Faculty of Engineering

Department of Textile Engineering

Thesis on

Studies on the Effect of Reduction Cleaning on Disperse Dyed Polyester Fabric.

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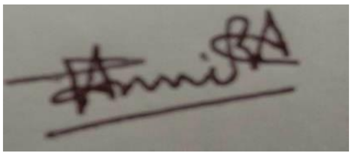
Letter of Approval

Nadim Khan Shanto (ID: 191-23-625) and Md. Abdullah (191-23-655) have prepared this thesis report as a partial fulfilment of the requirements for their B.Sc. degree in Textile Engineering. As their supervisor, I can attest to their sincerity, hard work, and enthusiasm during the research period.



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Dedication

I would like to dedicate my work to my beloved parents.

Abstract

Polyester is a commonly used synthetic fiber in the textile industry due to its excellent properties such as high strength, durability, and low moisture absorption. However, the quality of dyed polyester can be compromised due to various factors, including residual impurities and unreacted dyes. Reduction cleaning is a common method used to remove these impurities and improve the quality of dyed polyester. This research investigates the effect of reduction cleaning on the color fastness and rubbing fastness of dyed polyester.

The study involved the reduction cleaning of dyed polyester fabric using various reducing agents such as sodium hydrosulfite and sodium borohydride. The effectiveness of reduction cleaning was evaluated based on the change in color fastness and rubbing fastness of the fabric. The results indicate that reduction cleaning can significantly improve the color fastness and rubbing fastness of dyed polyester fabric.

The color fastness test results show that the reduction cleaning process improved the colorfastness to washing, light, and perspiration. The rubbing fastness test results demonstrate that reduction cleaning significantly improved the resistance of the dyed polyester fabric to rubbing and friction. However, it is worth noting that there was a slight reduction in the tensile strength of the fabric after reduction cleaning.

In conclusion, reduction cleaning is an effective method for improving the color fastness and rubbing fastness of dyed polyester fabric. The findings of this study can be useful for textile industries and researchers in improving the quality of dyed polyester fabrics. Further research is recommended to optimize the reduction cleaning process and minimize the negative impact on tensile strength.

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Chapter One: Introduction

1.1 General Discussion:

Reduction cleaning is a process commonly used in the textile industry to improve the color fastness and rubbing fastness of dyed polyester fabrics, which includes fabrics dyed with disperse dyes. Disperse dyes are commonly used to dye polyester and other synthetic fibers, but they can be difficult to fix to the fiber and can cause issues with color fastness. Reduction cleaning can help to remove any residual unreacted dyes and impurities from the fabric, improving the overall color fastness of the fabric. Therefore, reduction cleaning is an important process to consider when working with disperse dyes and polyester fabrics in order to ensure high-quality and long-lasting textile products.

1.2 Objectives of the Thesis:

- To evaluate the impact of reduction cleaning on the quality and performance of dyed polyester fabrics.
- To investigate the effect of reduction cleaning on the color fastness and rubbing fastness of dyed polyester fabrics.
- To determine the optimal conditions for the reduction cleaning process in terms of temperature, time, and concentration of reducing agents.
- To provide practical recommendations for the textile industry on the use of reduction cleaning to improve the quality and performance of dyed polyester fabrics.

Chapter Two: Literature Review

2.1 Review of Recent Research Work:

Recent research has shown that reduction cleaning is an effective method for improving the color fastness and rubbing fastness of dyed polyester fabrics. A study by Zhang et al. (2020) found that reduction cleaning with sodium hydrosulfite can significantly improve the color fastness and rubbing fastness of disperse-dyed polyester fabrics. Similarly, another study by Liu et al. (2019) reported that reduction cleaning can improve the color fastness of polyester fabrics dyed with acid dyes.

However, some studies have reported a slight reduction in the tensile strength of polyester fabrics after reduction cleaning. For example, a study by Zhang et al. (2019) found that reduction cleaning can reduce the tensile strength of polyester fabrics due to the removal of impurities and dye molecules. Therefore, it is important to optimize the reduction cleaning process to minimize any negative impact on the fabric's properties.

Overall, recent research supports the use of reduction cleaning as a method for improving the quality and performance of dyed polyester fabrics. However, further research is needed to optimize the process and investigate its impact on other properties of dyed polyester, such as shrinkage and crease recovery.

2.2 Polyester:

Polyester is considered as the most popular and versatile amongst all textile fibres. It was discovered in 1941 by JR Whinfield and JT Dickson in the United Kingdom. But the commercial production of the Polyester was started in 1953. Amongst different kinds of polyester, polyethylene terephthalate (PET) is the most common and widely used type due to its economic production, ease in physical and chemical modification and excellent end-use properties. According to a survey, the global production of polyester fibre in 2018 was 56M tons. China is the largest exporter of polyester holding around 70% of the global market share.

The word Polyester can be split into Poly, meaning many and Ester, meaning a basic organic chemical compound. According to ISO, Polyester can be defined as a fibre composed of linear macromolecules having in the chain at least 85% by mass of an ester of a diol and terephthalic acid.

According to FTC, Polyester can be defined as a manufactured fibre in which the fibre forming substance is any long chain synthetic polymer composed of at least 85% by weight of an ester of a substituted aromatic carboxylic acid including but not restricted to substituted terephthalate units and para substituted hydroxy benzoate units.

Fig. 2.1 Polyester

2.3 Classification of Polyester:

Polyester can be classified as follow,

- Based on Monomer Used:
    - PBT (Poly butylene terephthalate).
    - PCT (Poly cyclohexylene dimethylene terephthalate).
    - PET (Poly ethylene terephthalate).
    - PTT (Poly trimethylene terephthalate).

- Based on Chemical Modification:
    - Anionic Dyeable Polyester.
    - Cationic Dyeable Polyester.
    - Carrier-free Dyeable Polyester.
    - Flame Retardant Polyester.
    - Hydrophilic Polyester.

2.4 Properties of Polyester:

Polyester fibre possesses different kinds of properties. Such as,

Types of Properties	Properties
General Properties	• Abrasion Resistant. • Chemical (most) Resistant. • Mildew Resistant. • Shrinkage Resistant. • Stretch Resistant. • Wrinkle Resistant. • Easily Washable. • Quick Drying. • Crisp, Resilient and Strong. • Retention to pleats and crease.
Physical Properties	• Length: Variable cut length. • Fineness: 1.2, 1.5, 2.0 D. • Density (1.39 g/cc). • Moisture Regain (0.4%). • Color: White. • Flame: Melt, Shrink, Black Fume. • Melting Point (250-288℃)

Chemical Properties	• Resistance to dilute acid and alkali but gets damaged badly by their higher concentration. • Resistance to bleaches, organic solvents and surfactants. • Hydrophobic, water repellent and dried rapidly. • Higher tendency of static electricity formation. • Turns yellow along with 70-80% loss in tenacity when exposed to sunlight.
Optical Properties	• Excellent hand feel. • Lustrous like silk.
Thermal Properties	• Glass transition temperature (75°C). • Crystallization temperature (130°C). • Melting temperature (260°C).
Dyeing Properties	• Highly crystalline and dense in structure, dyed at higher temperature. • Polyester can be dyed at lower temperature (40°C or below) which will cause environmental problem.
Tensile Properties	• Similar tensile properties in both dry and wet condition. • Tenacity range 2-7 gpd (Up to 85 cN/Tex). • Tenacity varies due to the variation in draw ratio and annealer temperature. • Elongation (15-45%).
Other Properties	• Good resistance to sunlight. • Good oxidative and thermal resistance.

2.5 Production of Polyester:

Till 1976, polyester was produced commercially by the step growth polymerization of dimethyl terephthalate and ethylene glycol. After that, terephthalic acid became a dominant feedstock as very pure one was made available.

Advantage of TPA over DMT:

- Higher Productivity (15% more).
- Lower Cost (20% less).
- Less Hazard.
- Improved Polymer Quality.

Introduction of continuous polymerization along with direct spinning reduced the polyester production cost dramatically. Polyester is now produced industrially by the condensation polymerization of the monomer ethylene glycol and terephthalic acid.

However, the production of Polyester via batch polymerization can be illustrated through two steps:

- <u>Esterification:</u> Esterification can be happened in two ways. Such as,
    - <u>Transesterification:</u> In this process, DMT is first dissolved in hot EG. A reaction is happened at 180-210℃ in normal pressure for 3-6 hours in addition to the catalyst (Cd, Pb, Sb, Zn Acetate) and delustrant which distils off methanol.

    - <u>Direct Esterification:</u> In this process, DMT is first dissolved in hot EG. A reaction is happened at 240-260℃ in 1.5-2 barometric pressure using phosphate as stabilizer in addition to less amount of catalyst which distils off water.

- <u>Polycondensation:</u> In polycondensation stage, the presence of air causes thermos-oxidative degradation resulting lower quality polymer. Therefore, a reaction is happened under vacuum (0.13kPa) at 270-280℃ for 2-6 hours. The discharged EG is recovered by a column and recycled thereafter.

<u>Side Reactions:</u> During the production of Polyester following batch polymerization, some side reaction are also happened. Such as:

- Cyclic Oligomer Formation: As the ester interchange reaction happens, cyclic oligomers are also formed as biproduct.
- DEG Formation: During the initial phase of polycondensation, etherification of MEG produces DEG. As the DEG content increases, heat and light resistance get reduced along with the decrease in melting and glass transition temperature.

The production of Polyester via continuous polymerization can be illustrated through following steps:

- Paste Preparation: Initially, TPA is mixed with EG along with the catalyst in a mixer in order to produce paste which is furthermore fed to the esterification reactors.

- Esterification: In general, esterification takes place at 200℃ temperatures under atmospheric pressure. The process split off water which is eliminated thereafter along with excessive EG.

- Pre-Polycondensation: As the esterification is done, the product found is then feed to the pre-polycondensation system under vacuum increasing temperature up to 250-285℃ along with the reduction of pressure to 10mm Hg resulting the formation of polymer having lower molar mass (M_n = 4000-7000).

- Polycondensation: After the pre-polycondensation has done, polycondensation is happened under vacuum at 280-290℃ for 2-6 hours maintaining a pressure of 1.5mm Hg using phosphorus additives as stabilizer along with antimony or titanium compounds as catalyst resulting the formation of polymer having comparatively higher molecular mass (M_n = 17000-40000).

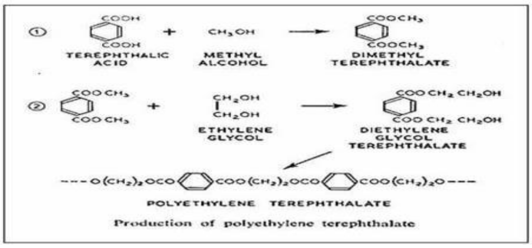


Fig. 2.2 Polyester Production

2.6 Recycling of Polyester:

The production and end uses of plastic is increasing dramatically day by day. It's been reported that the global plastic waste will be almost triple by 2060. Therefore, the recycling of polymer has been a matter of concern. Plastic can be recycled by different means e.g. Biologically, Chemically, Mechanically etc. Amongst all recyclable polymers, PET is mostly recycled terming it as rPET. We generally use billions of plastic bottles every year which can be recycled and spun into billions of yards of rPET. Production of rPET requires 90% less water, 85% less energy and produces 65% less greenhouse gas, 75% less carbon footprint as compared to that of virgin PET.

2.7 Applications of Polyester:

As polyester is the most versatile amongst all man-made fibre with a lot of special characteristics, they are widely used in the following areas,

- Apparel Sector: Polyester is used as almost every form of clothing. Such as, overcoats, jackets, leisure and sportswear, protective clothing and so on.
- Home Furnishing: In home furnishing, polyester is used as carpets, curtains, draperies, furniture covering, floor covering, pillows and pillow stuffing, upholstery, wall covering etc.
- Other Application: Polyester is used to make bottles, cones, dielectric film for capacitors, films, filters, floppy disk liners, holograms, Hoses, liquid crystal displays, musical instruments, power belting, ropes and nets, sails, tarpaulin, tire chords etc.

2.8 Disperse Dye:

Disperse dye can be defined as an organic color producing substance free from ionizing group with lower water solubility. The dye is called so due to its non-solubility, non-ionicity, molecularly dispersed characteristics along with the use of dispersing agent while dyeing.

Disperse dye is an excellent choice for dyeing hydrophobic textile material, specially, man-made fibre e.g., polyester, polyamide, acetate etc.

2.9 Classification of Disperse Dye:

- Based on Color Fastness:
  - Type A: Excellent dyeing and good fastness properties.
  - Type B: Excellent dyeing and moderate fastness properties.
  - Type C: Moderate dyeing and excellent fastness properties.
  - Type D: Excellent fastness properties, moderate dyeing properties.

- Based on Energy Requirement:
  - Lower Energy Dye: Dyeing is done at 77℃, shows poor sublimation fastness.
  - Medium Energy Dye: Dyeing is done at 104-110℃, shows moderate sublimation fastness.
  - Higher Energy Dye: Dyeing is done at 129℃, shows excellent fastness properties.

2.10 Properties of Disperse Dye:

Dispersed dye possesses the following characteristics:

- Ionic Nature: Disperse dye is a non-ionic dye.
- Solubility: Disperse dye is water insoluble.
- Origin: Disperse dye is ready made organic coloring substance.
- Suitability: Disperse dye is suitable for hydrophobic fibres e.g., polyester, polyamide, nylon, acetate, acrylic etc.
- Color Fastness:
    - Light: 4-5.
    - Wash: 3-4.

2.11 Different Brands of Disperse Dye:

SL	Brand Name	Company	Origin
01	Dispersol	ICI	UK
02	Foron	Sandoz	Switzerland
03	Palanil	BASF	Germany
04	Resonil	Bayer	Germany
05	Samaron	Herchst	Germany
06	Terasil	Cibageigy	Switzerland

2.12 Dyeing Mechanism:

Disperse dye is generally used to dye hydrophobic man-made fiber e.g. polyester. Initially, all dyeing auxiliaries along with dispersing agent is added to the dyebath. The dye as well as the fabric is taken in the dyebath maintaining a temperature of 60°C. The temperature is then raised to 130°C. At higher temperature, the fiber gets swelled. The dye molecules can easily penetrate to the fiber. The temperature is further reduced to 60°C. The fiber gets deswelled making the dye entrapped inside the fiber.

2.13 Factors affecting Dyeing Qualities:

The dyeing quality of Polyester fiber with disperse dye is generally affected by the following factors,

- P^H: The p^H should be between 4.5-5.5. Proper p^H provides stable color as well as excellent color fastness properties.

- Temperature: A temperature more than 100℃ should be maintained in case of high temperature dyeing. The career dyeing method demands 85-90℃ of temperature. Retaining this temperature for longer time may cause dye sublimation and loss in fabric strength.

2.14 Application methods of Disperse Dye:

Disperse dye can be applied to the fiber in different ways. Such as,

- Normal Dyeing Method: In this method, dyeing temperature generally lies between 80-100℃.
- Normal Dyeing with Career: In this method, , dyeing temperature also lies between 80-100℃. But career is used here for the swelling of the fibers.
- High Temperature Method: In this method, dyeing temperature generally lies between 105-140℃.
- Thermosol Dyeing Method: It’s a continuous method of dyeing which is carried out at between 180-220℃.
- Pad Roll Method: This is a semi continuous dyeing method carried out with disperse dye.
- Pad Steam Method: Pad steam method is a continuous method of dyeing.

2.15 Factors considered for the selection of a Dyeing Method:

While selecting a dyeing method for polyester fiber with disperse dye, following factors are considered,

- The type of available dyeing machine.
- Type of color effect (light, medium, dark) required.
- The type of color fastness required.
- The nature of the textile material to be dyed.
- Temperature of dyeing.
- Expenditure for dye, chemical and dyeing auxiliary.
- Overall economic condition of the organization.

2.16 Dyeing Method with Disperse Dye:

Polyester fiber is generally dyed with disperse dye. Amongst different dyeing methods, high temperature method of polyester dyeing is the most popular one. The process is carried out in accordance with the following procedure,

- Cold water is used to make dye solution, which is then allowed to sit for 15 minutes.
- Dispersing agent and salt are added to a dye bath that has been heated to 60°C.
- Without increasing temperature, the material is handled for 15 minutes.
- After adding the dye solution, CH3COOH is used to regulate the pH.
- In 30 minutes, the dye bath's temperature is increased to 130°C.
- One hour of dyeing is conducted at 130°C.
- As soon as is practical, the dye bath is cooled.
- The fabric may be rinsed in hot water.
- If necessary, reduction was cleared.
- The fabric is once more cleaned before being dried.

Dyeing Recipe:

Dye: x% on the weight of the fabric.

Dispersing Agent: 0.5-1%

Salt: 0.5-1%

Acetic Acid: 0.75-1 g/L

P^H: 4.5-5.5

M:L- 1:8

Temperature: 130°C.

Time: 1 hour

Polyester is sometimes dyed in thermosol method as well. This method is carried out in accordance with the following procedure,

- Using the right recipe, the dye solution is padded onto the fabric.
- Depending on the dryer being used, the fabric gets dried at 100°C.
- Solid shade can't be obtained if the dryer temperature is too high.
- Depending on the type of fabric fiber, color, and shade depth, dyes are fixed at 203°C for 60 to 90 seconds.
- The unfixed chemicals and dyes are removed using warm water.
- Washing with soap or clearing with reduction, as necessary.
- The fabric is finally washed and dried.

Dyeing Recipe:

Dye: x% on the weight of the fabric.

Wetting Agent: 1-2 g/L

Thickener: 20-40 g/L

Acetic Acid: 1-1.5 g/L

P^H: 4.5-5

Time: 2 hours

2.17 Reduction Clearing:

The process reduction clearing can be defined as an after treated carried out after the dyeing of polyester fiber with disperse dye. The simple purpose of the process is to remove the deposits of dye and other residual impurities from the surface of the dyed polyester.

In case of dark shade dyeing, a greater number of dyes and chemicals are used which should be removed from the fabric surface after dyeing. Therefore, a special process named reduction clearing is carried out. In this process, surface dye molecules or unfix dye molecules are stripped causing level dyeing.

Generally, clearing agents of different kinds e.g. Chloroform, Xylene, Toluene, Paraffin, Methyl Benzoate, Methyl Salicylate etc. are used in the dyeing process of Polyester with disperse dye. Amongst all these, Xylene is the most commonly used reduction clearing agent.

Reduction clearing improves the colorfastness properties of the dyed Polyester.

Recipe for Reduction Clearing:

Detergent: 1 g/L

Sodium Hydrosulphite: 2 g/L

Caustic Soda: 1-2 g/L

Temperature: 70-80°C.

Time: 20-30 minutes.

Chapter Three: Materials & Methods

3.1 Materials:

Name of the Sample: 100% Polyester. Type of the Fabric: Knit. Count: 50D GSM: 87 Weight of the Fabric: 10 gm

3.2 Dyeing Recipe:

Type of Shades	Name of the Dye	Shade (%)
Light	Disperse Dye (Blue)	0.33%
Medium	Disperse Dye (Blue)	0.88%
Dark	Disperse Dye (Blue)	1.20%

3.3 Different Physical Test(s):

Test Name: Determination of CMC values of the samples.

Equipment: Spectrophotometer, Data color, Fabric.

Working Procedure:

- At first take 6 different samples having light, medium and dark shades.
- Half of them should be taken just after dyeing and the rests are after the reduction cleaning has done.
- Take the light reduction cleaned sample to be considered as standard and compare it with the light non-reduction cleaned batch.
- Find the DL*, Da*, Db*, DC*, DH* values using spectrophotometer.
- Perform similar action for the medium and dark sample too.
- The data color will show if our experiment has passed or not.

Fig. 3.1 Spectrophotometer

Test Name: Color fastness to Rubbi

Test Method: ISO 105 X12.

Equipment: Fabric, Rubbing Cloth, Crockmeter, Grayscale.

Working Procedure:

- At first take twenty samples in total of 25*6 cm square.
- Half of the samples should be from warp direction and the rest are from weft direction.
- Take two scoured, bleached, undyed and unfinished rubbing cloths among which one should be kept dry and another should be 100% (ISO) or 65% (AATCC) absorbent.
- Place the sample in the crockmeter, attach dry rubbing cloth, load 9 N of loading.
- Rub 10 cycles in 10 seconds.
- Perform the similar action for wet rubbing cloth as well.
- Evaluate color change using grey scale.

Fig. 3.2 Crockmeter

Test Name: Color fastness to Wash.

Test Method: ISO 105 C06 B2S.

Equipment: Fabric, Multifibre.

Chemicals:

- Sodium Perborate (1gpl), ECE Phosphate Detergent (4gpl), Sodium Carbonate (1gpl), Distilled Water (1L).

Working Procedure:

- At first take a sample of 10*4 cm square along with a multifibre of same dimension.
- Produce a solution using the chemicals mentioned above.
- Take 150 ml of solution along with 25 (60) or 10 (40) steel balls in a pot.
- Place the pot on the machine, run it for 30 minutes at 40 degree celcius.
- Cold wash the sample.
- Evaluate the color change and stain using grey scale.

Fig. 3.3 CF to Wash

Test Name: Color fastness to Water.

Test Method: ISO 105 E01.

Equipment: Fabric, Multifibre, Perspirometer.

Working Procedure:

- At first take a sample of 10*4 cm square along with a multifibre of same dimension.
- Impregnate it on the water for 30 minutes.
- Take the sample in perspirometer loading a weight of 12.5 kP.
- Keep that arrangement in the oven at 37 degree celsius for 4 hours.
- Dry the sample at 50-60 degree celsius.
- Evaluate the color change and stain using grey scale.

Fig. 3.4 CF to Water

Test Name: Color fastness to Perspiration.

Test Method: ISO 105 E04.

Equipment: Fabric, Multifibre, Perspirometer.

Chemicals:

- For Acid Test: L-Histidine Mono Hydrochloride Mono Hydrate (0.5gpl), Sodium Chloride (5gpl), Sodium dihydrogen ortho phosphate dihydrate (2.2gpl), Distilled water (1L).
- For Alkali Test: L-Histidine Mono Hydrochloride Mono Hydrate (0.5gpl), Sodium Chloride (5gpl), Di Sodium Hydrogen ortho Phosphate dihydrate (2.5gpl), Distilled water (1L).

Working Procedure:

- At first take a sample of 10*4 cm square along with a multifibre of same dimension.
- Produce acidic/alkaline solution using the chemicals mentioned above.
- Adjust the p^H within 5.5 and 8 for acid and alkali test, keep M:L in 1:50.
- Impregnate the sample along with the multifibre on the solution for 30 minutes.
- Take the sample in perspirometer loading a weight of 12.5 kP.
- Keep that arrangement in the oven at 37 degree celsius for 4 hours.
- Dry the sample at 50-60 degree celsius.
- Evaluate the color change and stain using grey scale.

Chapter Four: Result & Discussion

4.0 Comparison

4.1 Comparison between CMC values:

Sample		Light Sources														
Standard	Batch	D65					TL83					TL84				
		DL*	Da*	Db*	DC*	DH*	DL*	Da*	Db*	DC*	DH*	DL*	Da*	Db*	DC*	DH*
RC_L	NRC_L	2.22	0.39	1.13	-1.18	0.19	2.39	0.59	1.44	-1.53	0.28	2.33	0.40	1.33	-1.37	0.19
RC_M	NRC_M	-2.06	-0.05	1.15	-1.14	-0.15	-1.93	0.09	1.43	-1.42	-0.14	-1.97	-0.02	1.33	-1.32	-0.14
RC_D	NRC_D	-0.91	-0.18	0.63	-0.63	-0.20	-0.81	-0.11	0.90	-0.88	-0.21	-0.86	-0.13	0.76	-0.75	-0.16

In this thesis, six different samples of Polyester having 0.33% (Light), 0.88% (Medium), 1.2% (Dark) shades respectively were taken. Three of them were just after the completion of dyeing process considered as batch and the rests were after the reduction cleaning had done considered as standard.

In case of light sample, the values of DL*, Da*, Db*, DC*, DH* under D65 were found to be 2.22, 0.39, 1.13, -1.18, 0.19 respectively which were 2.39, 0.59, 1.44, -1.53, 0.28 respectively under TL83 and 2.33, 0.40, 1.33, -1.37, 0.19 respectively under TL84.

In case of medium sample, the values of DL*, Da*, Db*, DC*, DH* under D65 were found to be -2.06, -0.05, 1.15, -1.14, -0.15 respectively which were -1.93, 0.09, 1.43, -1.42, -0.14 respectively under TL83 and -1.97, -0.02, 1.33, -1.32, -0.14 respectively under TL84.

In case of dark sample, the values of DL*, Da*, Db*, DC*, DH* under D65 were found to be -0.91, -0.18, 0.63, -0.63, -0.20 respectively which were -0.81, -0.11, 0.90, -0.88, -0.21 respectively under TL83 and -0.86, -0.13, 0.76, -0.75, -0.16 respectively under TL84.

4.2 Comparison between CF to Rubbing:

Sample	CF to Rubbing Before RC		CF to Rubbing After RC		Changes		Changes (%)		Average (%)	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Light	5	4	5	4	0	0	0%	0%	8.33%	11.11%
Medium	5	4	5	4	0	0	0%	0%		
Dark	4	3	5	4	1	1	25%	33.33%		

In this thesis, colorfastness to rubbing test were performed taking twelve different samples of Polyester having 0.33% (Light), 0.88% (Medium), 1.2% (Dark) shades respectively. Six experiments, in total, were performed in dry condition among which three were just after the completion dyeing process and the rest were after the reduction cleaning process had done. Here in case of light and medium samples, colourfastness to rubbing before and after reduction cleaning were found same, therefore, no change (%) happened. On the other hand, the colourfastness values before and after reduction cleaning were found 4 and 5 for dark samples. A 25% change were noticed which was 8.33% in average for all six samples in the acidic condition.

Another six experiments, in total, were performed in wet condition among which three were just after the completion dyeing process and the rest were after the reduction cleaning process had done. Here in case of light and medium samples, colourfastness to rubbing before and after reduction cleaning were also found same, therefore, no change (%) happened. On the other hand, the colourfastness values before and after reduction cleaning were also found 3 and 4 for dark samples. A 33.33% change were noticed which was 11.11% in average for all six samples in the wet condition.

4.3 Comparison between CF to Wash:

Sample	CF to Wash Before RC	CF to Wash After RC	Changes	Changes (%)	Average (%)
Light	4	5	1	25%	27.78%
Medium	4	5	1	25%	
Dark	3	4	1	33.33%	

While performing colorfastness to wash test, six different samples of Polyester having 0.33% (Light), 0.88% (Medium), 1.2% (Dark) shades respectively were taken. Six experiments, in total, were performed among which three were just after the completion dyeing process and the rest were after the reduction cleaning process had done. In case of light sample, colourfastness to wash before and after reduction cleaning were found 4 and 5 respectively. Similarly, the colourfastness values were found 4 and 5 for medium and 3 and 4 for dark sample. Both the light and medium samples showed 25% changes as a consequences of reduction cleaning. But the significant change (about 33%) were observed for the dark sample. However, an average of 27.78% improvement in colorfastness to wash were noted on account of reduction cleaning.

4.4 Comparison between CF to Water:

Sample	CF to Water Before RC	CF to Water After RC	Changes	Changes (%)	Average (%)
Light	5	5	0	0%	16.67%
Medium	4	5	1	25%	
Dark	4	5	1	25%	

While performing colorfastness to water test, six different samples of Polyester having 0.33% (Light), 0.88% (Medium), 1.2% (Dark) shades respectively were taken. Six experiments, in total, were performed among which three were just after the completion dyeing process and the rest were after the reduction cleaning process had done. In case of light samples, colourfastness to water before and after reduction cleaning were found same, therefore, no change (%) happened. On the other hand, the colourfastness values before and after reduction cleaning were found 4 and 5 for both medium and dark samples. Both samples showed 25% changes as a consequences of reduction cleaning. However, an average of 16.67% improvement in colorfastness to water were noted on account of reduction cleaning.

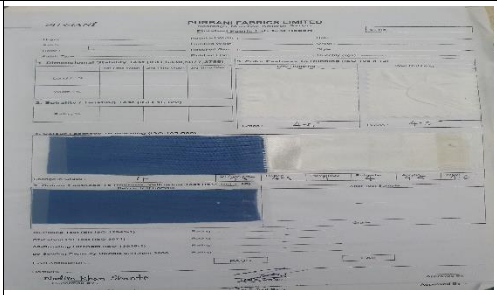
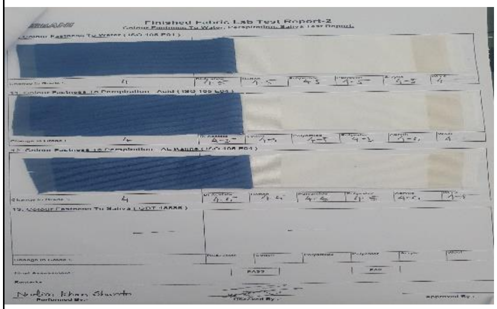
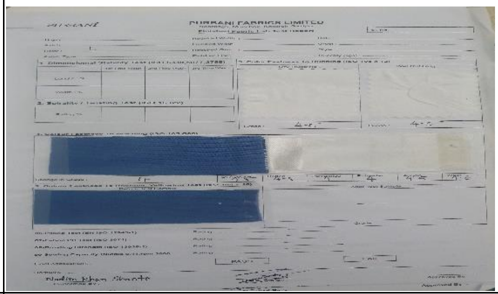
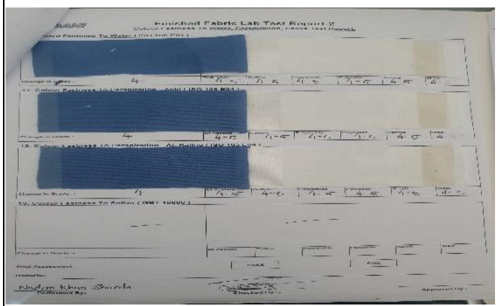
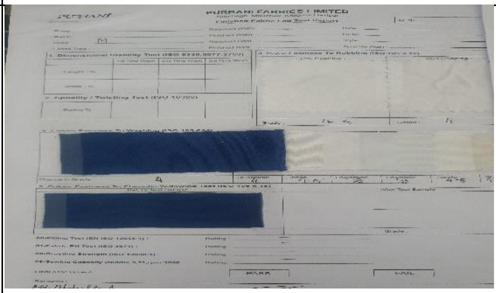
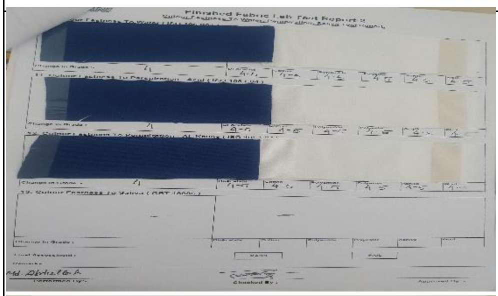
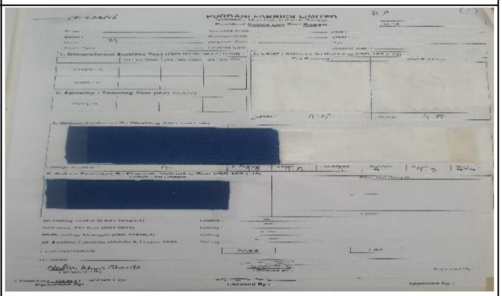
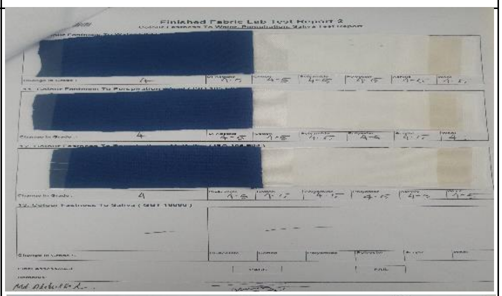
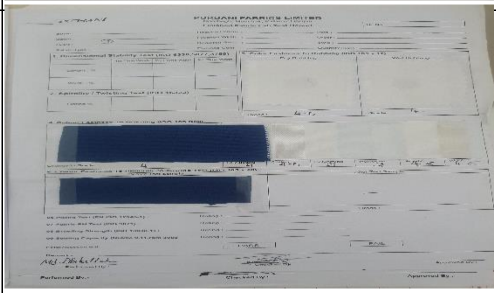
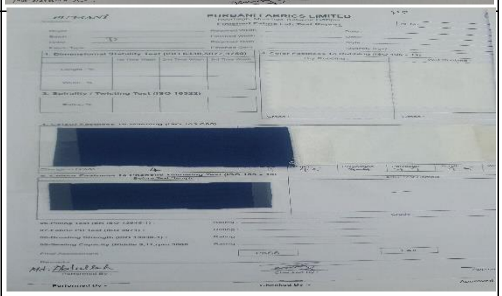
4.5 Comparison between CF to Perspiration:

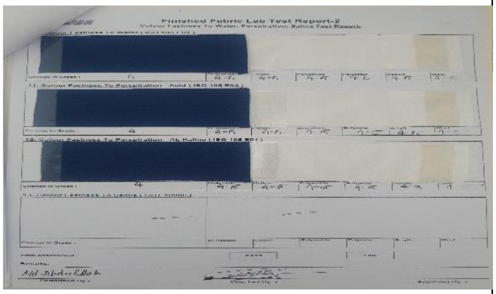
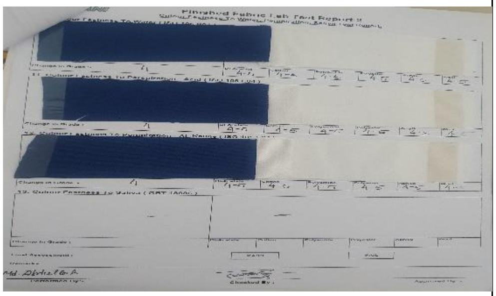
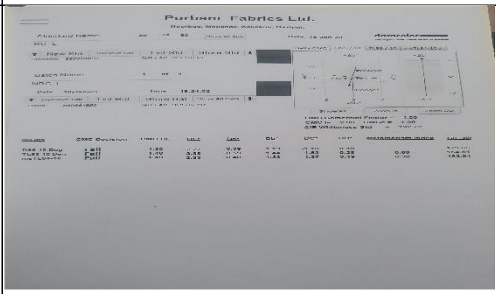
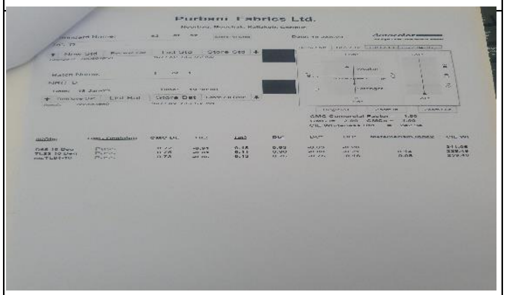
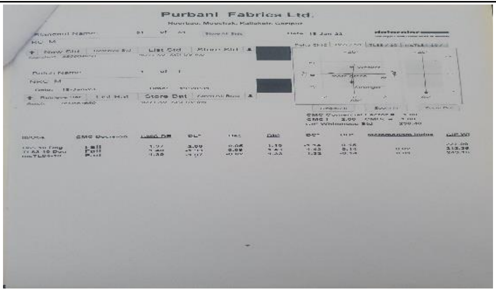
Sample	**CF to Perspiration Before RC**		**CF to Perspiration After RC**		**Changes**		**Changes (%)**		**Average (%)**	
	Acid	Alkali	Acid	Alkali	Acid	Alkali	Acid	Alkali	Acid	Alkali
Light	4	4	4	4	0	0	0%	0%	8.33%	8.33%
Medium	4	4	4	4	0	0	0%	0%		
Dark	4	4	5	5	1	1	25%	25%		

In this thesis, colorfastness to perspiration test were performed taking twelve different samples of Polyester having 0.33% (Light), 0.88% (Medium), 1.2% (Dark) shades respectively. Six experiments, in total, were performed in acidic medium among which three were just after the completion dyeing process and the rest were after the reduction cleaning process had done. Here in case of light and medium samples, colourfastness to perspiration before and after reduction cleaning were found same, therefore, no change (%) happened. On the other hand, the colourfastness values before and after reduction cleaning were found 4 and 5 for dark samples. A 25% change were noticed which was 8.33% in average for all six samples in the acidic condition.

Another six experiments, in total, were performed in alkaline medium among which three were just after the completion dyeing process and the rest were after the reduction cleaning process had done. Here in case of light and medium samples, colourfastness to perspiration before and after reduction cleaning were also found same, therefore, no change (%) happened. On the other hand, the colourfastness values before and after reduction cleaning were also found 4 and 5 for dark samples. A 25% change were noticed which was 8.33% in average for all six samples in the alkaline condition.

Samples:

Samples Name	Samples	
	Before Reduction Cleaning	After Reduction Cleaning
Light	 	 
Medium	 	 
Dark		

		
CMC Values	 	

Chapter Five: Conclusion

5.1 Conclusion

The study finds that reduction cleaning can significantly improve the color fastness and rubbing fastness of dyed polyester fabric specially for darker shade. This is due to the removal of residual impurities and unreacted dyes that cause fading and discoloration over time.

The results suggest that reduction cleaning is an effective method for improving the quality and performance of polyester fabrics. The improved color fastness and rubbing fastness can lead to better performance and longer lifespan of polyester garments and textiles. However, further research is needed to optimize the reduction cleaning process and investigate its impact on other properties of dyed polyester. Apart from this, the reduction cleaning process can slightly reduce the tensile strength of the woven fabric. The researchers can also emphasise on this side for further improvement.

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