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Design, Development, Characterization, and Application of Jute-based Needle-Punched Nonwoven

Sanjoy Debnath

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/61705>

Abstract

Out of different technical textiles, needle-punched nonwoven is one of the promising technical textiles which has wide ranges of applications. This present chapter deals with jute and synthetic fibre-based needle-punched nonwoven. The design and manufacturing of such nonwoven and proper characterization of the developed fabrics based on the end use has been covered. Jute and jute-based material has some added advantages in certain technical applications like composites, agro-textiles, geotextiles, etc. Various machine parameters as well as processing parameters have been varied to design the fabrics for certain end uses. Applications of advanced modelling techniques like statistical and artificial neural network modelling have also been considered to achieve optimum properties in the fabric for certain end uses. Hence, the overall aspects of designing to end uses of the fabrics, considering its development and characterization, have been covered in this chapter.

Keywords: Jute, natural fibre, technical textiles, properties of nonwoven, designing of needle-punched nonwoven

1. Introduction

Jute fibre is one of the best fibres grown majorly in Bangladesh, India, Nepal, and China. The British introduced jute processing in India and Bangladesh. Initially, jute processing was made through flax machinery and found unsuitable. This forced the development of jute processing machinery, which was developed in Dundee, Scotland, and then the processing started in that country. Later the industry started in Bengal and India by the East India Company in the year 1856. Those days, jute fibre was imported from these Asian countries and products were developed in Europe (Dundee, Scotland). With the development and diversification of jute products from its conventional jute sacks as packaging material and carpet backing, the jute

nonwoven products are developed. These jute fibres are comparatively coarse in nature and have wide variation in fineness apart from its mesh-like structure. Its high moisture regain also places its suitability in certain applications. These properties make it more popular in the development of needle-punched nonwoven rather than the other nonwoven like thermal bonded and adhesive bonded nonwoven structures. Apart from these properties, the jute fibre is one of the cheapest natural fibre available commercially in countable amount.

Jute includes good insulating and antistatic properties, as well as having low thermal conductivity and a moderate moisture regain. It includes acoustic insulating properties and are manufacture with no skin irritations. Jute has the ability to be blended with other fibres, both synthetic and natural and accepts cellulosic dye classes such as natural, basic, vat, sulphur, reactive, and pigment dyes. Jute can also be blended with wool. By treating jute with caustic soda, crimp, softness, pliability, and appearance are improved, aiding in its ability to be spun with wool. Liquid ammonia has a similar effect on jute, as well as the added characteristic of improving flame resistance when treated with flame proofing agents.

Jute has a long history of use in the sackings, carpets, wrapping fabrics (cotton bale), and construction fabric manufacturing industry. However, the major breakthrough came when the automobile, pulp and paper, and the furniture and bedding industries started to use jute and its allied fibres with their nonwoven and composite technology to manufacture nonwovens, technical textiles, composite production of sheet moulding compound, resin transfer moulding, vacuum pressing techniques, and injection. In this chapter, the emphasis has been made on the design and development of jute-needle-punched nonwoven and their characterization in specific applications. Also, different important applications of jute and jute-based needle punched nonwovens have been covered.

2. Design and development of jute-based needle-punched nonwoven

Designing of needle-punched nonwoven from jute and its blend plays a very important role as far as the end product is concerned. The variation on fabric properties changes on various factors, like fabric weight, needling density, depth of needle penetration, needle gauge, blending of jute with other fibres, type of jute fibre used, pre-treatment of jute fibre, etc. Out of these various factors, the most influencing parameters are fabric weight, needling density, depth of needle penetration, and blending of jute with other fibres. Thus, the designing and development of jute needle-punched nonwoven neural network modelling approach holds good for designing, modelling, and the prediction of important properties. The following discussions describe these aspects.

2.1. Artificial neural networks modelling

The physiology of neurons present in biological neural system such as human nervous system was the fundamental idea behind developing the artificial neural networks ANNs. This computational model was trained to capture a nonlinear relationship between input and output variables with scientific and mathematical basis. In recent days, a commonly used

model is layered feed-forward neural network with multilayer perceptions and back propagation learning algorithms [1-4].

The ANNs are computing systems composed of a number of highly interconnected layers of simple neuron-like processing elements, which process information by their dynamic response to external inputs. The information passes through the complete network by linear connection with linear or nonlinear transformations. The weights were determined by training the neural nets. Once the ANN was trained, it was used for predicting new sets of inputs. Multi-layer feed-forward neural network architecture (Figure 1) was used for predicting the tenacity, initial modulus, air permeability, initial thickness, percentage compression, thickness loss, and compression resilience properties of fabrics [5-8]. The circle in Figure 3.5 represents the neurons arranged in five layers as one input, one output and three hidden layers. Three neurons in the input layer, three hidden layers, each layer consisting of three neurons and one neuron in the output layer. HL-1, HL-2, and HL-3 are the first, second, and third hidden layers, respectively, whereas i and j are two different neurons in two different layers. The neuron (i) in one layer was connected with the neuron (j) in next layer with weights (W_{ij}) as presented in Figure 1.

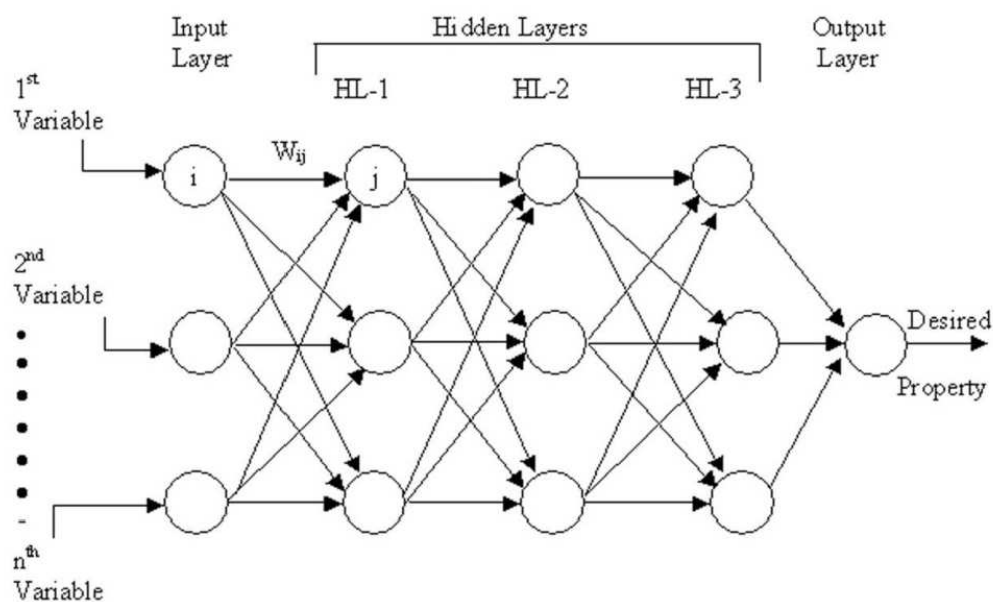


Figure 1. Neural architecture of the fabric property [8]

The data were scaled down between 0 and 1 by normalizing them with their respective values. The ANN was trained with known sets of input-output data pairs.

3. Characterization of jute-based needle-punched nonwoven

Unlike other fibre-based needle-punched nonwoven, jute needle-punched also requires specific tests to be evaluated to match its suitability in specific applications. This is because the

jute fibre has some of the unique features which others do not have, like high moisture regain, coarseness, biodegradability, high surface roughness, etc. Following are some of the important tests to be carried out to suit its suitability in some of those application areas.

3.1. Measurement of tensile property

Tensile is one of the most important properties to be evaluated for any textile material. To evaluate this property, all the samples are tested for tensile strip test on Universal Tensile Tester (UTM) following the standard test method ASTM D1682-64 under standard atmospheric condition ($65 \pm 2\%$ relative humidity and $27 \pm 2^\circ\text{C}$ temperature). For needle-punched nonwoven, the sample specimen width is 25.4 mm and the gauge length is to be set at 75 mm. The strain rate has to be set in such a way that the failure of the samples occurs between a time-span of 20 ± 3 seconds, depending on the type of fabric samples. Maximum load (in terms of Newton unit) breaking extension in percentage have to be recorded. From the value of breaking load, the tenacity values are calculated by the following formula [9]:

$$T = \frac{BL}{SW \times FW} \times 100$$

where, T – fabric tenacity (cN/tex); BL – breaking load (N); SW – specimen width (mm); and FW – fabric weight (g/m²).

The initial modulus and secant modulus have also been calculated from the respective stress–strain curves.

3.2. Measurement of air permeability

The jute needle-punched nonwoven fabrics are porous in nature and hence they are permeable. To study the air permeability property, this test is carried out. Evaluation of air permeability nonwoven fabric samples can be done using any reliable air permeability tester (Shirley Air Permeability Tester). The results are expressed as the units of volume of air in cubic-centimetre, passed per second, through one square centimetre of fabric at a pressure difference of 10 mm or 1 cm head of water. But in some cases, the range of flow metre available in the instrument may not achieve the high flow rate required for this specific pressure difference. In such a case, superimposed layers of fabric on one another have been tested at a time and the flow rate reading for a single layer was calculated by multiplying the result by number of layers. Air permeability value was calculated by dividing the flow rate reading in cc/sec at 1 cm pressure head of water by the test area, which is in this instrument 5.07 cm² (1 inch²). Sectional air permeability (SAP) value was used to compare the permeability of different fabric samples. The SAP values of all the samples were determined from the following formula [10]:

$$SAP = AP \times T_0$$

where, SAP is the sectional air permeability in cm³/s/cm; AP, the air permeability in cm³/cm²/s; and T₀, the mean thickness in meter at 1.55 kPa pressure of the fabric sample. This test is

recommended to carry out at $65 \pm 2\%$ relative humidity and $27 \pm 2^\circ\text{C}$ temperature after conditioning the sample for 24 hrs. For each sample 10 tests were performed.

3.3. Measurement of bending property

The stiffness of the jute needle-punched nonwoven textile fabric is used for technical textile, and samples are investigated by examining different bending parameters, for example, flexural rigidity and bending modulus, at $65 \pm 2\%$ relative humidity and $27 \pm 2^\circ\text{C}$ temperature after conditioning the sample for 24 hours. The flexural rigidity of the fabric samples was determined by measuring the bending length following the standard cantilever principle by using the stiffness tester. The average value was calculated from 10 specimens in both warp and weft directions of the woven fabrics. Similarly for nonwoven samples both machine and cross directions of the fabric specimens were considered. The specimen size of each sample was 150 mm $\times$ 25 mm for higher flexible fabrics. The bending length was measured directly from the instrument. Flexural rigidity was calculated from the following formula [9]:

$$FR = \frac{WC^3}{10^4} \times 9.81$$

where FR = flexural rigidity in Newton in Newton-cm; W = fabric area density (g/m^2); and C = bending length in cm.

For bending modulus, the thickness of each sample was measured under the pressure of 1 lb/in² by using a thickness tester (ASTM D5199-91⁷). The bending modulus of the samples was determined from the following formula:

$$BM = \frac{12G}{g^3}$$

where BM= bending modulus in Newton/cm²; G= g = thickness (cm) of sample at 1 lb/in².

In case of thick and rigid fabric, the above method of measurement of bending length is not valid. In such a case, a loop method is suggested [11].

3.4. Design measurement of water imbibition property

For the measurement of water retention characteristics, the samples were cut into equal size of 4 cm $\times$ 4 cm and weight under the following natural atmospheric conditions, for example, dry bulb temperature 87°F, wet bulb temperature 81°F, and relative humidity 77%.

The samples are soaked in distilled water for about 48 hours. Later, all these samples are hung in free air for about 40 minutes to drip out the excess water absorbed by the samples. These samples are then kept on a blotting paper for 5 minutes to absorb further excess water present on the surface of the samples. Now, the weight of the wet samples is taken to find the absorbency of water by using the following formula [9]:

$$WA = \frac{W_{wet} - W_{dry}}{W_{dry}} \times 100$$

where WA is water absorbency in percentage, W_{wet} is the weight of fabric in wet condition, and W_{dry} is the weight of the fabric in dry condition.

Release of moisture with respect to time are determined for all samples unit they achieved the constant weight.

3.5. Compression

Compression is one of the important properties to be measured to evaluate the performance of the needle-punched nonwoven jute fabric for some specific application point of view like carpet, geotextile, etc. The initial thickness, compression, thickness loss, and compression resilience can be calculated from the compression and decompression curves. For measuring these properties, a thickness tester is required. The pressure foot area is 5.067 cm^2 (diameter = $\phi 2.54 \text{ cm}$). The dial gauge with a least count of 0.01 mm and maximum displacement of 10.5 mm is attached to the thickness tester. The compression properties are studied under a pressure range between 1.55 kPa and 51.89 kPa .

The initial thickness of the needle-punched fabrics is observed under the pressure of 1.55 kPa . The corresponding thickness values are observed from the dial gauge for each corresponding load of 1.962 N . A delay of 30 seconds is given between the previous and next load applied. Similarly, 30 seconds delay was also allowed during the decompression cycle at every individual load of 1.962 N . These compression and recovery thickness values for corresponding pressure values are used to plot the compression–recovery curves.

The percentage compression, percentage thickness loss, and percentage compression resilience are estimated using the following three relationships [12]:

$$C = \frac{T_0 - T_1}{T_0} \times 100$$

$$TL = \frac{T_0 - T_{21}}{T_0} \times 100$$

$$CR = \frac{W'_c}{W_c} \times 100$$

where C is the compression in percentage, TL is the thickness loss in percentage, CR is the compression resilience in percentage, T_0 is the initial thickness, T_1 is the thickness at maximum pressure, T_2 is the recovered thickness, W_c is the work done during compression, and W'_c is the work done during the recovery process.

The average of 10 readings from different places for each sample need to be considered. The coefficient of variation should be within 6%, if not a greater number of readings is necessary.

All these tests must be carried out in the standard atmospheric condition of $65 \pm 2\%$ RH and $20 \pm 2^\circ\text{C}$. The fabrics are conditioned for 24 hours in the above mentioned atmospheric conditions before testing.

3.5.1. Compression in wet condition

In some specific applications like geotextile, the jute and jute-based needle-punched nonwoven fabrics require special conditioning to test the fabrics under wet condition. To study the compression behaviour of needle-punched nonwoven fabric under wet condition [13-15], samples have to be cut into pieces of 25 cm x 25 cm and soaked in distilled water for a period of 24 hours before conducting the experiment. After 24 hours of soaking in distilled water the samples are passed through a pair of padding mangle with a uniform pressure exerted upon them by applying a constant load on either side of the top roller. The pressure between the padding mangles and their speed are constant. Under this condition, it can be assumed that the water pickup of the sample remained constant. Then, the sample is tested immediately for its compression property. The initial thickness, compression, thickness loss, and compression resilience were calculated from the compression and decompression curves. The compression, thickness loss, and compression resilience can be calculated from the above relationship mentioned above in Section 3.5.

3.6. Compression creep

There are some instances where the jute-based needle-punched nonwoven fabrics are used for floor mat and carpet applications. In such applications, the compression creep is one of the essential parameters required to be carried out to evaluate the compression deformation over a period of time. An instrument has been suggested as shown in Figures 2, to measure the compression creep of the needle-punched nonwoven fabrics [16-17].

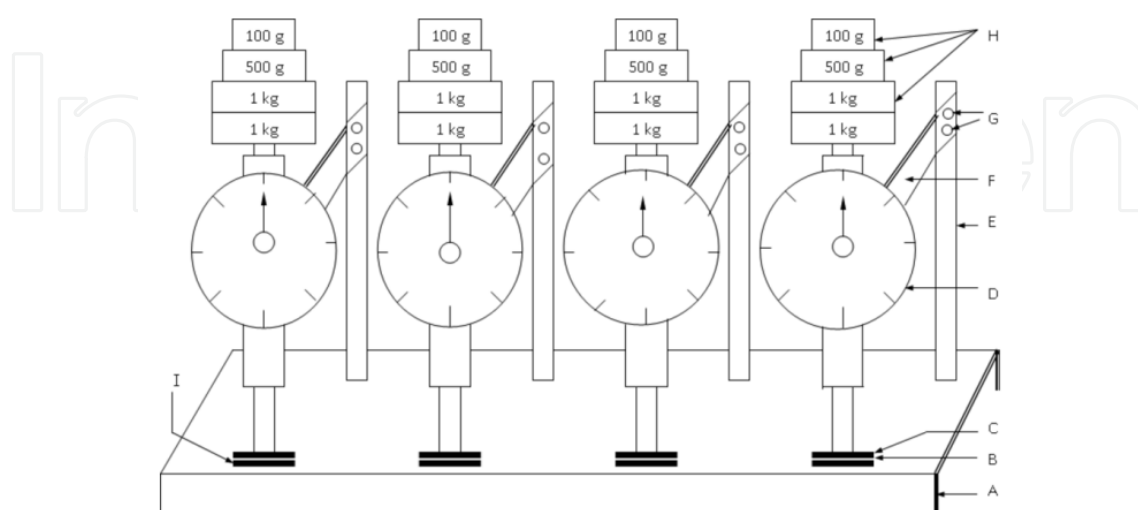


Figure 2. Instrument for measurement of compression creep [16-17]

The instrument is capable enough to measure the compression creep for four samples at a time. The fabric samples are mounted under a known compression load with a dial gauge (D) to measure the thickness under the compression. The pressure foot (C) diameter was chosen as 25.4 mm (1 inch) for all samples. The least count of the dial gauge (D) was 0.01mm. The nonwoven sample is placed between the pressure foot (C) and anvil (I). The initial thickness can be noted without adding any additional load. The instant deformation (T_0) is noted from the dial gauge after applying the compression load (H) of 25.51 N (2.6 kg) at the top of the weight pan (J) of the dial gauge (D). The selection of this pressure foot diameter of 25.4 mm and compression load of 2.6 kg is to simulate the area of the foot of a normal chair and the weight of a normal empty chair comes on the carpet surface through each leg of the chair, respectively. To study the compression creep, each sample is allowed to remain under this compression load for 168 hours (7 days). This compression creep time was selected because it was found from previous study that all the fabric's compression creep reaches equilibrium within 168 hours. The compression creep (%) is evaluated from the thickness deformation values, which are measured using the following relation:

$$CR = \frac{T_0 - T_t}{T_0} \times 100$$

where CR is a compression creep in percentage, T_0 is the instant thickness after applying the maximum load, and T_t is the thickness after 7 days.

The average of 10 readings from different places for each sample is considered. The coefficient of variation should be less than 6% in all the cases. The fabrics required conditioning for 72 hours in the above-mentioned condition before carrying out the experiment.

3.7. Thermal resistance

The thermal resistance of a textile material is usually defined by the ratio of the temperature difference between the two faces of the fabric material to the rate of flow of heat per unit area normal to the faces. It is analogous to the electrical resistance in case of current flow through an electrical conductor. Disc method, an application of Lee's disc apparatus to textiles, was employed to evaluate thermal resistance of polyester needle-punched nonwoven fabric samples. In this method, the material under test is held between two metal discs of which one has known thermal resistance. In steady condition, the temperature drop across the metal disc with known thermal resistance and across the material under test is measured, and from the values obtained the thermal resistance of the specimen is determined by the following techniques.

Let TR_k and TR_s be the thermal resistance of the known disc and the sample under test, respectively. Let t_1 be the temperature registered by the lower surface of the known disc, t_2 be the temperature registered by the lower surface of the sample under, and t_3 be the upper surface of the sample under test. Assuming constant rate of flow of heat at steady state condition, the TR_s is computed from the following formula in degrees Kelvin square metre per Watt:

$$\frac{t_1 - t_2}{TR_k} = \frac{t_2 - t_3}{TR_s}, \text{ or } TR_s = TR_k \times \frac{t_2 - t_3}{t_1 - t_2} \quad (1)$$

In this experiment, a guarded two-plate thermal resistance instrument has been used to measure the thermal resistance of jute-based needle-punched fabrics [18-19]. The thermal resistant instrument is based on a microprocessor and provides automatic results of thermal resistance value in 'tog'. The area of the test specimen used is 706.85 cm² (diameter 30 cm). The test is non-destructive and the process of preparation of sample is free from human error. Thermal insulation of each fabric sample is measured randomly at five different places under a pressure of 0.3352 kPa. The average of five readings was considered and the coefficient of variation of readings was < 2%.



Figure 3. Instrument for measuring the thermal resistance of fabrics [19]

The specific thermal resistance (STR_s) value is used to compare the thermal resistance of different fabric samples. STR_s values of all the samples are determined using the following equation:

$$STR_s = \frac{TR_s}{T_0}$$

where STR_s is the specific thermal resistance in K m²/W; TR_s , the thermal resistance value of fabric in K m²/W; and T_0 , the mean thickness in meter at 1.55 kPa pressure of the fabric sample.

3.8. Evaluation of water absorbency

The fabric samples were cut into equal size of 4 cm × 4 cm, and conditioning in the standard atmospheric condition of $65 \pm 2\%$ RH and $20 \pm 2^\circ\text{C}$. The fabrics were conditioned for 24 hours in the above-mentioned atmospheric conditions and the dry weight (W_D) was measured. To study the water absorbency, samples were dipped in distilled water for 24 hours to ensure uniform soaking of water and then wet samples were hung in free air for about 30 minutes to drip out the excess water absorbed by the samples. Now, the weight (W_W) of wet samples was measured. The water absorbency [20] was calculated using following relationship:

$$WA(\%) = \frac{(W_W - W_D)}{W_D} \times 100$$

The average of 10 results was considered.

3.9. Evaluation of soil moisture control

The soil moisture can be efficiently controlled by the jute agro-textile. This is very essential to maintain the soil moisture for longer duration and thereby the water requirement during irrigation can be minimized. Suitable jute agro-textile can be used as mulching material. To find the efficacy of the performance of the jute-based mulching material for controlling the soil moisture, two simulated methods are recommended, namely, non-contact method and contact method. The importance of these two different methods is that during application of the agro-textile the fabrics are not assured to touch the contours of the soil surface uniformly both in lengthwise as well as widthwise directions of the fabrics. Following are the two methods recommend to measure the soil moisture control using jute needle-punched nonwoven fabrics [21].

3.9.1. Non-contact method

Some place of the mulching needle-punched nonwoven agro-textile will not come in contact with the soil surface due to the contours of the soil. To study the moisture of soil on those non-contact areas of the fabric, this method is considered [21]. In this measurement, six beakers of 100 ml are taken containing 25 ml of water in each beaker. Among them, the mouths of five beakers are tightly covered with the fabric samples and the rest are kept as control without any fabric cover. These beakers containing water and samples were weighed initially and weights were repeatedly taken at certain time interval until they reached a constant weight. This experiment is conducted under normal atmospheric conditions. At each time interval, the percentage evaporation loss is calculated from the weight difference of the individual beaker assembly at that point of time with respect to its initial weight. The results are plotted as a time versus cumulative evaporation loss to compare the performance of various agro-textile fabrics of different fabric weight.

3.9.2. *Contact method*

In this test, six similar size petri dishes have to be taken containing 90 gm of standard alluvial soil with saturated moisture in each pretty dish. The five petri dishes are covered with fabric samples in such a way that the fabrics have direct contact with the moist soil. The control dish is not covered with any sample fabric. To determine the moisture barrier property, the weight of each dish with soil and sample is measured initially. These weights are further taken at certain time intervals until all the dishes reach a constant weight. The cumulative evaporation loss is calculated in a similar method like non-contact process [21]. The results are plotted as a time versus cumulative evaporation loss to compare the performance of various geotextile fabrics of different fabric weight. This experiment is replicated five times and the average of five readings for each sample was calculated.

3.10. Evaluation of soil temperature control

The application of jute agro-textile mulch has influence on the control of soil temperature. This factor depends on various aspects of jute needle-punched nonwoven fabric design and parameters selected during manufacture of the fabrics. In this test, jute needle-punched nonwoven and commercial plastic mulch (black polyethylene sheet 50 g/m² and thickness 20 µm) materials are compared with respect to control soil (without any mulch). A plot is made to determine soil temperature behaviour with respect to time against control [21].

Three earthen pots of the same size and shape were taken and the same quantity of alluvial soil is filled in each pot. The same quantity of water is poured in all the pots till saturation level is achieved and excess water is poured out. Under this condition, the surface water is allowed to evaporate for 24 hours so that the same ambient conditions are attained in all the pots. Needle-punched jute nonwoven and commercial black polyethylene sheets of 50 g/m² microns are laid on the top of the soil on each pot. Utmost care is to be taken to see to it that no part of the soil surface is left exposed/uncovered by the agro-textiles/experimental materials. Before covering with the mulching materials, the soil temperature is measured in each pot. The temperature is measured approximately 1 inch below the soil surface at five different spots and averaged to determine the mean temperature. Soil temperatures are determined identically as above at a fixed interval of two hours. This study needs to be continued for four days and temperatures recorded for all the three pots including control and can be represented graphically.

3.11. Measurement of sound insulation

An unwanted noise, a part of sound is irritating and which caused many problem of human related to mental and psychological aspects. Jute needle-punched nonwoven textile materials have good property to control sound if they are properly designed for this purpose. A simple design of such an instrument to measure the sound insulation of the textile nonwoven materials has been explained by Sengupta, 2010 [22]. It consists of a sound insulating box which is made out of 12 mm thick rigid plastic (acrylic sheet) and has a provision of removable top lid. Inside one vertical wall of this box, a sound source and a decibel meter (s) are fixed. In

another movable (to adjust the distance between sound source and receiver) vertical wall, a decibel meter (R) is fixed coaxially opposite to the sound generator to measure the sound intensity. In between these two decibel meters, a sliding (to adjust the distance between sound source and fabric) arrangement is there to fix the fabric sample vertically. An electrical panel has been used to control the sound intensity. Figure 4 shows the schematic diagram of the sound insulation tester as described above [22].

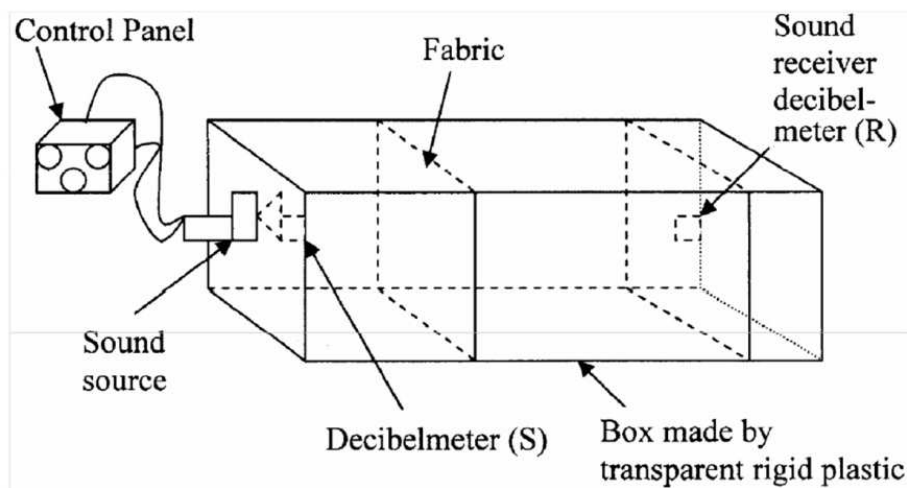


Figure 4. Schematic diagram of sound insulator tester [22]

Operating the control panel, a sound of particular decibel sound is created. The source decibel and the receipt decibel are measured by two-decibel metres S and R, respectively, without and with fabric samples. The sound reduction responsible for fabric, where sound insulation is expressed as the difference between the decibel reduction with sample and decibel reduction without sample, is shown below:

$$db_F = (dB_S - dB_R)_{WS} - (dB_S - dB_R)_{WOS}$$

where db_F is the sound reduction responsible for fabric; dB_S is the sound intensity at source; db_R is the sound intensity at receiver; WS is with sample; and WOS is without sample.

3.12. Measurement of electrical resistance

Textile materials have good electrical insulation property provided they are in dry condition. There are many such applications where the textile materials (fibre/yarn/fabric) are used as electrical insulation purposed. The electrical insulation application of the textile materials are used in medium voltage ranges (within 415 V). To measure the electrical insulation a circuit is necessary which measures the current-voltage (V-I) characteristics of textile material as shown in Figure 5 [23-24].

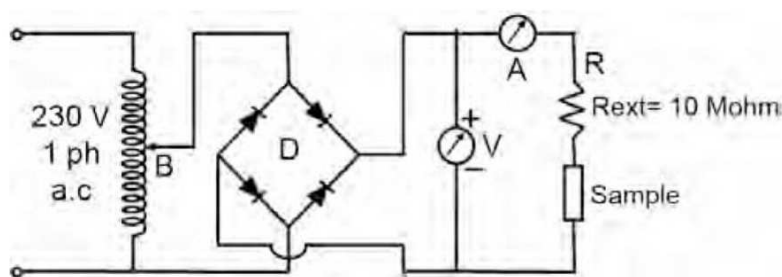


Figure 5. Circuit for electrical resistance of nonwoven [23]

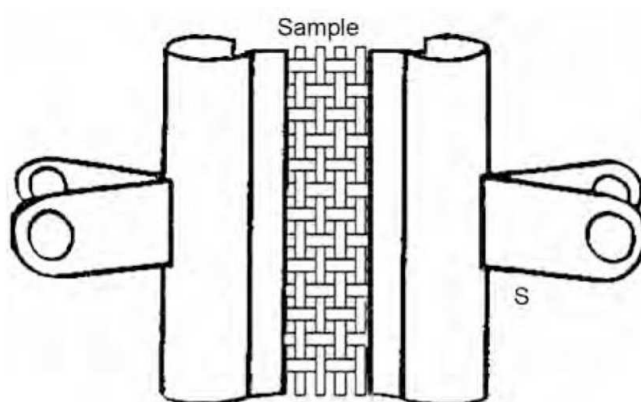


Figure 6. Sample holder

This circuit consists of sample holder (S), variac (B), rectifier unit (D), ammeter (A), voltmeter (V), and 10 M Ω discrete resistance (R). Two bulldog-clips are used between which the sample is placed (Fig. 6) with gauge lengths 2.54, 5.08, and 10.16 cm. The sample is in series with a known resistance (10 M Ω) and is connected to a D.C. power supply. The voltage is varied from 80V to 220V in 5 steps and corresponding current through the sample is measured after 10s to calculate the resistance [25-26]. The measurement is done at 27°C and 65% relative humidity. Five sets of voltage-current readings are taken for plotting V-I characteristic curves. The slope (voltage/current) or resistance for each V-I characteristic is determined. The specific resistance has been calculated normalizing the resistance by thickness [multiplying/dividing the resistance (Mega ohm) by thickness (cm)].

4. Application of jute-based needle-punched nonwoven

Needle punched nonwoven are mostly used in various applications. Jute itself is popular for application in the packaging industry and in carpet industry as carpet backing material. However, the jute-based needle-punched nonwoven find its application in geotextile, agro-textile, composite reinforcing material, sound insulating material, air filter, carpet, thermal

insulating material, etc. as per as the agricultural application is concerned; it is mostly used as mulching material, thermal insulating material for control soil temperature, soil moisture control material, channel lining material, horticultural nursery pot, etc. some of the promising applications and case studies are covered below.

4.1. Application for mulching application

Efficient management of soil moisture by jute needle-punched nonwoven for cultivation of horticultural crops in red lateritic zone has been attempted at West Medinapur District of West Bengal, India. The experiments on vegetable cultivation were laid out in randomized block design (RBD) with three vegetables – cauliflower, tomato, and beans – and four types of jute nonwoven mulch of fabric densities 150 g/m², 200 g/m², 250 g/m², and 300 g/m² excluding control. There is evidence that mulching with jute geotextiles increased the yield of cauliflower substantially and that of tomato to a lesser extent. It had practically insignificant effect in the yield of beans. Maximum yield of 73.66 t/ha of cauliflower was obtained with jute nonwoven fabric of 250 g/m² (control 49.08 t/ha) whereas tomato's increased yield was 110.39 t/ha with 150 g/m² fabric as compared to 83.39 t/ha achieved under controlled conditions. However, beans had negative effect with mulching by jute nonwoven. The results also confirm that mulching with jute nonwoven of 300 g/m² fabric density increased the yield of sweet lime fruits substantially, that is, more than 100 fruits per plant per year as compared to only 34 fruits per plant per year obtained under traditional cultivation method [27-28].

Nonwoven fabric samples were selected as mulch materials at the experimental field of tea plantation, situated at Gopali village (near IIT, Kharagpur, West Bengal). In the first phase, these fabric samples were laid in between the two rows of tea plants (Tocklai of Assam variety) where the spacing between the two rows was 1 metre and between the two plants in a row was 0.7 metre. The length of each row was 16 metres. For each sample two rows were used for mulching experiment. Jute nonwoven samples (150, 200, and 250 g/m²) each of 32 metres in length were used for the continuous row mulching process. Two separate rows were kept for control/without any mulching material. Uniform amount of water was spread over the tea plantation in both the control and mulched area using standard sprinkler at the rate of 5 hours/day. The mulch performance was studied by measuring the biomass in 2-month intervals. Some critical observations regarding the types of weeds grown were also reported. This experiment was replicated five times for test of significance.

4.2. Application for channel lining

Four trapezoidal channels of 50 metre length each were constructed with zero bed slope and were lined with jute geotextile (nonwoven geotextile coated with polythene sheet either on single side or double sides) of 1 metre width and different fabric densities. Final dimensions of the channels were measured at different sections of each of the channels and average dimensions were determined as shown in Table 1 [29]. The experiment was undertaken in field channels laid out in the experimental farms of BCKV, Mohanpur, Nadia, West Bengal.

The weather data consisting of daily maximum and minimum temperatures, evaporation, rainfall, and maximum and minimum relative humidity were collected from the weather

station located in the farm. From the difference in water depths and water level widths between two consecutive days, the total loss of water from the channel was calculated. Total loss consists of evaporation and seepage losses from the channel as shown in Table 2. Evaporation loss was estimated by daily evaporation and channel dimensions. The seepage volume was calculated by adjusting the evaporation loss that occurred from the average surface area of water level during the period. The rate of seepage was determined by dividing the seepage volume by average wetted area of the channel. The observations and results noted and statistical analysis of the daily seepage values have been done on one factor randomized complete block design and the analysis of variance.

Both ends of the channels were blocked so that water can be retained in them. The channels were filled with water and depth and top width of water in the channels were recorded every day at 8 A.M. till the water levels reached about half of the initial level.

Various lining materials such as precast channel, brick masonry, bituminous mixture, soil cement, polythene sheets, etc., have so far been used for controlling seepage in irrigation channels. Some are too costly to be locally used while others have short life and are not much effective. Keeping it in view, this work was taken up to find out a viable alternative to these traditional materials. In this project, jute nonwoven geotextile of 250 g/m² and 300 g/m² fabric weight were coated with polyethylene sheet on one side and both sides and were experimented to assess the seepage loss through open channels. 300 g/m² fabric with both sides coated controlled seepage most efficiently. Single side coated sheets also performed well in seepage control, but allowed more water to seep compared to double side coated sheets. However, 250 g/m² fabric with both sides laminated yielded optimum performance.

Water losses in watercourses and field channels may occur by seepage, breaches along the channels through rat holes, and ponding of water in depressions and channel sections. Unlined irrigation channels account for overall seepage losses between 20% and 30%. Geotextile fabrics are very effective in controlling seepage from open channels. Jute nonwoven fabric of 300 g/m² (double sides coated) controlled seepage losses most efficiently. However, considering the permissible limit of seepage and cost factors, 250 g/m² fabric (both sides coated) may be recommended.

4.3. Application for horticultural nursery pot

Horticulture pot of 3' x 8' has been made from jute needle punched fabric for use in nursery in place of conventionally used plastic bag. The jute needle punched nonwoven is made from TD3 jute and waste jute. In both cases, scrim cloth reinforcement has been given at the back to avoid the damage during use and to retain dimensional stability [30].

4.4. Application for jute geotextile application

Jute needle-punched nonwoven has been successfully used as reinforcing material in the construction of rural road in Guptipara, Hooghly, West Bengal, India. There are also examples of using jute geotextile on river bank protection. The bank was first cut to a suitable slope of 30°, approximately same as the angle of internal friction of the bank soil. The surface was levelled and made free from angular projections, undulations, soil slurry, and mud. JGT rolls

were unrolled and placed along the slope from top down to the lowest water level. Care was taken to see that JGT was laid with the overlapping in the direction of water flow. More rolls were rolled along the length of the bank and two layers of same area/fabric density were placed one upon the other with sufficient overlap. JGT was fixed to the bank with the help of bamboo pegs in either direction. Care was taken to ensure that JGT does not suffer damage due to puncture, tear, and similar operational stresses and it touches the bank slope at all points (proper drapability). Suitable grass seeds were then spread on the treated bank for better stabilization. The growth of grass was observed at 15-day intervals by determining the average number of seedlings per unit area and the average length of grass [31].

4.5. Application for jute-based needle-punched nonwoven in garment

In the manufacturing of warm garments like jackets, very fine jute-polypropylene fibre-blended needle-punched nonwoven of 90 g/m² as inner lining material can produce good thermal insulating property. Due to very poor strength of 90 g/m² reinforced cotton gauge cloth of 20g/m², produce sufficient strength for easy handling during manufacturing process of the garment. The five repetitive washing of jacket made of jute-polypropylene fibre blended needle-punched nonwoven used as inner lining material and outer material is of jute-polyester and cotton blended union fabric shows no significant change on its performances.

5. Conclusions

Jute needle-punched nonwoven has vast application in different industrial sectors. Proper designing and development of material is needed for particular application. Selection of jute fibre and blended material in specific application makes the needle-punched nonwoven product more useful. Apart from the applications mentioned, there exists ample scope in the development of specific product for air filtration, sound insulation materials, etc., for which specific tests have been recommended. Overall jute-needle-punched nonwoven has wide scope in future industries due to its sustainability in product development. Moreover, nonwoven from jute-based materials has added advantage of environment friendly disposal. This gives jute-based nonwoven a priority over synthetic fibre-based nonwovens.

Author details

Sanjoy Debnath*

Address all correspondence to: sanjoydebnath@yahoo.com

ICAR-National Institute of Research on Jute & Allied Fibre Technology, Kolkata –West Bengal, India

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