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Thermal insulation properties of jute, polypropylene and recycled polyester nonwoven fabrics for automotive textiles

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Three different nonwoven fabrics, namely jute, polypropylene and recycled polyester, have been produced using needle-punching method. The nonwoven fabric samples are then characterised by thermal conductivity, thermal resistance, air permeability, areal density and thickness. Objective and subjective evaluation are carried out for the fabric samples. The fibres are blended in various proportions and further converted into cross laid needle punched nonwoven fabrics. The thermal resistance of carded needle punched nonwoven fabrics are determined by using lee's disc apparatus. Experimental results show that 100 % recycled polyester nonwoven fabrics thermal resistance behaviour is higher than the jute and polypropylene needle punched nonwoven fabrics. This nonwoven fabric can be used in the automotive field as a headlining material for the purpose of thermal insulation.

Keywords: Jute, Needle punching, Nonwoven fabric, Polypropylene, Recycled polyester, Thermal insulation

The properties of nonwoven fabrics determine their end use and durability factors. The physical properties of nonwoven fabric directly affect the thermal insulation property of the material[1]. Different raw materials used to produce the nonwoven needle punched fabrics vary with the types of fibre used to produce the fabrics. Web forming techniques also influence the thermal properties of needle punched nonwoven fabrics[2]. The properties of nonwoven fabric are determined by the types of fibre, method of fabric formation, method of web preparation and bonding technique followed during their manufacturing process. The end use of the fabric is the main factor for choosing the type of bonding. Needle punching technique is the most popular method for producing the fabric for specific end uses, particularly in the field of thermal insulation.

The needle punched nonwoven fabric can be used in various areas of technical textiles such as automobile textiles, geo textiles, filtration applications, as oil sorbents, bio-medical devices, sports textile, apparels and agricultural textiles [3,4]. The type of fibre, bonding method and purpose of production are the important factors considered for the production of needle punched nonwoven fabrics. Thermal properties of nonwoven fabrics are highly important in the application areas of automobiles, blankets, interlining and building materials[5].

The effect of fabric weight, needling density and blend proportion on thickness, thermal resistance, air permeability of needle punched nonwoven fabric made from jute and polypropylene blends were analyzed[6]. The weight of the nonwoven fabric directly increases the thermal resistance of the material, whereas the air permeability is gradually decreases with increase in fabric weight. Nonwoven fabrics have large number of air voids entrapped inside the fabric structure, thereby giving better barrier against heat flow[7].

The recycling is an important task to utilise the waste material into effective raw material and to reduce the land filling of material. The waste fabric materials are converted as a raw material by suitable technique and this raw material is mostly used in industrial textile products[8]. The type of reclaimed fibres used to produce the nonwoven fabric highly influences the end use application especially thermal conductivity of the fabrics[9]. The thermal resistance behaviour of jute fibre nonwoven fabrics increases with increase in the proportion of jute content in the fabric[10].

The packing density of nonwoven fabric affects the heat transfer through the fabrics. The more packing density increases the tortuosity of the needle punched nonwoven fabrics[11]. The polyester and polypropylene fibres needle punched nonwoven fabrics were used as thermal insulation materials at different blend proportion and punch densities. Needle punched

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nonwoven fabrics were used to maintain the thermal characteristics inside the automobiles. The thermal conductivity of polyester needle punched nonwoven fabrics were lesser than polypropylene needle punched nonwoven fabrics, but the blends of polyester and polypropylene needle punched nonwoven fabrics showed the better thermal properties[12, 13]. The fabric weight per unit area and the thickness were determined and it was recommended that the air permeability of blended fabric depends upon the fibre volume fraction on nonwoven fabrics [14-17].

The thermal insulation value of needle punched nonwoven fabrics increases with increasing the weight of polyester fabrics and there is no influence of cross sectional shape. At the same time, the trilobal cross- section of polyester exhibits better insulation value than hollow and regular shape of polyester fabrics [18]. The fabric thickness and temperature variations of the fabrics show interrelation contacts. The higher thickness and fabric density increase the thermal insulation value of the nonwoven fabrics [19]. The polyester needle punched nonwoven fabric exhibits better insulation due to the structural effects, which has higher thickness and small uniform pores[20]. The natural renewable resource materials like hemp, bamboo and Sansevieria stuckyi fibres were used to identify the thermal characteristics. Among this, hemp fibre show good insulation property than the other fibres in this study [21-23].

There is a direct relation between the thermal insulation and the depth of needle penetration of nonwoven fabrics. The depth of needle penetration increases the compactness of nonwoven fabrics, reduces the heat transfer through the structure and increases the value of thermal insulation[24]. Cotton fibres blended recycled polyester fibres in technical textiles lead to more eco-friendly process[25]. Cotton and recycled polyester fibres have been used to produce nonwoven fabrics even though the recycled fibres have poor strength. In this, the weight of the fabric increases and it affects the air permeability characteristics of nonwoven fabrics. When the weight increases, the thicker as well as denser and compact fabrics were produced[26.] Jute and polypropylene based needle punched nonwoven fabrics are bulky, strong and have tough characteristics. The blend composition plays an important role in the mechanical properties of jute and polypropylene nonwoven fabrics[27]. Banana/polypropylene, bamboo/ polypropylene and jute/ polypropylene nonwoven fabrics were produced by needle punching technology. Among this, bamboo/ polypropylene nonwoven fabrics with its compact structure, show higher tensile strength & stiffness and lower elongation, air permeability and thermal conductivity for the noise control of automotive interior[28]. The polypropylene fibre blended with banana fibre based nonwoven fabrics exhibits good thermal insulation property and is suited for interior of automobiles[29-30]. Thermal insulation is directly proportional to the moisture regain value of the material. When the moisture content increases the thermal insulation value decreases. Jute and recycled polyester needle punched nonwoven fabrics with different blend proportions have been studied. In this, the increase in proportions of recycled polyester increases the thermal insulation value of the nonwoven fabrics[31, 32.]

The recycled PET fibre is derived from waste PET bottles and the usage of this fibre reduces the land pollution by avoiding the landfill. Thermal insulation value of recycled PET fibre is found higher than the cotton needle punched nonwoven fabrics. The performance of cotton and recycled PET fibre needle punched nonwoven towards the thermal properties has been studied. In this, light weight PET fibre performance is found acceptable [33].

In this work, an attempt has been made to investigate the blends of jute, polypropylene and recycled PET fibres in various proportions for assessing their suitability as thermal insulation material in the form of carded needle punched nonwoven fabric for automotive industry.

Experimental

The jute, polypropylene and recycled pet fibres were used for the preparation of needle-punched nonwoven fabrics. These fibres were blended with different blend ratios, maintaining the areal density unchanged. The denier of all the fibres was maintained at 3. The fibres were directly used for the production of nonwoven fabrics with needle punched technique method. The staple length values of jute, polypropylene and recycled polyester are 80, 42 and 64 mm respectively.

There are three fibres blended at different blend proportion ratios. Triple fibre blending principle was followed to obtain very unique products which are not available in the market. Two fibres blending process was followed. Triple fibres were blended together at certain proportion in order to measure the deviation of product based on the fibre content**.** Blend proportions are indicated in Table 1.

Carding Process

With a view to produce the nonwoven fabric with different proportions, nonwoven fabric samples were carded. The blending process was carried out by feeding of fibres into the feed lattice as per blend ratio. The blended materials were thoroughly opened by passing them through one carding passage. The blended fibres were fed to the lattice of the roller and clearer card at a uniform and predetermined rate so that a web of 200 areal density could be achieved.

The material was processed in DILO Loom of OD-26. As per the fabric weight (g/m^2) requirement, required quantity of webs was taken and passed through the needling zone of the machine for a number of times, depending upon the punch density required. A punch density of 112 punches/cm^2 was applied on each passage of the webs reversing the face of the web alternatively. The fabric samples were produced as per blend ratio with different thickness in same areal density. The depth of needle penetration was kept constant at 11 mm. For all webs, 15×17×40×3 mm needles were used.

Table 1 — Blend proportions

Sample code	Blend proportion
S1	100% Jute
S2	100% Polypropylene
S3	100% Recycled PET
S4	33.3% Jute+ 33.3% Polypropylene + 33.3% Recycled PET
S5	50% Jute+ 25% Polypropylene + 25% Recycled PET
S6	25% Jute + 50% Polypropylene + 25% Recycled PET
S7	25% Jute+ 25% Polypropylene+ 50% Recycled PET
S8	40% Jute+ 30% Polypropylene+ 30% Recycled PET
S9	30% Jute+40% Polypropylene + 30% Recycled PET
S10	30% Jute+ 30% Polypropylene+ 40% Recycled PET

Results and Discussion

Nonwoven fabric samples were produced using jute, polypropylene and recycled pet fibres and their blends. Results are reported in Table 2.

Effect of Thickness

The effect of thickness on thermal properties of needle punched nonwoven is shown in the Fig.1(a). The precise measurement of the distance between two plane parallel plates separated by the cloth was done. A known pressure was applied and maintained on the plates. The thickness of the samples was tested by fabric thickness tester, using ASTM D 5729 – 97 standards.

The thickness of the needle punched nonwoven fabric is based upon the compression behaviour of the fibre. Here, the area density is maintained as 200 gsm. Areal Density means grams per square meter of a knit, woven or nonwoven fabric. It is essential to know the weight of the fabric before manufacturing and after getting the finished fabric. The Areal Density of the samples was tested by using areal density cutter. The thickness of the samples varies between 1.80 cm and 2.14 cm; this is due to the type of fibre and the cohesion property of the fibre. The jute fibre is a high stiffness fibre which has higher thickness than the remaining samples in this study.

Effect of Air Permeability

Evaluation of air permeability of needle punched nonwoven fabric a sample is conducted using the Shirley air permeability tester by ASTM D737-96 standard and the values are shown in Fig.1(b). The results have been expressed as the units of volume of air (cm^2) passed per second, through one square

Table 2 — Dimensional and thermal properties of nonwoven fabrics

Sample code	Thickness cm	Areal density gsm	Air permeability cc/s/cm^2	Thermal conductivity (Avg), wm^{-1}k^{-1}	Thermal resistance (Avg), mkw^{-1}	Temperature difference, ^{o}C
S1	2.14	230	302.77	0.190	6.24	4.0
S2	2.05	200	205.5	0.160	6.25	5.8
S3	1.80	195	295.83	0.112	8.87	7.2
S4	1.82	200	254.1	0.183	5.44	4.2
S5	2.09	200	261.1	0.160	6.2	4.4
S6	1.80	200	268.05	0.141	7.06	4.8
S7	2.02	210	261.11	0.130	8.08	6 .6
S8	1.81	200	288.88	0.185	5.40	4.2
S9	2.09	215	233.33	0.120	8.07	6.0
S10	1.98	200	275	0.124	8.02	6.8

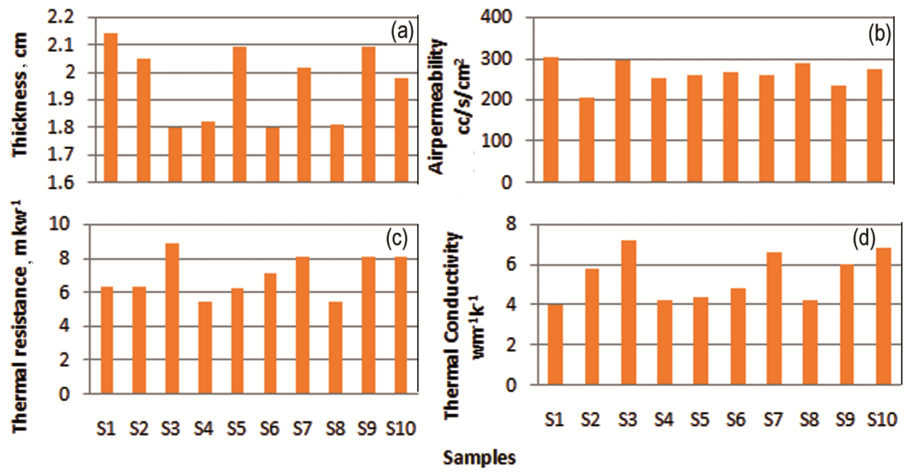

Fig. 1 — Dimensional and thermal properties of nonwoven fabrics (a) thickness, (b) air permeability, (c) thermal resistance and (d) thermal conductivity of nonwoven fabrics

centimetre of fabric at a pressure difference of 20mm or 2cm head of water. The air permeability of nonwoven needle punched fabric is based upon the thickness and areal density of the fabrics. The air permeability of jute fibre nonwoven fabrics is more due to its open porous structure of needle punched jute nonwoven fabrics.

Effect of Thermal Resistance

The thermal resistance of the samples is tested by using Lee's Disc Apparatus (Objective method). A steam chamber is placed on circular metal disc. The lower part of the steam chamber is made of a thick metal plate of the same diameter as that of circular metal disc. The upper part is a hollow chamber in which two side tubes are provided for inflow and outflow of steam. Two thermometers are inserted into two holes in the upper and lower disc respectively. There are three hooks attached to the metal disc. The complete setup is suspended from a clamp stand by attaching threads to these hooks. Steam is passed through the steam chamber. As heat gets conducted into the brass disc through the bad conductor, it gets heated up. The temperature is noted from time to time. When the temperature is steady for at least 10 min, the steady state temperature and temperature of steam chamber are noted.

The thermal resistance or insulation value of needled punched nonwoven fabrics is shown in Fig.1(c) From the test results, it is found that the recycled polyester fabric behaves better in thermal resistance property. The nonwoven fabrics S7 and S10 show good insulation related to thermal property. So, depending upon the recycled PET percentage, in nonwoven blended fabrics, the effect of thermal insulation is varied.

Effect of Thermal Conductivity

The thermal conductivity value of needle punching nonwoven fabrics is shown in Fig.1(d). From the test results, it is found that the jute fabric behaves better in thermal conductivity property. The samples S5 (50% jute+ 25% polypropylene + 25% recycled PET) and S8 (40% jute+ 30% polypropylene+ 30% recycled PET) show good thermal conductivity property. So, depending upon the percentage of jute in nonwoven blended fabrics, the effect of thermal conductivity is varied.

Temperature difference of Fabric (Manual Method)

The samples are placed in the car top metal plate and then this set up is placed in open sunlight. The sunlight directly falls on the metal side only. The samples are placed below the metal and there is no direct contact between the sample and the sunlight. After few minutes, the temperature raised to maximum level of sunlight temperature. Two thermometers are used to measure the temperature of both sample and the metal plate. The temperature of the plate (T_1) and the temperature of the sample (T_2) are noted.

The thermal resistance of the samples is calculated by subjective method. In this, the samples are subjected to open sunlight with car (automobile) roof metal plate to find out the thermal resistance of the samples by calculating the temperature difference. The temperature of automobile top panel is measured with and without samples and the temperature difference is noted by using subjective method

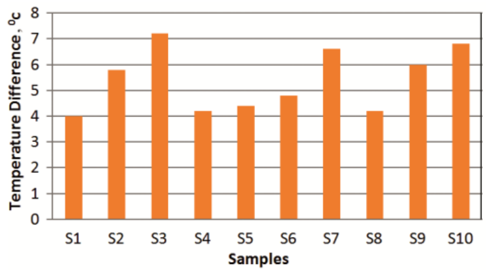

Fig. 2 — Temperature difference of nonwoven fabrics

(Fig. 2). The reading is taken for a period of particular interval of half an hour and the average of this value is reported against the respective samples.

From the test results, the temperature difference of sample S3 is found more as compared to the other samples. The sample S7 and S10 show almost equal value as compared to the sample S3. The samples S1, S5 and S8 have the lowest temperature difference as compared to other samples.

ANOVA Results

The ANOVA statistical tool is used to analyze the effect of different needle punched nonwoven fabrics proportion on thermal resistance value. It is observed that the P value is lesser than 0.05 in between column groups. Between columns the p value is lesser than 0.05, hence there is a significant difference between the thermal resistances of the samples. The effect of triple fibre proportion fabrics on the thermal insulation value of needle punched nonwoven fabrics is observed. The change in the fibre proportion directly influences the thermal insulation behavior of the nonwoven fabrics.

From the analysis of results, the following inferences are made:

- Thermal resistance values are normally increasing with the increase in fabric thickness and weight.
- Thermal resistance of S3 fabric shows a highest value than other samples as well as sample S7 and S10 show good thermal resistance value.

Hence, it can be concluded that 100% recycled PET can be used as automotive roof headliner in automotive fields. In case of industrial and automotive products where high thermal resistance is essential, 100% Recycled PET nonwoven fabric is suitable. 25% Jute + 25% Polypropylene + 50% Recycled PET and 30% Jute + 30% Polypropylene + 40% Recycled PET nonwoven fabrics can be used in dashboard insulation, carpets and flooring, seats, wheel housing, engine hood insulation and boot insulation.

References

1 Vinay K M and Mukhopadyay A, *Indian J Fibre Text Res*, 30 (2005) 218.
2 Sengupta S, Samajpati S & Ganguly P K , *Indian J Fibre Text Res*, 24 (1999) 103.
3 Youjiang W , *Indian J Fibre Text Res* , 1 (2010) 135.
4 Ganesan P & Karthik T, *J Text Inst*, 107(4) (2016) 477.
5 Hosseini M, Rahimzadeh H , Bafekrpoor H & Jeddi AA, *The Open Text J*, 4 (2011) 1.
6 Debnath S & Madhusoothanan S, *Indian J Fibre Text Res*, 1 (2011) 122,.
7 Tanabe, Shin-ichi & Choi J, *J Korean Home Econo Assoc*, 3(1) (2002) 55.
8 Kucukali O M, Nergis B & Candan C, *Int J Mech Mat Eng*, 10 (2016) 1510.
9 Sakthivel S, & Ramachandran T, *Int J Eng Res App*, 3(1) (2012) 2983.
10 Sanjoy D, *Indian J Fibre Text Res* , 36 (2011) 122.
11 Subankar M, Kunal S , *Frontier Sci*, 2 (2012) 226.
12 Anusha T, Rinsey Antony V A & Jayasri P, *Int Technol Explo Eng*, 8 (2018)564.
13 Parikh D. V, Chen Y & Sun L, *Text Res J*, 76 (11) (2016) 813.
14 Dent R W, *J Text Inst*, 67 (4) (2008) 220.
15 Subramaniam V, Madhusoothanan M & Debnath C R, *Text Res J* , 58 (11) (1988) 677.
16 Shu Yang S & Yu W D, *J Fibre Bio Informatics*, 3 (2011) 203.
17 Yang S, Weidong Y & Pan, N, *Text Res J* , 81 (7) (2011) 673.
18 Sanjoy D, *Indian J Fibre Text Res*, 35 (2010) 38.
19 Zeinab S , Saad M M , Shankankery M & Hanfy I, *Autex Res J*, 6 (2006) 148
20 Sujit kumar S, Akahay S & Subhankar M, *Tekstilec*, 62(2019) 258.
21 Buvaneshwari M & Sangeetha K, *Int J Appl Eng Res*, 21(2018) 14903.
22 Liga F, Silvija K & Guntis S. *Sci J Riga Technol Univ*, 6 (2011) 36.
23 Freivalde L & Kukle S, *Mat Sci Text Clothing Technol*, 7 (1) (2012) 84.
24 Nahla N F, *J Basic Appl Sci Res* , 6 (2016) 10.
25 Sharma R & Goel A , *J Text Sci Eng* , 7(2017) 1.
26 Sakthivel S, EzhilAnban J J & Ramachandran T, *J Eng Fibers Fabrics*, 9 (1) (2014) 149.
27 Ganguly P K & Sengupta S , *Indian J Fibre Text Res*, 24 (1999) 34.
28 Islam R & Ahmed S, *Adv R Text Eng* , 4 (2) (2019) 1039.
29 Thilagavathi G, Pradeep E, Kannaian T & Sasikala L, *J Text Inst*, 39 (3) (2010) 267.
30 Lassaad G, Halimi M , Hassen M & Sakli F, *Adv Mat Phy Chem* , 4 (2014) 116.
31 Ibrahim C, *Perodics Eng Nat Sci* , 5 (2) (2017) 210.
32 Swapan K G, Satyaranjan B, Souranil D, *Am J Eng*, 5(2016) 43.
33 Goynes W R, Graves E E , Tao W & Day M P, *Nepal Com Camp* , 1(2000) 782.