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Fabrication and Characteristics of Sustainable Needle Punched Non-Woven from Water Hyacinth and Okra Fibres

Anuja Sri C[1], Geetha Margret Soundri S[2], Poornisha K[3]
[1]M.Sc. Student, [2]Associate Professor, [3]Research Scholar, Department of Costume Design and Fashion, PSG College of Arts and Science, Coimbatore

Abstract: The textile sector is among the rapidly expanding industries; however, it significantly contributes to pollution, depletion of resources, and waste accumulation. As sustainability gains importance, the sector is progressively embracing environmentally friendly materials, renewable resources, and advanced sustainable manufacturing practices. Water hyacinth, which is a floating perennial water plant, is a considerable threat to biodiversity. It decreases the levels of dissolved oxygen in aquatic environments and obstructs the natural water flow. In spite of its ecological ramifications, it has a high fiber content and absorbs water similarly to cotton. This research examines the method used for extracting fiber from water hyacinth. The okra stem, a semi-woody product that comes from agricultural byproducts, is combined with the fiber from water hyacinth. The publication discusses the characteristics of these fibers and improves the efficacy of the non-woven needle punching technique utilizing them. This research emphasizes the possibility of merging water hyacinth and okra fibers for creating appropriate non-woven textiles that meet the increasing environmental needs.

Keywords: Nonwoven fabrics, water hyacinth fibre , Okra fibre, Needle punched mechanism

I. INTRODUCTION

Sustainability has become a major priority, prompting sectors like construction, engineering, and textiles to shift away from non-renewable materials in favor of renewable, bio-based options. This transition mirrors contemporary industrial approaches that emphasize ecological sustainability and the enduring availability of resources. [2]Textiles are anticipated to be instrumental in transforming the fashion industry by adapting to swift technological developments and changing consumer needs. The water hyacinth is a fast-growing aquatic species that adjusts effortlessly to different environmental settings. Its rapid growth and renewability have led to its recognition as a promising natural fiber source. A noteworthy characteristic of this fiber is its substantial holocellulose content, which boosts its effectiveness as a reinforcement in material uses. Natural fibers such as water hyacinth can be utilized within synthetic polymer matrices as fillers to enhance their physical and mechanical properties, thereby satisfying the requirements of specific applications.[1]

Okra is a crop that is straightforward to cultivate, owing to its resilience to drought and low water needs. Although agricultural stem waste has been studied for potential uses over the last fifty years, concentrated research into fiber extraction from this waste has only accelerated in the past decade. Okra fibers are obtained from the leftover stems after harvesting the okra plant, Abelmoschus esculentus, which is part of the Malvaceae family. These stem leftovers, which were often seen as agricultural by-products, are now acknowledged as a significant source of natural fiber. [10] The chemical makeup of okra stem fibers is comprised of about 67.5% α-cellulose, 15.4% hemicellulose, 7.1% lignin, 3.4% pectin, 3.9% fats and waxes, and 2.7% water-soluble elements. The high level of α-cellulose suggests strong possibilities for use in textiles and composites, while lignin and hemicellulose support the overall strength of the fibers.

In general, plant fibers are more cost-effective and readily obtainable than many other types of natural fibers. Therefore, combining various plant fibers can reduce manufacturing costs while maintaining or even improving the fabric's desired functional and aesthetic qualities. Since plant fibers are biodegradable and sourced from renewable materials, their mixture with other natural fibers aids in the creation of more eco-friendly and sustainable nonwoven products, addressing the rising consumer interest in green goods. [4,5] The combination of different plant-based fibers in the production of nonwoven textiles presents numerous benefits. By cleverly blending fibers with complementary attributes—like durability, strength, moisture management, or flexibility—producers can enhance the overall functionality, performance, and versatility of the end product.

Additionally, such blending promotes resource optimization and waste utilization, thereby enhancing the sustainability credentials and usage potential of nonwoven fabrics.[5]

II. CLASSIFICATION OF PLANT BASED FIBER

Due to their significant amounts of cellulose and lignin, natural fibers derived from plants are called lignocellulosic fibers, making them the most commonly found type of natural fiber. These fibers are categorized mainly into two groups: woody fibers, which contain a high level of lignin, and non-woody fibers, which have a lower lignin content. Bast fibers are sourced from the stems of dicotyledonous plants, one of the two primary classes that encompass all flowering plants, characterized by having two cotyledons, or seed leaves. In plants, bast functions as a tissue for nutrient transport to various parts of the organism, primarily composed of sieve tubes. This tissue can yield fiber bundles consisting of elongated, thick-walled cells interconnected at both ends and sides. Known for their soft texture and typically greater length than hard fibers, these fibers are often classified as soft fibers.[6]

A. WATER HYACINTH FIBER

Water hyacinth stems can be gathered from a local river after locating mature specimens that are roughly 15 to 30 inches long and have a diameter of 0.15 to 1.2 inches. The collected plants need to be rinsed thoroughly with clean water to eliminate any dirt. Following the rinsing process, the roots and leaves should be detached, with only the stems kept for subsequent processing. [1] The gathered stems are then treated chemically to boost their absorbency and enhance the quality of the fiber.

Various techniques are employed for the collection of Water hyacinth, which includes physical, chemical, and mechanical methods:

- Physical techniques involve the manual cutting and removing of the plants using simple tools or hand-operated equipment. Sometimes, the plants are cut from the water's surface and loaded onto barges for transportation.[3]
- Chemical techniques make use of herbicides to manage or eradicate water hyacinth proliferation. Nonetheless, this method is often less favored due to the possible environmental hazards and harm to ecosystems.
- Mechanical techniques utilize specialized machinery to effectively gather and extract substantial amounts of water hyacinth from water sources.

Among these, physical and mechanical techniques are more frequently employed for fiber extraction, as they reduce chemical contaminants and promote sustainable use of the plant biomass.[3]

B. OKRA FIBER

The okra plants were gathered while still fresh and green, and the stems were sorted and bundled for the purpose of extracting fibre. A method involving stagnant water was implemented for retting. The gathered bundles were submerged in water for around two weeks to facilitate the natural action of microorganisms, which helped to decompose the pectin and other substances that bind the fibres together. Following the retting process, the softened outer layer was carefully beaten and manually scraped away.[9,10]

The extracted fibres were subsequently cleaned, brushed, and dried under the sun until they were entirely free from impurities and odours. The entire extraction procedure lasted roughly 17 days, encompassing both soaking and drying phases. The yield of fibres was roughly 4% in relation to the weight of the fresh plants. The fibres obtained from the residual okra stems possess an amorphous nature due to their lignocellulosic makeup. The main components of these fibres consist of cellulose, hemicellulose, and lignin.[9] The unique attributes of these elements play a crucial role in determining the physical, mechanical, and chemical characteristics of the fibres.

III. NEEDLE PUNCHINGMECHANISM

Needle punching stands as one of the most ancient methods for creating nonwoven fabrics, with its use in industry tracing back to the 1870s. It is commonly utilized for crafting nonwoven materials that are medium to heavy in weight. In this mechanical bonding method, a mass or batt of fibers is repeatedly pierced by specially crafted barbed needles. These needles operate by moving vertically through the fiber web, leading to an interlocking and entangling of the fibers. The structure's adhesion is achieved through the intertwining of fibers and the frictional forces that arise from compression, yielding a strong and unified fabric that does not require adhesives.[7]

The process of producing nonwovens generally consists of three primary phases: web creation, consolidation, and finishing. These phases may be carried out individually or in a continuous manner.

During the web creation phase, fibers are frequently fed through a carding machine, which utilizes rotating drums equipped with fine wire bristles to comb and align the fibers into a consistent web. The choice of web creation method is influenced by the characteristics of the fibers, including length and fineness.

There are various consolidation techniques available, such as needle punching, hydroentanglement, thermal bonding, and stitch bonding. However, the majority of research focused on nonwovens made from plant materials highlights needle punching, as it is particularly suitable for natural fibers.

The final characteristics of nonwovens created through needle punching are determined by several factors. The properties of raw materials—including fiber length, fineness, type, cross-sectional shape, crimp, and mechanical strength—are crucial. The orientation of the fibers within the web also affects the performance of the fabric. Furthermore, parameters related to the machinery, such as needle density, penetration depth, and both entry and exit speeds, can be modified to achieve the desired structural and mechanical attributes.[8] Given that plant fibers originate from natural growth or cultivation, their quality and yield can fluctuate based on environmental factors, including sunlight, moisture, pests, and overall plant health. These fluctuations may further affect the attributes of the resulting nonwoven fabric.

Different types of plant fibers exhibit distinct physical and mechanical attributes. By combining them with other fiber types, it becomes possible to merge their unique strengths and attain a wider variety of functional features. Such combinations facilitate the creation of nonwoven fabrics with customized properties, making them appropriate for a range of specific applications and requirements.

IV. APPLICATIONS

Needle-punched nonwoven textiles are extensively utilized in numerous fields like blankets, shoe interiors, felts for papermaking, protective layers, thermal and sound insulation, medical fabric, filtering media, and geotextiles. Alongside industrial uses, these fabrics are also prevalent in household textiles. They function proficiently as linings in items like placemats, coasters, table runners, and other useful or decorative domestic products, offering support, padding, and thermal insulation.

This production method allows for the creation of nonwoven textiles with a range of functional characteristics, which can be customized by selecting specific fibers, web development methods, and consolidation processes. In addition, machine settings—such as the density of needle-punching, depth and speed of penetration, and fiber arrangement—significantly influence the final nonwoven material's strength, thickness, porosity, and overall effectiveness.

V. CONCLUSION

This evaluation focuses on the shift to using natural plant-based fibers in nonwoven products, motivated by a growing concern for the environment and a need for eco-friendly options to replace synthetic fibers. Plant-based fibers have been recognized as an attractive, environmentally friendly alternative to traditional synthetic options, mainly because they can biodegrade and can be recycled. In conclusion, this piece acts as an in-depth examination of plant fiber nonwovens in the textile industry, underscoring the critical nature of this area while highlighting how plant fibers can offer sustainable and ecologically sound answers applicable across various industries.

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