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Tensile and Thermal Comfort Characteristics of Nonwoven Fabricsmade From Banana Pseudostem Fibres

KEYWORDS: Banana fibre, Nonwoven, needle punched, Tensile, Thermal

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ABSTRACT *India is the largest producer of banana fruit in the world and cultivated in an area of 0.77 million ha. After harvesting the fruit, the pseudostem is not used for any purpose and stems are dumped on the drainage. Fibres were extracted from these pseudostems and were used for the manufacture on nonwoven using needle punching process. Nonwovens were prepared with different areal densities and studied for its effect on tensile and thermal comfort characteristics. The tensile strength in length wise direction is found to be on the higher side when compared to width wise direction due to the fact that fibers are aligned in the machine wise direction during needle-punching process. Thermal insulation parameters measured namely clo, tog and TIV% decreases in value when the areal density of the fabric decreases. Banana fibre needle-punched nonwoven can be used as thermal insulation medium effectively.*

Introduction

Huge potential for nonwoven industry in India can be seen from the fact that Indian geotextiles, wipes, sanitary napkins and baby diapers are advancing at 23%, 12.8%, 20% and 5.6% growth rate respectively(Matt Carey, 2014). The per capita nonwoven fabric consumption in India, which is 350 gm now is expected to touch 600 gm by 2020, whereas the per capita consumption of nonwovens in developed markets such as US and Western Europe is around 3 - 3.5 kg(Joseph S, 2013). The raw materials used for production of nonwovens chiefly involve synthetic fibres, polypropylene being the major fibre consumed. Man-made fibres completely dominate nonwovens production, accounting for over 90% of total output. The world usage of fibres in nonwovens production is: Polypropylene 63%; Polyester 23%; Viscose rayon 8%; Acrylic 2%; Polyamide 1.5%; other fibres 3%(Joseph S, 2013). Due to enhanced concern towards environment, natural fibres are being used in the production of nonwovens. Natural fibre are environmentally friendly as they are biodegradable and natural fibres are being extracted through mechanical process they do not consume any chemicals during fibre manufacturing. Among the various techniques of manufacturing nonwovens, the needle punching process is widely used for natural fibres.

Needle-punched nonwoven fabrics were made from 100% jute fibres using various levels of fabric weight, punch density, and depth of needle penetration and it was observed that with the increase in fabric weight, tenacity, initial modulus, and work of rupture initially increase, but at greater fabric weight, though the tenacity becomes steady, initial modulus and work of rupture show a declining trend(Roy & Ray, 2009a). Elongation at break is reduced with an increase in fabric weight, punch density, and depth of penetration. After studying the effect of two parameters, punch density and needle gauge, on the properties of jute-polypropylene nonwovens(Lupu, Cramariuc, Hogas, &Hristian, 2013) reported that an increase in needling density is influencing the fabric weight more than an increase in needle gauge. In an another study, three types of nonwovens were developed using needle-punching technique by blending bamboo, banana, and jute fibers with polypropylene staple fibers and it was observed that the bamboo/polypropylene nonwoven with its compact structure showed, higher tensile strength, higher stiffness, lower elongation, lower thermal conductivity, lower air permeability, and good absorption coefficient(Thilagavathi, Pradeep, Kannaian, &Sasikala, 2010). Debnath (1983) observed that the needle punching process is the most suited to produce medium and heavy weight non-woven from 300 gsm to 3000 gsm. Blending cotton with flax in needle-punched nonwovens increased tensile, tearing and bursting strength, and influenced other properties normally affected by a high percentage of flax such as stiffness and resilience(Annis et al., 2005). Studies on banana fibres use in nonwovens in needle punching studies were carried out in blends with other natural and manmade fibres for making into composites(Joseph, Sreekala, Oommen, Koshy, & Thomas, 2002). It can be seen from the literature search that not much work is reported about the studies on the preparation of nonwovens from 100% banana pseudostem fibres.

India is the largest producer of banana fruit in the world and cultivated in an area of 0.77 million ha(Tiwari, 2014). After harvesting the fruit, the pseudostem is not used for any purpose and are dumped on the drainage. In this wok, fibres were extracted from these pseudostem and were used for the manufacture on nonwoven using needle punching process. Nonwovens were prepared with different areal densities and studied for its effect on tensile and thermal comfort characteristics.

Material and Methods

Banana pseudostems collected from farm were cut into two halves and sheaths are manually removed for processing. The sheaths were then fed into banana fibre extractor for separating fibres from sheath. Thus separated fibres were washed with water and dried in sunlight. The dried fibre strands were of varying length ranging from 0.75 to 1.5 metres. These fibres were combed using a steel comb and separated into single fibres and cut into single fibres of sufficient length so that it is properly gripped by jaws of Instron. These fibres were tested in Instron with a test length of 50 mm. The test speed was adjusted such a way that the fibre broke within 20±5 sec. Broken bits of each fibre after test was collected and weighed together to get the average tex value of the fibre tested. Fifty fibres are tested and the average breaking load and breaking elongation reported by the instrument was noted. The average tex value obtained by the using the weight of broken fibre bits was used to calculate the average tenacity.

The banana fibres weighing 500 kg was processed in a jute non-woven mill for the preparation of non-woven felts. The process flow chart of nonwoven preparation is given at Fig. 1. Full length banana fibre strands (without any cutting) was passed through mechanical softening machine having 21 helical fluted rollers and applied 15% emulsion on the weight of the fibre. The emulsion is made of 8.56% jute batch oil, 0.04% P40 Emulsifier and 91% Water. After the application of emulsion, banana fibre strands were piled for 24 hours. The pile was covered with hessian cloth. The temperature of the pile was checked after 24 hours and it was found to be 30 Degree Celsius. In case of jute, during piling the temperature goes up to 60 degree centigrade. Moisture content was checked using jute moisture meter and it was showing the maximum meter reading of 40%. The softened fibre was then fed to the spreader. In the spreader no emulsion was applied and linear density of lap was kept at 162 grams per yard. Each spreader lap was weighing around 20 kg.

Ten spreader laps were fed to breaker card and the breaker card lap linear density was kept at 60 grams per yard. The breaker card laps were taken to non-woven plant for needle punching. The breaker card laps were fed to the feeder card of needle punching machine. The output needle punched felt was measured for linear density and it was found to be 320 grams per metre. The draft at needle punching machine was reduced at the feeder card to prepare 450 gsm needle punched felt. The Needle punching machine used for the preparation of nonwoven felt has a width of 2.0 metre, running at delivery rate of 2.5 metres per minute with needle penetration depth of 12 mm. The width of the nonwoven felt produced was 1.3 metre. The same processing sequence used to produce three types of felts having gramps per metre of 500, 700 and 900 having a thickness of 3 mm, 5 mm and 6 mm respectively.

Thickness of nonwoven felt was measured using thickness gauge. In the thickness gauge the nonwoven felt was kept on a flat anvil and a circular pressure foot was pressed on it at a pressure of 100 gm/cm2 and the dial indicator directly indicates the thickness in millimetre. Ten readings are taken and average reported. Bursting strength was tested using bursting strength tester by applying load in multidirectional. Five specimens were cut from nonwoven felt and clamped over a thin rubber diaphragm and hydrostatic pressure is applied to the underside of diaphragm until the specimen bursts. The bursting pressure as indicated in the pressure gauge of the instrument was noted and average of five readings reported. For determining the weight per square metre, 10 cm x 10 cm specimen was cut from five places and weighed in precision balance. The average five readings value was used for calculation of weight per square metre. Tensile testing was carried out using universal testing machine with a cut strip of 5 cm x 20 cm and at the rate of traverse of 12 inches per minute. Five readings are taken for length way and five reading were taken for width way.

ThermoLabo II was used to obtain the thermal conductivity and thermal insulation value. The Instrument measures thermal conductivity by steady heat flow method. This method employs the steady state of thermal equilibrium to evaluate the thermal conductivity of the fabric. In this method, the energy required for maintaining a constant temperature gradient between a heat source and a heat sink is measured after a steady state dynamic equilibrium is reached. The Water-Box of the Thermolabo II was maintained at a constant temperature by circulating water. Temperature of BT-Box was adjusted to a temperature 10oC above that of the Water-Box. The specimen was laid flat over the water-box so that the bottom surface was in contact with the water-box. The BT-Box was then placed above the specimen and electrical energy required to maintain 10oC temperature difference between the BT-Box and Water- Box was noted from the instrument.

If Q is the heat energy required to maintain a constant temperature gradient between the BT-Box and Water box and ΔT is the temperature gradient between them then thermal conductivity K is given in the unit of W/cm^0C as-

$$K = Q.\ D/\Delta T$$

Where, D is the thickness (cm) of the specimen. The room temperature and relative humidity were 27°C and 65 % respectively. The mean of five measurements for every sample was calculated.

Thermolabo II was used to determine the thermal insulation based on Guarded Hot Plate Method. A 10cmX10cm large BT-Plate was used for this purpose. The fabric was kept over the BT-Plate, which was maintained at the human skin temperature (35°C). The BT-Plate was kept inside the wind tunnel which was maintaining an air draught of 0.1m/s. During the measurement, the sample mounted on the sample frame was placed on the large BT-Plate and the front door of the wind tunnel was closed. The specimen was allowed to come to thermal equilibrium and after that mean of energy consumption to maintain 10°C difference of temperature with the atmospheric temperature was noted from the display. Parameters like ambient temperature, BT-plate temperature and RH% were noted. This procedure was repeated twice for each specimen.

$$Thermal\ resistance = \frac{T1 - T2}{E} \times \frac{1}{10} \times A$$

Where T1 is Hot plate temperature in Centigrade, T2 is ambient air temperature, E is watt meter reading, and ‘A’ is area of specimen (1dm2). Thermal insulation in clo unit is calculated using the formula,

$$clo = 0.645 \times tog$$

The TIV is the percentage of reduction in heat loss when the body is covered with the given sample. Thus TIV is defined as-

$$TIV = \left(1 - \frac{Heat\ lost\ from\ the\ uncovered\ body}{Heat\ lost\ from\ the\ covered\ body}\right) \times 100$$

TIV is also called as warmth keeping ratio (α).

Results and Discussion

Banana fibre of grand naine variety which is used in this study is having characteristics similar to that of Jute fibre. The tensile characteristic of the banana fibres used in the preparation are having a fineness – 9.2 tex, Tenacity – 35.5 g/tex and elongation at break – 2.3%. Nonwoven fabric bursting and tensile strength are given at Table 1. It can be seen from the Table 1 that when areal density of the fabric increases the thickness of the fabric also increases. This is known fact and confirms the findings of earlier researchers(Anandjiwala&Boguslavsky, 2008). The tensile strength in length wise direction is found to be on the higher side when compared to width wise direction due to the fact that fibers are aligned in the machine wise direction during needle-punching process. Similar observation was reported in the study of Needle-punched nonwoven fabrics with three different areal weights made from staple polyester fibres(Thangadurai, Thilagavathi, & Bhattacharyya, 2014). Breaking load is increasing with the increase in areal density of the nonwoven fabric and rate of increase is 17%, when areal density is increased from 500 to 700 gsm and it is 17.6% when areal density is increased from 700 to 900 gsm for length way direction. In case of breaking load in width way, it was found that the increase is at the rate of 128% and 23.9% for areal density increase from 500 to 700 gsm and 700 to 900 gsm respectively. The rate of areal density increase in width way is very high in comparison to length way and this could be attributed to the fact that at lower areal density, the distribution of fibres are not uniform in the nonwoven fabric leading to poor cohesion and which in turn resulted in more thin places in the web of low areal density nonwoven fabric. Bursting strength of banana fibre nonwoven fabric is found to be in the range of 20.4 to 24.5 Kg/cm2. Bursting strength of needle punched jute nonwoven fabrics at 700 gsm was found to range from 100 to 150 N/cm2 depending up on punch density and depth of needle penetration(Roy & Ray, 2009b). As bursting strength is at par with jute nonwoven fabrics, it can concluded that banana nonwoven fabric can be used as a replacement to jute nonwovens, wherever bursting strength is a major requirement.

Thermal characteristics of banana nonwoven felt is given at Table 2. Thermal insulation parameters measured namely clo, tog and TIV% decreases in value when the areal density of the fabric decreases. This is due to the fact that decrease in fabric weight, the number of fibers unit area of the fabric decreases. This causes decrease in fabric thickness and also amount of pores in fabric structure, causing decrease in thermal insulation. No trend is observed for the thermal conductivity for change in areal density of nonwoven banana fibre fabric.

Conclusions

Banana fibre needle-punched nonwoven can be used as thermal insulation medium effectively. Thick and porous banana fibre needle-punched nonwoven contains evenly dispersed void, which are responsible for thermal insulation. Needle-punched nonwoven technology is highly suited for the production of nonwovens from banana fibres. Banana nonwovens can be converted into composites and can be exploited its use in geotextile, technical, agricultural, filter media, automobiles and industrial textiles due to its recyclable and biodegradable nature. Research work has been initiated to prepare various composites using banana nonwoven fibre with biodegradable binders for exploiting its use in automobiles particularly in car interiors.

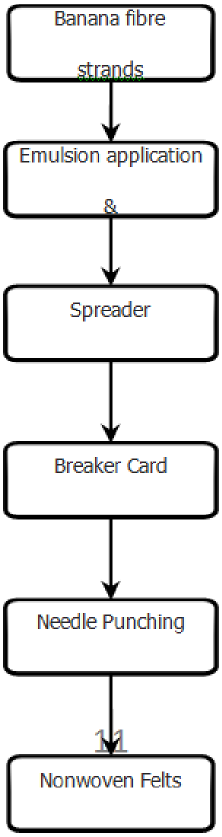
Table 1 – Tensile and bursting strength of nonwoven fabric

S.No.	Sample code	Thick-ness (mm)	Bursting Strength (Kg/cm^2)	Weight/ m^2 (grams)	Breaking load Length way (grams)	Breaking load Width way (grams)
1	500GSM/3mm	3.8	20.4	558	3460	1465
2	700GSM/5mm	5.3	22.6	817	4050	3347
3	900GSM/6mm	5.9	24.5	910	4762	4146

Table 2 – Thermal characteristics of nonwoven fabric

Parameter/Sample code	900GSM/6mm	700GSM/5mm	500GSM/3mm
Bulk Density (g/c^3)	0.056	0.065	0.086
Thermal Insulation (clo)	1.55	1.36	1.22
Thermal Insulation (tog)	1.00	0.88	0.79
Thermal Insulation Value (%)	79.06	76.07	73.31
Thermal Conductivity (W/cm°C)	3.299×10^{-3}	3.489×10^{-3}	2.312×10^{-3}

Fig 1 – Nonwoven process flowchart



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