BANGLADESH UNIVERSITY OF TEXTILES

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PROJECT REPORT ON

Comparative Study Among Different Dyeing Methods of Polyester Fabric With Disperse Dyes

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TITLE OF THE PROJECT

Comparative Study Among Different Dyeing Methods of Polyester Fabric With Disperse Dyes

ABSTRACT

The objective of our project was to compare among different dyeing methods of polyester fabric with disperse dyes. At first the polyester fabrics (knit and woven) were dyed with disperse dyes. Three methods have been used for dyeing polyester fabrics (knit & woven):

1. Aqueous dyeing with a carrier (90°- 100°C) (batch dyeing)
2. High-temperature (120°- 140°C) aqueous dyeing (batch dyeing)
3. "Thermosol" dyeing (180°- 220°C) (continuous dyeing)

After dyeing the dyed sample were subjected to several tests-

1. Color fastness to perspiration.
2. Color fastness to rubbing.
3. Color fastness to washing
4. Process effectiveness
5. Cost analysis
6. Tensile Stregnth test
7. Pilling Test

Finally from the overall comparison for different processes , we found that High Temperature & High Pressure method is the most suitable dyeing method used in industrial production.

Acknowledgement

First our never-ending gratitude is to the cherisher & sustainer of the world Almighty Allah for giving us the strength and ability to perform the industrial training and this report. May thy name be exalted, honored and glorified.

Now we wish to take this excellent turn to thank a lot of people who have support and inspired me in the completion of our Project Work. **PROF. DR. ENG. MD. ZULHASH UDDIN,** Dean, Faculty of Textile Chemical Processing Engineering and Applied Science our supervising teacher , whom We are extremely liable for his tremendous support and guidance and also to Mrs. Sharfun Nahar Arju, Head of the department of Wet Processing Engineering. Being worked with him we have not only earned valuable knowledge but also inspired by his innovativeness which has helped enrich my skills to a greater extent. His ideas and way of thinking is truly praise-worthy. We are also very grateful to Dr. Ummul Khair Fatema, Assistant Professor, Department of Wet Processing Engineering; Prof. Dr. Nitai Chandra Sutradhar, honorable V.C, Bangladesh University of Textiles

May We also take the opportunity to express my sincerest gratitude to General Manager of Metro Dyeing & Knitting Mills Ltd & Micro Fibre Group for kind co-operation to allow us to work in Lab.

Above all, We would like to acknowledge our deep debt to all teachers of our University and especially of Wet Processing Engineering department for their kind inspiration and help, which remain as the backdrop of all our efforts.

Finally, We would like to acknowledge that We remain responsible for the inadequacies and errors, which doubtless remain.

TABLE OF CONTENT

LIST OF FIGURE

LIST OF TABLE

CHAPTER-01

GENERAL INTRODUCTION

The project work, which builds understanding, skill & attitude of the performer, which improves his knowledge in boosting productivity & services. Thesis work provides us vast theoretical as well as more practical knowledge; which helps us to be familiar with technical support of modern technology, skillness about various processing stages.

Our project work is ***Comparative Study Among Different Dyeing Methods of Polyester Fabric with Disperse Dyes***. To complete this project work effectively we have to know about some important points, such as : polyester fiber, disperse dyes, dyeing parameters, dyeing methods & so on. Now-a-days polyester fiber is used extensively in textile field. To be expert in polyester dyeing it is necessary to know about the effect of parameters on dyeing polyester fabric with disperse dyes. So our project work is an effective one.

Disperse dyeing is probably the best described as an industrial art, having an assured future. The full gamut of color in the disperse class of dyes which is one of its significant advantages, is obtained by employing a wide range of chromophores. The introduction of disperse dyes for Polyester fibres has given the dyer the possibility of using only one type of dye & simple application conditions, in place of the complex permutations necessary at one time.

We have prepared this report sincerely as required on completion of our project work according to the guideline given by our supervising teacher, which will lead to a strong guideline & milestone for our future carrier.

Objectives of our Project:

1. To compare the effectiveness of different process of polyester fabric dyeing
2. To analyze the cost of dyeing of each mehtod of dyeing
3. To assess the color fastness properties of dyed polyester fabric using different dyeing method
4. To find out the overall comparison.

CHAPTER-02

LITERATURE REVIEW

The dyeing of polyester microfibres with both high energy and low energy disperse dyes has been investigated. The results show the rate of exhaustion on these fibres are more rapid than on regular polyester fibres with no corresponding increase in the colour yield. With the low energy dye, a wide fluctuation in the amount of dye exhausted during dyeing was observed. It is postulated that changes in the degree of crystallinity of micro fibres could attribute to such phenomenon[3-4].

Since their emergence in the late 1980s, fabrics made by polyester microfibre soon found popularity in the production of causal wear, performance sportswear, wind-proof and waterrepellent outwear, imitation peach skin and suede. In general, microfibre refers to fibre having a fineness of less than 1.0 denier and the ones below 0.3 denier are often described as supermicro-fibres (Leadbetter & Dervan, 1992). Fabrics made from polyester microfibre are thin, light, compact with god draping and handle properties. In most cases, such fabrics are manufactured by a combination of fibres with different deniers in order to compromise their individual characteristic properties.[3]

It is well known that a larger amount of dye is necessary to produce a certain colour depth for polyester microfibre than for the regular ones. This phenomenon is believed to be caused by the larger surface area that increases surface light reflection and a shorter path for light absorbance due to the smaller fibre diameter. For the same dye, both the exhaustion rate and temperature to attain to an equal depth on fibres of different fineness are similar, although a larger amount of dye is needed for finer fibres (Akatani, 1994). The amount of dye needed to produce a certain colour depth was found to be roughly proportional to the surface area of the fibre (Jerg & Baumann, 1990). Based on the respective filament fineness of the microfibres, it is possible to estimate the amount of dye to produce an identical depth (Chong, 1994). It was also 'observed that with microfibres the maximum colour yield is usually achieved at a comparatively lower temperature than that with regular (Hoechst Mitsubibishi Kasei Co. Ltd,1993).

This paper describes a detailed study of the parameters that influence the dyeing properties of polyester microfibre. Findings from this study provide a better understanding of the different behaviour of the dyeing properties between regular and microfibre polyesters and could form a firm basis for the design of proper processing methods and precautions necessary to achieve good dyeing qualities. behaviour of the dyeing properties between regular and microfibre polyesters and could form a finn basis for the design of proper processing methods and precautions necessary to achieve good dyeing qualities.[3,6,7]

EXPERIMENTAL

Material Polyester flat filaments with deniers of 0.52, 0.55, 1.04, 2.35 and textured filament with fineness of 4.16 denier were used. Before dyeing, additives were removed by treating the filaments with 1 gil of an anionic detergent and 1 gil of caustic soda at 90°C for 30 minutes followed by rinsing with hot water until the pH of the rinsing water was neutral.[3]

Dyeings were carried out under the following conditions :

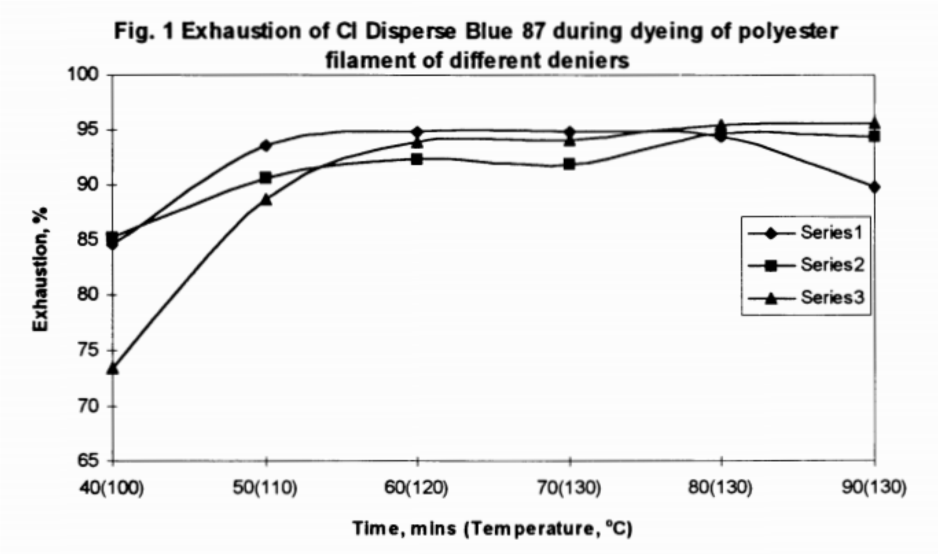
Dyes used	4% owf CI Disperse Blue 87 (high energy dye) 4% owf CI Disperse Blue 128 (low energy dye)
Auxiliary	1 g/l anionic dispersing agent
pH	5.5 (adjusted with acetic acid)
Dyeing temperature	start at 60°C and heat to 100°C or 130°C at 1°C/min.
Dyeing time	60 minutes (unless otherwise stated)
Liquor-to-goods ratio	20:1

Where colour depths were to be compared, the K/S (Kubelka Munk function) values were determined by measuring the reflectance of the dyed samples at the wavelength of minimum reflectance according to the following equation :

$$K/S = (1-R)^2/2R$$

where K = light absorption
S = light scattering
R = reflectance measured at wavelength of minimum reflectance 495 nm for CI Disperse Blue 87, 465 nm for CI Disperse Blue 128

Following figure 1 shows the exhaustion of CI Disperse Blue 87 (high energy dye) on polyester of different filament deniers during dyeing and at the dyeing temperature of 130°C for 20 minutes.

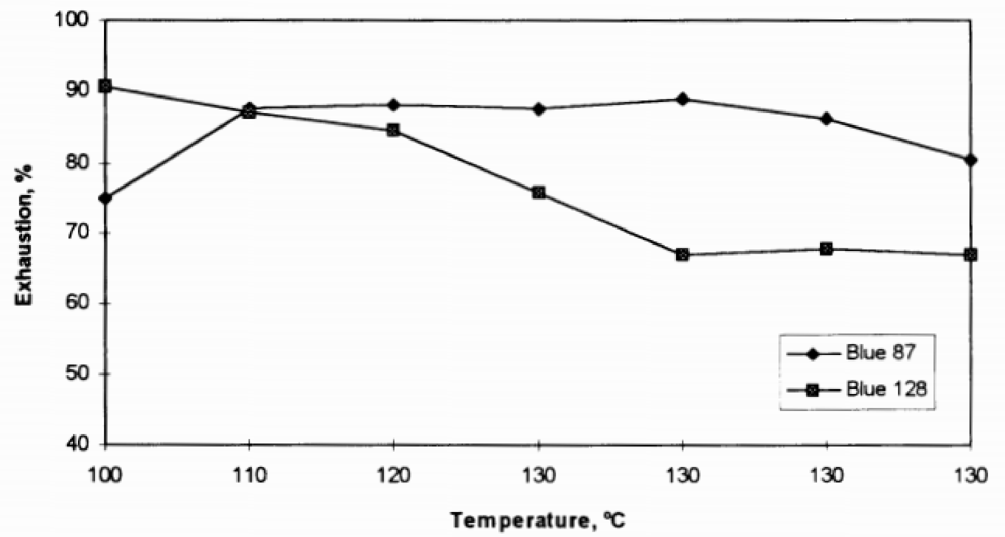


It can be observed that under identical dyeing conditions, exhaustion of the dye on polyester of different deniers are not the same . It is apparent that coarser fibres adsorbed dye more slowly at lower temperatures and it attained a maximum exhaustion at 130°C. The maximum exhaustion remained more or less constant during dyeing at 130°C. With finer filaments, however, maximum exhaustion is attained at lower temperatures between 120-130°C and the maximum exhaustion dropped and fluctuated at the dyeing temperature of 130°C.

To further investigate the importance of dye exhaustion characteristics, this high energy dye together with a low energy dye (CI Disperse Blue 138) were used to dye a 0.S2 denier filament. Results shown on Fig. 2 indicate that the high energy dye achieved its maximum exhaustion at 120°C followed by a steady decrease with only slight fluctuation when the dyeing was prolonged at 130°C. With the low energy dye, the exhaustion fluctuated much more widely before reaching the final dyeing temperature at 130°C. The final exhaustion was found to be much lower than the maximum and is depending on the temperature and the time at which the dyeing is terminated.[3]

In an attempt to find out the relationship between the final dyeing temperature and the maximum dye exhaustion of polyester microfibre, the two selected disperse dyes were used to dye a 0.52 den fibre under different temperatures and the results are shown on Fig. 3

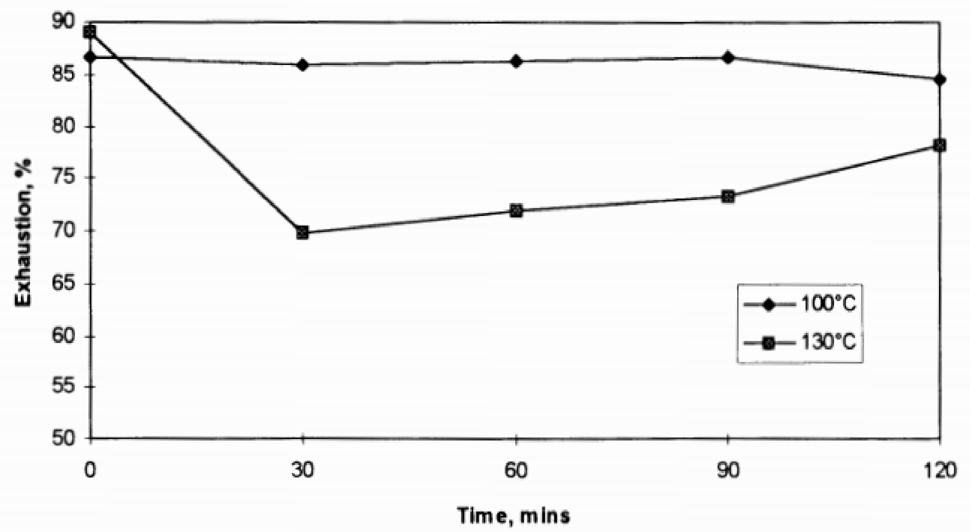
Fig. 3 Exhaustion of CI Disperse Blue 87 & 128 on 0.52 denier polyester filament under different temperatures



It can be seen that irrespective of the types of dye employed, the maximum exhaustion were attained at temperatures ranging from 100 - 110°C. Beyond this range, the exhaustion decreased with increasing temperature. The low energy disperse dye, which is characterised by a higher rate of diffusion, showed a much higher dependency at the higher temperature range. It appears that a lower dyeing temperature would be more favourable for this type of dyes.

Fig. 4. shows the exhaustion of C.I. Disperse Blue 128 on 0.52 den. fibre at different time under the dyeing temperatures of 100°C and 130°C respectively.[2,7,3]

Fig. 4 Exhaustion of CI Disperse Blue 128 on 0.52 denier polyester vs time at different dyeing temperatures



When dyed at 100°C, the exhaustion of the dye remained fairly constant when the dyeing was prolonged. However, when dyed at 130°C, the exhaustion dropped during the prolonged period although it rose again at a latter stage. If dyeing was to terminate at 60 min. after reaching 130°C, then the final exhaustion achieved would be much lower than its maximum.

Since crystallinity plays an important role in the exhaustion behaviour of polyester, the crystallinity of four selected polyester fibres were determined and the results are shown on Table 1.

Table 1 Crystallinity of selected polyester fibres

Fineness (den)	Filament type	% Crystallinity
0.52	flat	36.4
0.55	flat	34.0
1.04	flat	30.7
4.16	textured	20.1

Results clearly indicate that the finer the polyester is, the higher the degree of crystallinity would become. Thus, crystallinity is probably not a major contributing factor to the increased rate of exhaustion of microfibres during dyeing. It is believed that a large surface area of these fibres for dye adsorption is the main cause to account for the faster rate of exhaustion.[3,7]

The above have demonstrated that the exhaustion of a disperse dye would fluctuate during the dyeing, particularly when using a low energy disperse dye dyed under high temperature. For a dyeing time of 60 minutes, the exhaustion of a low energy disperse dye at 100°C could be much higher than that achieved at 130°C. However, since the colour yield achieved is not totally dependent on the exhaustion and is governed by the degree of dye penetration, the colour depth of these dyeing were also investigated. Fig. 5 shows the K/S values of dyeing, using the same dye, obtained for different time of dyeing at 100°C and 130°C respectively.

Apparently, the colour yield or K/S values for dyeing at 130°C increased with the first 30 minutes after reaching the dyeing temperature. The colour yield achieved after 30 minutes is much higher than that achieved at 100°C and is irrespective of the corresponding fluctuation in the exhaustion during the same period. On the other hand, when dyeing was carried out at

100°C, the colour yield or K/S values vary only slightly and they coincided closely with the corresponding exhaustion. This phenomenon can be due to the changes in the degree of dye penetration during dyeing at the indicated temperature. Dyeing at high temperatures could cause the desorption of dyes from the large surface of microfibre and at the same time could promote the diffusion of disperse dye into the fibre interior. In other words, the lower colour yield achieved for dyeing at 100°C despite the higher exhaustion is mainly attributed to the inadequate dye diffusion. Indeed, further heat treatment at a higher temperature for microfibre material dyed at 100°C can considerably improve its colour yield.[3]

In the investigation of the changes in fibre crystallinity during dyeing on fibres of different fineness, it is interesting to note that fibre crystallinity also fluctuates during both the heatingup and dyeing phases of dyeing. Fig. 6 shows the changes in fibre crystallinity during dyeing of fibres of different fineness. It clearly shows that finer fibres are more subjected to crystallinity changes than coarser fibres. Therefore, the changes in fibre crystallinity during dyeing could provide the answer accounting for the fluctuation in dye exhaustion. Indeed, this could also explain the larger degree of fluctuation in exhaustion in dye exhaustion. Indeed, this could also explain the larger degree of fluctuation in exhaustion for the low energy disperse dyes since they are more sensitive to the degree of fibre crystallinity.

Certainly, the changes in the fibre crystallinity during dyeing would depend on the temperature used in dyeing. Fig. 7 shows the changes in fibre crystallinity during dyeing when dyeings were conducted respectively at 130°C and 100°C on a fine fibre of 0.52 den. Apparently, the changes in fibre crystallinity is very remarkable only when dyeing was conducted at 130°C. This correlates well with the changes in dye exhaustion during dyeing (refer to Fig. 4)

In the DSC study, it was also noticed that when a 0.52 den fibre is dyed at 130°C - a temperature higher than the Tg of the fibre, it caused the Tg of the fibre to shift from 120°C to 160°C. This change did not occur when dyeing was conducted at 100°C. It is believed that such change is due to the increase in the mobility of -the chain segments that resulted In reorganisation of the physical structure of the polymer.[1,7]

CHAPTER-03

MATERIALS AND METHODS

List of dyes & chemicals which are used in our project work[23]:

Serial no	Name	Commercial name	Supplier
1	Disperse dye (yellow)	Megaperse Yellow YNA	Matex Internationals Ltd
2	Disperse dye (red)	Megaperse Red RNA	Matex Internationals Ltd
3	Disperse dye (black)	Megaperse Black KNA	Matex Internationals Ltd
4	Leveling agent	Metalevel LPF primium	Matex Internationals Ltd
5	Sequestering agent	Matquest US liquid	Matex Internationals Ltd
6	Anticreasing agent	Matluve UCA liquid	Matex Internationals Ltd
7	Dispersing agent	Matperse Mask pow	Matex Internationals Ltd
8	Acetic acid	Matacid	Matex Internationals Ltd
9	Thickener	Matcmc	Matex Internationals Ltd
10	Carriers		Our WP lab

CARRIER DYEING METHOD

Carriers:

It has been established that certain hydrocarbons, phenols, amino acids, amides, alcohols, esters, ketones, nitriles etc. accelerate the rate of dyeing polyester fibre with disperse dyes from aqueous medium at temperature up to 100°C. These dyeing assistants alter the dispersing properties of the dyes and the physical characteristics of the fibre so that more dye can be transferred from the dye bath to the fibre. These are called carriers and are necessary for dyeing polyester fibres at the normal pressure and temperature below 100°C to increase the dyeing rate and to permit dye migration within the fibre. Level dyeing of disperse dyes depend on the migration power of the dye which is affected by nature and amount of carrier, dyeing time, temperature and the shade[11,12]

Factors Considered For Selecting a Carrier:[12]

1. High carrier efficiency.
2. Availability at low cost.
3. Little or no effect on light fastness of final dyeing.
4. Absence of unpleasant odor.
5. Non toxicity.
6. No degradation or discolouration of fibre.
7. Ease of removal after dyeing.
8. High stability under dyeing conditions.
9. Compatibility with dyestuffs.
10. Ease of dispersion in the dye bath.
11. Low volatility of the carrier including low volatility in the steam.
12. Uniform absorption by the fibre.

Mechanism of Carrier Action[12,17]:

In carrier method of polyester dyeing, carrier is used. Carriers swell the fibre and ultimately cause relaxation. They may operate by opening up the internal fibre structure and allow the dye molecules to diffuse more rapidly. They act as molecular lubricants reducing inter-molecular forces operating in the fibre, thereby following the dye molecule to force its way in. Its action may be described as below:

1. It creates dye film on fibre surface.
2. Carrier takes dye inside the fibre from dye carrier association.
3. It increases the solubility of dye in the dye bath.
4. Carriers penetrate inside the fibre polymer chain and thereby reduce inter-chain attraction. Thus polymer chains become movable and so dye molecules may enter the polymer system of fibre.
5. It increases fibre swelling.
6. The absorbed carrier increases the rate of dye uptake by creating liquid co-fibre.
7. It increases the absorbency power of fibre.
8. It lubricates the thermally agitated fibre molecules.
9. 2-10 gm/lit carrier is used depending on material and liquor ratio and depth of shade.
10. The automatic portion of carrier is postulated to have Van Der Waal's force and attraction for hydrophobic group of it attracts water.
11. With increasing molecular weight the carrier efficiency also increases up to a certain limit.

The extreme crystalline nature of polyester fibres creates problems in obtaining dark shades by conventional dyeing methods even at high temperature. The carriers are found to assist the disperse dyes to enter the polyester polymer, enabling dark shades to be produced. The carriers swell the polyester fibres, increase inter polymer space and let the dye molecules to enter the polymer system easily.

Typical Recipe:

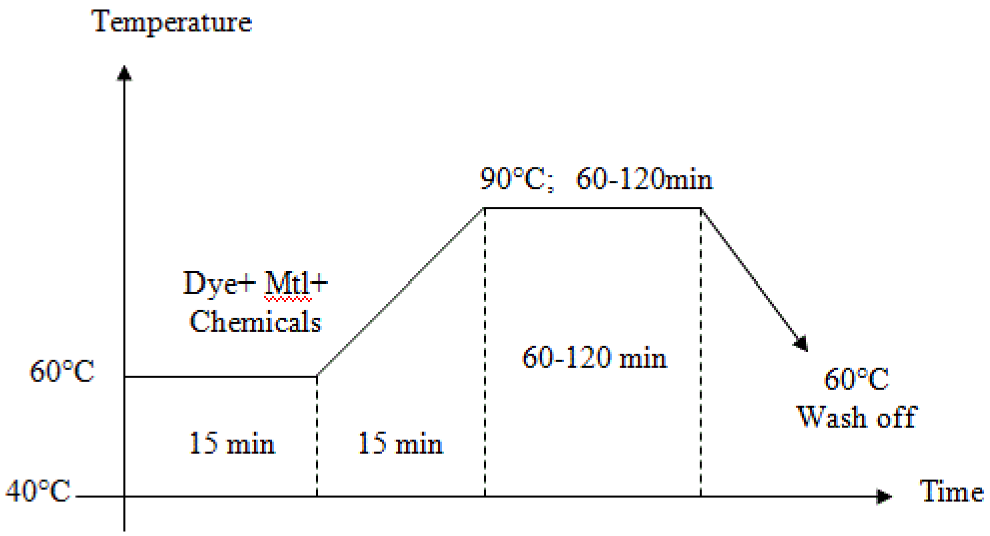
Dye	**- For light shade = 0.5% (owf)**	
	Carrier	: 4 gm/lit
	Acetic acid	: 0.5cc/lit
	Dispersing agent	: 1 gm/lit
	Leveling agent	: 1 cc/lit
	Sequestering agent	: 1 cc/lit
	Anticreasing agent	: 1 cc/lit
	P^H	: 4.5 - 5
	M:L	: 1:10
	Time	: 60 min
	Temperature	: 100°C

Dye	**- For medium shade=1.5%**	
	Carrier	: 4 gm/lit
	Acetic acid	: 0.5 cc/lit
	Dispersing agent	: 1gm/lit
	Leveling agent	: 1 cc/lit
	Sequestering agent	: 1 cc/lit
	Anticreasing agent	: 1 cc/lit
	P^H	: 4.5 - 5
	M:L	: 1:10
	Time	: 60 min
	Temperature	: 100°C

Dye - For deep shade=3%	
Carrier	: 6 gm/lit
Acetic acid	: 0.5 cc/lit
Dispersing agent	: 1gm/lit
Leveling agent	: 1 cc/lit
Sequestering agent	: 1 cc/lit
Anticreasing agent	: 1 cc/lit
P^H	: 4.5 - 5
M:L	: 1:10
Time	: 60 min
Temperature	: 100°C

PROCEDURE:

1. At first, a paste of dye and dispersing agent is prepared and then water is added to it.
2. Dye bath is kept at 60°C temperature and all the chemicals along with the material are added to it. Then the bath is kept for 15 min without raising the temperature.
3. P^H of bath is controlled by acetic acid at 4-5.5.
4. Now temperature of dye bath is raised to 90°C and at that temperature the bath is kept for 60 min.
5. Then temperature is lowered to 60°C and resist and reduction cleaning is done if required. Reduction cleaning is done only to improve the wash fastness.
6. Material is again rinsed well after reduction cleaning and then dried.



After treatment:

Reduction cleaning:

In case of dark shade dyeing we have to use more amounts of dye & chemicals. But these chemicals should be removed from fabric after dyeing. Because in disperse dyeing the fabric surface becomes rough & for this reason to make the fabric surface smooth a special process is used in case of disperse dyeing. This cleaning process is called reduction cleaning. A typical recipe for reduction cleaning is given below:

2 gm/lit Hydrosulphite

2-3 ml/lit NaOH (56.5^{0} T_w)

By reduction cleaning surface dye molecules or unfixed dye molecules are stripped & this in turn results in level dyeing. Reduction cleaning also improves wash fastness property of textile materials.

Advantages of Carrier Dyeing[12]:

1. In conventional dyeing method, the extremely crystalline polyester fibres can not be dyed in deep shade. But by using carrier we can get medium to dark shade in boiling temperature.
2. Materials can be dyed with simple equipments at atmospheric pressure and temperature below 100°C.
3. Moderate level dyeing of polyester fabric can be done.
4. Some carriers reduce the staining of wool while dyeing polyester-wool blends.
5. Rate of dyeing can be increased by using carriers.
6. Can be dyed quickly by using carriers.
7. Improves fastness properties of fabric except light fastness.

Disadvantages of Carrier Dyeing:

1. Carriers add to production cost of dyeing. Firstly, for dyeing it is used which is costly and secondly for its removal alkali is required.
2. Carriers are unhygienic and toxic. It creates skin diseases.
3. Some dyeing machines may create carrier spot.
4. Carriers affect the light fastness property of dyed material. This effect may be reduced by treating the material with hot air for 30 min.
5. Some carriers are dyed specific. They posses different efficiencies with different dyes; others have compatibility with certain dyes.

High Temperature Dyeing Method

In high temperature dyeing method either material or liquor should circulate. Otherwise dye molecules won't penetrate inside the material. They will stay on surface only. In this method, temperature is kept in between 105-140^{0}c & pressure is kept from 0 to 170 kpa. This method is also known as pressure dyeing which is used for highly crystalline synthetic fibres & their blends. This technique causes the fibre to swell even more than which achieved at 100^{0}c temperature. So that dye molecules penetrate the fibre polymer system. It eliminates the need of carriers.[10,11,22]

Recipe:

Dye	**: 0.5% (For light shade)**
Acetic acid	: 0.5cc/lit
Dispersing agent	: 1.0 gm/lit
Leveling agent	: 1 cc/lit
Sequestering agent	: 1.cc/lit
Anticreasing agent	: 1cc/lit
P^H	: 4.5 - 5
M:L	: 1:10
Time	: 45 min
Temperature	: 135°C

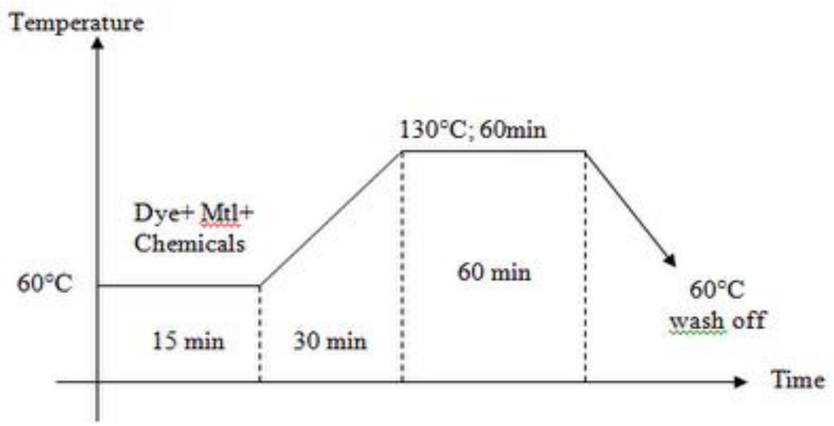
Dye	**: 1.5% (For medium shade)**
Acetic acid	: 0.5cc/lit
Dispersing agent	: 1.0 gm/lit
Leveling agent	: 1 cc/lit
Sequestering agent	: 1.cc/lit
Anticreasing agent	: 1cc/lit
P^H	: 4.5 - 5
M:L	: 1:10
Time	: 45 min
Temperature	: 135°

Dye	**: 3% (For deep shade)**
Acetic acid	: 0.5cc/lit
Dispersing agent	: 1.0 gm/lit
Leveling agent	: 1 cc/lit
Sequestering agent	: 1.cc/lit
Anticreasing agent	: 1cc/lit
P^H	: 4.5 - 5
M:L	: 1:10
Time	: 45 min
Temperature	: 135°

Procedure:

1. At first a paste of dye & dispersing agent is prepared & water is added to it,
2. P^H is controlled by adding acetic acid,
3. This condition is kept for 15 minutes at temperature 60^0c,
4. Then dye bath temperature is raised to 130^0c & this temperature is maintained for 1 hour. Within this time dye is diffused in dye bath, adsorbed by the fibre & thus required shade is obtained.
5. The dye bath is cooled as early as possible after dyeing at 60^0c.
6. The fabric is hot rinsed & reduction cleaning is done if required.
7. Then the fabric is finally rinsed & dried.

Dyeing curve:



After treatment:

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In case of dark shade dyeing we have to use more amounts of dye & chemicals. But these chemicals should be removed from fabric after dyeing. Because in disperse dyeing the fabric surface becomes rough & for this reason to make the fabric surface smooth a special process is used in case of disperse dyeing. This cleaning process is called reduction cleaning. A typical recipe for reduction cleaning is given below:

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2-3 ml/lit NaOH (56.5^0 T_w)

By reduction cleaning surface dye molecules or unfixed dye molecules are stripped & this in turn results in level dyeing. Reduction cleaning also improves wash fastness property of textile materials.[4,11]

Advantage of HT Method

1. Dyeing time are frequently shorter
2. Higher temp require No need of carrier
3. Maximum 98% dye fixation
4. Loss of dye is less
5. Light fastness and wet fastness is usually higher
6. Better exhausion and deeper dyeing can be produced.
7. Faster diffusion of the dye in the fibre at elevated temp.[4]

THERMOSOL DYEING METHOD

Principle:

Thermosol method is continuous methods of dyeing with disperse dye. Here dyeing is performed at high temperature like 180-220°C in a close vessel. Here time of dyeing should be maintained very carefully to get required shade and to retain required fabric strength.[22]

Sequence:

This dyeing process is developed by Du Pont Corporation in 1949. here at sufficient temperature the fibres are soften and their internal structure is opened, polymer macromolecules vibrates vigorously and dye molecules diffuse in in fibre. It requires only a few seconds to 1 min and temperature about 200-230°C. The sequence of operation is[11]:

Padding → *Drying* → *Thermo fixing* → *After Treatment*

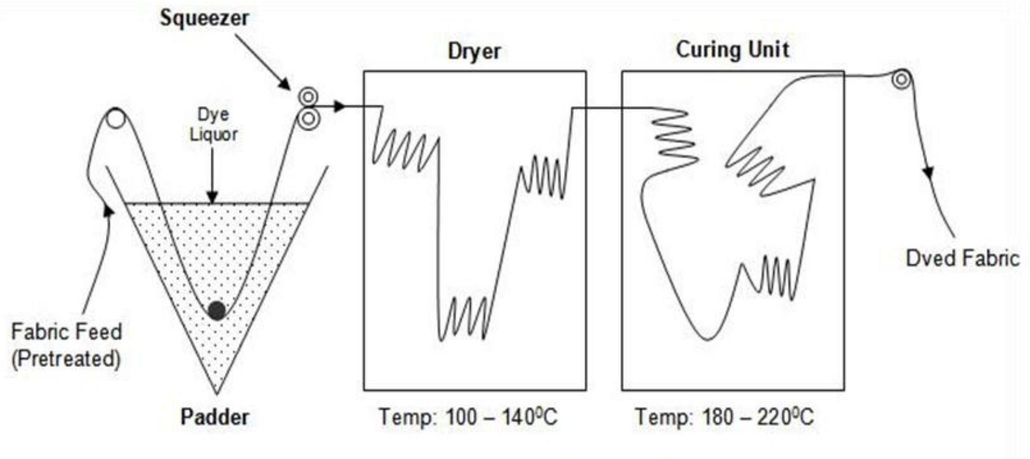


Fig: TM of Dyeing Polyester Fabric (2 Min)

Dye Selection for Thermosol Dyeing[14]:

Desirable dye characteristics:

1. Liquid or granule brands
2. Better dispersing properties

3. Better penetration
4. Even dyeing
5. Excellent sublimation fastness
6. Good yield and leveling at HT [7]

Padding condition:

1. Constant pad liquor temperature
2. Uniform feed of fresh padding liquor over the whole width during the complete pad dyeing process
3. The smallest possible volume of liquor in
4. the foulard trough
5. The sufficient immersion times, especially with fabrics with poor wettability

Typical Recipe:

Dye	**: 0.5% (For light shade)**
Dispersing agent	: 0.5gm/lit
Levelling agent	: 0.5 cc/lit
Sequestering agent	: 0.5 cc/lit
Thickener	: 3 gm/lit
Acetic acid	: 0.5 gm/lit
Time	: 30-50 sec (curing)
Temperature	: 190^0c
P^H	: 4.5 – 5.5

Dye	**: 1.5% (For medium shade)**
Dispersing agent	: 0.8gm/lit
Levelling agent	: 0.8 cc/lit
Sequestering agent	: 0.8 gm/lit
Thickener	: 4 gm/lit
Acetic acid	: 0.5 cc/lit
Time	: 30-50 sec (curing)
Temperature	: 190^0c
P^H	: 4.5 – 5.5

Dye	**: 3% (For deep shade)**
Dispersing agent	: 1.0gm/lit
Levelling agent	: 1.0 cc/lit
Sequestering agent	: 1.0 cc/lit
Thickener	: 5 gm/lit
Acetic acid	: 0.5 cc/lit
Time	: 30-50 sec (curing)
Temperature	: 190^0c
P^H	: 4.5 – 5.5

Procedure:

1. At first the fabric is padded with dye solution using above recipe in a three bowl padding mangle.
2. Then the fabric is dried at 100°C temperature in dryer. For dyeing, infra red drying method is an ideal method by which water is evaporated from fabric in vapor form. This eliminates the migration of dye particles.
3. Then the fabric is passed through thermasol unit where thermo fixing is done at about 205°C temp for 60-90 seconds depending on type of fibre, dye and depth of shade. In thermasol process about 75-90% dye is fixed on fabric.
4. After thermo fixing the unfixed dyes are washed off along with thickener and other chemicals by warm water. Then soap wash or reduction cleaning is done if required

Migration inhibitor[14]:

❖ **Function**

1. To prevent dye migration to wet fabric zones during drying
2. Should not increase viscosity of liquor too much

❖ **Types**

1. Sodium alginate (2-4 g/l)
2. CMC (4-8 g/l)
3. Polyacrylic acid derivatives

Squeezing

1. Uniform squeeze pressure maintained over the whole fabric width
2. Both squeeze rollers should have the same shore hardness
3. Constant production speed

Pick up %:

i. Factors
   a. Roller pressure,
   b. Roller hardness
   c. Fabric speed.
ii. Liquor pick-up should be kept as low as possible so that drying energy is reduced.
iii. Pick-up should not be reduced too much as this could lead to penetration problems.
iv. Normal liquor pick-up should be between 60 and 80

Advantage of Thermosol Process[11]

1. Dyeing time is very short.
2. No need of carrier
3. Non toxic.
4. There is no additional problem of removing carrier by using alkali.
5. Very bright shade is obtained.
6. Excellent dye utilization (75-90%) is achieved.

Disadvantage of Thermosol Process:

1. Shade may be changed due to sublimagpnat high temp.
2. Spedal M/C required.
3. Loss of strength when time of treatment is prolonged.
4. Costly due to this process requires special arrangement[5]

Different Color Fastness Tests

Color fastness to washing[26]:

Principle: A specimen/dyed material with specified adjacent fabric (MFF) are laundered rinsed and dried. The specimen/composite sample is treated under appropriate condition in a chemical bath for recommended time. The abrasive action is accomplished by the use of a liquor ratio and an appropriate number of steel balls. The change in color of the specimen (dyed sample) and the staining of the adjacent fabric (MFF) is assessed by recommended Grey scales (1-5)

Apparatus & Materials:

Wash wheel with a thermostatically controlled water bath & rating speed of (40±2) rpm

Stainless steel container (capacity 55±5 ml)

Stainless steel ball (dia = 0.6 cm, weight = 1 gm)

Bleached cotton fabric

Thermometer

Sewing machine

Dryer

Color matching cabinet and

ISO Scales[21]

Fig: Washing Machine

Reagent:

Reference detergent

Sodium Carbonate / Soda ash

Distilled water (Grade – 3) and

Test Specimen: Cut a sample of dyed goods 10 cm × 4 cm and sew it with same size multifibre fabric. This is the composite test sample.

Test Procedure: ISO recommended no **ISO 105 C 03**

ISO recommended no. ISO 105 C 03: Composite sample is treated in a wash wheel for 30 minutes at (60±2)^{O}C with 5 gm/l standard soap and 2 gm/l soda ash.

Test	Temperature ^{O}C	Time (Minute)	Steel Ball	Chemicals
ISO – 105 – CO3	60	30	00	Soap (5 gm/l) + Soda 2 gm/l

Evaluation: Compare the contrast between the treated and untreated sample with grey scales for changing color of dyed sample & and staining of adjacent fabric in a color matching cabinet.

Color fastness to rubbing[26]

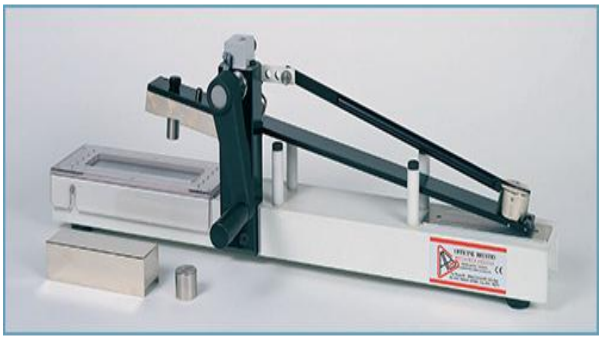


Fig: Crock Meter

Sample size:

Dyed fabric – 15 cm x 5 cm

White Test Cloth - 5 cm x 5 cm

Procedure:

1. White test cloth is put on to the grating and stag by steel wire.
2. Crock cloth is placed under finger & tight by clip.
3. The sample is run ten times manually for ten seconds. and the rubbing fastness of the sample cloth and degree of staining is accessed.
4. For rubbing fastness (Wet), the rubbing cloth is placed in the water and socked and squeeze. The wet rubbing cloth is placed on to the grating and stag with stainless steel wire and run ten times manually then assess the staining on to the rubbing cloth and the rubbing fastness of the sample cloth is accessed.

Evaluation :

Evaluation is done by grey scale in a color matching cabinet and rated from 1 to 5.

Color Fastness Test to Water (ISO 105 EO1)

Theory:

Color fastness to water is designed to measure the resistance to water of dyed, printed, or otherwise colored textile yarns and fabrics.The test method by which this test is carried out is AATCC 107-1991 or ISO 105 E01. This method is to assess the degree of cross staining which may occur when garments are left in contact when damp. The test measures the resistance to water of any colored textiles.

Apparatus:

1. Perspiration Tester
2. Oven
3. Multi fiber fabric
4. Grey scale
5. Color matching cabinet
6. Glass plate or Acrylic resin plates
7. Weight 12.5 kPa or 5kg pressure
8. Glass beaker
9. Stirring rod

Reagent:

Distilled water or de-ionized water is used in this test method because natural (tap) water is variable in composition.

Sample Preparation:

Cut the specimen & multi-fibre at 10×4cm & sewn together. This is the composite test sample.

Working Procedure:

Wet in distilled water at room temperature & it will suck water.

↓

Place it in acrylic resin plates & put the weight on to the plates.

↓

Keep it in oven & keep the temperature at 37± 2°C for 4hrs.

↓

Open the specimen & dry it in the air hot exceeding 60°C.

↓

Change in color is assessed with the help of Grey Scale.

Color fastness to perspiration[26]:

Test specimen:

• Sample fabric – 50 mm × 50 mm
• Multifibre fabric – 50 mm × 100 mm
• Cut the multifibre into two piece
• Sandwich the test specimen between two piece of multifibre

Fig: Perspirometer

Testing Solution:

1. Alkaline Solution:

- Histidine monohydro chloride monohydrate ($C_6H_{10}ClN_3O_2.H_2O$)-5.00 g/l
- NaCl- 5.00 g/l
- Disodium hydrogen orthophosphate $(Na_2HPO_4.2H_2O)$ -2.5 g/l
- P^H -8 (Adjust by 0.1 N NaOH)

2. Acidic Solution:

- Histidine monohydro chloride monohydrate ($C_6H_{10}ClN_3O_2.H_2O$)-5.00 g/l

  NaCl- 5.00 g/l
- Disodium hydrogen orthophosphate $(Na_2HPO_4.2H_2O)$ -2.2 g/l
- P^H -5.5(Adjust by 0.1 N NaOH)

Method:

1. The composite specimen is put in a peri dish (2 specimen of a sample).
2. Solution (Alkaline & Acidic) is taken in the two peri dish. Here, M:L is taken 1:20.
3. Bubble is made out from the specimen by tapping.
4. The specimen is put for 30 minutes.
5. A glass plate is placed on the composite specimen for 15 minutes at room temperature.
6. Excess solution is poured off.
7. Peri dish with composite specimen & glass plate is placed into the incubator at (37±2) ^{0}C for 4 hours.
8. The specimen is dried (Temp ≤ 60^{0}C)

Report:

Change of shade & degree of staining is measured by the Grey Scale & Staining Scale.

Pilling Tests[27]:

For this test four specimen s each 125m m X 125m m are cut from the fabric. A seam allowance of 12mm is marked on the back of each square . In two of the sample s the seam is marked parallel to the warp direction and in the other two parallel to the weft direction . The sample s are then folded face to face and a seam is sewn on the marked line . This give s two specimens with the seam parallel to the warp and two with the seam parallel to the weft. Each specimen is turned inside out and 6mm cut off each end of it thus removing any sewing distortion . The fabric tube s made are then mounted on rubber tube s so that the length of tube showing at each end is the same. Each of the loose ends is tape d with poly (vinyl chloride) (PVC) tape so that 6mm of the rubber tube is left expose d as show n in Fig. 7.4. All four specimen s are then place d in one pilling box. The sample s are then tumbled together in a cork-line d box as shown in Fig. The usual number of revolution s used in the test is 18000 which takes 5 h. Some specifications require the test to be run for a different number of revolutions.

Fig: Digital Pilling Tester

Assessment:

The specimen s are remove d from the tubes and viewed using oblique lighting in order to throw the pills into relief . The sample s are then given a rating of between 1 and 5 with the help of the description s in Table 7.1 .

Table 7.1 Pilling grades

Rating	Description	Points to be taken into consideration
5	No change	No visual change
4	Slight change	Slight surface fuzzing
3	Moderate change	The specimen may exhibit one or both of the following: (a) *moderate fuzzing* (b) isolated fully formed pills
2	Significant change	Distinct fuzzing and/or pilling
1	Severe change	Dense fuzzing and/or pilling which covers the specimen.

CHAPTER-04

RESULTS AND DISCUSSIONS

Sample

Dyeing of Polyester Fabric (Woven) with disperse dyes

Method of Dyeing : Thermosol

Sample :

Shade	3%	1.5%	0.5%
Megaperse Red RNA			
Megaperse Yellow YNA			
Megaperse Black KNA			

Method of Dyeing : High Temperature

Sample :

Shade	3%	1.5%	0.5%
Megaperse Red RNA			
Megaperse Yellow YNA			
Megaperse Black KNA			

Method of Dyeing : Carrier

Sample :

Shade	3%	1.5%	0.5%
Megaperse Red RNA			
Megaperse Yellow YNA			
Megaperse Black KNA			

Dyeing of Polyester Fabric (Knitted) with disperse dyes
Method of Dyeing : Thermosol

Sample :

Shade	3%	1.5%	0.5%
Megaperse Red RNA			
Megaperse Yellow YNA			
Megaperse Black KNA			

Method of Dyeing : High Temperature

Sample :

Shade	3%	1.5%	0.5%
Megaperse Red RNA			
Megaperse Yellow YNA			
Megaperse Black KNA			

Method of Dyeing : Carrier

Sample :

Shade	3%	1.5%	0.5%
Megaperse Red RNA			
Megaperse Yellow YNA			
Megaperse Black KNA			

Color fastness to washing:

		Black		Red		Yellow	
		Woven	Knit	Woven	Knit	Woven	Knit
Shade% =0.5	CM	3/4	3	2/3	3/4	3	3
	HT	4	3/4	3/4	3/4	4	4
	TM	4/5	4	4	3	4/5	4
Shade% =1.5	CM	3	3	3	3/4	3/4	3/4
	HT	4	3/4	3/4	3	4/5	4
	TM	4	3/4	3/4	3/4	3/4	3/4
Shade% = 3	CM	3	2/3	3	2/3	3/4	3
	HT	3/4	3	3	3/4	3/4	3/4
	TM	4	4	3/4	3/4	3/4	3/4

Results are shown in chart below:

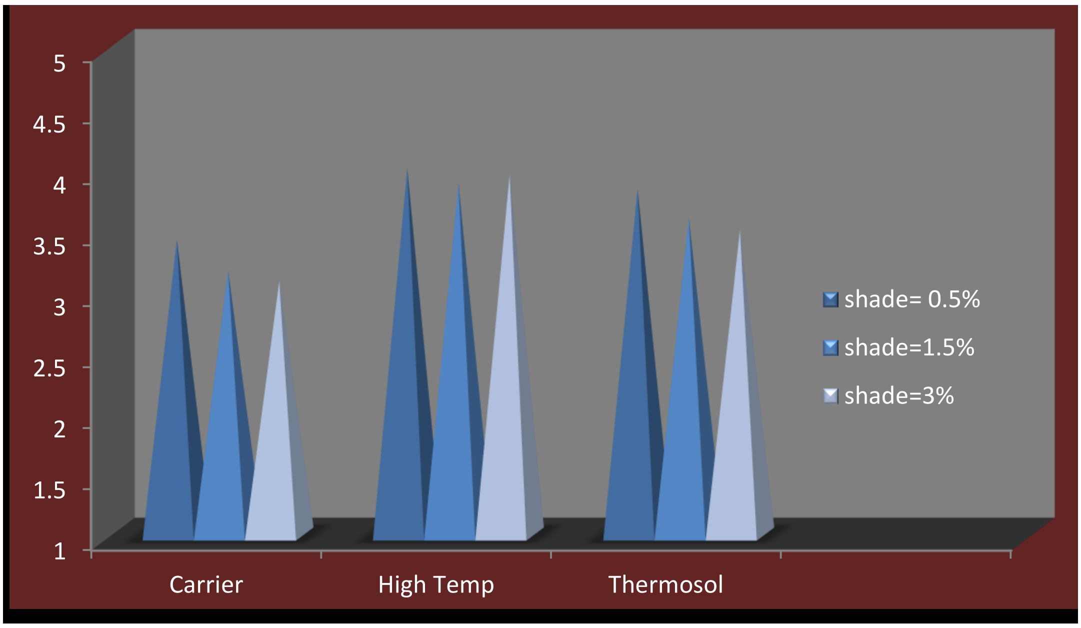


Fig : Comparisons of color fastness to washing (Buyer approved grade ≥3)

Color fastness to rubbing :

		Black		Red		Yellow	
		Woven	Knit	Woven	Knit	Woven	Knit
Shade% = 0.5	CM	4	3/4	3	3	3/4	3
	HT	4/5	4	3/4	3	4/5	3/4
	TM	4/5	4	4	3/4	4/5	4
Shade%= 1.5	CM	3	3	3/4	3	3	3
	HT	3/4	3	3	3	4/5	4
	TM	4/5	4	3/4	3	4/5	4/5
Shade%= 3	CM	3	3	3/4	3	3/4	3/4
	HT	3/4	3/4	3/4	3	3/4	3
	TM	4	3/4	3/4	3/4	3/4	3/4

Results are shown in chart below:

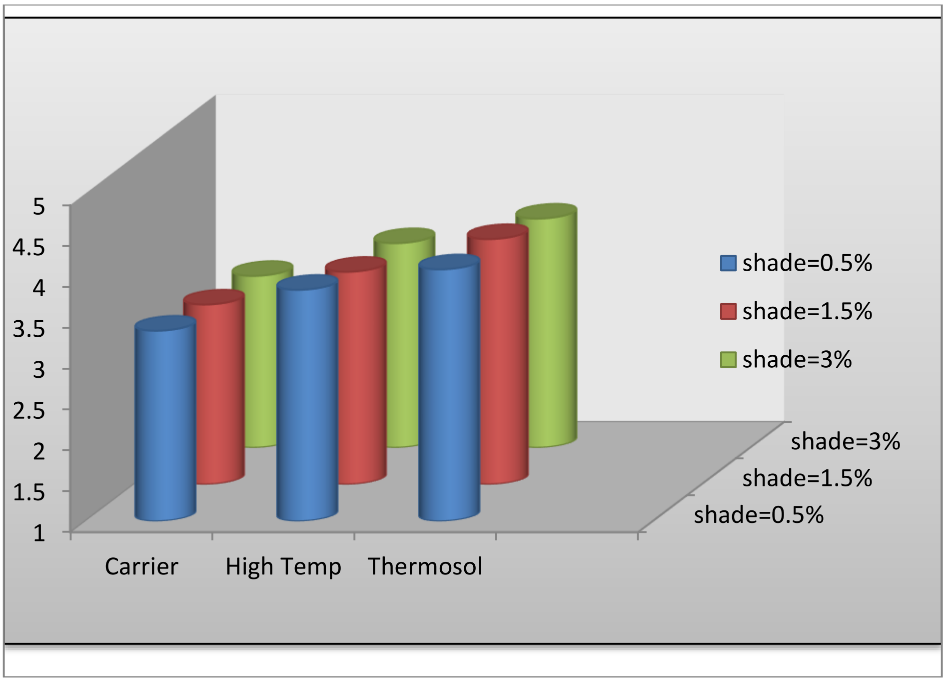


Fig : Comparisons of color fastness to rubbing (Buyer approved grade ≥3)

Color fastness to Water:

		Black		Red		Yellow	
		Woven	Knit	Woven	Knit	Woven	Knit
Shade% = 0.5	CM	4	3/4	3	3	3/4	3
	HT	4/5	4	3/4	3	4/5	3/4
	TM	4/5	4	4	3/4	4/5	4
Shade% = 1.5	CM	3	3	3/4	3	3	3
	HT	3/4	3	3	3	4/5	4
	TM	4/5	4	3/4	3	4/5	4/5
Shade%= 3	CM	3	3	3/4	3	3/4	3/4
	HT	3/4	3/4	3/4	3	3/4	3
	TM	4	3/4	3/4	3/4	3/4	3/4

Results are shown in chart below:

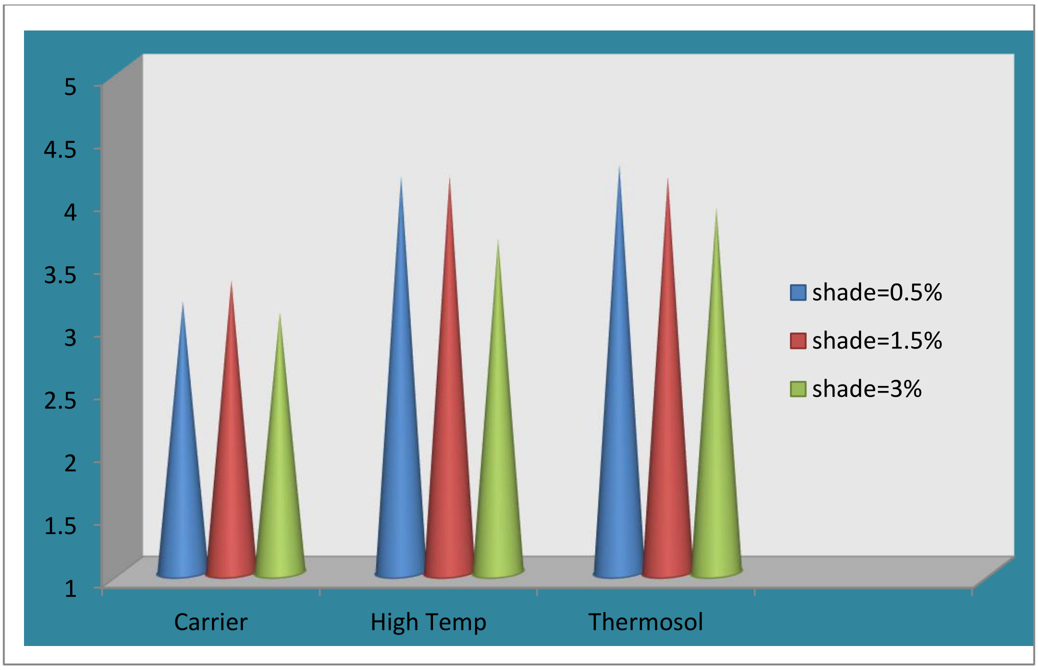


Fig : comparisons of color fastness to water (Buyer approved grade ≥3)

Color fastness to Perspiration:

		Black		Red		Yellow	
		Woven	Knit	Woven	Knit	Woven	Knit
Shade %= 0.5	CM	3/4	3/4	3/4	3	3/4	3
	HT	4	3/4	3/4	3/4	4	4
	TM	4/5	4	4	3/4	5	4/5
Shade %= 1.5	CM	3	3	3	2/3	3/4	3/4
	HT	4	3/4	3/4	3	3/4	3/4
	TM	4	4	4	3/4	4	3/4
Shade %= 3	CM	3	3	3	2/3	3	3/4
	HT	3/4	3	3/4	3	3/4	3/4
	TM	4	3/4	3	3	4	3/4

Results are shown in chart below:

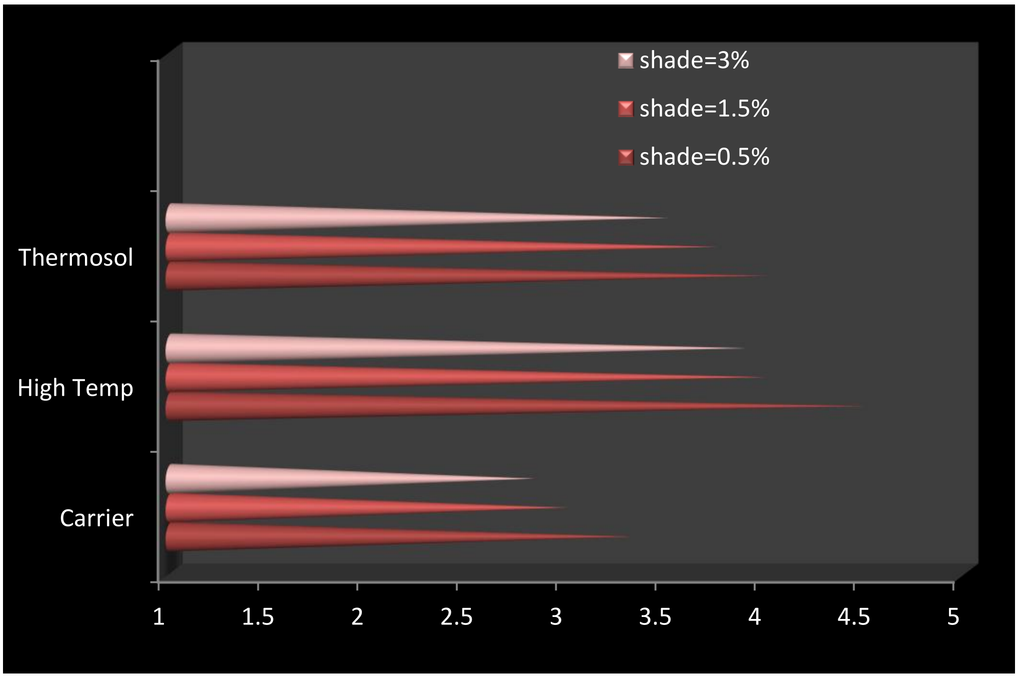
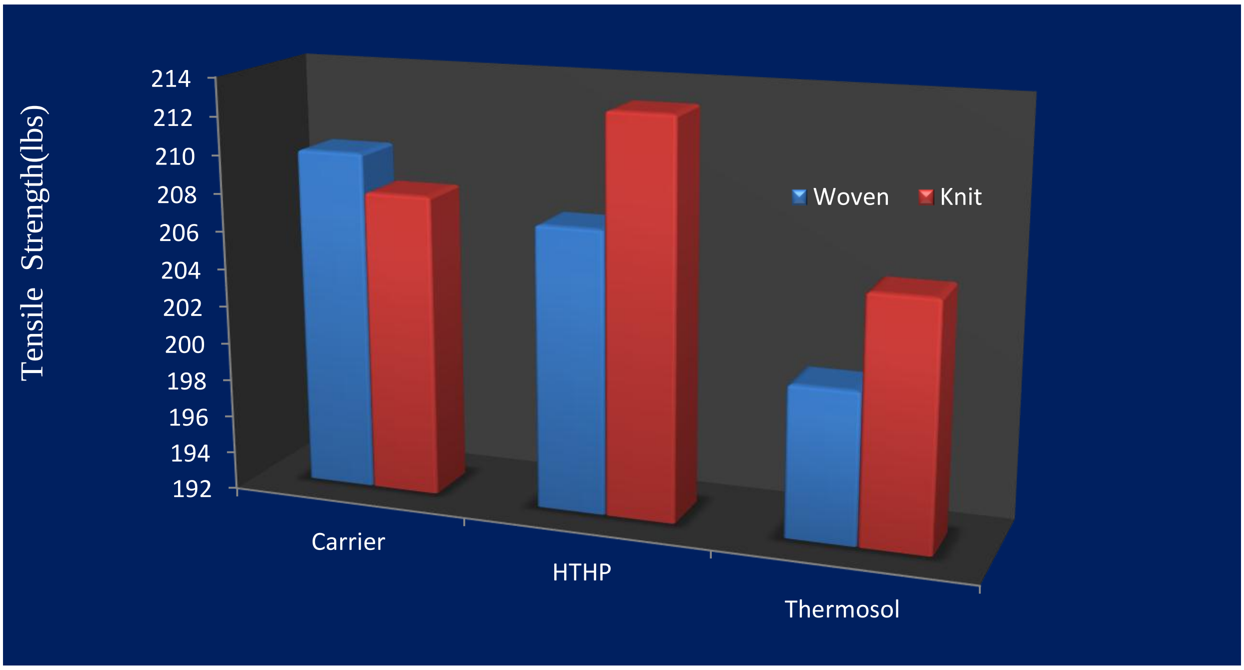


Fig : comparisons of color fastness to perspiration (Buyer approved grade ≥3)

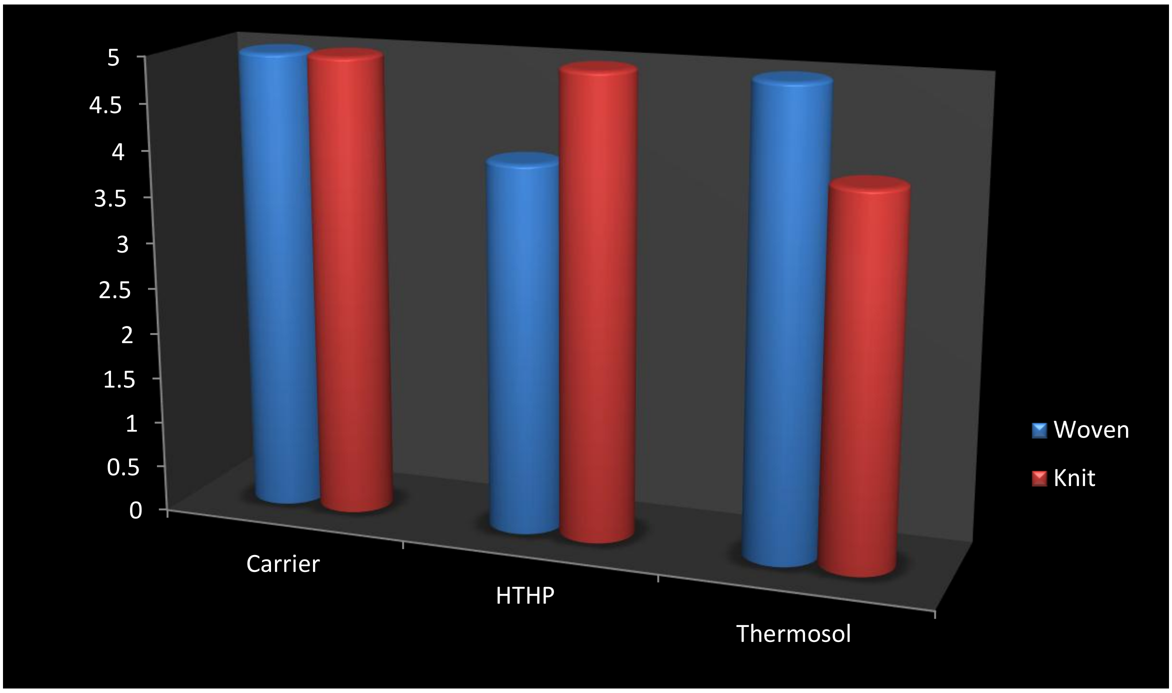
Tensile Strength:

	Tensile Strength(lbs) For woven(Vertical Tensile Strength Tester) For Knit (Bursting strength Tester))					
	Black		Red		Yellow	
	Woven	Knit	Woven	Knit	Woven	Knit
CM	210	209	207	220	210	208
HT	208	200	205	215	215	214
TM	205	207	208	210	190	205

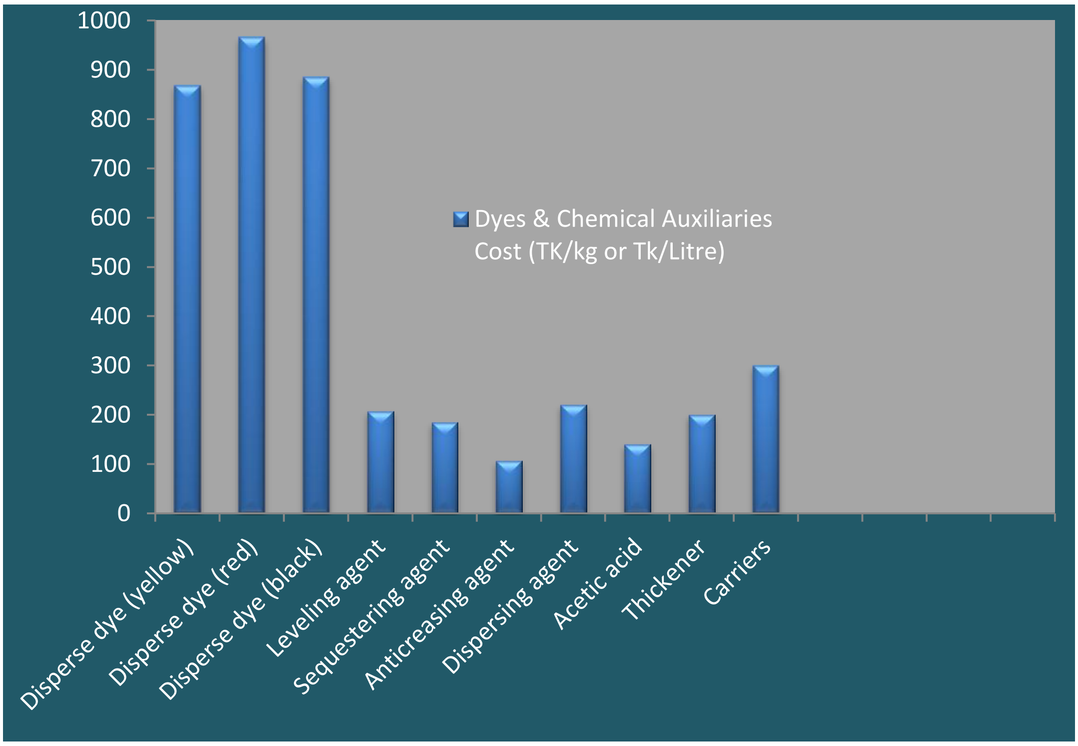
Results are shown in chart below:



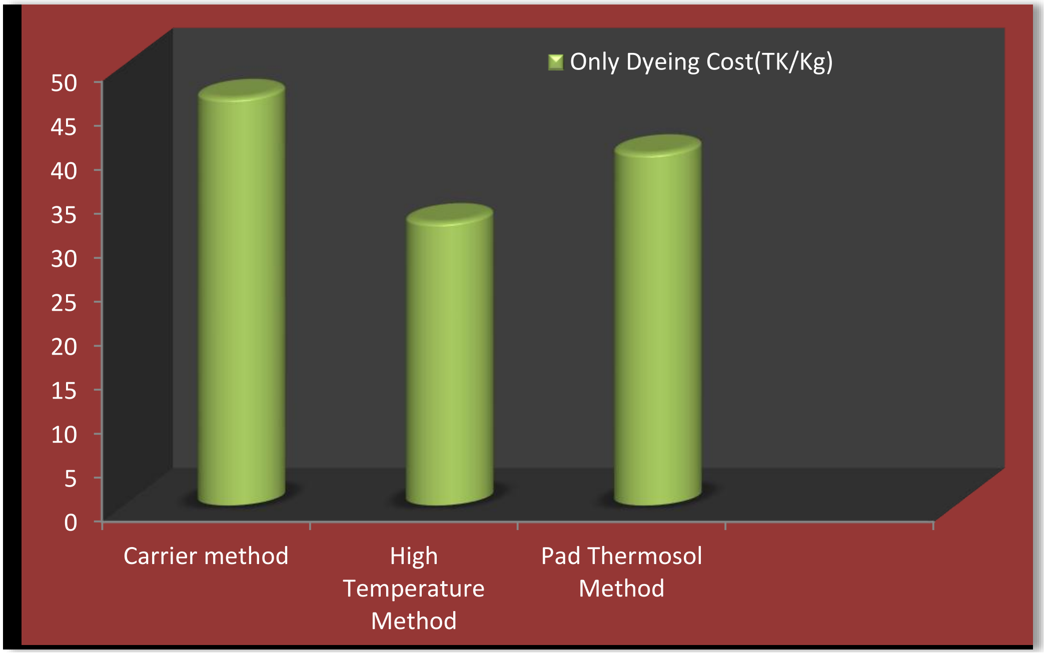
Pilling Test:



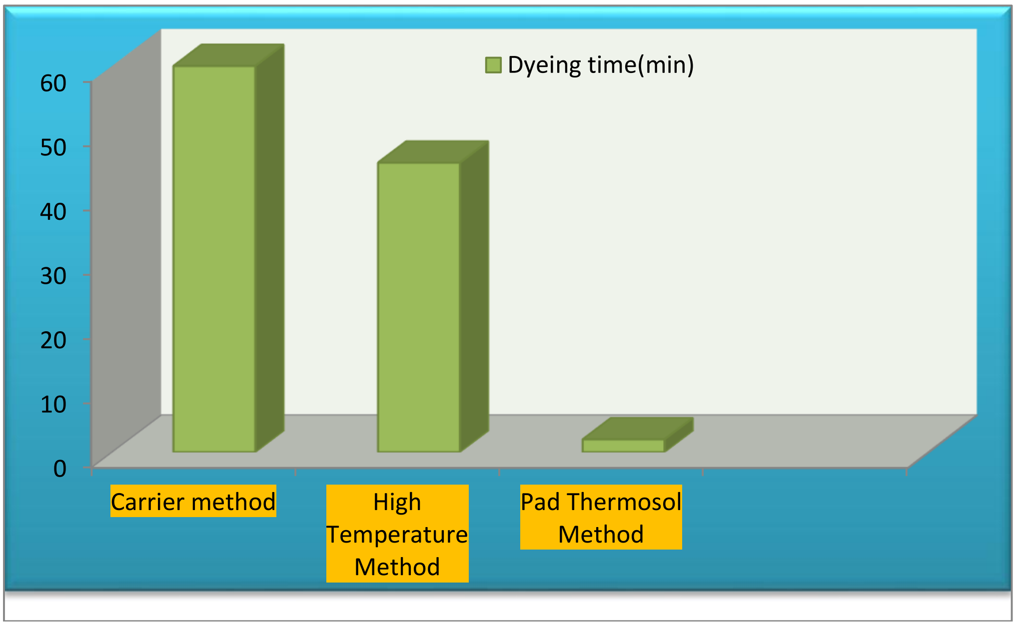
Dyes , Chemical & Auxiliaries Cost:



Dyeing Cost:



Dyeing Time:



CHAPTER-05

CONCLUSION

From this comparative study among different dyeing methods of polyester dyeing with disperse dyes we can submit that-

1. **Color fastness to Washing on HTHP method is more than the others.**
2. **Color fastness to rubbing on HTHP method is more than the others.**
3. **Thermosol method requires very few time for dyeing.**
4. **Color fastness to perspiration on HTHP method is more than the others.**
5. **An odor problem occurs in case of Carrier dyeing.**
6. **Pilling tests results are satisfactory on all methods.**
7. **In case of cost comparison HTHP method is less expensive than others**

Considering all condition, High Temperature High Pressure method is the most effective for industrial production. Because in carrier method, carrier is costly, toxic & it may produce odor problem, removal of carrier with alkali is also costly .In pad thermosol method, it requires special machine arrangement & in this case shade may change due to sublimation at high temperature.

But in High Temperature High Pressure method, no carrier & thicker is used. So it is comparatively cheap process. No special machine is required i.e same machinery can be used after dyeing with another dyes in bulk production.

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