acetic acid for 5 minutes at 40 ºC. The dyed samples were removed, rinsed in tap water and allowed to dry in the open air. The dyed fabrics were washed in aqueous solution with a liquor ratio1:20 containing 3 g/l nonionic detergent solution (Hostapal, Clariant) at 50 ºC for 30 min to remove impurities, then rinsed thoroughly in cold tap water, and dried at room temperature [4].

Transfer dyeing:

The previously dyed polyester fabric (donor) was used as a dye reservoir in the heat transfer coloration technique as a replacement of the printing paper. The white unprinted polyester fabric (receptor fabric) was brought into contact with the donor fabric. Dye transfer from the donor fabric to the receptor fabric was carried out under constant pressure using manual heat transfer press under the selected transfer printing conditions (time and temperature)

Measurements:

Color strength measurements:

The color strength (K/S) of each printed sample was measured using a Data Color SF 600 plus Colorimeter using a measured area with diameter of 9mm.

Scanning electron microscope SEM:

Dye samples were located on copper coated carbon tap double face, and then coated by the gold layer by evaporization of gold in argon atmosphere using sputter coater. The dye samples were scanned using (Quanta FEG250). The magnification was set at 200,400 to 1700. All samples were scanned at room temperature.

Tensile strength and Elongation test:

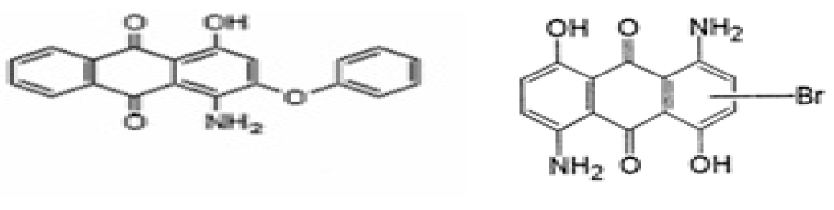
Tensile Testing Machine, of the CRE, CRL, or CRT type conforming to Specification D 76, with respect to force indication, working range, capacity, and elongation indicator and designed for operation at a speed of 300 ± 10 mm/min (12 ± 0.5 in. /min); or, a variable speed drive, change gears, or interchangeable loads as required to obtain the 20 6 3 s time-to-break. [5]

Fastness properties:

Washing fastness of the dyed samples was done according to the AATCC test method 16-1972. Fastness to perspiration was measured according to ISO-E04: 1994. The color fastness to rubbing was determined according to the AATCC test method 8-977. Fastness of light was measured according to the ISO 105:1997 using standard gray scale as reference in all testes. [6]

Results and Discussion

The feasibility of using pre-dyed polyester (donor) fabrics to transfer print other polyester (receptor) fabrics, as a replacement for the printed



C.I. Disperse red 60 C.I. Disperse blue 56

chemical structure of disperse blue 56 and red 60

paper used in the well-known transfer printing technique, was studied , aiming at reducing the cost of the operation via multiple use of these donor fabrics and replenishing their dye contents as needed.

The possibility of applying this technique for achievement of a continuous transfer printing operation reflecting in lowering the production cost was also investigated.

As mentioned before, two disperse dyes in the nano form were applied, (nano disperse red 60 and nano blue 56). These dyes were carefully selected or the basis that they have suitable molecular weights as this is a main requirement for the sublimation process. The presence of these dyed in nano form would also enhance the dye transfer. TEM photographs of these two dyes are represented in Fig. 2, 3.

Figures 1 represent the scanning electron micrograph images of the nano disperse blue 56 and red 60. The resulting nanoparticles are spherical in shape, and average diameters of about 50 ± 20 nm have been observed. This confirms that, the two dyes in the nano scale form.

Dye transfer process:

It is expected that several factors may influence the heat transfer process of the dyes from the dyed donor fabrics to the white receptor fabrics via applying heat and pressure. These factors are; dye content of the donor fabrics, conditions of the dye heat transfer (temperature & time) as well as type and weight of the polyester donor fabric. When no heat is applied to the printing system, the dye vapor pressure could be considered equal to zero. As heat and pressure are applied to the back side of the donor fabrics a temperature gradient is expected to occur across the system. The resultant heat flux would be dependent mainly on the transfer temperature and sublimation energy of the dye molecule.

Dye transfer from heavy weight polyester donor fabrics:

It is suggested that the vapors of the sublimed dye (due to the effect of heat) flow into the interior of the donor fabric until equilibrium is reached. Simultaneously, the dye molecules diffuse across the slight air gap enclosed between the donor and receptor fabric surfaces under the applied pressure.

Figure 2 shows the color strength (K/S) values of the heavy weight polyester donor fabrics dyed with dye concentration ranging between 3-10% (w.o.f) with disperse blue 56 before and after multiple dye transfers (up to 8 transfers).

The results show that the original heavy weight polyester donor fabrics dyed with concentration of 3, 5, 7 and 10 % (w.o.f) disperse blue 56 possess color strength values of 25.9, 29.21, 29.79 and 31.47. The results also show clearly that the K/S values of the dyed donor fabrics depend on the dye concentration originally applied.

It was found that after the first run of dye transfer to the receptor fabrics, the K/S values of the donor fabrics decreased markedly to 16.68, 19.64, 21.06 and 21.61. The K/S values for the next successive runs of dye transfer to the receptor fabrics remain comparable with the results obtained for the first transfer run with very slight or no reduction in value occurring in every successive transfer run. For example, for donor fabric dyed with 7% shade the K/S values were 29.79, 21.06, 20.61, 19.22, 18.77, 18.75, 18.22, 17.99 and 17.91 for the original donor fabric and the eight successive runs indicating that substantial amount of dye vapors were transferred to the receptor fabrics in the first transfer cycle, and similar or slightly less amount of dye vapor are transferred to the receptor fabrics in the successive transfers. This means that, the donor fabrics almost retain their comparable color strength values as noted from the first to the eights transfer cycles.

This behavior is applicable for all donor fabrics dyed with 3 and 5 % dye shades while some decrease in the color strength values is noticed in case of donor fabrics dyed with higher dye shades 7 and 10 %.

It is expected that more transfer cycles could be managed, as long as, no deterioration occurs to the donor fabrics.

Figure 3 shows the color strength of the heavy weight polyester donor fabrics dyed with different dye concentration ranging between 3-10 % w.o.f with disperse red 60 before and after multiple dye transfers (up to 8 transfers). For example, donor fabrics dyed with 7 % shade disperse red 60, the color strength values were 25.59, 16.8, 16.73, 16.36, 16.11, 15.81, 14.78, 14.6 and 14.3 for the original donor fabric and the eight successive runs. The above results indicate that, very similar pattern of results is noticed as with the previous dye.

Dye uptake:

The dependence of the dye uptake of the polyester receptor fabrics on the dye amount carried originally by the heavy weight polyester

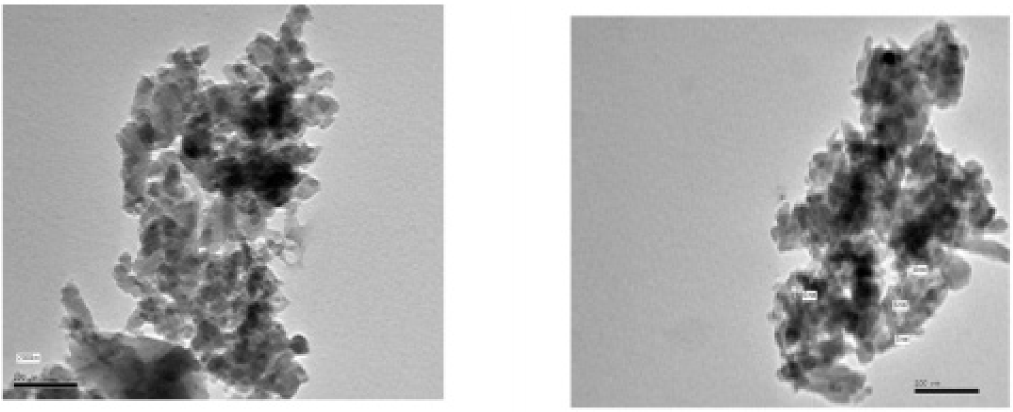
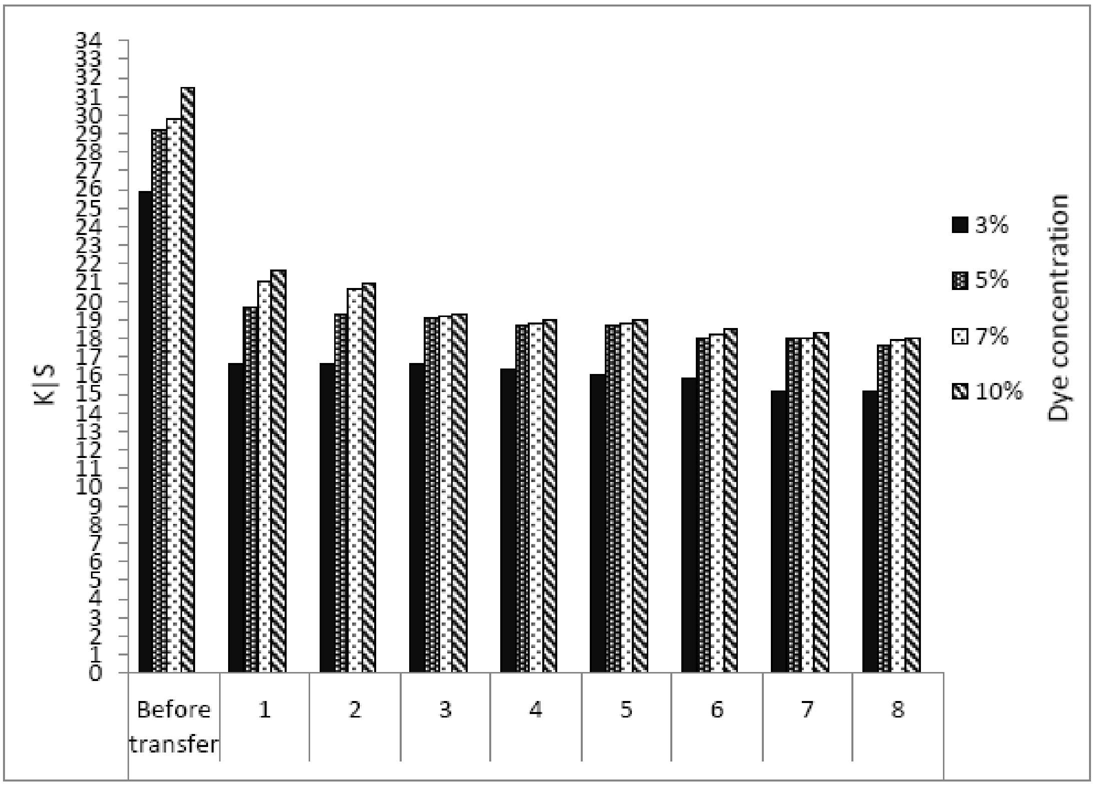


Fig. 1. (a) TEM of disperse blue 56 **(b) TEM of disperse red 60**



***Transfer conditions 200° C for 30 Secs.**

Fig. 2. Color strength of dyed heavy weight polyester donor fabrics with different concentration of disperse blue 56 before and after multiple dye transfers (8 transfers)*

donor fabrics under selected transfer conditions is studied. It was noticed that, during the process of transfer, bright color prints were obtained on the receptor polyester fabrics.

Figure 4 represents the color strength of the receptor polyester fabrics transferred with dyed heavy weight donor fabrics with different concentration (3-10%) of disperse blue 56 after multiple color transfers. Conditions of transfer were 200 ºC for 30 secs.

Heavy weight polyester donor fabrics dyed with different concentration of disperse blue 56 produce receptor prints with gradual decrease in the color strength after every transfer cycle. For e.g. with donor fabric dyed with 7% shade the receptor fabrics acquired K/S values of 2.04, 1.92, 1.77 , 1.74, 1.72, 1.67, 1.66 and 1.32 for the first to the eights dye transfer cycle.

Figure 5 represents the color strength of the receptor polyester fabrics transferred with dyed heavy weight donor fabric with different concentrations of disperse red 60 (ranging between 3-10%) after multiple dye transfers.

Heavy weight polyester donor fabrics dyed with different concentrations of disperse red 60 produced receptor prints with gradual decrease in color strength after every transfer cycle. For example, with heavy weight polyester donor fabric dyed with 7 % shade, the receptor fabrics acquired K/S values of 4.69, 3.48, 2.31, 2.19, 2.04, 1.86, 1.34 and 1.2 for the first to the eights transfer cycle.

It was found that, similar pattern of results are obtained as in the case of disperse blue 56.

Dye transfer from medium weight polyester donor fabrics:

In order to study the effect of the weight of polyester donor fabrics on the dye transfer process, the previous study was conducted using medium weight polyester donor fabrics as donor fabrics. For the sake of comparison, dye shade concentration of 7 % w.o.f for both disperse blue 56 and red 60 was selected as an example. The dye transfer conditions were selected as 200 ºC and 30 secs.

Figure 6 shows the color strength of medium and heavy weight polyester donor fabrics originally dyed with 7 % concentration of disperse blue 56 and disperse red 60 after multiple dye transfers.

The figure shows clearly that, the K/S value of the originally dyed medium weight donor fabrics with disperse blue 56 was 20.31 compared with the heavier w.t donor fabrics dyed under the same conditions and acquiring K/S of 29.79 i.e. higher dye content present in the heavy weight donor fabrics. Consequently similar trend is noticed during all eight transfer cycles. Similar trend is noticed also in case of using disperse red 60.

Figure 7 represents the color strength of the receptor polyester fabrics transferred with medium and heavy weight polyester donor fabrics dyed with 7 % concentration disperse blue 56 and disperse red 60 after multiple dye transfers .

The results show clearly that much higher and values are obtained on the receptor fabric upon using the medium weight donor fabric as compared to the heavy weight one under the same conditions. A gradual decrease in the color strength values is noticed after each dye transfer from the first to the eighth cycle in all cases.

This is true in case of using donor fabrics dyed with either disperse blue 56 or red 60 dyes.

The above results favor the use of medium weight rather than heavy weight polyester donor fabric, as it seems that although it absorbs less disperse dye during the original dyeing process compared to the heavier weight one , it releases more dye during the process of dye transfer from the donor to the receptor fabric.

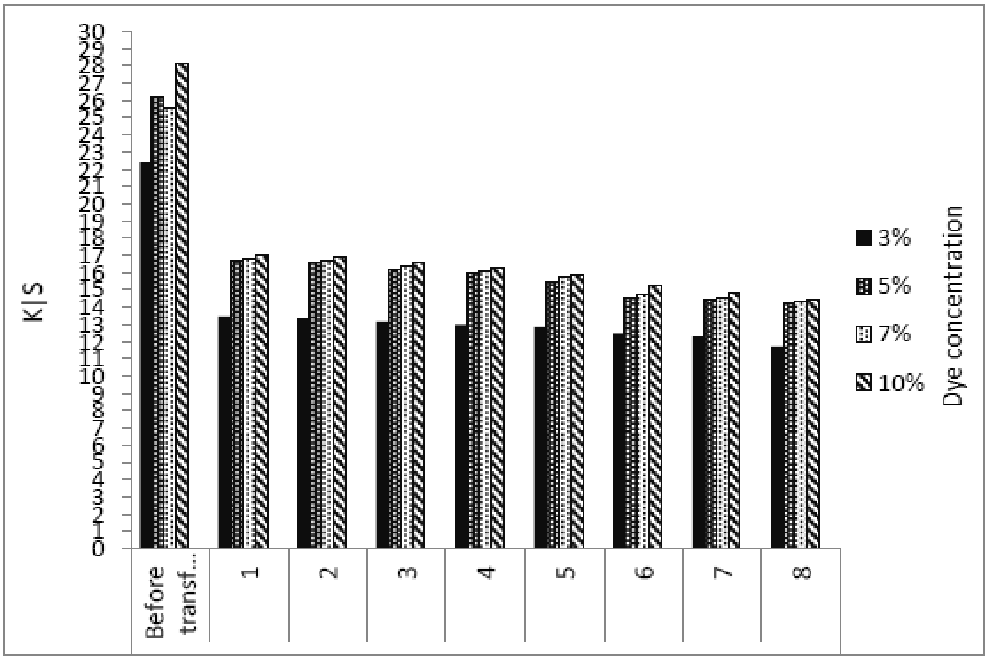
The possibility of application of the process as a continuous process.

The process of continuous coloration of polyester receptor fabrics by disperse dye vapors is investigated. The dye donor fabric is brought into contact successively with white receptor polyester fabrics using the heat transfer printing process at 200 ◦ C for a short a dwell time of 30 sec. The trial investigation reveals the capability of producing colors on the polyester receptor fabrics which are visually on the same level.

The color on the donor polyester fabric is expected to fade after several successive runs. Recharging the same reservoir fabric via repeated dyeing and reusing it again many times as a dye-donor fabric for coloration of white receptor polyester fabrics was successfully done. More work and further investigations will be conducted on the subject in future works.

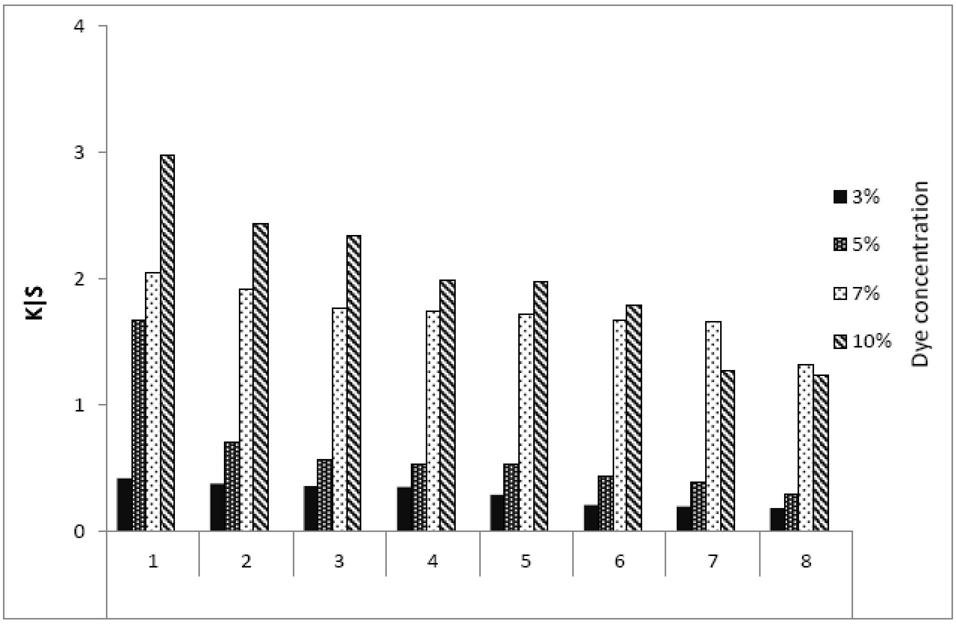
Tensile strength and elongation results:

Some selected fabrics were chosen to investigate their tensile strength and elongation



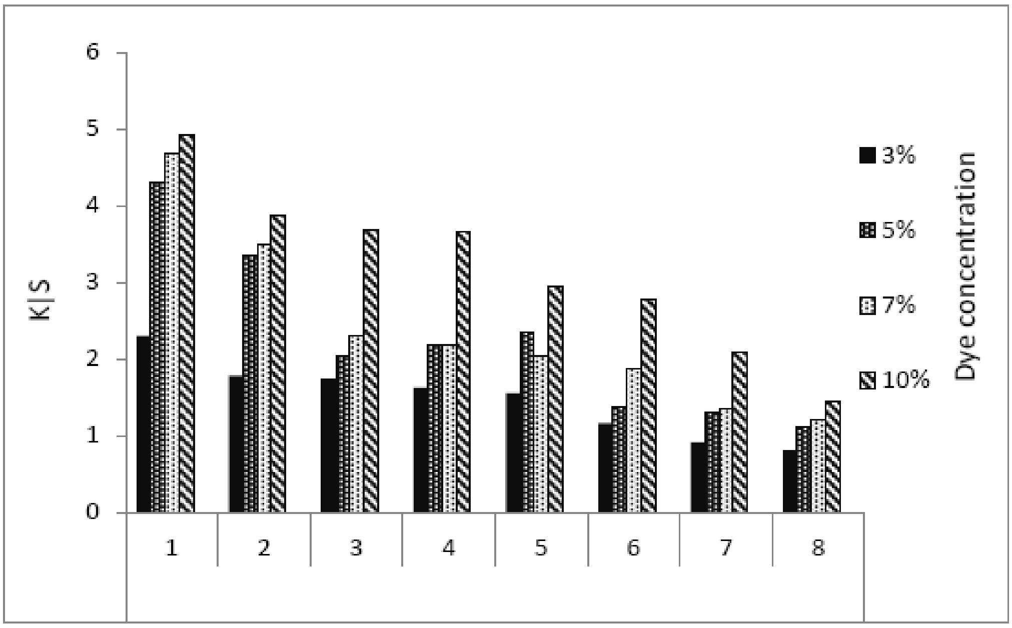
***Transfer conditions 200° C for 30 Secs.**

Fig. 3. Color strength of dyed heavy weight polyester donor fabrics with different concentration of disperse red 60 before and after multiple dye transfers (8 transfers)*



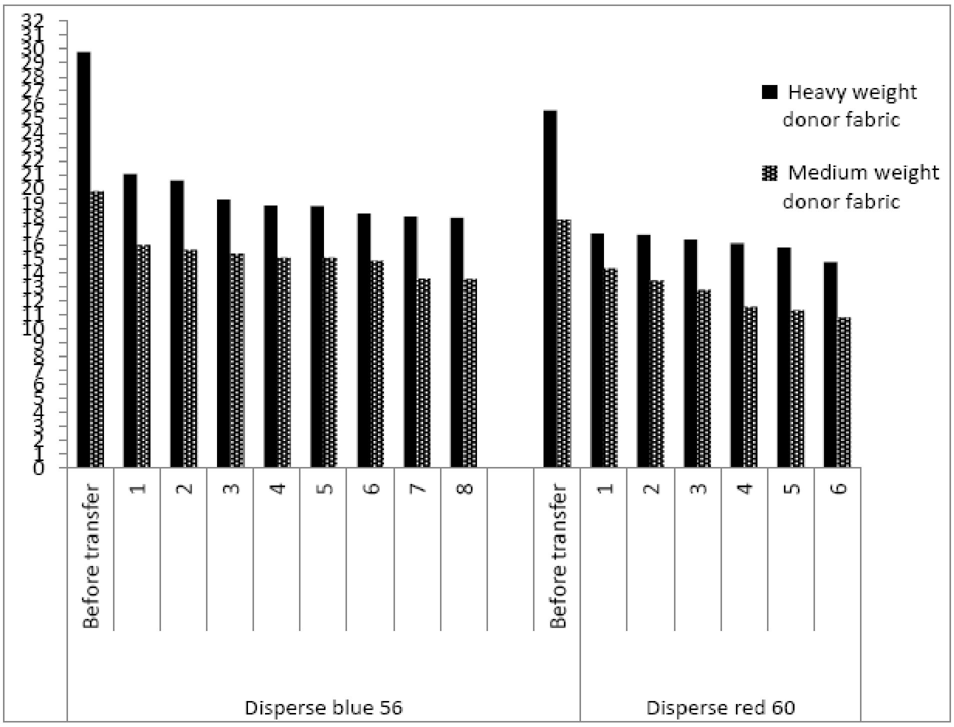
***Transfer conditions 200° C for 30 Secs.**

Fig. 4. Color strength of the receptor polyester fabrics transferred with the heavy weight donor fabrics (dyed with different concentration of disperse blue 56 after multiple dye transfers)*



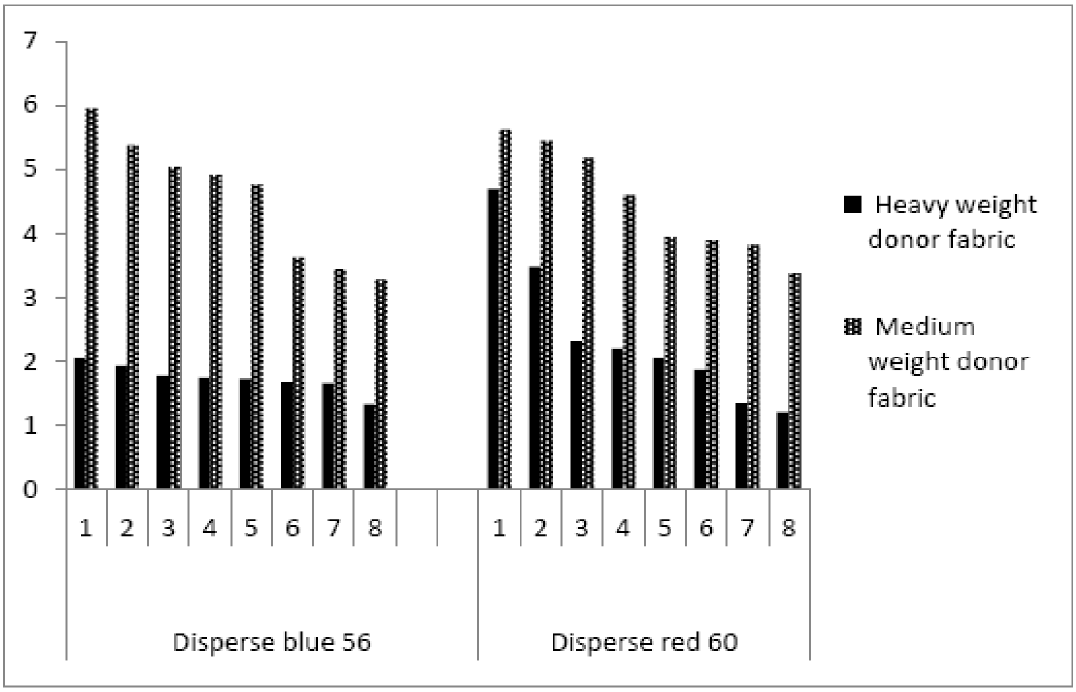
*Transfer conditions 200° C for 30 Secs.

Fig. 5. Color strength of the receptor polyester fabrics transferred with the heavy weight donor fabrics (dyed with different concentration of disperse red 60 after multiple dye transfers)*



*Transfer conditions 200° C for 30 secs.

Fig. 6. Color strength of medium and heavy weight polyester donors fabric dyed with 7% disperse blue 56 and disperse red 60 after multiple dye transfers*



***Transfer conditions 200° C for 30 Secs.**

Fig. 7. Color strength of the receptor polyester fabrics transferred with medium and heavy weight polyester donor fabrics (dyed with 7% disperse blue 56 and disperse red 60) after multiple dye transfers*

TABLE 1. Tensile strength and elongation

Sample		Tensile strength value (Kg|F)	Elongation (%)
Blue 56 dyed with 7% dye shade concentration	Donor fabrics	90	120
	Corresponding receptor fabrics	50	110
Red 60 dyed with 7% dye shade concentration	Donor fabrics	90	120
	Corresponding receptor fabrics	50	110

TABLE 2. Fastness properties of some selected printed fabrics

Sample Dry		Rubbing fastness		Washing fastness	Perspiration fastness					Light fastness
					Acidic		Alkaline			
		Wet	Alt	St	Alt	St	Alt	St		
Blue 56 dyed with 7% dye shade concentration	Donor fabrics	4-5	4	5	4-5	4	5	5	5	4-5
	Corresponding receptor fabrics	5	5	4	5	5	5	5	5	5
Red 60 dyed with 7% dye shade concentration	Donor fabrics	4	4	5	5	5	5	4-5	5	5
	Corresponding receptor fabrics	4-5	5	5	5	5	5	5	5	5

Where: Alt. is alteration in color and St. is stinting on cotton

tests results. These were heavy weight donor fabric dyed with 7 % dye shade with disperse blue 56 and disperse red 60 and corresponding receptor fabric transferred with them.

The tensile strength test is carried out to illustrate the effect of the high frequency of direct heat on the surface of the fabrics during the transfer printing cycles and their effect on the fabric composition of the fabrics.

It is clear from the tensile strength and elongation tests result that, a some decrease in their values from 90-50 and from 120-110 for the donor receptor fabrics respectively using disperse blue 56 and red 60 upon using heat and pressure during the process of color transfer.

Fastness properties results:

The same selected fabrics listed before were chosen to investigate their fastness properties results.

In general, the fastness properties were found to range between very good to excellent.

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