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Development of Natural Fiber Nonwovens for Thermal Insulation

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Abstract

Natural fibers are employed in large numbers for making nonwovens by replacing the synthetic fibers due to environmental consciousness. This study aims to investigates on the properties of the needle punched nonwoven fabrics made of natural fibers extracted from the plants such as Sansevieria stuckyi, Banana and Hemp for assessing their suitability for Insulation products. The prepared fabrics are analyzed for the physical properties such as thickness, areal density, bulk density, air permeability, porosity, stiffness and thermal conductivity and the results are reported.

Keywords: Banana, Fiber, Hemp, Insulation, Nonwoven, Sansevieria stuckyi, Thermal conductivity

INTRODUCTION

Today the nonwoven technology is considered as the most modern method constitutes for the low cost substitutes for producing textiles. Among textile applications, nonwoven are one of the fastest growing sector constitutes about one-third of the fiber industry [1]. The commonly used fibers include natural fibers (Cotton, Jute and Flax), synthetic fibers (Polyester, Polypropylene and Viscose) and special fibers (Glass, Carbon and Superabsorbent fibers) [2-4]. The properties and performance of the fabrics are influenced by the fiber characteristics such as fiber diameter, length, tensile properties and the structure of the nonwovens [5]. Based on the properties, the nonwoven fabrics are used in large number of applications such as membranes, bio-medical devices, automotive textiles, constructional textiles for acoustic and thermal insulation, filtration applications and as oil sorbents [6].

Needle punching nonwoven fabrication is one of the simplest and oldest methods of textile fabric. The needle punched nonwoven fabrics are has the feasibility for new application called acoustics and thermal insulation. The nonwoven fabric has a porous structure to hold the sound and take much time to transfer the heat. Hence the needle punching technique of nonwoven is used for the study.

While considering the natural fibers, the Sansevieria stuckyi plants are grown abundant in rocky areas with the maximum leaf length and the fibers obtained from leaves are more smooth and lustrous. The Sansevieria stuckyi fibers are the emerging fiber with good cellulose content and physical properties. The banana fiber is a natural plant fiber extracted from the pseudo stem, composed of a true stem forming center core which is encircled by many long sheaths. The fiber can be obtained from the pseudo stem using different methods results in soft or coarse fibers [7]. The banana fiber has good cellulose content with good strength, elongation and absorption properties compared to other fibers and are environment friendly [8]. Hemp fiber is extracted from the bast of perennial plant called *Cannabis* cultivated in wastelands. The hemp fibers are graded according to color, cleanliness, lustre, density and strength [9]. Hemp fiber has the common characteristics such as good absorption, high strength, soft, slender, good air permeability and has antibacterial functions [10]. Hemp fibers are used earlier as a substitute for flax and some synthetic fibers. With the intention of biodegradability, environmental protection and to utilize the agricultural waste as natural resources for the development of green fiber and as reinforcement for synthetic materials in the technical textiles these fibers have chosen for the study.

The research is concerned with the development of needle punched nonwoven fabrics by utilizing the natural fibers for greater economic benefits. In this study, the needle punched nonwoven fabric is developed from the natural fibers such as Sansevieria stuckyi, Banana and Hemp. The prepared nonwovens are analyzed for the physical properties such as thickness, areal density, bulk density, air permeability, porosity, mechanical properties such as tensile strength and elongation and for the thermal characteristics such as thermal conductivity and resistivity. The influence of fiber properties on the nonwoven fabrics are analyzed and reported.

MATERIALS

The Materials need for the study is the matured Sansevieria stuckyi plants (Fig. 1a) which are collected from the forest areas of Coimbatore, Tamil Nadu, India, to obtain the Sansevieria stuckyi fibers (Fig. 1b). The pseudo stems of cultivated banana plants ((Fig. 1c) are collected from the farm lands of Pollachi, Tamil Nadu, India, to extract the Banana fibers (Fig. 1d). The Hemp fibers (Fig. 1e) are purchased form the local market of Coimbatore, Tamil Nadu, India.

(a) **(b)** **(c)** **(d)** **(e)**

Figure 1: (a) Sansevieria stuckyi plants (b) Sansevieria stuckyi fibers (c) Banana pseudo stem (d) Banana fibers (e) Hemp fibers

METHODS

Fiber Extraction

The fibers from the above collected Sansevieria stuckyi leaves and banana pseudo stems are extracted using the decorticator, washed and dried in shade. The physical, mechanical and structural properties of the fibers are analyzed and used for the further process.

Needle Punching

The extracted fibers are precut to the length of 6 – 9 cm. the fibers are opened manually in order to avoid damages during further processing. The fibers are then fed into the Dilo nonwoven plant consisting of opener, circular drums for carding and needle loom. During the operation the pre-needled web was prepared and the layers of the web were entangled by needle punching using barbed needles in the needle loom. The details of the needle punching operations are given in table 1. The prepared nonwoven fabrics are shown in figure 2.

Table 1: Details of Needle punching operation

Parameter	Values	Parameter	Values
Machine width	100 cm	No. of needle board	2
Working width	60 cm	No. of needles	5000
In feed speed	0.75 m/min	Needle penetration depth	12 mm
Draw off speed	0.60 m/min	Punch density	25 punch/cm^2
Type of Lay	Parallel	Stroke frequency	225 strokes/min
No. of laps	30	Needle motion	Down stroke

(a) **(b)** **(c)**

Figure 2: Needle punched Nonwoven fabrics (100%)

(a) Sansevieria stuckyi (b) Banana (c) Hemp

TESTING AND EVALUATION

Testing of Fibers

The extracted fibers are analyzed for the physical properties such as length, diameter (SEM), fineness (ASTM D 1577); mechanical properties such as single fiber strength and elongation (ASTM D 3822) by standard test methods and the structural properties using Scanning Electron Microscope (SEM).

Testing of Fabrics

The prepared nonwoven fabrics are tested for the physical properties such as thickness (ASTM D 5729), areal density (ASTM D 6242), bulk density (ASTM D 3776), air permeability (ASTM D 737), porosity (ASTM B 809) and bending length and flexural rigidity using Shirley stiffness tester according to ASTM D 5732 – 95. The insulation properties of the nonwovens are analyzed by testing the thermal conductivity and resistivity using lee's disc method.

RESULT AND DISCUSSION

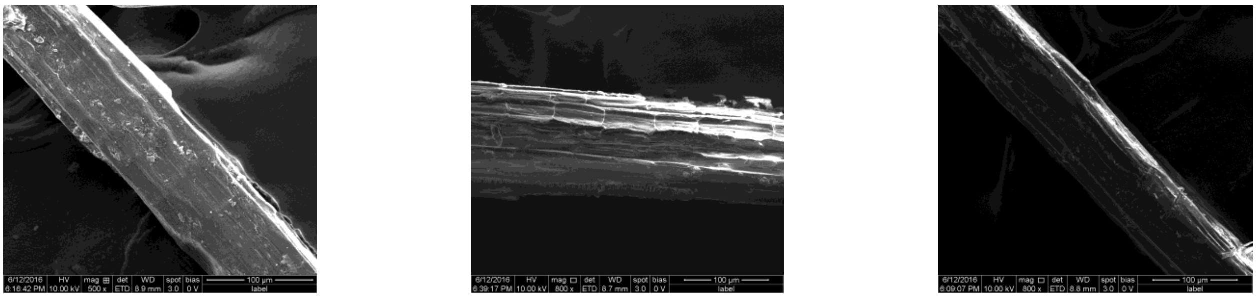
Evaluation of Fiber Properties

The table 2 shows the physical properties of the Sansevieria stuckyi, Banana and Hemp fibers. The structural characterization of Sansevieria stuckyi (Fig. 3a), Banana (Fig. 3b) and Hemp (Fig. 3c) fibers are shown in figure 3.

Table 2: Fiber Properties

Fiber Properties	Sansevieria stuckyi	Banana	Hemp
Fiber Length (cm)	116.2 ± 5.28	112.6 ± 3.94	119.9 ± 9.87
Fiber Diameter (µm)	367.8 ± 17.26	424.8 ± 9.57	107 ± 3.91
Fiber Fineness (tex)	7.67 ± 0.27	4 ± 0.94	18.1 ± 3.14
Single fiber Strength (g/tex)	379.5 ±11.74	477.35 ± 88.27	232.05 ± 62.19
Elongation at break (%)	2.99 ± 0.35	1.60 ± 0.48	0.47 ± 0.23

Note: Mean ± Standard Deviation



(a) (b) (c)

Figure 3: Scanning Electron Microscope images of fibers (100 µm)
(a) Sansevieria stuckyi (b) Banana (c) Hemp

EVALUATION OF FABRIC PROPERTIES:

The table 3 shows the properties of needle punched nonwoven fabrics made of Sansevieria stuckyi, Banana and Hemp fibers.

Table 3: Fabric Properties

Fabric Properties		Sansevieria stuckyi	Banana	Hemp
Thickness (mm)		6.19	6.22	6.14
Areal Density (g/m^2)		530	533	525
Bulk Density (g/cm^3)		0.089	0.088	0.091
Air Permeability ($cc/s/cm^2$)		31.99	34.21	26.89
Porosity (%)		93.50	93.48	93.85
Stiffness (inch)	Machine Direction	7.86	6.75	7.92
	Cross Direction	7.60	5.55	7.32
Thermal conductivity (W/mK)		0.044	0.041	0.049
Thermal Resistance (m^2K/W)		0.134	0.147	0.118

1. Effect of Natural fibers fineness on thickness of fabric:

The figure 4 shows the influence of fiber fineness on Thickness of nonwoven fabric. From the figure, it is clear that the increase in fiber fineness tends to decrease the thickness of the nonwoven fabric. Lower the density of fibers leads to more number of fibers per unit area of the nonwoven fabric and thus increases in thickness of the samples and result in the reduction of nonwoven fabrics Bulk Density. Thus it is concluded that the areal density, thickness and bulk density are the interrelated physical parameters of needle punched nonwoven fabrics which simultaneously changes due to the needling operation.

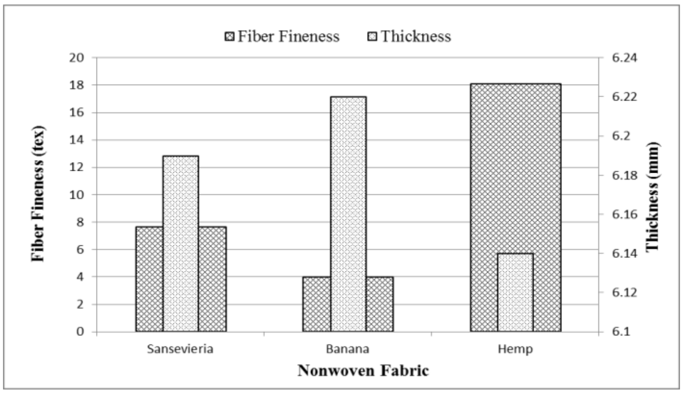


Figure 4: Effect of Natural fibers fineness on thickness of fabric

2. Effect of Natural fibers fineness on Air Permeability of the fabric:

The figure 5 shows the influence of fiber fineness on Air Permeability of nonwoven fabric. From the figure, it is clear that the increase in fiber fineness tends to increase the air permeability of the nonwoven fabric. Hence it is concluded that due to the higher density of the fiber and the porous structure of the fabric the mass of the fabric increases with the increase in air permeability. In this study, the Banana nonwoven fabric shows the high air permeability compared to other samples with the decreasing order of Banana > Sansevieria Stuckyi > Hemp. These differences may due to the higher diameter of the fiber.

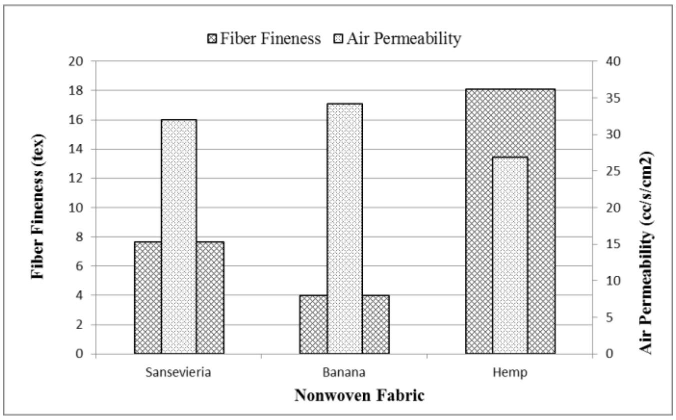


Figure 5: Effect of Natural fibers fineness on Air Permeability of the fabric

3. Effect of fibers on Thermal Conductivity:

The figure 6 shows the effect of fibers on thermal conductivity of nonwoven fabric. From the figure, it is clear that the higher thermal conductivity of the Hemp is due to increase in fiber density and decreases in the order of Hemp > Sansevieria stuckyi > Banana.

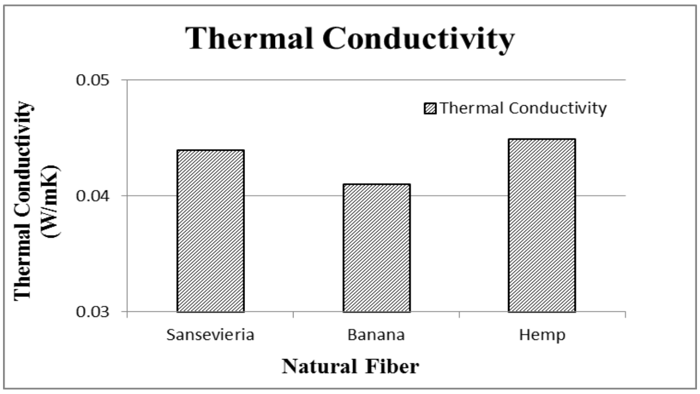


Figure 6: Effect of fiber on Thermal Conductivity

CONCLUSION:

The conclusion emerges from the study are,

1. The physical parameters of needle punched nonwoven fabrics like thickness, areal density and bulk density are interrelated and are changed simultaneously due to the needling operation and can be controlled with the carding and needling.
2. Higher the diameter of the fiber; higher the air permeability of the nonwoven fabric. Thus the natural fiber with higher air permeability helps to transmit sound waves and may results in high sound absorption of the material. Thus these nonwoven fabrics may be used for acoustic materials in automobiles and room interiors.
3. The thermal conductivity of the nonwoven fabric prepared with natural fibers like Sansevieria stuckyi, Banana and Hemp shows that the fabric is suitable for insulation materials.
4. Thus the biodegradable products from natural resources are developed from the plant fibers are used in the technical textiles as an alternative for synthetic fibers.

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