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# Acrylic Fabric Printing with Different Techniques

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**Abstract**

One of the printing issues that have received the most attention recently is the coloration of acrylic fibers. Most dyes used in conventional printing techniques have little or no affinity for acrylic fiber. However, due to the highly appealing and intriguing qualities of these fibers, it was important to look for new printing methods and procedures to assure their further development. The technical manufacture of various colors of the fiber alone or in blends with other natural fibers is thought to be facilitated by expanding the range of acrylic coloring using several classes of dyes. The most wool-like of all synthetic fibers is acrylic. Fabrics composed of wool and acrylic have similar looks, feels, and wear characteristics. To increase the printability of acrylic using different techniques and improve certain properties, such as dyeability, hydrophilicity, conductivity, antimicrobial properties, fire resistance, tensile strength, and performance properties (smoother surface), acrylic fibers are modified for this offer, which widely used in apparel, fabrics, home furnishings, awnings, hand knitting and craft yarn, and stuffed toys.

**Keywords:** Acrylic fabric, printing textile, printing techniques.

## Introduction

One subset of wet processing technology for textiles is textile printing. It is a particular type of dyeing and the process of printing is done after the fabric has been dyed or pre-treated. Printing is the process of painting fabric with color in predetermined patterns or motifs, the color is bonded to the fiber in correctly printed fabrics, to withstand washing and friction. Textile printing is similar to dyeing, dyeing proper when the entire fabric is evenly covered in one color, but printing simply applies one or more colors to specific areas of the fabric in strongly defined patterns. Screen printing, digital ink-jet printing, or the use of thermal transfer technologies are the printing methods that are most appropriate for textile substrates. On a printed fabric, a design's outer edges are well defined, and it typically does not extend to the fabric's back. [1]

Vat, reactive, naphthol, and dispersion colors which have strong fastness properties are the most often used dyes for printing. Since they are not dyes, the pigments are also widely employed in printing. Resins that are particularly resistant to washing or dry cleaning are used to bond these colors to the fiber. Pigments work well for light to medium shades and are among the quickest-known colors. Vat and reactive dyes are typically used for cotton printing. Usually, acid colors are used to print on silk. Wool is printed with acid or chrome dyes, but it is first given a chlorine treatment to make it more color-responsive. Disperse and cationic dyes are typically used to print on man-made fibers.[2]

First produced in Germany in 1893, acrylic fiber was designed to have qualities and features similar to those of wool. The acrylic fabric started to be used extensively in 1991 for blankets, sweaters, and other things that consumers were required to often wash and wear. There are two ways to manufacture acrylic fibers, most notably wet spinning, and dry spinning. Even though acrylic can be used in place of wool, there are certain distinctions and parallels between the two materials. Similar to how wool is crimped during the dry spinning process, however, acrylic is

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substantially less expensive and offers bulk and warmth without adding extra weight.[3]

Due to acrylic fibers' inability to accept the majority of the dyes used by conventional printing techniques, coloring acrylic fibers has been a major challenge in recent years. However, new acrylic printing techniques employing various colors were developed as a result of these fibers' advantageous qualities. anionic dyes, such as reactive, acid, and direct dyes, which are often not used to color acrylic because they suffer from the repelling effects of the anionic groups in the fibers and the dye molecules Subjected to some modifications to suit the acrylic coloring process.[4]

There have been numerous attempts to color acrylic fabric, such as printing acrylic with anionic dyes that have rendered the surface of the fibers with amino and/or quaternary amino groups to make fibers that are both antibacterial and have improved anionic dyeability. [5]

Additionally, pretreating acrylic fiber with hydroxylamine hydrochloride in the presence of acetate salt made the fabric anionic dyeable with acid dyes, which improved dyeability compared to untreated fabrics because of the ion-ion interactions between the protonated amino groups in the fibers and the sulphonic groups present in the dye molecules. [6]

By pretreating acrylic fabrics with cationic aqueous polyurethane that contains varying amounts of quaternary nitrogen, acid-dyeable acrylic fabrics have been created that are both basic sites for acid dyeing and interact with the carboxylic groups in the acrylic fabrics. [7]

Chitosan was applied to the acrylic fabrics using the pad-dry method in both the presence and absence of a binder. With acid dye, the pretreated fabrics were printed. The color strength of the prints was three times greater in the presence of the binder than it was in the absence of it. The increase in color strength mostly depended on the chitosan's nitrogen content percentage. [8]

In proportion to the amount of hydrazine hydrate fixed to the fibers, the modified acrylic fibers containing hydrazine hydrate host active basic groups that can permit the availability of acid and reactive dye interactions[9]. Aqueous hydrazine solution treatment of acrylic cloth improved dye retention and color firmness. The improved color was also obtained by pre-treating acrylic/wool blends with hydrazine solution and then dyeing them with acid or reactive dyes [10].

Therefore, the research focuses on the chemical modification of acrylic fibers to improve their colorability and fastness properties by using different printing techniques such as modifying acrylic fabrics for improved transfer printability, printing acrylic fabric with anionic dyes by silk screen, screen printing acrylic fabric modified with cationic aqueous polyurethane, digital printing acrylic fabric with cationic dyes, and textile pigment printing on poly acrylic and polyester/acrylic fabrics.

**Printing textile techniques**

The process of applying ink to textile substrates while utilizing certain printing equipment and methods is known as textile printing. Screen printing, digital ink-jet printing, or the use of thermal transfer technologies are the printing methods that are most appropriate for textile substrates.[11-18]

The most common method of printing on textiles has always been screen printing, which has benefits in terms of productivity, total costs, and ease of use in large print runs. Additionally, compared to machines for other printing techniques, screen printing equipment is typically less expensive. On the other side, digital inkjet textile printing provides faster short-run printing, flexibility, innovation, and advantages for the environment. Additionally, it is significant to remember that adopting digital printing techniques offers superior visual effects and greater print format versatility. Additionally, it provides improved control over the uniformity of print quality throughout manufacturing runs. [19-37]

The first methods were employed for printing on textiles, and only afterward were they modified for more precise printing on paper. China's three-color silk prints, which date to 220 BCE, are the oldest printed textiles still in existence today. However, Brunello claims that the earliest dyed cotton was discovered in the Indus Valley, dating to about 3000 BCE [38]. The research aims to identify various printing strategies and approaches for using them on acrylic material.

**Methods of printing**

Three basic methods can be used to print on textiles:

- Direct printing method.
- Discharge printing method.
- Resist printing method.

Different approaches or techniques are prevalent for printing color on a fabric such as [1]:

**Direct printing**

It is the method used the most frequently to add a color pattern to fabric. It is possible to perform it on a white or colored fabric. A thickening agent and dye are dissolved in a small amount of water to create the print paste.

**Block printing**

The first direct printing technique is woodblock printing, which has its roots in China. On a wooden or metal block, the designs are carved, and then the paste dyestuff is put to the design on the block's face. By hand, the block is firmly pressed on the fabric's surface.

**Stencil printing**

Initially, the design is cut out of cardboard, wood, or metal. The stencils may have huge areas or thin, delicate motifs through which color is applied to the fabric. Due to the significant expenses involved, its use is restricted.

**Screen printing**

Stencil printing, which began in Japan in the 17th and 18th centuries, has evolved into screen printing. It can be done using flat or cylindric screens made of metal, nylon, polyester, vinyon, or silk threads. On the screen, the printing paste or dye is poured and pressed through the open spaces onto the fabric. It is referred to as "Flat Screen Printing" or "Rotary Screen Printing" depending on the type of screen used.

- **Flat screen printing**

  The printing substrate is flat, as is the screen printing mesh that is fastened to the rectangular frame. Although it is possible to make prints up to 8 square meters, the size of the printed image with this printing method is restricted by the size of the frame and it is typically used for printing smaller portions on clothing (T-shirts, jackets, etc.). Although it is feasible to print on curved surfaces, textile printing does not frequently use this technique.

- **Roller Printing**

  Instead of using hand-carved blocks, this machine-based variation on block printing uses engraved copper cylinders or rollers. The design is printed repeatedly with each rotation of the roller. The printed fabric is then placed in a drying chamber, followed by a steam chamber, where the heat and moisture help the color set.

**Duplex printing**

Both sides of the cloth are printed, either in two steps with a roller printing machine or in one step with a duplex printing machine.

**Blotch printing**

It is a direct printing technique in which the design and the background color are typically printed onto a white fabric in one step. Any technique, including block, roller, or screen, may be employed.

**Digital printing**

This type of printing uses an inkjet print head to apply tiny droplets of dye to the fabric. The data provided by the academic Textile digital image file is interpreted by the print system software. To manage the droplet output and maintain the image quality, the digital image file contains the necessary data.

**Transfer printing**

Vaporization is used to transfer a paper design to a fabric. Wet heat transfer printing and dry heat transfer printing are the two main methods used for this.

**Discharge printing**

In this method, the cloth is dyed in sections before being printed with a substance that obliterates the color where the design is intended. Sometimes a different color is printed over the basic color instead. After steaming, the printed fabric is thoroughly cleansed.

**Resist printing**

In this method, the fabric is stamped with a resist paste before being colored. Only the areas not covered by the resist paste are impacted by the dye. The resist paste is taken off after dyeing, leaving a pattern on a dark background.

**Acrylic fabric**

Acrylic fiber a long-chain synthetic polymer with at least 85% by weight of acrylonitrile units [-CH2-CH (CN)-] serves as the fiber-forming ingredient [39]. There are two main types of spinning (extrusion) used to create acrylic fibers: dry and wet. The wet spinning creates filaments by extruding the spinning solution into a liquid-coagulating bath, which are then pulled out, dried, and processed. [3]

Acrylic fibers are synthetic fibers made from a polymer (polyacrylonitrile) with an average molecular weight of ~100,000, about 1900 monomer units. The Dupont Corporation created the first acrylic fibers in 1941 and trademarked them under the name "Orlon". Acrylic has warm and dry hand-like wool. Its density is 1.17 g/cm3 as compared to 1.32 g/cm3 of wool 3. Acrylic has a moisture regain of 1.5-2% at 65% relative humidity (RH) and 25 C [40].

Its tenacity ranges from 4 to 8 gm/denier when wet and 5 gm/denier when dry. Elongation breaking is 15% (in both states). Its thermal stability is good. If acrylic is exposed to boiling water for 30 minutes, it shrinks by around 1.5%. It is well-tolerant of mineral acids. While acrylic has a good resilience to weak alkalis, it is quickly attacked by hot, powerful alkalis.

It is extremely resistant to standard bleaching treatments. To achieve superior characteristics, acrylic fibers have undergone several changes.

Acrylic fabric does have some flaws such as being susceptible to stretching and shrinkage, Fair strength, and hydrophobic nature results in static electricity and pilling, decomposes, and discolors when exposed to extreme heat. But provides several great material qualities like Lightweight, excellent resilience (fabric recovers to its original form and shape after washing or alteration), elastic (the cloth may stretch and rebound after being under tension), a soft touch that gives the wearer warmth, removes moisture from the skin, extremely good weather and sunlight resistance Washable.[3]

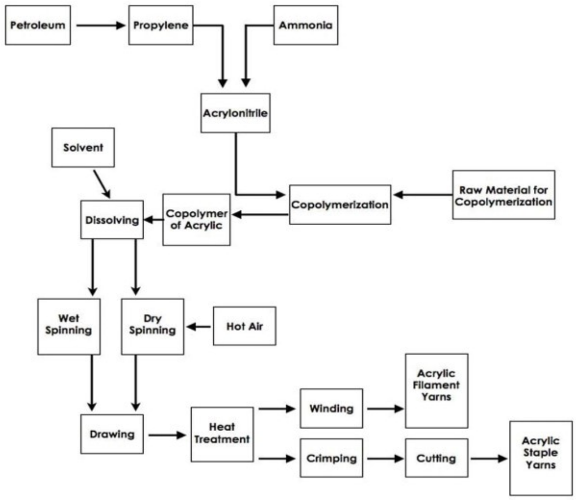


**Fig. 1. Manufacturing process for acrylic fibers.**

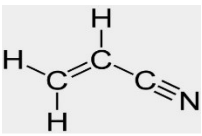

**Fig. 2. Chemical structure of acrylonitrile**

**Applications of acrylic fabric**

- Clothing: knitted clothing, fleece textiles, socks, and sweaters.
- Interior: rugs, furniture covers, and window treatments (some drapery uses acrylic fabric).
- Industrial: Awnings, bags, boat covers, and car covers
- Miscellaneous: blankets, stuffed animals (fur)

**Printing of acrylic fabric with different techniques**

There are many printing Techniques used to color acrylic fabrics, and we will show some of these techniques:

**Modification of Acrylic Fabrics for Enhanced Transfer Printability**

Disperse dye transfer printing on acrylic fabrics yields dull colors and poor washing resistance; in addition, when this technique is carried out at about 190 °C, the fiber turns yellow. This study's primary goal is to improve acrylic textiles' transfer printability and fastness qualities by utilizing clay nanocomposites, specifically nano bentonite, and nanocomposites.

Different sodium polyacrylate /bentonite nanocomposite concentrations were used to modify the pretreated and untreated acrylic textiles. The outcomes demonstrated that treating acrylic fabrics enhanced their physical qualities, transfer printability, and color fastness.[40]

**Nano clays** are nanoparticles of layered mineral silicate. Depending on chemical composition and nanoparticle morphology, Nano-clay is divided into numerous classes, including montmorillonite, bentonite, kaolinite, hectorite, and halloysite.

In polymer nanocomposites, nano clay is utilized as a rheological modifier, a gas absorber, and a medication delivery system. Nanoclay particles are employed as active dye sites and sorbents for nonionic, anionic, and cationic dyes.[41]

**Scouring of Fabrics Before Treatment**

With a liquor ratio of 1:2 and 2 g/l nonionic detergent, the acrylic fabrics were washed for 45 minutes at 45 °C. The materials were then dried at room temperature after being cleaned twice in cold tap water.

**Modification of Acrylic Fabrics**

With 10% sodium hydroxide and 80 °C for 1 hour, the nitrile groups (CN) on the polymer chain of the acrylic textiles were hydrolyzed. The fabrics were then chilled, rinsed with ethanol, and let to dry naturally at room temperature.

**Treatment of Alkali-Treated Acrylic Fabrics with Sodium Poly acrylate /Bentonite**

For one hour, nano-bentonite was mixed with distilled water. Different quantities of nano bentonite (1, 3, and 5% w/w) distributed in a 20% sodium polyacrylate polymer aqueous solution were used to cure untreated and alkali-modified acrylic fabrics. Using an ultrasound homogenizer run at 100 W for 1 hour, this mixture was thoroughly homogenized, incorporating the nano clay into the polymer matrix to create a polymer/bentonite nanocomposite [42]. The pad-dry-cure method was used to provide the treatment. The treated fabrics underwent padding to achieve a wet pick up of 100% and were then washed and dried at room temperature after being dried at 80°C for 5 minutes and cured at 150°C for 3 minutes.

**Transfer Printing Technique**

varying transfer temperatures (150, 170, and 190°C) and varying transfer periods (15, 30, 45, and 60 s) were used to put acrylic fabrics into contact with the transfer paper. A manual heat transfer press was used to perform the dye transfer under steady pressure.

**Physical Properties of the Treated Acrylic Fabrics**

**UV Protection**

The samples that have been treated with sodium hydroxide by 5% bentonite have good UV protection (UPF = 36), in contrast to the untreated samples that have no UV protection (UPF= 9). This is due to the existence of significant levels of silicon and aluminum oxides, which provide UV protection [43].

**Moisture Regain, Lateral Migration, and Sinking**

The moisture recovery rate increases as nano bentonite concentration rises. All of the outcomes can be linked to the bentonite's hydrophilic behavior since hydration causes the pores in the clay to open up and enhance absorption capacity by up to several times the clay's dry mass.

**Effect of Transfer Printing Time and Temperature**

- The treated fabrics' color intensity and transfer **printing time** both increased. For all of the chosen transfer printing up to 45 s, the color intensity values were noticeably higher than those of the untreated materials.
- The color intensity of the treated fabrics increases as the transfer **printing temperature** rises from 150 to 190°C. The treated samples' K/S values are 14.06 at 190°C, but the samples transfer printed at 170°C has a K/S value of 11.97.

**Washing and Rubbing Fastness Properties of the Printed Fabrics**

- Sodium polyacrylate and sodium polyacrylate /bentonite nanocomposite treatments increase the samples' washing speed compared to untreated samples. These outcomes can be related to the thin coating that is created on the surface of acrylic fabrics after nano clay treatment and the nano clay polymer matrix, which prevents disperse color from penetrating the fabrics and enhances washing fastness.
- Additionally, the washing, perspiration, and rubbing fastness of the untreated fabric are 3, whereas those of the treated fabrics are 4-5.

**Printing Acrylic Fabric with Anionic Dyes by silk screen technique**

- Nmethylol dihydroxyethylene urea (N-MDHEU), a finishing agent and cross-linker is used to print reactive colors on acrylic fabrics. Reactive, acid, and direct anionic dyes are not typically employed for acrylic coloring because of the repellent interactions between the anionic groups in the fibers and those in the dye molecules.
- printing acrylic fabrics with Reactive dyes (based on the monochlorotriazine structure) has been devised by N-methylol- dihydroxy-ethylene urea, which makes the surface more cationic, strengthening the electrostatic interaction between the dye molecules' negative charges and the protonated carbenium group of N-MDHEU. [4]

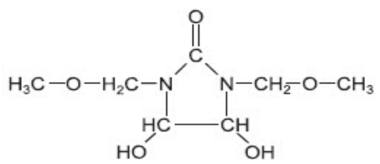

**Fig. 3. Nmethylol dihydroxy ethylene urea (N-MDHEU)**

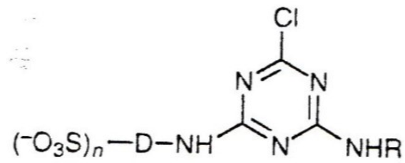

**Fig. 4. Reactive dyes based on the monochloride-triazine structure**

**Scouring of Fabrics Before Treatment**

The acrylic fabric was washed at 60 °C for 45 minutes with a 2 g/l nonionic detergent solution, completely rinsed, and air dried.

**Printing acrylic fabric by the flat silk screen technique**

When using reactive dye to print acrylic materials, there are several key elements:

- Effect of crosslinking agent concentrations
- Effect of catalyst type and concentrations
- The temperature /time of steaming

**Table 1. Printing paste recipes**

| | | |
|---|---|---|
| 20 | gm/kg | Reactive dye (suncion scarlet H-E3G) |
| X | gm/kg | Cross Linking agent |
| 500 | gm/kg | Thickener (sod. alginate), (10%) |
| 50 | gm/kg | urea |
| 8 | gm/kg | magnesium chloride or (catalyst) |
| Y | gm/kg | Balance (between thickener or water) |
| 1000 | gm/kg | (at pH5.5-6) |

- When fixing the prints in saturated steam at a high temperature, a hygroscopic agent makes sure there is enough water, in the form of moisture, to acquire the fiber surface of PAN negative charges.
- Printing-Drying at a temperature of no higher than 100° C to prevent fiber yellowing-Soaking in a bath containing 4g of nonionic detergent and L.R. 1: 30 at 60° C for 30 minutes-Rinsing again-Drying.

### Physical Properties of the Treated Acrylic Fabrics

#### Effect of cross-linking agent concentration on the color intensity (K/S)

With a high affinity for reactive dye printing, the increase in cross-linker concentration up to 80g/kg has a beneficial impact on color intensity K/S yield values (K/S = 77.73). This is most likely because crosslinking alters the hydrophobicity/hydrophilicity ratio. [42, 43]

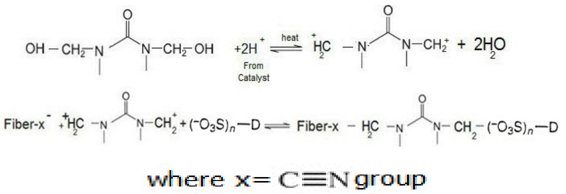


**Fig. 5. Effect of cross-linking agent on the acrylic fabric**

#### Effect of Catalyst types & concentration on K/S

The color intensity K/S values improve when the catalyst concentration in the printing paste is increased to 8g/kg for (Mg Cl2) Magnesium chloride and Citric acid (1:1) and 2g/kg for Ammonium chloride (NH4Cl). This improvement may be attributed to the catalyst's oxidative effect during steaming.

#### Effect of urea concentration on K/S

Urea is added to the acrylic fiber dyeing process to accelerate dye depletion. Color intensity K/S was 9.98 while urea concentration was 50g.

#### Effect of Steaming Temperature and Time on K/S

The color value of the prints gradually increases (K/S =12.83) when the steaming temperature is increased to 125 C for 15 minutes. This is because more dye is released, adsorbed, diffused, and retained onto the substrate, allowing for more dye fixing.

#### Fastness properties of printed acrylic

According to research, the color difference between printed fabrics with and without cross-linkers is 144.5%. The materials increase in rubbing fastens with employed cross-linker and have good perspiration fastness qualities ranging from 3 to 4. The washing fastness is really good, scoring 4-5.

### Digital Printing of Acrylic Fabric with Cationic Dyes

Media-dependent inks are also referred to as dye-based inks [44]. On the other hand, provided a proper binder is used, pigment-based inks are media-independent and can be applied to any type of fiber. Without a doubt, there are some limitations to fabric printing using inks that use pigments as colorants. The physical and chemical characteristics of the used binder have a significant impact on the physical characteristics of pigment-printed fabrics, including the handling and the fastness behaviors of products. As a result, the textile printing industry uses dyes as colorants more frequently. While dyes have an inherent substance to associated materials, the ink recipe lacks a binder, making printing with these inks media-dependent.[45]

The acrylic fabric was printed using a traditional four-color inkjet printer equipped with piezoelectric technology. The ink was water-based and contained basic dyestuffs. The optimization of dyestuff concentrations and the viscosity of the vehicle are the two most crucial key parameters since the size of the nozzles in these types of printers is in the range of micrometers.

This indicates that ink cannot be efficiently extruded from the nozzles in concentrated inks because ink droplets firing toward the substrate would not be practically significant. The amount of ink that has been emitted from nozzles for diluted inks, on the other hand, is greater than the optimized defined value. Due to capillary pressure and the absorbent surface of the fabric, causes the ink drop to stretch extraordinarily when it contacts the substrate, which causes a tone value increase (TVI). [45]

#### Acrylic Fabric Preparation for Printing Process

A4 papers were adhered to on A4 acrylic textiles. Liquid acrylic glue was employed as the adhesive in this situation. This glue ensures that the cloth will come away from the paper sheet after printing. This process allows printing on cloth as simple as printing on paper.

**Ink Recipe Preparation**

For the preparation of the ink recipe;

- To make a humectant (ethylene glycol), cationic dye powder was weighed and dissolved in ethylene glycol and dt-ethylene glycol. Stirring is important to speed up the dissolving process.
- As a co-solvent and a surface tension reduction, respectively, isopropyl alcohol and non-ionic detergent were added. Co-solvent makes basic dyestuffs more soluble.
- A minor amount of acetic acid was also added to keep the ink's pH in the acidic range. The following step involved adding hot distilled water as the primary solvent while gently swirling the mixture to create a homogenized colored liquid ink.
- Lastly, after being prepared, liquid inks were filtered.
- For 30 minutes, the printed materials were fixed in saturated steam at 96 C. This was done with the use of a dye fixation container, after which the materials were dried and washed with cool and hot soapy water, respectively.

**Table 2. Ink Recipe Preparation**

| Material | Amount |
|---|---|
| Cationic dye | 3 g. |
| Ethylene glycol | 10 cc. |
| Di-ethylene glycol | 20 cc. |
| Isopropyl alcohol | 5 cc. |
| Non-ionic detergent | 2 cc. |
| Acetic acid | 3 cc. |
| Distillated water | 210 cc. |

**Printed Color Patches' Color Gamut**

Following dye fixing, the color saturation of the color patches has risen significantly, as has the color gamut. Increased dye oxidation and these phenomena could be explained by penetration. In actuality, dye aggregation was fully prevented after fixing because colors were absorbed into the polymeric structure of fibers molecule by molecule.

**Acid Printable Acrylic Fabrics Treated with Cationic Aqueous Polyurethane by using the flat-screen printing technique**

The preparation of acid-printable acrylic fabric with cationic aqueous polyurethane, which contains varying levels of quaternary nitrogen and can interact with the carboxylic groups in the acrylic textiles.

Due to Aqueous polyurethane advantages in terms of soil resistance, fire safety, and environmental contamination[46, 47], Aqueous polyurethane has been utilized extensively in textile coating. The cationic aqueous polyurethane (CAPU)has drawn particular interest, which possesses features including water dispersibility, high adhesion to a variety of polymeric and glass substrates, and film-forming capacity. [48, 49]

The reaction of isophorone diisocyanate with quaternized diethanolamine and polyethylene glycol produced cationic aqueous polyurethanes (CAPU). The carboxyl groups in acrylic fabrics are anticipated to react with the cationic sites in the CAPU, and any extra cationic sites will be accessible to interact with acid dyes.[7]

Approximately 2 weight percent of acrylic, methacrylic, allyl, methallylsulfonic, itaconic, 2-acrylamide- 2-methylpropanesulfonic, and p-styrene sulfonic acids are used as co-monomers to improve the dyeability of cationic dyes for polyacrylonitrile fibers.[7]

**Scouring of Fabrics Before Treatment**

The fabric was properly rinsed and dried at room temperature after being washed with a nonionic detergent (2 g/l) at 60°C for 45 minutes before treatment. As a thickening agent, Meypro Gum NP-16, a plant-seed gum ether, was utilized.

**Quaternisation of diethanolamine**

To one mole of diethanolamine at 5C, two moles of methyl iodide were added dropwise while being continuously stirred. The reaction was allowed to finish overnight at room temperature after the temperature was raised to 30 for 3 hours.

**Preparation of cationic aqueous polyurethane (CAPU)**

- A vacuum reactor is used to eliminate any moisture before adding polyethylene glycol, the quaternary salt of di-ethanol amine, and DBTDL (0.02% based on the total reaction mass).
- IPDI, a solution containing butanone, is then added. the quaternized diethanolamine to glycol molar ratio used to prepare polyurethane. The reaction was conducted in a three-necked flask equipped with a nitrogen gas input, a thermometer, a mechanical stirrer, and a reflux condenser.
- The reaction mixture was vigorously swirled while adding water for emulsification after 5 hours of stirring at 75–80°C. To eliminate the MEK, the liquid was heated to 80C, producing CAPU dispersion.

**Treatment of acrylic fabrics with CAPU**

The samples were thoroughly washed at 50C for 15 minutes before being air dried at ambient temperatures. The acrylic fabrics were treated with

CAPU solutions of concentration (4%) using the exhaustion technique; the liquor ratio was 1: 50, at various temperatures (60-100C) and for various amounts of time (10-60 min).

**Printing of pretreated acrylic fabrics**

**Table 3. Printing Paste recipes**

| Constituent | Normal technique Weight in g |
|---|---|
| Acid dye | 20 |
| Urea | 50 |
| Thickener | 100 |
| citric acid | 5 |
| Ammonium sulphate solution (1 : 2) | 60 |
| Water | X |
| Total | 1000 |

- The thickener (Meypro Gum) was stored at room temperature overnight after being soaked in a tiny amount of water.
- -The urea and water were combined with the dye to form a paste, to homogenize the dye solution, the dye paste was diluted with hot water (60C).
- The thickening suspension was then added, and the wetting agent, ammonium sulfate solution, and citric acid were all added while thoroughly stirring the mixture.

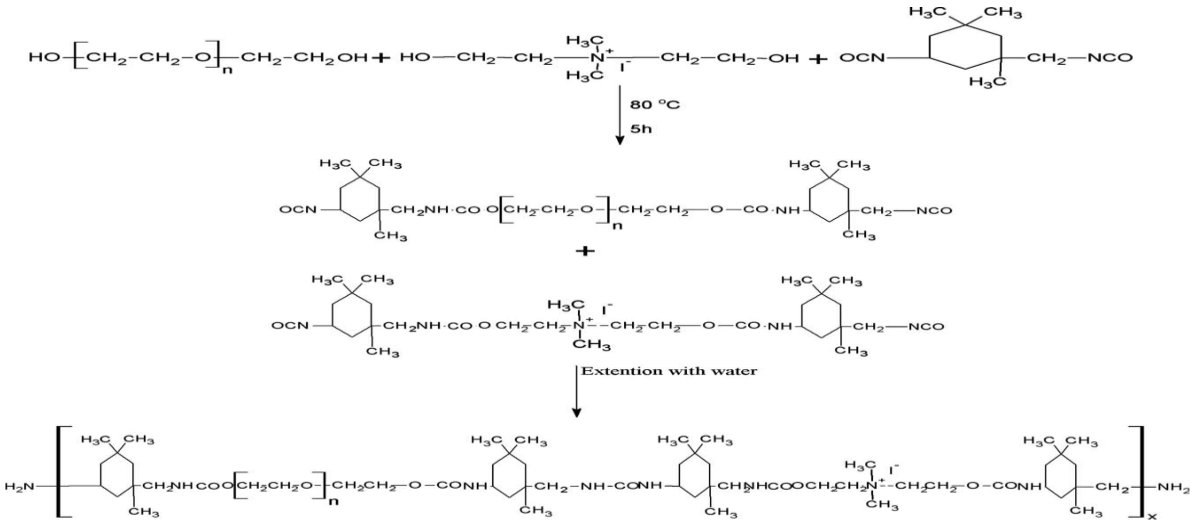

**Fig.6. Preparation steps of the cationic aqueous polyurethane**

- The addition of water then adjusted the total mass of the entire paste to 1 kg.
- The flat-screen printing method was used to apply all of the printing pastes on the fabrics.
- Then, for a further two minutes, 150C of thermos fixation was applied to the printed samples. The thickener was then removed from the printed samples by washing them in water.

**Effect of treatment conditions of acrylic fabrics**

- At temperatures over 70°C, the exhaustion (%) grows quickly and reaches its peak level at about 80–90°C, which is close to the acrylic fiber's glass-transition temperature (Tg). The CAPU is once again responsible for the dyeability with acid dye.
- Above the Tg of the fiber, at which the polymer chain segmental movement occurs, the free volume within the polymer chain increases, allowing more CAPU molecules to migrate easily into the interior of the fiber.

**Fastness Properties of the Printed Acrylic Fabrics Pretreated with CAPU**

Printing samples with acrylic fabric coated with CAPU produce good results in the k/s values when using various acid dyes, while samples with 4% of polyurethane display outstanding fastness capabilities for both dry and wet washing about (3-4).

**textile pigment printing of poly acrylic and polyester/acrylic fabrics**

Making a Nano-keratin-based binder (NKBB) out of inexpensive renewable natural resources, like coarse Egyptian wool or feather fabric, to replace the more expensive and environmentally harmful commercially available binder. The produced NKBB is used in textile pigment printing of pure polyacrylic and acrylic/polyester (40/60) fabrics as a biodegradable, environmentally friendly, and reasonably priced binder. [50]

Nanoparticles can alter surface characteristics, but they have no impact on the textile's breathability or hand feel.[51]

**Binders** are polymers or copolymers of unsaturated monomers such as ethyl acrylate, butyl acrylate, styrene, acrylonitrile, vinyl acetate, butadiene, etc. which are used in pigment printing of textiles. [52, 53].

**Keratin** is a high relative molecular weight natural polymer. They are crucial parts of the tissue of both animals and plants, and they are highly common in nature. The basic structures of proteins are -amino acids, which have the generic formula: H2N–CH (R) – COOH. [54]

### Scouring

Using 2 g/L sodium carbonate and 1 g/L non-ionic detergent at 60°C for 15 minutes, coarse wool and chicken feathers were scoured, followed by thorough rinsing with cold water, then squeezing, and finally air drying at ambient temperature.

### Preparation of Nano-keratin Binders and Printing Paste

- Coarse wool and chicken feather were dissolved for 10 min at 50 °C in a solution of 2% NaOH, 8% urea, and 6.58% thiourea.
- The resulting soluble keratin was subsequently precipitated in a coagulating solution of 6% H2SO4 and 12% NH4Cl (w/v).
- The precipitate was then thoroughly rinsed with distilled water to pH 7 and filtered through the polyester fabric.
- Which was ground into nano-sized keratin after being allowed to dry overnight.
- To make the created NKBB in the pigment paste more resistant to wet treatment and to increase the fastness qualities of the printed samples, gluten-dialdehyde has been utilized as a cross-linker.

### Printing process

Flat screen printing was used to apply all printing pastes to the fabrics. Prints were air-dried before being set in an automatic thermostatic oven at various temperatures (120°C to 160°C) for varying lengths of time (2–5 minutes).

**Table4. Printing Paste recipes**

| | | |
|---|---|---|
| Ammonia (25%) | : | 0.5 g |
| Binder (NKBB) | : | 1, 3, 5, or 8 g |
| Thickener | : | 3 g |
| Diammonium hydrogen phosphate | : | 0.5 g |
| Urea | : | 4 g |
| Pigment | : | 5 g |
| Water | : | 86, 84, 82, or 79 mL |

### Physical Properties of the Fabrics

### Effect of NKBB Concentration

Using 1% of the Nano-keratin Binders show good results of the k/s which was 14.5.

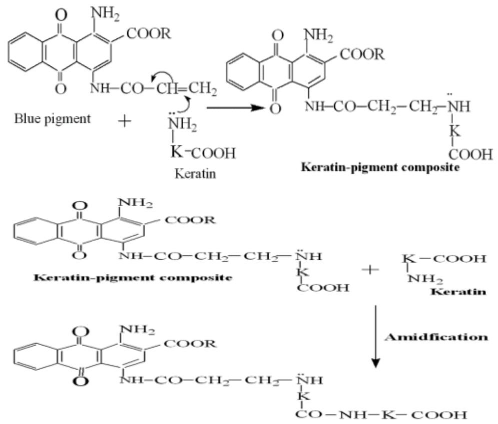


**Fig. 7. Mechanism for amide formation reaction between keratin-pigment composite and excess Nano-keratin**

### Effect of Thermo-fixation Temperature and Time

It is discovered that the K/S values rise with the increase in thermo-fixation time. Higher K/S ratios, 15.27, were obtained by thermos fixing printed materials by curing at 150 C.

The best conditions for employing NKBB in the pigment printing paste are 1% NKBB, 150 C thermo-fixation temperature, and 4 min treatment time.

### Conclusions

A long-chain polymer that has at least 85% acrylonitrile units is used to create synthetic acrylic fibers. The two primary spinning techniques used to create acrylic fibers are dry and wet. Due to acrylic's inability to accept the bulk of the dyes used by normal printing techniques, there have been various attempts to color acrylic fabric. As a result, printing acrylic fibers has become more challenging in recent years. These fibers' beneficial properties, such as their excellent stability towards regularly used bleaching agents and their good resistance to mineral acids and weak alkalis, led to the development of novel acrylic printing techniques using a variety of dyes. Various modifications of acrylic fibers are made to improve their printability, hydrophilicity, conductivity, antimicrobial, fire resistance, tensile strength, and performance properties which are utilized in carpets, knit Jerseys, sweaters, blankets, pile, and fleece materials that resist wrinkles.

**Conflicts of interest**

There are no conflicts to declare

**Funding sources**

There is no fund to declare

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## طباعة اقمشة الاكريليك بتقنيات مختلفة

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**الملخص**

واحدة من قضايا الطباعة التي حظيت بأكبر قدر من الاهتمام مؤخرا هي تلوين ألياف الأكريليك. في الواقع ، فإن معظم الأصباغ المستخدمة في تقنيات الطباعة التقليدية لها تقارب ضئيل أو معدوم لألياف الأكريليك. ومع ذلك ، نظرا للصفات الجذابة والمثيرة للاهتمام لهذه الألياف ، كان من المهم البحث عن طرق وإجراءات طباعة جديدة لضمان تطويرها بشكل أكبر. يعتقد أن التصنيع التقني لألوان مختلفة من الألياف وحدها أو في مزيج مع ألياف طبيعية أخرى يتم تسهيله من خلال توسيع نطاق تلوين الأكريليك باستخدام عدة فئات من الأصباغ. أكثر الألياف الاصطناعية شبها بالصوف هو الأكريليك. الأقمشة المكونة من الصوف والأكريليك لها مظهر وملمس وخصائص تآكل متشابهة. من أجل زيادة قابلية طباعة الأكريليك باستخدام تقنيات مختلفة وتحسين خصائص معينة ، مثل قابلية الصباغة ، والماء ، والتوصيل ، وخصائص مضادات الميكروبات ، ومقاومة الحريق ، وقوة الشد ، وخصائص الأداء (سطح أكثر سلاسة) ، يتم تعديل ألياف الأكريليك لهذا العرض ، والتي تستخدم على نطاق واسع في الملابس والأقمشة والمفروشات المنزلية والمظلات والحياكة اليدوية والخيوط الحرفية والألعاب المحشوة.

**الكلمات المفتاحية:** نسيج أكريليك ، طباعة المنسوجات ، تقنيات الطباعة.