

Review Article

A Comprehensive Review: Printing Auxiliaries and Applications in Textile Pigment Printing

Asaye Dessie Wolela* 

Department of Textile Engineering, Wollo University, Kombolcha, Ethiopia

Abstract

Pigment printing is the most popular method of printing all over the world. More than 80% of the printed goods are based on pigment printing. In principle, all types of fibers can be printed in pigment printing. Printing paste is the main constituent of printing which enables the formation of the predefined patterns. The printing paste for pigment printing generally contains pigments, emulsifiers, binders, softeners, thickeners, antifoaming agents, and crosslinking agents. The use of different auxiliaries depends upon various parameters such as style of printing, substrate to be printed, and dyes used for printing etc. Therefore it is necessary to give individual consideration to each of the printing paste constituents. Accordingly, an insight into the printing auxiliaries and their role in pigment printing was made in this paper. Besides, process of pigment printing, composition of printing paste, mechanism of printing, characteristics of pigment printing, and features of printing auxiliaries were discussed briefly. Furthermore, advantages and disadvantages of pigment printing were discussed in this paper. Textile auxiliaries play a vital role in the final outcome of a good quality printed product.

Keywords

Pigment Printing, Printing Auxiliaries, Printing Paste, Application, Textile Substrates

1. Introduction

Textile printing is the most versatile and important of the methods used for introducing color and design to textile fabrics. Considered analytically it is a process of bringing together a design idea, one or more colorants, and a textile substrate (usually a fabric), using a technique for applying the colorants with some precision. Several techniques have been used and the colorants available have multiplied [1-3].

The main objective in textile printing is the production of attractive designs with well-defined boundaries made by the artistic arrangement of motif (design) in one or more colors. In other words, dyes and pigments are applied locally or discontinuously to produce the various designs. In fact,

printing is described as localized dyeing. The force, which operates between the dye and the fiber, is the same in dyeing and printing [4, 5].

Textile printing is the branch of the textile wet processing industry and is becoming increasingly popular for all fibers and varieties of fabrics as well as garments. Basically, printing is a form of dyeing in which the colors are applied to specified areas instead of the entire fabric. The resulting multicolored patterns have attractive and artistic effects which enhance the value of the fabrics much more than the plain dyed ones [5, 6].

Printing is localized dyeing. Printing is the most important

*Corresponding author: ase25dessie@gmail.com (Asaye Dessie Wolela)

Received: 8 August 2025; **Accepted:** 21 August 2025; **Published:** 30 September 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

of all the processes used at present to decorate textile materials. The main idea of printing is the deliberate and controlled application of dye to exactly defined locations on the fabric leaving the rest of the fabric essentially unaffected [7].

Textile printing can be envisaged as a technique of localized dyeing, wherein the colouring matter is applied only on to restricted areas. The film of thickened print paste can be visualized as an extremely short bath from which the dye-stuff is transferred to the surface of fibre from where it diffuses to the interior of the fibre under the influence of thermal energy supplied during fixation [8].

In principle, all types of fibers can be printed in pigment printing. The advantage of pigment printing is that the goods only have to be dried and the binder system cross-linked. There is no need to post-wash. In addition to conventional pigments, this process can also be used to apply neon, luster or glitter pigments as well as 3-D effect prints.

In pigment printing, insoluble pigments, which have no affinity for fibers, are fixed on to the fibers with binding agents or binders [2, 9, 10]. In textile printing, dyes or pigment are transferred to textile fabric by printing pastes. The rheological properties of pastes are principally determined by thickeners. Success of a printing process is established by the sharpness of mark, levelness, correct color, good hand and high fastness. Three factors are responsible for the flow properties of print pastes: viscosity, fluidity and viscoelasticity [1-3, 11, 12].

In pigment printing of textiles, fabrics are colored by adhering small inert colored particles called pigments to the surface of the fabrics by binders. Good binders must be colorless, odorless compounds that are easily and smoothly dispersed in print pastes without adversely affecting the viscosity and are easily removed from printing equipment, such as screens and rollers [13, 14].

Pigment printing is not only the oldest but also the easiest printing method as far as simplicity of application is concerned [10, 15-21]. More than 80% of the printed goods are based on pigment printing due to its obvious advantages, such as versatility; ease of near final print at the printing stage itself, applicable to almost every kind of fiber or mixture, and the ability to avoid any washing processes after fixation [10, 17-26].

Printing paste is the main constituent of printing which enables the formation of the predefined patterns. The printing paste for pigment printing generally contains pigments, emulsifiers, binders, softeners, thickeners, antifoaming agents, and crosslinking agents [10, 22, 27]. It is therefore necessary to give individual consideration to each of the printing paste constituents. All the above constituents are not used simultaneously in any pigment printing paste depending on the class of pigment used and style of printing employed, suitable component are selected in making in printing paste [14, 28-33].

Printing auxiliaries use the film forming effect of adhesive which attach insoluble dyes to fabric firmly to color the fabric. Printing auxiliaries includes textile chemical thickener,

binding agent, crosslinking agent, emulsifier, fixing agent, dispersing agent, silicone softener, defoamers and so on [34].

The most widely used technique for printing textiles is pigment printing. Aqueous formulation for pigments print pastes typically consist of pigment(s), a suitable thickener, binder and cross linking agents. Because the pigments have almost no affinity for the substrate, the binder and cross linking agents bind the pigments to the surface of the substrate during the heat-curing or fixation step. Binders are also responsible for the hand and many performance properties of the printed textile [35].

2. Pigment Printing Process

The process of pigment printing can be defined as a process consisting of the following operations.

Basic stages of a printing process [36]:

- 1) Preparation of printing color paste
- 2) Printing
- 3) Drying
- 4) Fixing with steam or hot air (for pigments)
- 5) After treatment such as washing and drying of the printed substrate [optional]

Constituents of pigment printing paste are pigment, binder, emulsion/synthetic thickener, crosslinking agent, catalyst, hand modifier, hygroscopic agent, etc.

Printing involves deposition of viscous paste containing the dyestuff, a thickening agent, a small amount of water and other printing assistants. It is immediately dried to prevent the spreading of the colour beyond the boundaries of the design. The actual transfer of the dyestuff from the thickener film into the fiber of the fabric is carried out by steaming, curing or sometimes chemical fixation [37].

3. Printing Paste Components

The composition of a pigment printing paste is determined by the printing method, the substrate, the application method and fixation. Nevertheless, the paste should be capable of being applied to print a variety of synthetic and natural fibers, and be wash-fast and dry clean resistant, once applied to the textile.

Printing paste is the main constituent of printing which enables the formation of the predefined patterns. Printing paste consists of four main components: Pigments, Binders, Thickeners, and Auxiliaries. The general range of composition of printing paste is given by the figure 1 below. It is therefore necessary to give individual consideration to each of the printing paste constituents. All the above constituents are not used simultaneously in any pigment printing paste depending on the class of pigment used and style of printing employed, suitable component are selected in making in printing paste [5, 38].

The viscosity of the print paste is tested with a rotary vis-

cometer. The principle of which is a rotating body operating with constant speed is immersed into the print paste; the twist resistance is then the measure for the viscosity of the print

paste. The viscosity is registered directly in mPa. s [cp]. The temperature is an important factor during measurement, care should be taken that the temperature remains constant.

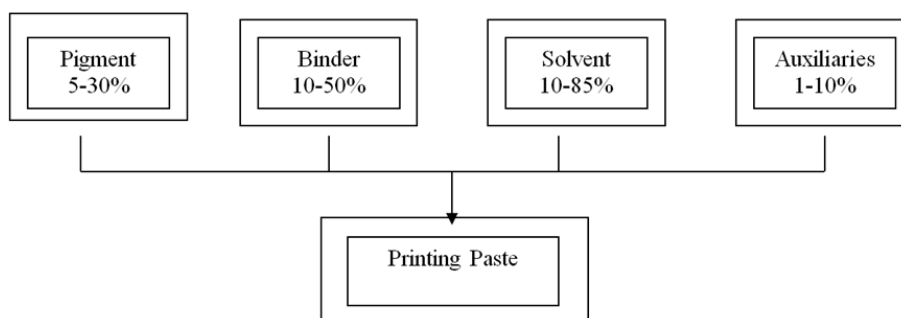


Figure 1. Composition of printing paste.

4. Application of Pigment Printing Paste

Pigment printing can be used in almost all types of textile substrates. The application of the paste onto the substrate can be done by manual methods and machineries. Rotary and flat screen take the primary stage in volume in applying pigment

printing paste to textile substrates the former being almost 75%. Typical example of pigment printing paste is given below. The basic difference in applying pigment printing paste is that for different substrates different auxiliaries are used depending on the end use.

Table 1. Typical recipe of pigment printing paste.

Chemical	Typical Range [g/kg paste]
Thickener {acrylate, 5-10% mineral oil}	10-30
Emulsifier {n-surfactant}	10-15
Pigment binder { polyacrylate}	50-250
Cross linking agent, fixing agent	2-5
Softening agent {dicarbonic acid ester, polysiloxane}	10-20
Defoamer {silicone emulsion}	1-3
Urea	10-20
Preservative/biocide {isothiazolon based}	0.5-2.0
Coloring pigment preparation	0-50

5. Mechanism of Pigment Combined with Fabric

The mechanism of printing and combinations of pigment with textile substrates are shown in [Figure 2](#).

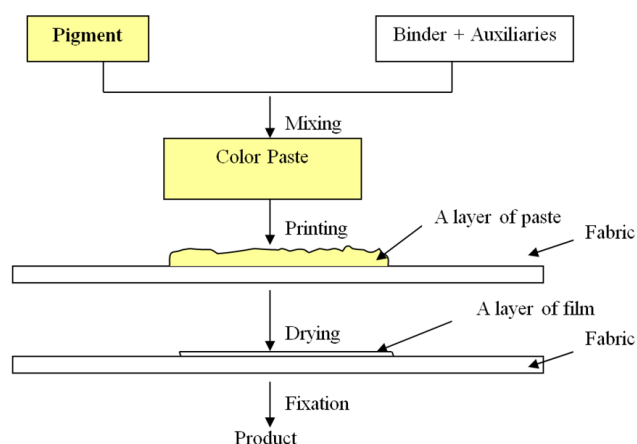


Figure 2. Mechanism of pigment combined with fabric.

6. Characteristics of Pigment Printing

The characteristics of pigment printing of textile substrates are described as follows [39, 40]:

- 1) Preparation of print paste is simple and printing process is short.
- 2) Pigments can be applied to all fiber types. When it is applied to blended fabrics, there is not the color difference resulted from the different fibers of the fabrics.
- 3) Properties of products of pigments are determined by pigment and binder.
- 4) Binder determines properties like fastness to rubbing, washing, soaping and hand feeling.
- 5) Properties like color brightness, fastness to light, weather, etc are determined by the properties of pigment.
- 6) There is a wide range of pigments that provide a perfect color gamut and good fastness to light.
- 7) Pigments can be used together with many dyes to carry out combined printing.
- 8) It can produce special designs, such as metallic or pearl prints.
- 9) Metallic pigment to get golden luster.
- 10) Pearled pigment to pearl luster.
- 11) It gives clear and well-defined design.
- 12) Pigment printing usually leads to the decrease in hand and softness of printed fabrics.
- 13) The brilliance of pigments is usually less than that of reactive or insoluble azo dyes.
- 14) Fastness to rubbing, brushing is usually not good.

7. Auxiliaries Used in Pigment Printing

An ingredient used in the printing paste includes solvents, antifoaming agents, hygroscopic agents, carriers, oxidizing/reducing agents, thickeners and binders etc [8]. Auxiliary chemicals are added in the printing paste to ensure good and reproducible print.

The chemicals added to printing paste that facilitate pro-

duction of effective and quality printing are called printing auxiliaries. There are different printing auxiliaries. They are classified according to their functions and various uses. The auxiliaries are selected based on the method of printing, dye class, fabric to be printed and compatibility with other ingredients in the paste. The different printing auxiliaries are presented in Figure 3 below. Some typical printing auxiliaries are briefly discussed below [37].

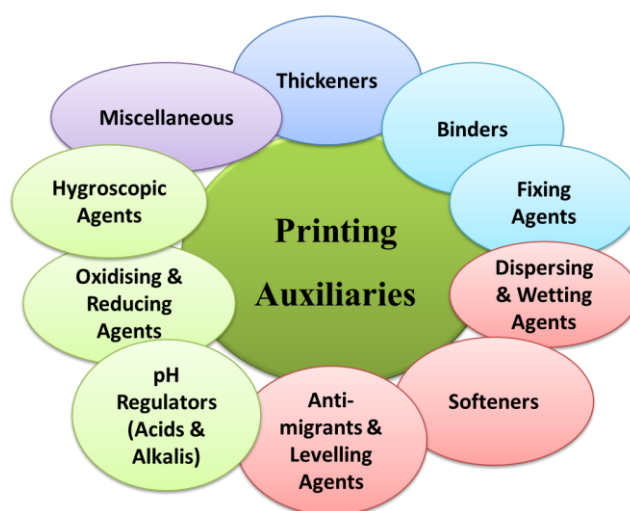


Figure 3. Printing auxiliaries.

7.1. Pigments

Pigments are considered to be the chief constituent of pigment printing paste. They are finely ground colored substances. They impart color to the printing paste. Pigments are tiny particles having size $0.2 - 0.5 \mu\text{m}$ and are insoluble in water. They don't have affinity or substantivity for any type of fiber. There is no chemical bond between pigment and fiber. Being insoluble products, pigments can only be fixed to the surface of the fiber. Fixation of pigment on fabric is by the adhesion force provided by binder. The binder covers particles of pigment and forms a layer of film whose thickness is only several microns and adheres on fabric.

Pigments are sold in two physical forms: paste and powder. Most pigments are sold in paste form because powders will pollute the environment. The paste consists of organic or inorganic colorant, glycerin, Peregol O, water and protective colloid such as Emulsifier EL. Paste's solid content (colorant) is 14 – 40%. Particles of pigment should be very small. Decrease in particle size can increase the diffusability and wet fastness properties of pigments but decrease their brilliance [41].

7.1.1. Chemical Composition and Classification of Pigments

The range of the pigments may be conventionally divided

into five sub-groups on the basis of preparation for use [4, 5].

By their chemical composition pigments can be classified into five [5, 41]:

- 1) Mineral pigments: Titanium dioxide white, carbon black
- 2) Metallic powder: Gold bronze powder, silver powder
- 3) Pearled pigments: Pearl paste AC – 6
- 4) Organic compounds: more than 90% of the pigments are organic. They can be:
 - a) Azo pigment – can provide yellow, deep blue, red, brown colors.
 - b) Phthalocyanine pigment – green, ultramarine.
 - c) Vat pigments- gold, yellow, heliotrope.

There are no water soluble groups in organic pigments. Water soluble groups decrease fastness properties.

Fluorescence resin pigment (Luminous pigment) – lumogen

Most of the pigments used in textile printing are synthetic organic materials, except carbon black, titanium dioxide of the rutile and anatase types (for white pigments) copper and aluminum alloys (for metallic bronze pigments), and sometimes iron oxide (for browns) and titanium dioxide coated glimmer (for pearl luster pigments). When choosing synthetic pigments, the price, the fastness properties, the brilliance and the coloring power of the many products available are all taken into consideration [5, 6].

The trade names of some of the commercial pigments are given in Table 2. Acramin pigments are considered best pigments and have maximum fastness to light, boiling water, chlorine, sublimation and acid. They belong to azo, vat diazo, dioxazine, quinacridone and phthalocyanine pigment classes [41].

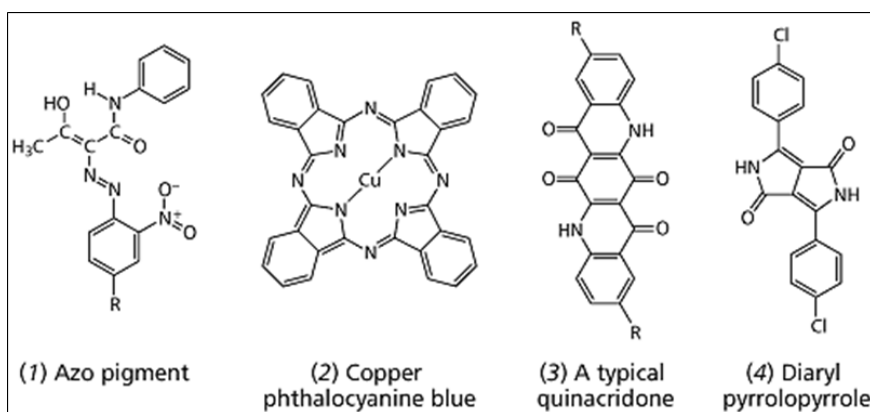


Figure 4. Molecular structure of some important pigments.

Table 2. Trade names of Pigment emulsions.

No.	Trade Name	Manufacturer	Country
1	Acramin	F. Bayer AG	West Germany
2	Acron	Parekh Dye-Chem Indus	India
3	Aquaprint	Interchemical Corp.	USA
4	Helizarine	Basf AG	West Germany
5	Imperon	F. Hoechst AG	West Germany
6	Microfix, Orema	Ciba	Switzerland
7	Lifebond	Hilton Davis Chem Co.	USA
8	Tinolite	Geigy	Switzerland

7.1.2. Desirable Characteristics of Pigments Used in Printing

In order to meet the requirements of printing, pigments should have [41]:

- 1) Good stability, durability to light, heat, acid, alkali, oxidant and organic solvent, etc.
- 2) High color yield and coverage value.
- 3) Appropriate gravity to prevent pigment paste from stratification.
- 4) Good brilliance and fastness.

7.2. Binders

Pigments are fixed on the fabric by the help of binders hence binders provide durability of the pigment on the fabric. Binders are high molecular weight film forming agents produced by the polymerization of simple intermediates (pre-polymers) initially present in the paste in a homogeneous, dissolved or dispersed state. After evaporation of the solvent or other liquid vehicle, a thin coherent coating or film is produced by heating. The incorporation of reactive groups in the macromolecule enables linking to occur within the binder after film formation by a simple heat treatment. Pigments are fixed to the fabric by the help of binders [10, 27, 28].

The polymer film formed by the binder in pigment printing is a three dimensional structure of long chains of macromolecules, which, when applied to textiles together with pigment dyes, create a three - dimensional cross-linked structure. Such a cross-linked structure is formed in the phase of fixing the prints, which is usually carried out in hot air in pigment printing, where by the so – called self-cross linking or to reaction with suitable cross linkers which, as auxiliaries, are added to the printing paste. Cross-linkers ensure elasticity and optimal film adhesion [36].

Pigment printing of textiles has become widely popular due to its economy and versatility. The binder has to fix the pigment particles on the surface of textile fibre as far as possible without affecting the shade and handle. This is highly complicated task and it is possible only by using binder composed of several components. Several combinations of acrylonitrile, butadiene, and styrene have been successful [8].

Prints of good fastness property on cellulosic fibres can be achieved using binders/fixers such as melamine formaldehyde, vinyl resins, urea formaldehyde precondensates, chlorinated rubber and acrylic resins. The latest chemicals used are Acramin and Lutexal HD. Acrylic binders can affect crocking fastness, colour yield, handle and print appearance [37].

Desirable properties of binders for pigment printing

- 1) By curing or steaming binders form a layer of film adhered firmly on the fabric which is colorless, transparent and has good fastness to rubbing, dry-cleaning, etc.
- 2) The film is not yellowing even by the effect of heat and/or light especially UV.
- 3) The film should have good flexibility and chemical stability without being tacky. Its aging speed must be slow.
- 4) At room temperature it should not form film (not be solidified) but at high temperature of curing or steaming the film should be formed quickly. Furthermore, there should not be poisonous gas resulted from the film forming process.
- 5) It cannot stain printing machine and can be eliminated easily from the printing machine. Pigment printing may have two problems on printing machines: blocking off mesh of the screen and building up pattern in the roller [10, 27, 41].

7.3. Cross-linking Agent (Fixing agent)

The aim of cross-linking agents is to increase fastness and decrease curing (steaming) temperature and shorten curing/steaming time. Cross linking agents are used to ensure good and reproducible print.

Crosslinking agents are the compounds containing two or more than two functional groups that can crosslink with the functional groups of binder, such as -OH, -NH₂, -COOH, -CONH₂, etc. to form reticular structure [39].

Cross linking agents are divided into two groups:

- 1) Thermosetting resin: such as DMDHEU [dimethylol dihydroxy ethylene urea],
- 2) Organic compounds containing multiple reactive groups: such as Crosslinking Agent EH and Acrafix FX.

Due to the reactivity of the crosslinking agent, it must be first added in to thickener or diluted with water (1: 3) then mixed with binder.

Different crosslinking agents have different reactivities, for example: Farter ME has fixing temperature of 100 – 110 °C and fixing time of 30-60 sec. Helizarine Fixing Agent S needs higher fixing temperature (110 -120 °C) [39].

Quantity of cross linking agents should be controlled; otherwise, the print will be stiff and brittle. Cross-linking agent is used for non-reactive binders [39, 40].

7.4. Thickening Agents

In printing of textiles, thickener constitutes an essential and integral component of the print paste formulation [8]. Thickeners as its name implies are used to localize the printing paste on the desired area of the fabric.

Thickeners used in textile printing are high molecular weight compounds giving viscous pastes in water. These impart stickiness and plasticity to the printing paste so that it can be applied to a fabric surface without spreading and be capable of maintaining the design outlines even under high pressure. Their main function is to hold or adhere the dye particles in the desired place on the fabric until the transfer of the dye into the fabric and its fixation are complete [37, 42]. A thickener adds viscosity to printing pastes, prevents early reactions between the print paste's chemicals, and aids in the seizing of the print paste's constituents on textiles [42-45].

Thickeners mainly employed in giving consistency to colouring matter. The final printing results obtained mainly depend on the selection of a suitable thickener. The thickener is a critical part of the printing formulation because it allows controlled coloration of textile materials. The thickeners control rheology or flow behaviour of the print formulation, which in turn controls presentation and migration resistance of the printed color. Both natural and synthetic products serve as print thickeners [8].

The main criteria for the selection of a thickener are [46, 47]:

- 1) Substrate to be printed
- 2) Proper viscosity

- 3) Print paste stability
- 4) Good adhesion of dried thickener film
- 5) Minimum effect on the colour yield
- 6) Ease of removal during wash-off treatments
- 7) Acceptable cost

However, the requirements of the thickener properties generally vary with the application. Both natural as well as synthetic thickening agents are used in textile printing. The natural products are commonly employed for printing textile substrates, but they are variable materials and the requirements are complex and ill defined. Natural thickeners include sodium alginate, which is derived from seaweed. Sodium alginates are a common thickener for fibre reactive and disperse dye printings. It is considered the only satisfactory thickener for printing with the reactive dyes, for the absence of reactivity with these dyes. However, the cost of sodium alginate is very high due to the restricted imports and insufficient supply of the indigenous material [48]. Guar gums, often used in disperse dye printing, and starch, useful for vat dye printing, are other examples of natural thickeners. Natural print thickeners exhibit near-Newtonian rheology, meaning that the viscosity of the paste changes only a little with changing shear conditions. Slow and sometimes incomplete recovery of the stress is characteristic of natural thickeners [8].

7.4.1. Desirable Properties of Thickeners for Pigment Printing

The desirable properties of thickeners used in pigment printing [47]:

- 1) Have low solid content
- 2) Be transparent and colorless.
- 3) Don't decrease the fastness and hand of textile prints
- 4) Have good leveling power without spreading sideways.
- 5) Give a clear and well-defined design.

Conventional thickeners used for dye printing are not suitable for pigment printing as they interact with binder and reduce its interaction with fiber thus affecting the fastness properties. Suitable thickeners for pigment printing are emulsion thickeners which have zero solid content and synthetic thickeners having low solid contents.

7.4.2. Classification of Thickeners

Synthetic and emulsion thickeners are suitable for pigment printing [46].

Emulsion thickener: Obtained by emulsification of two immiscible liquids with the help of emulsifier. Emulsion thickeners are of two types: oil-in-water (O/W) emulsion which are mostly used and water-in-oil (W/O) emulsion [39].

Emulsion thickeners are obtained by emulsifying oil with water. Emulsion thickeners give a clear and well-defined design and high apparent color yield and soft handle, but their stability is poor and they contaminate environment due to the evaporation oil during curing or steaming [37].

Synthetic thickener: they are long chain ionic homo-or copolymer derivatives of:

- 1) Vinyl polymer based thickeners – PVA, Polyvinyl pyrrolidone.
- 2) Acrylic polymer based thickeners.
- 3) Other thickeners... polystyrene.

Since they are ionic products they have more interaction with water molecules and give good thickening effect.

Synthetic thickeners are the copolymers made from three or more monomers. Usually, synthetic thickeners are sold in the form of emulsion. Before they are mixed with pigment, binder, etc they should be pasted using ammonia water. Most of synthetic thickeners have high paste-forming yield and high rheopexy. So they can give good handle and are suitable for flat and rotary screen-printing and give clear-cut definition but not suitable for roller printing [39, 46].

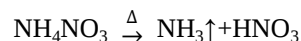
Synthetic thickeners have good washing-off property that can increase the color brilliance of design. Some of the synthetic thickeners are sensitive to electrolytes that decrease the viscosity of paste of these thickeners greatly. So these thickeners are not suitable for the dyes that contain a large number of electrolytes.

Usually, adhesion strength of synthetic thickeners to fabrics is not high. Quick and over drying should be avoided; otherwise, printed film may be stripped down and fall off from the printed fabrics.

Synthetic thickeners have good hygroscopicity and can absorb much water during steaming process. This change can cause the paste to spread sideways easily and non-clear-cut pattern results. So it is advisable to use curing or over heated steam for fixation [39].

7.5. Catalyst

The aim of catalysts is to catalyze the cross linking reaction of the binder. Most cross linking reactions occur under acidic condition, some of them occur in the presence of alkali. So catalysts are either acidic or alkaline types. Acidic catalysts used frequently are ammonium nitrate, ammonium sulphate, ammonium phosphate, hydrogen phosphate, etc. During steaming or curing, these chemicals decompose and catalyze the cross linking reaction.



Choice of catalyst depends on the pH value at which crosslinking reaction occurs [39].

7.6 Hygroscopic Agent [Water Retaining Agents]

Hygroscopic agents are added in printing paste to enhance the transfer of the dye or pigment from the thickener film to fabric and facilitate subsequent washing off of the thickener. Hygroscopic agents are especially used for certain class of dye

like vat dyes. These are used to absorb sufficient amount of water during steaming and enable the dye molecules to diffuse into the fibre thereby resulting in good colour yield [37].

Hygroscopic agents are used to maintain the content of water in printing paste and the flow ability of paste. The hygroscopic agents used frequently for pigments are:

- 1) Urea $\rightarrow (\text{NH}_2)_2\text{CO}$
- 2) Glycerol $\rightarrow \text{HOCH}_2\text{CHOHCH}_2\text{OH}$
- 3) Ethylene glycol $\rightarrow \text{HOCH}_2\text{CH}_2\text{OH}$

In addition to its hygroscopic effect, urea can be used as a buffering agent and free formaldehyde catcher. Urea is a weak alkali and can neutralize the amide produced by catalyst at high temperature and maintain the pH value of printing paste in the range of 5.5 – 6 which not only ensures cross linking reaction to carry out sufficiently but also prevent the printed fabric from embrittlement caused by acid at high temperature. Some thermosetting resins such as urea formaldehyde condensation products can produce free formaldehyde at elevated temperature. Urea can react with the free formaldehyde to form resin.

Excess of hygroscopic agent is likely to create problems in drying. The sharpness of print is also lost during steaming if the moisture condensed on prints were above certain critical value [39].

Certain amount of moisture is required for fixation of dye-stuff which can be controlled by use of dyestuff hygroscopic agents e.g. Glycerine is recommended in printing with vat colours. Presence of urea, solvents etc. also affect the moisture take up during steaming. The moisture not only swells the fibre, but it favours overall mechanism of dyeing. Excess of hygroscopic agent is likely to create problems in drying. The sharpness of print is also lost during steaming if the moisture condensed on prints were above certain critical value [8].

7.7. Softener

Softeners are used to improve the handle of textile prints made by pigment printing. Softeners are of two types such as organosilicon and fatty acid ester softeners.

Organosilicon softener: Lupnimol SIG (BASF)- it not only improves handle but also increases the fastness to rubbing. It also removes the tackiness of some binder films on fabric. Some organosilicon softeners will be yellowing if the temperature of curing is greater than 140 °C.

Fatty acid ester softener: have long fatty chain. These make the film soft due to their plasticization. They can swell the film of binder and soften the film. Since the film has been relaxed its fastness decreases. So the quantity of these softeners used in printing paste should be small [39].

7.8. Antifoaming Agent (Defoamer)

Antifoams are used to prevent color paste from foaming. Foam formed during stirring affect the quality of the print [37, 39].

Due to mechanical agitations in the presence of chemicals having surface activity and also film forming properties of thickening agents, foam is produced during printing operation. Presence of foam gives uneven transfer of color and affects the quality of textile printing. An antifoaming agent used in the printing paste inhibits the foam formation and thus preserves the quality of the print.

Defoamers such as silicone defoamers, octyl alcohol, turpentine, emulsifiable hydrocarbons etc can be used. Silicolapse and perminal KBI are commercial product [37].

The foam formed in the colour box produce faulty prints and to avoid this fault defoamer should be incorporated in the printing paste. Silicone defoamer readily emulsifiable hydrocarbon, sulphated oils, etc. may be used for this purpose. Perminal KB (ICI) is neutral yellowish brown liquid containing an aqueous emulsion of sulphated sperm oil and pine oil. It is anionic in nature, miscible with water, gives milky dispersion which is stable to alkalis. A mixture of ortho, para and meta - methyl cyclohexanol has a power of reducing the foam and widely used in textile printing. Emulsified pine oil is readily miscible with water and can be used as defoamer. Triactyl phosphate is also a very good defoaming agent [7].

7.9. Solvents and Hydrotropic Agents

As the water content of printing paste during preparation and fixation has limitations, the dissolution of dyes becomes a critical process. The yield of colour and the uniformity of pattern are affected by presence of solvents and hydrotropic agents.

Auxiliaries based on ethylene glycol, thiodiethyleneglycol are recommended for printing of direct, acid and indigosol colours. Simple solvents like methylated spirit for Rapidogen colours or pyridine bases for metal complex colours for printing wool are in vogue for a long time [8].

Hydrotropic agents are water-soluble compounds, which by their mere presence increase solubility of other compounds in water. The process of dissolution in water can be looked upon as a molecular dispersion. The hydrotropic agent aids this dispersing and dissolution operation by weakening intra-molecular binding forces.

Some practical examples of hydrotropic agents are, use of urea in dissolution of reactive, acid, direct, and basic dyes. Thiourea is stronger but more selective in action than urea. Many of the compounds like urea, phenol have multiple functions like hygroscopic agent, swelling agent etc. Use of solvent gives smooth prints of improved colour yields without any speckiness. Excess of solvents can cause flushing of prints due to their hygroscopic nature [8].

7.10. Swelling Agents/Carriers

Some common examples of swelling agents which make remarkable difference in printing effects are, use of phenol in printing of polyamides and use of ammonium thiocyanate in

printing of cellulose acetate with acid and metal complex colours.

Non-volatile carriers like p-phenyl phenol may be used to improve colour yield in pressure steaming for fixation of disperse colours on polyester. These also are recommended in discharge printing of polyester with suitable reducing agents like stannous chloride [8].

7.11. Oxidizing and Reduction Agents

For development of solubilised vat colours by acid oxidizing method, sodium chlorate is recommended as oxidizing agent. Similarly in printing of aniline black, the complex black pigment can be formed by using a chlorate in printing paste.

Oxidizing agents are also required to be used as reduction inhibitors to counteract reductive influences exerted by gum thickeners or impurities during steaming on dyestuffs. Sodium chlorate is recommended for retaining the brightness of disperse and acid prints. Potassium chromate improves tone of Rapidogen black in the same way. Other commonly used and perhaps even misused oxidizing agent is sodium salt of nitrobenzene sulphonic acid (resist salt). This functions as a mild oxidizing agent in an alkaline medium. It is used mostly in printing with reactive dyes [8, 37].

In order to develop the final colour in steaming or in subsequent after treatment as in printing of solubilised vat dye, aniline black, some oxidizing agents are added to the printing paste. They are also used in certain styles of printing such as colour discharge/oxidation discharge [7].

Most commonly used oxidizing agents are:

- 1) Chlorates of Na, K, NH₃, or Al
- 2) Dichromates of K & Na
- 3) Chromates of K & Na
- 4) Potassium ferricyanide (K₃FeCN₆)
- 5) Nitrites, Nitrates

The proportion of oxidizing agent should neither be less nor more. It should be such that it only discharges the colour. Oxidizing agents are added during the preparation of printing paste but it should be effective on colour only during steaming [7, 37].

Reducing agents are required in fixation mechanism of vat dyes and also for discharge printing. The most commonly used discharging agent is sodium sulfoxylate formaldehyde which remains in latent condition till the temperature above 80°C are reached in presence of mild alkalis. The corresponding zinc salt and thiourea dioxide are also a powerful reducing agents and are used for discharge prints on nylon and polyester. Certain discharge printing aids like Leucotrope O have capacity to combine with reduced form of dyestuff which is not fixed on the fibre and hence it helps to achieve better discharge effects along with sodium sulfoxylate formaldehyde.

Stannous chloride is another powerful reducing agent and was once very popular for discharge/resist effect on polyester

with suitable disperse dyes. This has many drawbacks such as high acidic pH, poor stability, and variation in quality etc [8, 37].

Most commonly used reducing agents are [7, 37]:

- 1) Na₂S₂O₄
- 2) Sodium sulfoxylate formaldehyde (NaHSO₂.2H₂O.HCHO)
- 3) This is commonly available as Rongalite C, Formosol, Hydrosulphite NF etc.
- 4) Sodium bisulphate (NaHSO₃)
- 5) Glucose
- 6) Tin compounds (SnCl₂, SnCOOCH₃)
- 7) Ferrous sulphate
- 8) Thiourea dioxide [NH₂C(SO₂)NH₂]

7.12. Resisting Agents

In the resist style of printing, a reducing agent is used to destroy the oxidizing at the printed area needed for the development of a particular dye and hence to resist its development. Acids are used in the resist print paste to neutralize the alkali, needed to fix the dyes. Citric acid is used as resisting agent in the printing of reactive dyes [8].

8. Features of Printing Auxiliaries

- 1) High color yield while low dye using. The printing auxiliaries is sticky and smooth, good dispersion performance, thus it can make the dyeing material evenly dispersed and accurately fixed in a certain position of the fabric without infiltration, making the outline of the pattern clear, bright color while saving the dye and avoiding the bad effect of using traditional paste, such as easy to produce uneven dyeing, color point, Fine lines broken and other shortcomings.
- 2) High color fastness. The printing auxiliaries does not occur condensation and hydrolysis phenomenon in the color paste when the PH value between 5 to 13. It has good resistance to acid, alkali, and electrolyte, with a strong ability to carry so that dye can fix on fiber through variety reactions.
- 3) Improve production efficiency and product quality. The viscosity of new thickener is suitable, sticky but not over stick. And thixotropic property of the new printing auxiliaries is high. The printing auxiliaries using this new chemical thickener will not stick on the tools of print or the printing fabric when printing, effectively avoiding the shortcoming of traditional paste that snap can't be cleaned or the fabric is difficult to desalinate. So the printing auxiliaries is a new breakthrough in printing industry through decreasing defective rate, improve work efficiency and product quality.
- 4) Wide use range. The printing auxiliaries is mainly applied to reactive dyes, disperse dyes in the printing process. It can reduce the amount of triethanolamine by

50% in the use of acid dyes and fast sulfon. It can be used in drum, flat screen and rotary screen printing process for cotton, flannel, polyester and other fabric printing.

- 5) Easy to operate. The usage of these products is completely the same as sodium alginate. First pour water or warm water into the bucket, then put the new paste slowly into the water in constant stirring, stir until no granulation exists [34].

9. Advantages and Disadvantages of Pigment Printing

9.1. Advantages of Pigment Printing

- 1) Pigment printing is the most economical printing process and allows maximum output of goods because of the elimination of washing - off, quick sampling and high printing speeds.
- 2) Properly produced pigment prints, using selected products, have an unsurpassed fastness to light and good general fastness properties.
- 3) Pigment printing can be applied to all substrates which are of interest to the printer, including glass fibers, PVC and imitation leather, subject to some limitations in color depth. It is extremely well suited for color resist effects, for example, under azoic and reactive dyes.
- 4) Pigment printing presents the fewest problems for the printer of all the coloration processes, with regard to labor costs, equipment, and reliability of production. Mistakes in printing can be recognized quickly.
- 5) From the ecological point of view, pigment printing, using pastes free from white spirit, is more acceptable than any other system, excepting only transfer printing methods [5, 49, 50].

9.2. Disadvantages of Pigment Printing

- 1) The fastness levels of medium or dark colored prints on materials made from polyester fibers are at best only suitable for articles that will not be subjected to a great deal of wear. Dark-colored prints on woven and knitted goods of synthetic fiber blends are especially susceptible to abrasive wear, as well as to reduction in color strength by use or washing.
- 2) The handle of the printed goods is often unduly hard because of the large amounts of external cross-linking agents, and this necessitates after treatment of the prints on breaking machines to produce some improvement.
- 3) Pigments are sensitive to crushing during roller, particularly where bulky materials and deep engravings are concerned. Pigment printing needs shallow engravings, and bulky textiles should be printed on screen printing machines.

- 4) The original surface of the textile material is covered by the binder film. This is occasionally aesthetically effective, but usually undesirable.

- 5) No pigment print is completely fast to dry cleaning. Depending upon the pigment and binder (which must be characterized as "fast to solvents") the prints can show rub-marks and / or a loss in color depth [5, 49, 50].

10. Conclusion

Pigment printing is the simplest, cheapest and most popular method of printing among all the known printing methods. Pigment printing can be used in almost all types of textile substrates. The application of the paste onto the substrate can be done by manual methods and machineries. The composition of a pigment printing paste is determined by the printing method, the substrate, the application method and fixation. Printing paste consists of four main components like pigments, binders, thickeners, and auxiliaries. An ingredient used in the printing paste includes solvents, antifoaming agents, hygroscopic agents, carriers, oxidizing/reducing agents, crosslinking agent, emulsifier, fixing agent, dispersing agent, softener, thickeners and binders etc. All of these constituents are not used simultaneously in any pigment printing paste depending on the class of pigment used, style of printing employed and substrate to be printed, suitable components are selected in making the printing paste.

Because the pigments have almost no affinity for the substrate, the binder and cross linking agents bind the pigments to the surface of the substrate during the heat-curing or fixation step. Thickeners are used to localize the printing paste on the desired area of the fabric. Cross linking agents are used to ensure good and reproducible print. Catalysts are used to catalyze the cross linking reaction of the binder. Softeners are used to improve the handle of textile prints made by pigment printing.

Printing auxiliaries have features like high color yield while low dye usage, high color fastness, improve production efficiency and product quality, wide use range and easy to operate. However, binders are also responsible for the hand and many performance properties of the printed textile. Quantity of cross linking agents should be controlled; otherwise, the print will be stiff and brittle.

As a result in this paper an insight into the printing auxiliaries and their role in pigment printing has been made. Textile auxiliaries play a vital role in the final outcome of a good quality printed product.

Abbreviations

Cp	Centipoise
mPa.s	Millipascal-second
UV	Ultra-Violet
DMDHEU	Dimethylol Dihydroxy Ethylene Urea

O/W	Oil-in-Water
W/O	Water-in-Oil
PVA	Polyvinyl Alcohol
PVC	Polyvinyl Chloride

Acknowledgments

The authors wish to thankful Kombolcha Institute of Technology (KIOT), Wollo University.

Author Contributions

Asaye Dessie Wolela is the sole author. The author read and approved the final manuscript.

Funding

The research, authorship, and/or publication of this paper were all done without any financial assistance from the author(s).

Availability of Data

The corresponding author can provide the data that were utilized to support the study's conclusions upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Miles, L. W. (1994). The production and properties of printing pastes. *Textile printing*, 240.
- [2] Asaduzzaman, M. F. H., Kamruzzaman, M., & MIAH, M. R. (2016). Effects of binder and thickeners of pigment printing paste on fastness properties of printed fabric. *International Journal of Scientific and Engineering Research*, 7(9), 710-719.
- [3] Textile focus. (2021). Textile Pigment Printing: Chemistry of Binders. Available: <https://textilefocus.com/textile-pigment-printing-chemistry-binders/> (Accessed Jan. 19, 2023)
- [4] Miles W. C. Textile Printing. 2nd Edition, Society of Dyers and Colorist, Bradford England, 2004, pp. 320.
- [5] Solangi, W. H., Noonari, Z. A., Channa, A. A., Khan, M. Q., & Siyal, A. B. (2014). Influence of binders and thickeners of pigment printing paste on light fastness and crocking fastness of the fabric. *International Journal of Science and Research*, 3(5), 1024-33.
- [6] Shore J. (1990). Colorants and auxiliaries,” *Society of Dyers and Colourists*, vol. 1- 2.
- [7] Chintan M. (2015). PRINTING AUXILIARIES. Available: <https://textilechemrose.blogspot.com/2015/09/printing-auxiliaries.html> (Accessed Feb. 25, 2023)
- [8] Shabbir M. (2004). Printing Auxiliaries: Synthetic Thickeners and Their Application in Pigment Printing.
- [9] Christie, R. (2000). *The Chemistry of Color Application*. Wiley-Blackwell. 296.
- [10] Dessie, A., & Eshetu, B. (2021). The role of binders and its chemistry in textile pigment printing. *Journal of Textile Science & Engineering*, 11(1), 1-6.
- [11] Guion, T. H., & Hood, J. R. (1985). Viscosity profiles of printing thickeners at high shear rates and their use in predicting paste flow in screen printing. *Textile research journal*, 55(8), 498-508.
- [12] Guion, T. H., Pak, T., Foushee, L. F., & Somerville, W. N. (1984). Shear Thinning Index for Printing Thickeners. *Textile Chemist & Colorist*, 16(4).
- [13] Schwindt, W., & Faulhaber, G. (1984). The development of pigment printing over the last 50 years. *Review of progress in coloration and related topics*, 14(1), 166-175.
- [14] Hamilton, L. E., & Chiweshe, A. (1998). Textile pigment printing binders prepared by modifying wheat gluten with methyl acrylate. *Starch - Stärke*, 50(5), 213-218.
- [15] Akbarzadeh, A., Kermani, B., Nasrabadi, M. A., & Najafi, H. (2011). Application of new reactive and disperse dye on textile dyeing, printing with acrylate Eco friendly copolymers. *International Journal of the Physical Sciences*, 6 (21), 4903-4909.
- [16] Kabir, S. M. M., Kim, S. D., & Koh, J. (2018). Application of jackfruit latex gum as an eco-friendly binder to pigment printing. *Fibers and Polymers*, 19, 2365-2371.
- [17] El-Molla, MM, El-Sayad, HS, El-Kashouti, MA, & El-Khawaga, RS (2012). Use of the newly synthesized aqueous polyurethane acrylate binders for printing cotton and polyester fabrics. *Advances in Chemical Engineering and Science*, vol. 2 no. 2 pp. 228-237, 2012, <https://doi.org/10.4236/aces.2012.22027>
- [18] Najafi, H., Yazdanshenas, M. E., & Rashidi, A. (2009). Effect of Binders on Fastness Properties of Pigment Printing in Textile Fabrics. *Asian Journal of Chemistry*, 21 (1), 433-445.
- [19] El-Molla, M. M., & Schneider, R. (2006). Development of ecofriendly binders for pigment printing of all types of textile fabrics. *Dyes and Pigments*, 71(2), 130-137.
- [20] Neral B., S. Šostar-Turk and B. Von äna, *Dyes and Pigments*, Vol. 68, No. 2-3, 2006, pp. 143-150.
- [21] Yaman, N., Ozdogan, E., & Seventekin, N. (2012). Improved fastness and color strength of pigment printed textile fabric. *Journal of Engineered Fibers and Fabrics*, 7 (2), <https://doi.org/10.1177/155892501200700207>
- [22] Teli M and Ramani V. (1992). American Dyestuff Reporter”, vol. 81, pp. 7-32.

- [23] Jassal, M., Acharya, B. N., Bajaj, P., & Chavan, R. B. (2002). Acrylic-based Thickeners for pigment printing—a review. *Journal of Macromolecular Science, Part C: Polymer Reviews*, 42 (1), 1-34.
- [24] Kutanaee, H. N., & Aghaee, H. R. (2011). Synthesis and characterization of methyl methacrylate and 2-methacrylate and their application on pigment printing textile fabrics. *Afr. J. Microbiol. Res*, 5(5).
- [25] Christie, R., Mather R. R., & Wardman R. H. (2004). The Chemistry of Color Application. Wiley-Blackwell.
- [26] A. Johnson. (1989). The theory of coloration of textiles. C. L. Bird and W. S. Boston, Ed., Society of Dyers and Colourists, Bradford, pp. 427.
- [27] El-Molla, M. M., Haggag, K., El-Shall, F. N., Shaker, N. O., & Alian, N. A. (2013). Use of novel synthesized aqueous binders for pigment printing of polyester fabrics.
- [28] E. P. Gohl, and L. D. Vilensky. (2012). Textile Science: An explanation of fibre properties. *Longman Cheshire Pty Limited, Melbourne, Australia*, pp. 122.
- [29] Patel, D. C. (1995). Synthetic binders for pigment printing. *Pigment Printing Handbook*, 63-95.
- [30] Hammonds, G. (1995). Pigment Printing Handbook. *American Association of Textile Chemists and Colorists, Research Triangle Park, NC*.
- [31] Kempf, W., Bergthaller, W., & Pelech, B. (1989). New Industrial Applications of Chemically Modified Wheat Gluten. *Wheat is Unique: Structure, Composition, Processing, End-Use Properties, and Products*. Ed. Y. Pomeranz, *American Association of Cereal Chemists, St. Paul, Minn.*, 541-561.
- [32] Jiang, X., Hu, H., Bai, Y., Tian, X., Huang, D., & Wang, S. (2013). Synthesis and properties of the vinyl silicone oil modified polyacrylate core-shell latex as a binder for pigment printing. *Journal of adhesion science and technology*, 27(2), 154-164.
- [33] Lamminmäki, T., Kettle, J., Puukko, P., Ketoja, J., & Gane, P. A. (2010). Printing: The role of binder type in determining inkjet print quality. *Nordic Pulp & Paper Research Journal*, 25 (3), 380-390.
- [34] Issuu. (2017). Printing Auxiliaries. *HT Fine Chemical Co, Ltd.*, Available: <https://www.htfine-chem.com/product/printing-auxiliaries/> (Accessed Jan. 18, 2024)
- [35] Elshemy, N. S., Niazy, W., Khalil, E. M., Hamed, M. S., & Haggag, K. (2010). Synthesis of Eco-friendly Binders from natural resources using microwave and their applications in textile printing. *Egyptian Journal of Chemistry*, 53(6), 903-921.
- [36] Hertleer, C., Terziev, A., Malengier, B., Saeed, H., Razic, S. E., Dimov, A.,... & Milusheva, P. (2021). Ict in textile and clothing higher education and business (ict-tex). In *EDULEARN21 Proceedings* (pp. 7259-7263). IATED.
- [37] Chinnammal S. K.. Auxiliaries for Printing - Textile Colouration and Finishes, [Online]. Available: <https://ebooks.inflibnet.ac.in/hsp09/chapter/auxiliaries-for-printing/> (Accessed Jan. 26, 2024)
- [38] Technical Bulletin. (2007). Printing of Pigments and Special Effects. *Cotton Incorporated*, North Carolina, Available: https://www.google.com/search?q=Printing+of+pigment+special+effects%2C+6399+Weston+Parkway%2C+Cary%2C+North+Carolina%2C&sca_ (Accessed March 22, 2024)
- [39] Mehra, R., Jhangiani, S., Tolia, A., Churi, R., & Shenai, V. (1980). Auxiliaries In Textile Printing. *Colourage*, 27 (1), 3-7.
- [40] Perkins, W. S. (1999). Printing 2000: entering the jet age. *Textile chemist and colorist & American dyestuff reporter*, 1 (3), 25-27.
- [41] Textile learner. (2012). Pigment Types, Properties, Trade Name, Uses, Advantages and Disadvantages. *textilelearner.net*, Available: <https://textilelearner.net/pigment-types-properties/> (Accessed Feb. 12, 2024)
- [42] Ebrahim, S. A., Othman, H. A., Mosaad, M. M., & Hassabo, A. G. (2023). Eco-friendly natural thickener (pectin) extracted from fruit peels for valuable utilization in textile printing as a thickening agent. *Textiles*, 3(1), 26-49.
- [43] Harlapur, S. F., Airani, N., & Gobbi, S. S. (2020). Natural gums as thickeners in the process of cotton fabric printing. *J. Fash. Technol. Text. Eng*, 8, 186-188.
- [44] Kibria, M. G., Rahman, F., Chowdhury, D., & Uddin, M. N. (2018). Effects of printing with different thickeners on cotton fabric with reactive dyes. *IOSR J Polym Textile Eng*, 5(1), 05-10.
- [45] Hamdy, D., Hassabo, AG, & Othman, H. (2021). Recent use of natural thickeners in the printing process. *Journal of Textiles, Coloration and Polymer Science*, 18 (2), 75-81.
- [46] Agarwal, B. J., & Naik, R. D. (2001). Recent Developments in Synthetic Thickeners for Textile Printing Applications. *MAN MADE TEXTILES IN INDIA*, 44 (9), 353-356.
- [47] Blogger. com. (2015). Thickener. *learning textile education*, Available: <https://textileengg.blogspot.com/2015/12/thickener.html> (Accessed March 28, 2024)
- [48] Bajaj, P., Chavan, R., & Manjeet, M. (1985). Reactive Dye-Acrylic Thickener Interactions. *American Dyestuff Reporter*, 74(11), 37.
- [49] Sohail R. (2015). Process Flow Chart of Pigment Printing. *Textile-flowchart*, Available: <https://www.textileflowchart.com/2015/07/process-flow-chart-of-pigment-printing.html> (Accessed May 02, 2024)
- [50] Sayed A. (2023). What is Pigment Printing | Advantages and Disadvantages of Pigment Printing, *Textile Apex - a guide to textile & clothing*, Available: <https://textileapex.com/what-is-pigment-printing-advantages-and-disadvantages-of-pigment-printing/> (Accessed May 04, 2024)