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EFFECT OF BLENDING RATIO OF WATER HYACINTH FIBERS ON THE PROPERTIES OF NEEDLE PUNCHED NONWOVEN FABRICS

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***Abstract* — Water hyacinth (Eichhornia Crassipes) is a free floating aquatic plant. When not controlled, grows rapidly, covers the water sources and creates a serious threat to bio-diversity. The plant is rich in cellulose content; hence it can be effectively utilized by extracting the fibers from its stem part and used as reinforcement for textile applications. This paper is an investigative study on the manufacture of nonwoven fabrics from the Water hyacinth fibers. It has been seen that the techniques used were carding for web formation and needle punching for web bonding. Water hyacinth fibers were blended with Sansevieria stuckyi fibers in order to investigate the acoustic performance of this newly known natural fiber. For this, the different blend ratios of Water hyacinth/Sansevieria stuckyi fibers were prepared. The physical, mechanical and functional properties of needle punched nonwoven fabrics have been analyzed. The influence of blend proportion of Water hyacinth fiber on the properties of nonwoven such as thickness, areal density, bulk density, porosity, stiffness, air permeability and thermal conductivity have been reported.**

***Index Terms* — Natural fiber, Needle punching, Nonwoven, Sansevieria, Water hyacinth.**

I. INTRODUCTION

Environmental awareness has prompted the population and industries for the procurement of better use of natural renewable resources. The industries, particularly in developed countries are now constantly focusing to develop new sustainable and environmental friendly products and materials using such precious renewable resources [1]. In past decades, efforts were made to produce environmental friendly products by recycling of wastes to capitalize the green movement [2]. Now the time has changed, the industries are looking for inputs from direct natural resources in more positive way. Natural inputs are considered as technically valid components as well as contribute more in pricing the premium final products because of their superiority in environment and social responsible attributes like production and disposals [3].

In technical applications of textiles, naturally derived fibers are increased in proportions thereby utilizing the renewable resources to replace synthetic fibers in wide range including nonwoven products [4]. The natural fibers include Cotton, Jute, Hemp and Bamboo are well known and commercially available. There emerges the possible risk of overconsumption and depletion of resources. Hence the research concerned with expansion of uses and value addition to the products prepared using farm, forestry and wetlands is technologically advanced for greater economic benefits [5]. As a result, research activity has attracted towards an aquatic plant named Water hyacinth due to its congested growth and fast spread which lead to serious problems. The Water hyacinth plants grow vigorously with double their population in two weeks [6]. When the plant is looked as a resource, it consists of many unique properties. The utilization of Water hyacinth plant has bloomed in past decades and the areas of application were fertilizer, biogas, furniture, paper making and waste water effluent [7].

The goal of this research is to produce fibers from the natural resources and to utilize in textile industry as a reinforcement of synthetics and other commercial fibers. As a result, Water hyacinth fibers were extracted from the dried stalks of Water hyacinth plants (Eichhornia Crassipes), a free floating perennial plant native to South America. The plant is available in abundance; it can be successfully utilized as an alternative to other textile fibers by incorporating in the value added products such as nonwoven for technical applications [8] [9].

The nonwoven fabrics have the applications such as acoustics, thermal insulation, biomedical devices and membranes. The raw materials used for the production of nonwoven include natural and synthetic fibers. Nonwovens have the tailored characteristics such as lightweight, flexibility, mold ability, low process and material cost, sound efficiency, performance ratio and recyclability [10]. The Water hyacinth fibers have the good physical and mechanical properties it has been developed into a needle punched nonwoven fabric by blending with Sansevieria stuckyi fibers. The study aimed to analyze the properties of the nonwoven fabrics and its influence on various blend proportion.

II. MATERIALS AND METHODS

A. Fiber Extraction

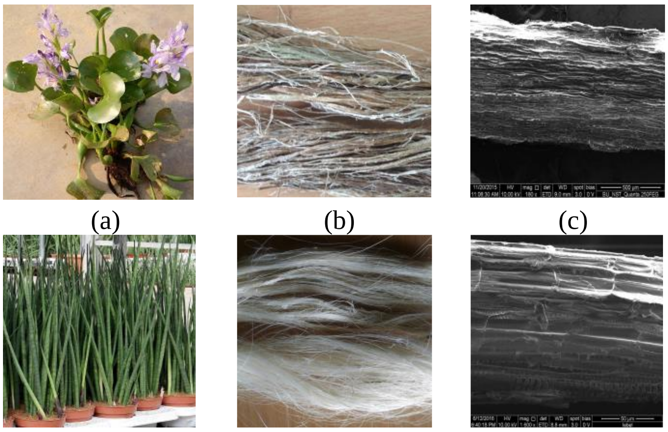
The Water hyacinth fibers were extracted from the matured stalks of Water hyacinth plant (Figure 1 (a)) which produces good number of fibers than the younger ones. The fibers were extracted from the dried stalks of Water hyacinth plants us by scrapping the stalks using needles [8], [9]. The morphology of the Water hyacinth fibers were shown in the Figure 1 (b) and Figure 1 (c). The Sansevieria stuckyi plants (Figure 1 (d)) are procured from the local sources around Coimbatore, Tamil Nadu, India and the fibers were extracted from the leaves using decortication method. The structural appearance of the

Sansevieria stuckyi fibers were shown in Figure 1 (e) and 1 (f). The properties of the extracted fibers were given in the Table I.

TABLE I. FIBER PROPERTIES

Fiber Properties	Fiber Properties	Fiber Properties
Staple Length (mm)	79.3 + 5.33	79.67 + 4.55
Fiber Diameter (µm)	819.5 + 39.96	367.8 + 17.26
Fiber Fineness (tex)	3.88 + 0.31	7.67 + 0.27
Density (g/cm3)	1.22 + 0.05	1.37 + 0.05
Single fiber Strength (g/tex)	220.5 + 76.51	379.5 + 11.74
Elongation at break (%)	2.8 + 0.81	2.99 + 0.35

(Mean + Standard Deviation)



(d) (e) (f)

Fig. 1: Plants and Fibers (a) Water hyacinth Plant (b) Digital image of Water hyacinth Fiber (c) Scanning Electron Microscopic view of Water hyacinth Fiber (d) Sansevieria stuckyi Plant (e) Digital image of Sansevieria stuckyi Fiber (f) Scanning Electron Microscopic view of Sansevieria stuckyi Fiber

B. Material Properties and Blend Proportion

The properties of nonwoven fabric mainly depend on the characteristics of the fiber and the method of manufacturing. Since Water hyacinth is a hollow fiber the influence of its properties over the nonwoven fabric is analyzed by mixing with other stalk fiber called Sansevieria stuckyi fibers at different ratios varying from 25 % to 75 %. The processing of 100% Water hyacinth fiber is not practically possible due to less cohesiveness, breaking of fibers and falling of web during web formation in carding and hence it is blended with other fibers. The Water hyacinth fibers are blended with Sansevieria stuckyi fibers, an emerging fiber with good physical properties in acceptable rate [11] and to analyze the same by changing its ratios within the sample. The constructional details of the nonwoven with blend ratios are given in Table II.

TABLE II. NOMENCLATURE OF NONWOVEN FABRIC

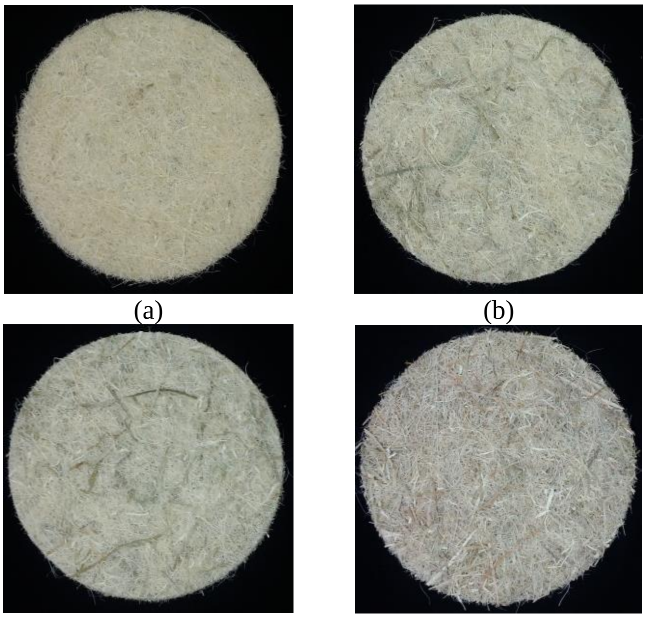
Sample	Sample code	Blend ratio of fibers in nonwoven fabric (%)	
		Sansevieria stuckyi (S)	Water hyacinth (WH)
1	S100	100	-
2	S75/WH25	75	25
3	S50/WH50	50	50
4	S25/WH75	25	75

C. Preparation of Needle Punched Nonwoven Fabrics

Both fibers are pre-cut to 6 to 9 cm in length. The fibers are then manually opened in order to prevent any undesirable damages and to decrease the probability of reduction in fibers length. Four different blends of the Water hyacinth and Sansevieria fiber are prepared at required weight ratios as given in Table II and mixing is done manually to ensure homogenous web. The blended fiber web is then fed into the Dilo nonwoven plant consisting of card, circular drums and needle loom. The pre-needled web was prepared and the layers of web were parallel laid, overlapped and are needle punched where the fibers are entangled by needle barbs. Needle punching was performed on 60 cm wide sample needle loom which uses regular barb needles. The needles are arranged in offset lines. The penetration of needles is 12 mm on both sides. Increase in needle penetration depth results in deeper interlocking and entanglement of fibers. The details of the needle punching operation are given in the Table III and the prepared nonwoven fabric samples are shown in Fig. 2.

TABLE III. DETAILS OF NEEDLE PUNCHING OPERATION

Parameter	Values
Machine width	100 cm
Working width	60 cm
No. of needle board	2
No. of needles	2500
Needle penetration depth	12 mm
Punch density	25 punch/cm2
In feed speed	0.75 m/min
Draw off speed	0.60 m/min
Stroke frequency	225 strokes/min
Needle motion	Down stroke
Type of Lay	Parallel
No. of Lay	30



(a) (b) (c) (d)

Fig. 2: Needle punched Nonwoven fabrics
(a) S100 (b) S75/WH25 (c) S50/WH50 (d) S25/WH75

D. Testing and Evaluation of Nonwoven Fabrics

The standard test procedures were used to evaluate the properties of the nonwoven fabrics such as Areal density (ASTM D 6242), Thickness (ASTM D 5729), Bulk density (ASTM D 3776), Porosity (ASTM B 809), Stiffness using Shirley stiffness tester, Air permeability (ASTM D 737) [12] and Thermal Conductivity using Lee's Disc Method.

III. Result and Discussion

The properties of needle punched nonwoven fabrics made from Sansevieria stuckyi and Water hyacinth fiber blends are shown in Table IV.

TABLE IV. Properties of Needle Punched Nonwoven Fabrics

Properties		***Sample Code***			
		S100	***S75/WH25***	***S50/WH50***	***S25/WH75***
Areal Density (g/m^2)		530	538	543	549
Thickness (mm)		6.19	6.27	6.32	6.41
Bulk Density (g/cm^3)		0.089	0.087	0.086	0.085
Porosity (%)		93.50	93.41	93.33	93.20
Stiffness (inch)	Machine Direction	7.86	7.42	7.34	7.25
	Cross Direction	7.60	7.20	6.85	6.25
Air Permeability ($cc/s/cm^2$)		31.99	41.49	54.00	62.10
Thermal Conductivity (W/mK)		0.044	0.035	0.030	0.020

A. Effect of fiber blend proportion on Areal Density and Thickness

The Figure 3 shows the influence of fiber blend proportion on Areal Density and Thickness of nonwoven fabric. From the figure, it is clear that the increase in proportion of Water hyacinth fiber in the blend tends to increase the Areal Density and thickness of the nonwoven fabric. There is a linear relationship between increase in Water hyacinth fiber blend proportion with Areal density and thickness of nonwoven which is clearly shown in the correlation equation (1) and (2) with the Regression value (R^2) of 0.9907 and 0.9894 respectively. This could be due to the lower density of Water hyacinth fibers compared to Sansevieria stuckyi fibers and leads to more number of fibers per unit area of the nonwoven fabric. The increase in thickness of the samples with the increase in blend proportion of Water hyacinth fiber thus leads to result in the decrease of Bulk Density of the nonwoven fabric.

$$y = 6.2x + 524.5 \quad \text{---- (1)}$$

$$y = 0.071x + 6.12 \quad \text{---- (2)}$$

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 [13].

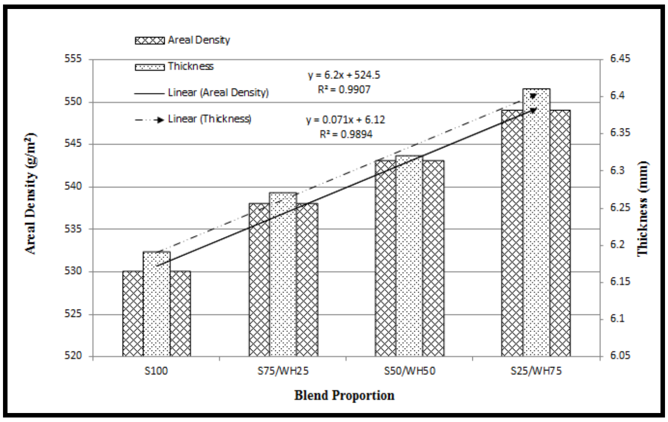


Fig. 3: Effect of fiber blend proportion on Areal density and Thickness

B. Effect of Fiber Blend Proportion on Areal Density and Air Permeability

The Figure 4 shows the influence of fiber blend proportion on Areal Density and Air Permeability of nonwoven fabric. From the figure, it is clear that the increase in proportion of Water hyacinth fiber in the blend tends to increase the air permeability of the nonwoven fabric. There is a linear relationship between Water hyacinth fiber blend proportions with air permeability of nonwoven which is clearly shown in the correlation equation (3) with the Regression value (R^2) of 0.9939. Hence it is concluded that when the mass of the fabric increases the air permeability also increases which is due to the density of the fiber in the blend proportion and the porous structure of the fabric. In this study, the sample S25/WH75 shows the high air permeability compared to other samples with the decreasing order of S50/WH50 > S75/WH25 > S100. These differences may due to the higher diameter and less density [14] of the Water hyacinth fiber.

$$y = 10.284x + 21.685 \quad ---- (3)$$

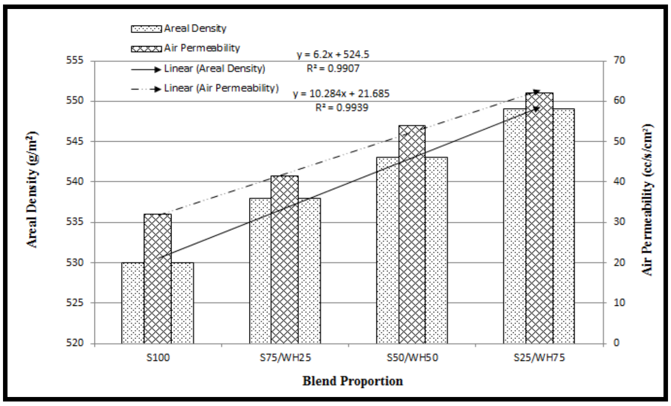


Fig. 4: Effect of fiber Blend proportion on Areal density and Air Permeability

C. Effect of Fiber Blend Proportion on Fabric Stiffness

The Figure 5 shows the linear relationship between the fiber blend proportion and stiffness of nonwoven fabric. The stiffness of nonwoven fabric decreases with the increase in Water hyacinth fiber proportion. This difference is due to the higher fiber strength of Sansevieria stuckyi fiber compared with Water hyacinth fiber. The equation (4) and (5) shows that there is a negative correlation between the stiffness and Water hyacinth blend proportion of the nonwoven fabric in both machine and cross directions respectively.

$$y = -0.201x + 7.995 \quad ---- (4)$$

$$y = -0.44x + 8.075 \quad ---- (5)$$

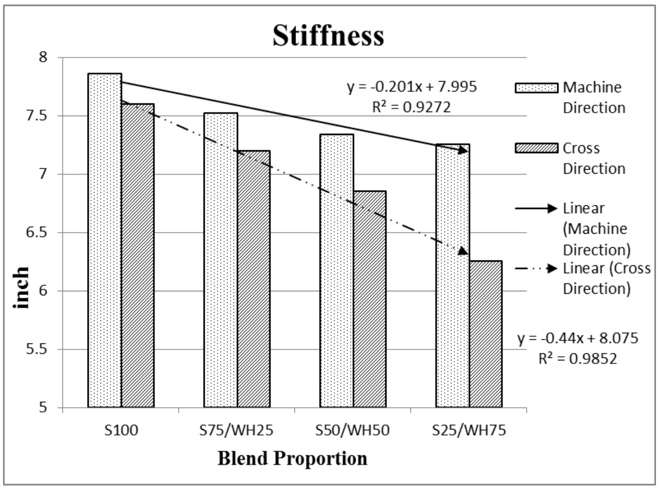


Fig. 5: Effect of fiber Blend proportion on Fabric Stiffness

D. Effect of Fiber Blend Proportion on Thermal Conductivity

The Figure 6 shows the effect of Water hyacinth fiber blend proportion on thermal conductivity of nonwoven fabric. From the figure, it is clear that the increase in proportion of Water hyacinth fiber in the blend tends to decrease the thermal conductivity of the nonwoven fabric. The equation (6) shows that there is a negative correlation between Water hyacinth fiber blend proportions and thermal conductivity of the nonwoven fabric. The higher thermal conductivity of the S100 is due to higher thickness of the fabric and decreases in the order of S75/WH25 > S50/WH50 > S25/WH75.

$$y = -0.0077x + 0.0515 \quad ---- (6)$$

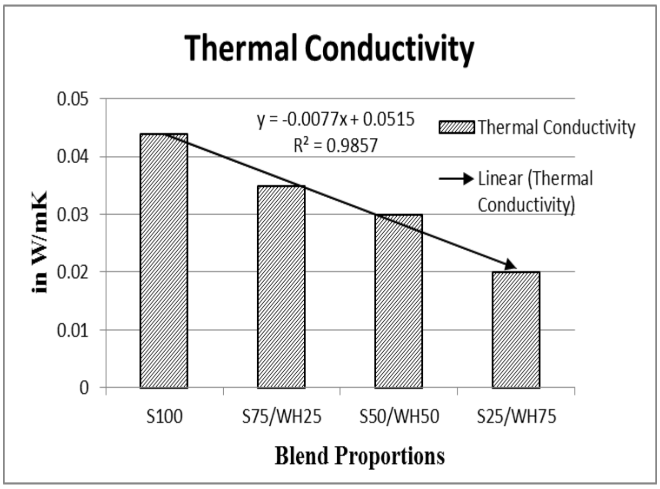


Figure 6: Effect of fiber Blend proportion on Thermal Conductivity

IV. Conclusion

The following are the conclusion emerges from the study.

1. 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 and can be controlled with the carding and needling.

2. The increase in diameter of the Water hyacinth fiber increases the air permeability of the nonwoven fabric thus helps to transmit sound waves and may results in high sound absorption of the material. Thus the fabric with Water hyacinth fiber may be used for acoustic materials in automobiles and room interiors.

3. The stiffness of nonwoven fabric decreases with the increase in Water hyacinth fiber proportion thus shows that the fabric with Water hyacinth fiber is easy to handle and are much comfort.

4. The thermal conductivity of the nonwoven fabric with Water hyacinth fiber blend proportions shows that the fabric is suitable for insulation materials.

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