

Chemical Innovations in Yarn Sizing: Selection of Sustainable Size Materials and Warp Performance

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Abstract

The process of woven fabric sizing plays a pivotal role in enhancing weaving efficiency by preparing warp yarns for high-performance operations. This study investigates the chemical properties and roles of sizing agents in controlling elongation and stretch during the wet and dry phases of the sizing process, which causes more breaks in weaving. Improper control of these parameters can significantly weaken yarn strength, leading to frequent warp breaks and reduced loom efficiency. By focusing on the chemical characteristics of sizing materials and their interaction with yarn fibers, this paper highlights innovative approaches to mitigate elongation losses and optimize weaving performance. It was established that starch was the suitable sizing agent for enhancing the weaving efficiency of the yarn as its hydroxyl group (OH) allows it to adhere well to hydrophilic fiber like cotton and viscose, making strong bonding between the cellulose of the fiber and starch molecule.

Keywords: yarn sizing, starch, sizing materials, OH group, weaving efficiency

1. INTRODUCTION

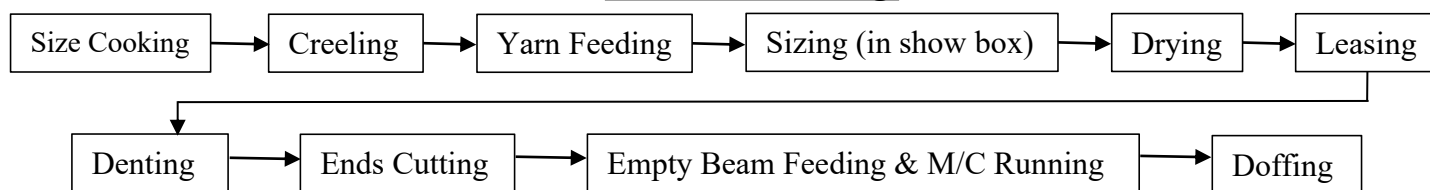
The improvement in the fabric for its protection requires suitable chemicals to affect color and appearance. Still, chemical treatments can also enhance resilience and advance its appearance, hand feel, durability, color, luster, and smoothness. Due to discoveries and the rigorous demands of high-quality products, textile processes have practiced essential alteration. In the near past, the advancement in new fibers, spinning methods, and weaving techniques, as well as the value addition of existing products, increased the efficiency of these methods. The topic of sizing is complex due to the significant interactions between fiber type, yarn structure, sizing chemicals, preparatory weaving processes, and the evaluation of sized yarn performance, which aids in predicting warp behavior during weaving[1].

Additionally, it involves ensuring easy size removal after weaving and addressing environmental concerns. Warp yarn sizing is crucial for minimizing yarn breakage and reducing production interruptions on the weaving machine. During weaving, warp yarns undergo various mechanical stresses, including cyclic strain, flexing, abrasion at different loom components, and inter-yarn friction (Fig.1). With sizing, the strength or the abrasion resistance of the yarn improves while its breakages decrease. The extent of strength enhancement depends on the adhesion force between the fiber and the sizing agent, as well as the degree of size penetration and yarn encapsulation[2].

1.1. Sizing Process

Sizing is a process by which films of chemicals are applied over the yarn. The main objective of sizing is resistance to abrasion and, thus, to improve the weaving performance. Some important objectives of sizing are as follows: i) to impart more strength in the yarn, ii) to reduce the yarn hairiness that would cause problems in the weaving process, iii) to upsurge the abrasion resistance of the yarn against other yarns, and various weaving machine elements iv) to impart flexibility in the yarn.v) to increase the weaving performance.vi) to reduce fluff and fly during the weaving machine process for high-speed weaving machines[3].

Flow chart for sizing:



Sizing, the application of chemical treatments to warp yarns, is an essential step in the textile industry aimed at improving weaving efficiency. The choice of sizing materials such as starches (e.g., maize, potato, and tapioca starch), synthetic polymers (e.g., PVA, CMC, and acrylic copolymers), and additives directly influences the mechanical and structural properties of the yarn[4, 5]. Starches like (e.g., maize, potato, tapioca), PVA, and CMC form a protective film around the yarn to enhance strength and reduce hairiness. Mineral oils, waxes (e.g., Japanese wax, vegetable wax), and animal fats improve yarn smoothness and elasticity. Zinc chloride, salicylic acid, and phenol prevent microbial growth and preserve the sizing material. Glycerin and calcium chloride which help maintain moisture balance and to avoid brittleness[6]. China clay and sodium phosphate add weight and fullness to the yarn. There have been significant studies on sizing, size materials, and other portions of this process (Fig. 1).

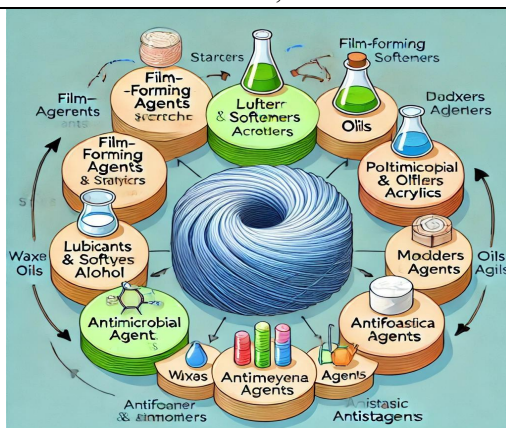


Figure 1. Illustrate the several steps in the sizing of the warp yarn and the interaction of various chemicals used in yarn sizing. It includes film-forming agents, lubricants & softeners, binders & adhesion promoters, and modifiers & additives. These components work together to improve the weaving performance of yarn.

To protect the yarn, various water-soluble polymers, known as textile sizing agents or chemicals, are applied. These include modified starch, polyvinyl alcohol (PVA), and carboxymethyl cellulose (CMC). Additionally, wax is added to reduce the abrasiveness of the warp yarns (Fig.2). The choice of sizing formulation depends on factors such as the yarn material (e.g., cotton, polyester, linen), yarn thickness, and the type of weaving machinery used. The sizing liquor is applied to the warp yarn using a warp sizing machine. After the weaving process, the fabric undergoes de-sizing (washing) to remove the applied sizing agents[5,7].

By focusing on the chemical characteristics of sizing materials and their interaction with yarn fibers, this paper highlights innovative approaches to mitigate elongation losses and optimize weaving performance with reduced environmental impact.

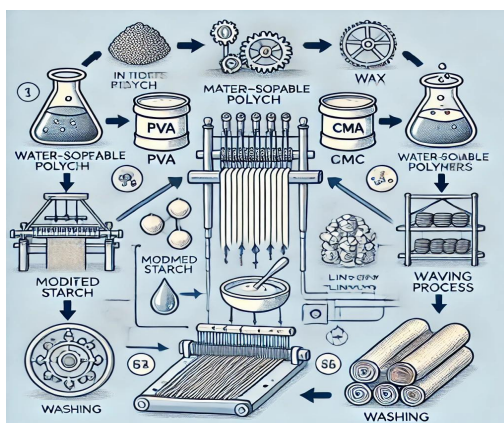


Figure 2. The process flow is visually represented with arrows, ensuring a clear understanding of the sequence. Key highlighting steps: i) Input Materials: Water-soluble polymers (Modified Starch, PVA, CMC), wax, and yarn (cotton, polyester, linen), ii) Sizing Application: A warp sizing machine applies sizing liquor to the yarn. iii) Weaving Process: The sized yarn is woven into fabric; iv) Desizing (Washing) or removal of the applied sizing agents from the fabric

2. MATERIALS AND METHODS

2.1. Sizing Chemicals

Sizing chemicals that are biobased, biodegradable, and eco-friendly, such as a starch-based sizing agent, were applied to warp yarns to advance their presentation during the weaving process. Hydrolysis and gelatinization of starch ($C_6H_{10}O_5$)_n in hot water is significant for sizing; it is used to improve smoothness and decrease the intensity of hairiness on the warp yarns. Our sizing chemicals come as blends, binders, softeners, lubricants, antistatic liquids, and cold sizing[8].

Then, the sized yarn passes through heated cylinders or drying chambers to remove excess moisture and solidify the film. Then, the yarn is cooled and conditioned to maintain proper flexibility and avoid brittleness. In the last, softening agents are used to reduce friction and enhance weaving performance. In the last, the sized warp yarns are wound onto a beam and ready for weaving. Each of these steps ensures optimal strength, reduced hairiness, and improved abrasion resistance of the yarn for efficient weaving[9].

2.2. Yarn Used

Yarn quality plays a vital role in sizing and the subsequent processes. The pickup is mainly dependent on the quality of the yarn. The amount of size to be applied depends on the CSP Value (Count Strength Product) of the particular yarn. It is

also crucial in sizing whether the yarn is carded or combed, coarser or finer, ring-spun or rotor-spun spun, etc. Yarn, which is usually used in sizing, is reported in Table (1).

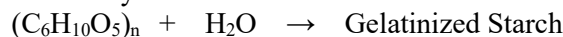
Table 1: A chart of different yarn quality is given below on the basis of our practical observation.

Fiber composition	Count (Ne)	Yarn type
Cotton	7, 10, 12, 13, 16, 20, 30	Carded
	16, 20, 30, 40, 50, 60, 80, 100/2, 80/2, 20/2, 30/2, 40/2, 50/2, 60/2	Combed
PC	16, 20, 30, 45	Carded or Combed
CVC	12.5, 20, 30, 38, 40, 45, 26/2	Combed
Fancy yarn	Slub yarn 10, 12, 13, 16, 20, 30, 40	Carded or Combed
	Mélange yarn 20, 30, 40	Combed or Carded
Polyester (Core spun)	(40 + 45D)	Combed
Polyester filament	70D, 75D, 100D, 120D, 150D	

3. RESULTS AND DISCUSSIONS

The role of chemistry in the textile industry is increasing, and it is the most complex industry, with multiple processes involved at one stage or another, where several chemical reactions are used even in smaller units to ensure proper management of chemicals. Chemistry plays a significant role in the textile industry at every stage, right from the manufacturing process to the final retail sale. Sizing Chemicals are applied because the fabric is too weak or shrinks with washing and needs to be strengthened before it can be sold. A starch-based solution is applied to the yarn to size the material in a quantity that swells the yarn and then dries it so that the fibers can hold their new shape.

The achievement of the weaving process is based on the complexity of several factors, including the characteristics of the desired material, the sizing process, the sizing ingredients, and yarn properties, but also the extensive knowledge of a textile technologist required in the field of chemistry, rheology, electronics, mechanical engineering, physics, mechanics, mathematics, etc., which makes this process more complex and more critical for the overall process of making woven fabric [1]. It was established that the starch molecules form a film on the yarn surface, providing strength and smoothness while easily washable, followed by reducing chemical discharge. It was observed that the starch swells and gelatinizes, forming a continuous, flexible film around the yarn.



After the application of starch with water in chemical sizing, it was ensured that it should properly adhere, film formation, and performance in weaving after the application of starch in chemical sizing. The starch-based size penetrates the yarn structure and adheres to the fiber surface, forming a protective coating under heating and moisture, while softening agent oil makes it easier to weave, leading to better fabric quality[9].

The interaction between yarn fibers and sizing agents involves complex chemical bonding, film formation, and adhesion mechanisms (Fig.3). A promising aspect of low-temperature conditions is that they do not achieve the desired dryness of the yarn. However, these conditions result in comparatively higher moisture levels, which promote more uniform size penetration. Consequently, the yarn exhibits greater strength under these conditions, leading to minimal yarn breakage during weaving, particularly for coarser yarns[10]. Moreover, after the application of sizing material, higher machine speeds contribute to increased yarn strength during weaving by reducing the drying time, thereby producing a more uniform, moist, and stronger yarn. Importantly, our results provide evidence that for fine yarn, lower squeezing roller pressure reduces yarn breakage, as finer yarn requires less pressure to remove excess sizing. Then, the sized yarn passes through heated cylinders or drying chambers to remove excess moisture and solidify the film. Then, the yarn is cooled and conditioned to maintain proper flexibility and avoid brittleness. In the last, softening agents are used to reduce friction and enhance weaving performance. In the last, the sized warp yarns are wound onto a beam and ready for weaving. Each of these steps ensures optimal strength, reduced hairiness, and improved abrasion resistance of the yarn for efficient weaving[11].

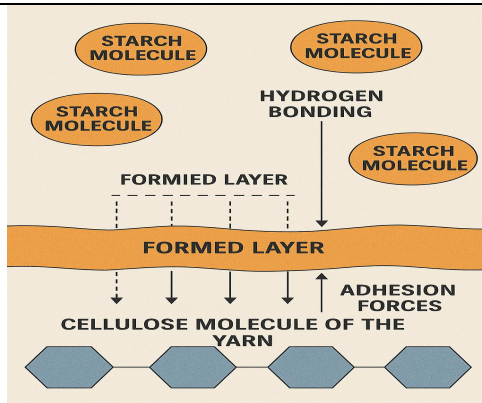


Figure 3: Interaction Between Starch and Cellulose in Yarn Sizing

The starch molecules form a film on the yarn surface, providing strength and smoothness (Fig. 4) while easily washable, followed by reducing chemical discharge. It was observed that the starch swells and gelatinizes, forming a continuous, flexible film around the yarn (Fig. 4).

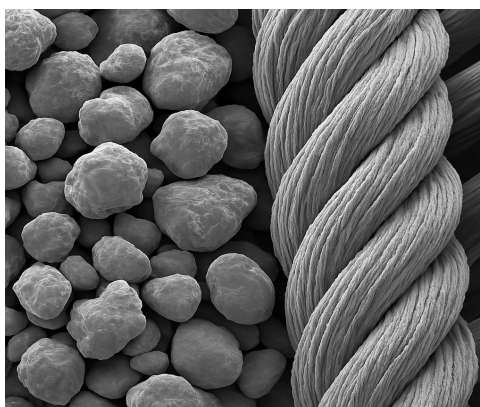


Figure 4: The contrast between the granular structure of starch and the fibrous nature of cellulose is clearly visible as $(C_6H_{10}O_5)_n + H_2O \rightarrow$ Gelatinized starch

The interaction between yarn fibers and sizing agents involves complex chemical bonding, film formation, and adhesion mechanisms (Fig.3). It was observed that a higher temperature desired dryness was achieved compared to lower. This phenomenon is attributed to the molecular restructuring of the yarn polymers under stress, which is intensified by the thermal and mechanical effects in the drying zone[6,12].

Chemical solutions that optimize the molecular weight and concentration of sizing agents are proposed to maintain negative or no stretch in the wet zone. Further exploration includes the use of cross-linking agents and additives to enhance the film-forming properties and flexibility of the sizing layer, thereby reducing the likelihood of warp breaks at the loom (Table 2).

Table 2: Size materials and auxiliaries used in weaving mills are mentioned below, along with their respective category and function

Materials	Chemicals	Function
Adhesive materials: Like modified starch, synthetic chemicals.	Bensize CD-298	-To increase strength.
	Sweet potato Maize Indica rice	-To impart adhesion, making the yarn less hairy. -To increase abrasion resistance. -To increase smoothness. -To increase elasticity and stiffness.
Wetting agent	surfactant	-It increases size exhaust.
	PVA	-To obtain a uniform distribution of sizing solution on yarn surface. -It helps to wet yarn instantly.
Acrylic sizing agent	Netacryl SS-100 Size-Bond-CO Acrylic Size RG	Ideal sizer for 100% polyester filament/spun and blended yarn. It will give better performance on fully automatic machines.
Lubricants softener	Neterlube AO-60	-It makes the yarn soft and slippery.
	Size soft-81 Fatty acids	-It reduces stiffness. -It increases yarn smoothness. -It increases elasticity.
Antifoaming agent	Defoamer RF	-To prevent foam formation.

CONCLUSION

Although starch and cellulose do not chemically react, starch's ability to physically bond with cellulose fibers makes it an excellent sizing agent for yarn. It enhances strength, reduces friction, and improves weaving performance while being easily removable.

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