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Printing Techniques of Silk Fabric

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Textile printing is the most versatile and significant method of imparting colors and patterns to textile materials. It is the process of merging a design concept with one or more colors by mixing natural or synthetic thickeners with a substrate (usually textiles) and utilizing a technique to correctly apply the colors Various approaches were used, and the number of possible hues increased. The many techniques used in the textile production business contribute significantly to pollution. Significant amounts of complicated effluent that fluctuate in both amount and feature regularly arise in the textile wet processing sector. The wastewater from the textile sector is known to be brilliantly colored, with a high concentration of suspended particles, pH swings, high temperatures, and high demand for chemical treatment.

Keywords: Silk fabric, printing technology, techniques.

Introduction

Silk fiber: The domesticated silkworm, Bombyx mori Linn., is a lepidopteran molecular model and an important economic insect that is emerging as an ideal molecular genetic resource for solving a broad range of biological problems. The silkworm, B. mori produces a massive amount of silk proteins during the final stage of larval development. These proteins are stored in the middle silk gland and they are discharged through the anterior duct and spinneret, at the end of the fifth instar.[1, 2] Two kinds of silk proteins have been distinguished as major components of silk cocoons, the first being fibroin, a fibrous protein composed of a heavy (H) chain, Light (L) chain, and glycoprotein linked by disulfide bonds and the second being sericin a natural macromolecular protein, serving as an adhesive to unite fibroin for making silk cocoons of the silkworm, B. mori. Recently, the silkworm is being used as a bio factory for the production of useful protein using the silk gland, which has promoted technological development in sericulture. With the above background, silkworms can be classified as a value-added biomaterial for medical application, application of silk protein fibroin and sericin as a biomaterial, and other seri-byproducts[1] fig.1

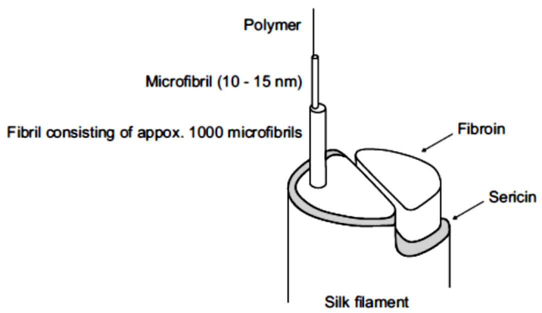

Fig.1. Structure a silk thread from fibroin and sericin

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Crystalline Areas

Silk is a protein fiber and consists of the elements carbon (35%), hydrogen (10%), oxygen (22%), and nitrogen (33%). Unlike wool and fine animal hair, it contains very little of the sulfur-containing amino acid cysteine [3]. The structure of the peptide chain of fibroin is shown in Fig 1. It consists essentially of a repeating sequence of 4 amino acids Fig. 2-3 Fibroin thread (left: longitudinal view with sericin sheath; right: cross-sections) hexapeptide: glycine-serine-glycine-alanine-glycine-alanine).

Therefore, glycine, alanine, and serine occur in a molar ratio of about 3:2:1. [4] There are several models for the spatial structure of the crystalline domains of silk fibroin. They all assume a folded sheet structure, comparable to the internal structure of wool

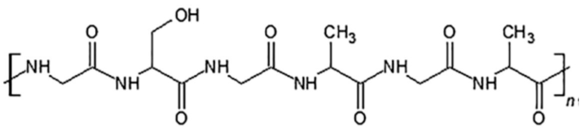

Fig.2. Chemical structure of fibroin with repeating unit

Fibroin

Silk fibroin consists of 18 different amino acids and accounts forapprox.75–83%of the weight of raw. The proportion of the four amino acids glycine, alanine, serine, and tyrosine is more than 90 mol %. Glycine dominates in mulberry silk with a proportion of around 45%, whereas alanine dominates in tussah silk. [5]

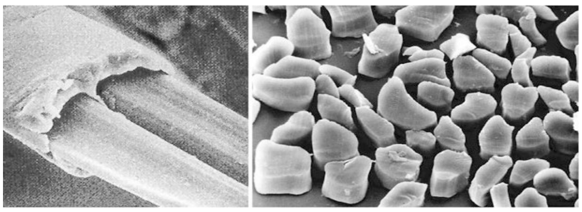

Fig.3. Fibroin thread (left: longitudinal view with sericin sheath; right: cross-sections)

Sericin

Sericin is a protein mixture with rubber elastic properties. The sericin content of raw silk is 17–25%and depends on breed, origin, and breeding conditions. The amino acid composition of sericin differs significantly from that of fibroin, the most abundant amino acid being serine(Fig.4)

Waxes and fats(approx.1.5%) as well as colorants and mineral components (1%) are found exclusively in sericin. Xanthophyll, carotene, and flavones were detected as coloring substances. [6]

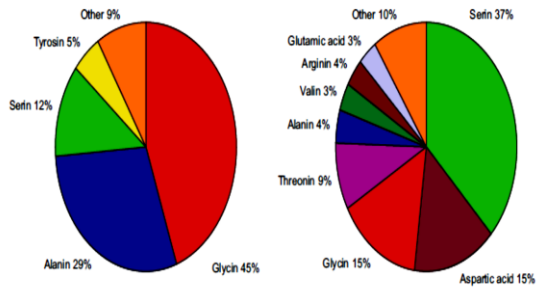

Fig.4. Composition of fibroin (left) and sericin (right) in mol %

Classification

In the classification of silk, a distinction is made between the classification of cocoons and the classification of the actual raw silk thread.[7]

Cocoons

The cocoons are classified according to appearance, size, color, and uniformity Silk accounts for about 15% of the total weight of the cocoon in the fresh cocoon and about 40% in the dry cocoon. The remainder consists of pupa and caterpillar skin[8, 9]. Classification is always carried out at the silk producer by visual in section (Fig5.)

Fig. 5. Visual classification of cocoons

Properties

Fineness, Density, Color, Luster, Handle The fineness of the cocoon thread (fibroin and sericin)and that of the fibroin thread depends on the breed and varies over the length of the thread (coarser at the beginning than at the end as the silkworm gradually improves its spinning process). [10] The average fineness of the single yarn is 1.0–3.5 dtex. Commercially available yarn counts for reel silk are given in DIN 60550. The average diameter of the cocoon thread is 15–25 μm. The density of the degummed silk is 1.37 g/cm^3. The color of the completely degummed cocoon thread is white. Incompletely degummed silk is yellowish to greenish in color. Degummed silk is shiny and has a supple handle.[11, 12]

Tenacity and Elongation

Silk has great tenacity in combination with good elongation. When wet, the strength decreases, and the stretch increases (Table1). The values for degummed silk are slightly lower than those given in the table above. [12, 13]

Table1. Mechanical properties of raw silk

Maximum tenacity [cN/tex]	25–50
Wet maximum tenacity [%]	75–95
Elongation at maximum tenacity [%]	10–30
Wet elongation at maximum tenacity [%]	120–200
E-modulus [N/mm^2]	8000–12,500

Mechanical Properties

Silk has high moisture absorption and a high water retention capacity. [14] Silk swells in contact with water, especially in the transverse direction (anisotropic behavior) (Table 2)

Table.2. Physical properties

Moisture absorption [%]	9–11 (21 °C/65% r.h.) 20–40 (24 °C/95% r.h.)
Water retention [%]	40–45 (degummed)
Electrostatic charge	Low–medium
Electrical conductivity	Good (loaded silk)
Electrical resistance	High
Swelling (degummed) [%]	Lengthwise: 1.65 Crosswise: 18.70

Chemical Properties

The resistance of silk to acids is somewhat lower and to alkalis somewhat better than that of wool. Silk is sensitive to water and very sensitive to perspiration. In concentrated sulfuric Hydrochloric, phosphoric, and formic acids, silk dissolves within 30 min. The isoionic point at which the ampholytic ions carry equal numbers of positive and negative charges is pH 5.0. [15, 16]

Thermal Properties

Silk can be washed at 30°C. The ironing temperature is 140–160°C and the discoloration temperature is 120°C. At 170–180°C, silk begins to decompose, and at 300–400°C charring sets in. Silk does not melt before ignition, but ignites in a pilot flame. When the pilot flame is removed, silk continues to burn slowly, producing an odor like a burnt horn. Its LOI is 24, the thermal conductivity is 0.2–0.4 W/mK, and the specific heat capacity1.4–1.5 kJ/kgK. [17, 18].

Other Properties

Silk is hygroscopic. the commercial moisture content is 11%. Silk is a polyampholyte with cationic and anionic side chains. Therefore, it can buffer strong alkalis and mineral acids to form salts. Silk can absorb considerable amounts of salt. This property is utilized when weighting the fiber. Because silk has a relatively good alkali resistance, it can be treated with 16 –18% sodium hydroxide solution. This produces a crèpe effect, which is used in particular for blended fabrics with a cotton content. [19-21]

Printing

The vast majority of silk fabrics are colored by printing (Fig.6). This mainly includes dress fabrics (shawls, scarves, ties) as well as decorative and upholstery fabrics. Printing on silk also requires prior, uniform degumming. As a rule, loaded silk fabrics are not printed. If this is nevertheless tried, the material can easily become brittle during steaming if the weighting is more than 15% above par. Furthermore, color Changes can occur during etching due to the formation of tin sulfide.[22, 23]

Fig.6. Quality control of pure white silk fabrics

Both, direct printing and etching, are suitable printing methods. In most cases, silk prints can be produced with the same dye types as wool prints. To achieve better fastness, acid, metal complex, and reactive dyes are preferred to other dye types. Vat dyes are also used for etching prints.[22, 24]

Silk printing is carried out mechanically as a table or machine printing with flat printing and rotary printing machines (Fig.7).

Fig.7. Printing of silk fabrics

Almost all dyes that are suitable for dyeing wool can also be used for dyeing silk. These include acid, basic, metal complex, reactive, vat, and pigment dyes. Natural dyes such as blue wood or tannins can also be used. Acid dyes are common both for rope silk dyeing and for piece goods dyeing. With them, good to very good light fastness properties are achieved. At the same time, a wide range of colors is available[25]. With basic dyes, one obtains glossy and clear dyeings, but the light fastness is not as good. Chrome complex dyes have a good leveling capacity and give high light and wet fastness properties. Furthermore, 1: 2 metal complex dyes are also used Vat dyes can be used to achieve washfast dyeings. However, considerable fiber damage occurs when exposed to light. Therefore, this type of dye does not apply to decorative or curtain fabrics. [26, 27]. Good results are achieved when dyeing under alkaline conditions with reactive dyes (especially with tussah silk because of the even higher alkali resistance). In this process, covalent bonds are formed with the functional groups that are present in many cases, which leads to very good color fastness. Jacquard weaving machines with punch card control for silk. [28]

Silk has a much lower affinity for wool dyes than wool, especially for reactive dyes. To obtain the same depth of color as wool, twice the amount of dye is required, in the case of tussah silk almost three times the amount. Uniform degumming is a prerequisite for high color fastness, which is why silk is normally dyed only after degumming[29, 30]

In general, all dyeing machines known for other textile fibers can be used for silk dyeing. However, due to their sensitivity concerning tensile effects and mechanical stress, they are modified accordingly. Silk is dyed in strand form (yarn), on perforated dyeing tubes, and in the piece (fabric). The dyeing units used for yarn dyeing are rope dyeing machines, cross-wound dyeing machines, and spray-arm dyeing machines, and for piece dyeing mainly reel skids, jiggers, beam dyeing machines, and jet dyeing machines[31]

Printing techniques

Textile printing is the practice of applying color to fibers in distinct patterns or designs with sharp outlines. Inappropriately printed fibers, the color is tied to the fiber, to defend against washing and crocking. The selection of dyestuffs used depends on several factors including fiber chemical structure, to achieve fibers with acceptable colorfastness properties.[32-39] Textile printing is the creation of color models or drawing on textile fabrics. But for the color being applied to limited sections according to a specific design ‹printing is nearly similar to the dyeing operation. However, modern advances in the area of printing, particularly in machinery, thickening agents, and manner of fixation have made printing a significant process in textiles coloration. In addition, due to improved aesthetic appeal, printed garments are in great demand.[40-45]

The key difference between textile dyeing and printing operations is in the application of color on fabric. In the dyeing process, the fabric is placed in a diluted solution of the dye bath and the extra dye solution is squeezed out of the dye bath. On the other hand, printing is performed via the inclusion of dyestuff in a thickener paste together with other auxiliaries. The substrate is printed utilizing a roller or screen on which a design is prepared previously. To limit the color from spreading out of the design portion of the fabric, and afford a sharp outlined design, the printing paste is provided viscous by merging one or more polymers which are known as Thickener which functions as a vehicle for dyestuffs and auxiliaries[41, 46-58]

The corresponding vehicle, in the textile dyeing process is water. The whole printing composite including dyestuff, thickener, and other auxiliaries is called printing paste which necessitates a thickening agent of particular apparent viscosity. Synthetic thickeners are usually extremely high-molecular-weight polymeric materials able to develop a very high viscosity at a relatively low concentration. However, the printing paste is hard to dispose of that generates sedimentation in the water streams during the disposal of its wastes which influences the water quality leading to harmful environmental impacts. Therefore, as a substitute for synthetic thickeners, natural biodegradable polymers can be employed as biodegradable thickeners for textile printing. The advantages of such biodegradable materials are environmentally friendly that is nontoxic and cheap to manufacture. Upon preparing a printing paste with appropriate components, it is applied to the substrate by a variety of styles and techniques, some of the significant ones are mentioned below.

- Block printing or stamping
- Photographic printing
- Batik printing
- Screen-printing
- Roller or machine printing
- Spray or stencil printing
- Resist and discharge printing

Discharge printing

Discharge printing is a type of fabric printing (extraction printing) in which particular areas of colored textiles are destroyed to create fine patterns in white or another color on a vibrant backdrop. [59]The base color is sometimes removed when another color is printed, however, a white region is usually desired to improve the overall pattern. [60] The chemical reagent degrades the chromophore system of the dyestuff applied to the textiles in the discharge printing theory. [61, 62]

Printing with discharge on silk fibers

Colors originating from plants, animals, and minerals are referred to as natural dyes. Occasionally, fashion necessitates the addition of huge patterns or dark backgrounds in hues or white with delicate lines of ornamental motifs. Technically, it is impossible to meet this condition with direct printing, thus we use discharge printing. German researchers discovered that by removing the hydrogen atom during the oxidation process, colored organic compounds may be converted to colorlessness and the original color regained[63]. Another German scientist proposed that color is typically seen in organic molecules that include unsaturated groups, i.e., groups with numerous bonds. For example, the most basic organic glyoxal molecule (O=H, C-C, H=O) is colored due to double bonding. is colorless. This is the fundamental operating concept of organic discharge printing. [64]

The resist printing

As the name implies, the resist printing style results from the material being printed with a substance that resists dyes thereafter. Only areas not coated with resistant paste will be affected by a dye, resulting in a pattern on a colored backdrop. [65] The leaf resistance is divided into two types: physical (wax used to prevent dye in fiber) and chemical (fiber). Chemical-resistant prints, on the other hand, are conducted(3) blocking) dye dissociation (oxidative or reductive), (2) dye insolubility (through the employment of an anti-solution agent), and dye site blockage. [11, 24][61]

Inkjet printing

technology has the advantages of low cost, high efficiency, and high precision. It is capable of producing pico-liter scale printing unit drops, dripped on demand, and printed in a contactless manner[66, 67]. Therefore, it is used to deposit polymer materials on different substrates, especially in textile pattern printing widely spreadly. Reactive dyes are widely used in the dyeing and printing of cellulose and protein fibers because of their wide color range, bright color, good color fastness, and strong applicability [68] Silk fiber is a kind of protein filament fiber, has become one of the most popular fabrics for reactive dye inkjet printing However, the smooth surface as well as the poor wettability of the raw silk fabrics, resulting in serious infiltration of printing pattern and low utilization rate of dye. Therefore, it is necessary to improve the surface microstructure of the silk fabric with effective methods before inkjet printing[69, 70]

Investigation of the Discharge Printing of Cotton and Silk

Mai Abd El-Aty et al textile substrates are printed in a variety of styles, including direct, discharge, resist, and so on. The dye of a ground-dyed fabric is released from the desired design or pattern in the discharge style of printing. This discharge might result in either a white or colorful pattern. Because of its emphasis on patterns with diverse colors on a dark backdrop, discharge printing is becoming increasingly popular in both local and foreign markets. It was discovered that a design might be bleached off or discharged from an already-piece painted material using chemical techniques. Printers may create elaborate and precise patterns using this discharge method. The chemicals used to discharge the dyes are classified as either oxidative or reductive agents. [62]

Discharge printing of natural fabrics (cotton and silk fabrics)

Cotton samples were pre-mordanted at boiling temperatures for 30 minutes before being evenly pressed, dried, and put in the dye bath without any intermediate washing. Two discharge agents were utilized to standardize the discharge printed; the color was more yellow in the shadow when alum mordant was used. Copper sulfate, on the other hand, is responsible for turmeric's red coloring. It was observed that oxidizing agents are excellent in removing all-natural color mixes. Reduced agents could not release myrobalan or natural mordant pomegranate rind. The best whiteness index, tensile strength, and minimum effluent emission were obtained by hydrogen peroxide. Although discharging natural silk coloring is straightforward, it results in a considerable loss of hue. Cotton is the polar opposite of strength. Natural pigments in small quantities can be used efficiently to reduce waste emissions while maintaining material strength. [71]

Inkjet printing of silk: factors influencing ink penetration and ink spreading

The study examined the impact of thickener type, amounts, pH, pretreatment liquor, and steaming time on ink penetration and spreading properties. The experimental runs were conducted using a blocked 25–1 fractional factorial design with four center points. The results showed that the interaction of thickener and urea (A*B) significantly influenced ink penetration, spreading in filling, and warp directions. The study also found that the two thickeners used separately in the pretreatment liquor significantly impacted ink penetration. Changing factors levels significantly affected ink penetration and spreading in PAA. PAM properties are less pronounced when factors are changed. This paper emphasizes the importance of selecting the right thickener for textile printers to make the process more predictable and controllable, resulting in better print quality. [68, 71, 72]

Pretreatment of silk for digital printing identifying influential factors using fractional factorial experiments

The study screened factors affecting digitally printed silk fabric fabrication using PAA and PAM as thickeners. Linear models were obtained and statistically tested, showing that alkali, urea, and pH concentrations increased color strength, while thickener and steaming duration decreased it. These findings were found to be accurate at a 90% confidence level. The concentration of alkali and urea affects dye fixation percentage in digitally printed silk fabrics. Steaming duration decreases the effect. PAM thickener-based pretreatment improves printing properties. ANOVA analysis shows significant curvature in design space, prompting future studies on central composite and Box-Behnken designs.

Enhanced Reactive Dye Inkjet Printing Performance of Antimicrobial Silk Fabrics Surface Modified with Plasma and Chitosan

This paper presents a clean production technology combining atmospheric pressure plasma jets and nano-chitosan to create durable bio-based coatings for improving inkjet printing performance on antimicrobial silk fabrics. The technology introduces green and environmentally friendly production methods, avoiding chemicals and pollution caused by dye hydrolysis. The plasma-chitosan treatment significantly improves the hydrophilicity of silk surfaces, enhancing antibleeding properties and increasing K/S value in color fixation. Scanning electron microscope (SEM) observations show firmer and more uniform chitosan coatings on silk fibers modified with plasma. X-ray photoelectron spectroscopy (XPS) analysis confirms the increased oxygenous group content on the silk fabric processed by plasma chitosan. The plasma processing effectively enhances the durability of chitosan against B. subtilis, resulting in long-lasting antibacterial silk fabric. The plasma-chitosan-treated fabrics still have excellent inkjet printing effects even after 45 cycles of soaping. This nontoxic, nonpolluting, low-energy-consumed chitosan coating offers an innovative option for inkjet printing on natural fabrics. [73]

Conflicts of interest

There are no conflicts to declare

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تقنيات طباعة الأقمشة الحريرية

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طباعة المنسوجات هي الطريقة الأكثر تنوعا وأهمية لنقل الألوان والأنماط إلى مواد النسيج. إنها عملية دمج مفهوم التصميم مع لون واحد أو أكثر عن طريق خلط المكثفات الطبيعية أو الاصطناعية مع الركيزة (عادة المنسوجات) واستخدام تقنية لتطبيق الألوان بشكل صحيح تم استخدام طرق مختلفة ، وزاد عدد الأشكال الممكنة. تساهم التقنيات العديدة المستخدمة في أعمال إنتاج المنسوجات بشكل كبير في التلوث. تنشأ بانتظام كميات كبيرة من النفايات السائلة المعقدة التي تتقلب في كل من الكمية والميزة في قطاع معالجة المنسوجات الرطبة. من المعروف أن مياه الصرف الصحي من قطاع النسيج ملونة ببراعة ، مع تركيز عال من الجسيمات العالقة ، وتقلبات الأس الهيدروجيني ، ودرجات الحرارة المرتفعة ، وارتفاع الطلب على المعالجة الكيميائية.

الكلمات الرئيسية: نسيج الحرير ، تكنولوجيا الطباعة ، التقنيات.