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Tailor discards: A potential waste for development of useable product

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Abstract
Environmental consciousness all throughout the world has triggered a need for developing sustainable materials from renewable resources. Thus, the main goal of the present study is to assess the physical and mechanical properties of prepared needle punched nonwoven mat from tailor discards. Hence, thermal conductivity and sound insulation properties of nonwovens consisting textile discards were blended with kapok fiber in different ratios of 100 and 50-50% were explored. Absorbtion coefficient ranging from 0.1Hz to 0.23Hz were measured, thermal conductivity values from 2.01 to 3.77 w/mk were obtained and an abrasion mass loss close to 18.9% was found. Measurement results showed that the manufacturing processes mainly affect the sound and thermal properties of the nonwoven mats.

Keywords: Textile waste, needle punching, sound absorption, thermal conductivity, abrasion resistance, flammability of nonwoven mats

1. Introduction

Reused textile discards can be utilized as raw material for insulation properties. Hypothetically, 97% of textile waste can be reused. Reusing textile waste has an ecological benefit as well as economical, making it progressively famous in the past decades. Reused textile waste has already found commercial application as insulation material but so far only waste that is easy to open down to fibers is being utilized. Evaluation of insulation materials is an issue which should be investigated from various perspectives: need to be analyzed from different aspects: physical properties of the material, their impact on people and the environment, installation difficulty and cost**.** (Jordeva S *et al*. 2015) [1] Considering excellent thermal and acoustic performance anticipated from fibrous building materials, the by- products of textile materials addresses an auxiliary opportunity to be utilized as new raw materials for the creation of high efficiency building composites. Along with these, it was feasible to diminish the environmental impacts of the development stage which address one of the most affecting phases of the life cycle of a building, consuming 30% of natural virgin resources (Bilal *et al*., 2020) [2]. Utilization of resources can be diminished by applying the circular economy standards and advancing more resource effective strategies to develop construction components (Munaro *et al*., 2020) [3].

Theoretically, 97% of textile waste can be recycled and used for developing many suitable products. Wool is a natural fiber obtained from shearing the sheep which is known to have many outstanding properties including excellent insulation and low flammability characteristics. Now a day's wool is recycled and reutilized for making acoustic panels and thermal insulation boards, mattress paddings. car seats, nonwoven mat for buildings etc. (Patnaik A *et al*. 2015) [4]. Kapok is the best fibers which can compete with manmade fibers such as polyester as regards thermal comfort. It has a very good conductivity and it can be used as insulator in the systems of protection as compared to the polystyrene or glass wool which has an average conductivity of 0.04 W/mK (Wereme A *et al*, 2010) [5] Kapok has a potential to be used as an alternative sound absorbing fiber material. It is abundant, cheap, and safe for humans and more importantly it is environment friendly (Balador *et al*, 2018) [6]. Fibers acquired from the discarded woolen materials such as waste wool are usually utilized for thermal and sound insulation in view of their great performances and minimal expense. Considering the importance of reused wool based textile wastes and its exploitation for the development of nonwoven products is still meager. Therefore the present work has been attempted for development of sustainable nonwoven mats.

2. Materials and Methods

2.1 Materials Selection and Preparation

Reusing and recycling waste materials addresses a great opportunity to help the society to improve its economy where the resources are reducing (Balador *et al*., 2020) [7]. There is numerous textile wastes those are not profitable recycling despite their potential (Danihelov_a *et al*., 2019) [8]. The waste material tailor discards were collected from Free-look Creation, Gandhipuram, Coimbatore which were mostly made of wool. Kapok fiber was then collected from Advanced Production Laboratory of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore. The fibers were then manually pull out from the selected textile discards for further processing. After that the fibers were blended in different proportion at carding stage using TRYTEX carding machine to make a uniform web. The machine is characterized by 100cm of width, 60 cm of working width with a speed of 20m/min. The machine has 5000 needles and needle penetration depth 12 mm, punch density 25 punch/cm2, stroke frequency of 225 strokes/min and needle motion was down stroke. Different layered needle punched nonwoven mats A, B and C were fed into the machine individually and the layers of web were entangled by needle punching machine. Therefore the nonwoven mats A, B and C was found to be thick and strong.

3. Assessment of Nonwoven Boards

The investigator carried out few tests to find out the properties of the prepared nonwoven like thermal conductivity, sound absorption, abrasion resistance and flammability which are discussed in result and discussion.

3.1 Thermal Conductivity

Thermal conductivity was tested by using Flat Plate Thermal Conductivity Tester as per (ASTM D-1518) [9]. The three samples namely A, B & C were inserted firstly for pre-conditioning for about 30 minutes in Humidity and Temperature Control Cabinet at a temperature range of 35 °C to perform three cycles of heating and then the samples were inserted into the conductivity chamber to get the average results of thermal resistance and heat transfer coefficient.

3.2 Sound Absorption

Sound absorption properties of the samples were investigated by using two-microphone impedance tube according to ISO 10534-2 [10] standard. It was developed to determine the absorption ability of materials for normal incidence sound waves. The loudspeaker present at one end of the impedance tube generates broadband, stationary random sound waves and also the tested sample were placed at the another end. The sound waves propagate in the tube and hit the sample surface. The reflected sound wave signals are picked up and compared to the incident sound waves where the not absorbed part is reflected back to the source side. Also, in the low (50-1000Hz) and medium frequency range (1000-2000Hz), these scales further assisted in damping the sound wave. The nonwoven mats made out of waste wool based fibers and natural fibers like kapok absorb more incident noise in the overall frequencies and exhibit good sound insulation as well as thermal insulation properties (Kucuk *et al*. (2012) [11].

3.3 Thermo Gravimetric Analysis (TGA)

Thermo Gravimetric Analysis (TGA) is an analytical technique used for measuring the thermal degradation properties of the fibres. The analysis is carried out from 25 °C to 500 °C in a nitrogen environment at a rate of 10 °C/min. Following the procedure, readings of all the three needle punched nonwoven mats A, B and C were measured and tabulated. The test was carried out in Bharat Ratna CNR Rao Research Centre in Avinashilingam Institute for Home science and Higher Education for Women, Coimbatore.

3.4 Fourier Transform Infrared Spectroscopy (FTIR)

Fourier Transform Infrared Spectroscopy is an analytical technique used to distinguish organic, polymeric and in some cases inorganic materials. It uses infrared light to scan test samples and observe chemical properties. The samples for FTIR test were prepared and the FTIR instrument send infrared radiations of about 10,000 to 100 cm-1 through a nonwoven samples namely A, B and C individually with some radiation absorbed and some passed through it. The absorbed radiation is then converted into rotational or vibration energy by the samples molecules. In this technique all the three Needle punched nonwoven mats A, B and C was analyzed for FTIR.

3.5 Abrasion Resistance

Abrasion resistance of a test specimen was measured according to ISO-13427 [12] standard in Geo-Textile Abrasion Tester. A test specimen of 38 mm diameter was cut and weighed. After that samples were placed in the instrument and allow running for 50 cycles per minute. Then again the weights of each of the tested samples were taken after completion of 50 cycles.

3.6 Flammability

The test specimen was measured according to ASTM D-6413 [13] Standard in Flame Retardant Tester to evaluate the Flame Resistance of Textiles. Under controlled laboratory conditions, materials response to heat and flame was measured. A specimen was placed in upward direction over a controlled flame and left for a predefined timeframe. Following exposure, the flame source was removed. Measurements are made on the length of time that the specimen continues to flame and the time glow continues after the flame source has been removed. Char or noticeable harm to the specimen after utilization of the tearing force was determined. Notations on observations of melting and dripping were also recorded. In this manner readings were taken for the entire three needle punched nonwoven mats A, B and C respectively.

4. Results and Discussions

4.1 Thermal Conductivity

The results of thermal conductivity of all the three nonwoven mats A, B. and C are expressed in Table 1.

Table 1: The results of thermal conductivity of all the three nonwoven mats A, B. and C are expressed

Sample	Thickness (mm)	Thermal Conductivity (W/m °C)	Thermal Resistance (m2 °C/W)	CLO (m2s °C/Cal)	TIV (%)
A	5.85	2.70	2.16	1.01	99.4
B	5.52	3.77	1.46	0.74	99.5
C	4.53	2.01	2.25	1.07	99.3

From the Table I, it is apparent that the thermal insulation properties of the samples were measured in terms of the thermal conductivity. It was observed that thermal conductivity of sample B was found higher followed by sample C and A respectively. The CLO value of sample B was found lower as it indicates the higher thermal conductivity. Furthermore it was noticed that there is a slight differences in TIV value among all the samples. Higher conductivity of the sample B may be due to the thickness of the sample as well as combination of fiber in the sample. Accordingly sample C has lesser thermal conductivity which may be also due to the thickness as well as the combination (kapok, Wool (50-50%) because the heat retention of kapok was better than that of other fibers due to the static immobile air held in the large lumen region of kapok as such the heat flow is restrained. Lower values of the thermal conductivity imply higher resistance to conduction of the heat through the material which creates a barrier between the surrounding environment and the samples. While comparing wool samples with natural fibers like Kapok, a slight increase in the thermal conductivity was observed. The thermal conductivity of needle punched fabrics has one per cent level of significant difference on the fabrics. Hence, from the discussions it could be concluded that sample C has the lower thermal conductivity with better insulation property and were suitable for roof ceiling insulation application, thermal insulator as well as for waterproof applications.

4.2 Sound Absorption Coefficient

The results of Sound Absorption Coefficient measurement of all the three nonwoven mats A, B and C are presented in the Table 2.

Table 2: The results of Sound Absorption Coefficient measurement of all the three nonwoven mats A, B and C are presented

Sample	Sound absorption coefficient ɑi			Average sound absorption coefficient ɑm
	50-1000 Hz	1000-2000 Hz	2000-5700 Hz	
A	0.342	0.050	0.050	0.147
B	0.737	0.076	0.060	0.291
C	0.596	0.060	0.050	0.235

From the Table II, it is found that sample B which consist of the combination Kapok shows good sound absorption coefficient in overall frequency range from (50-5700 Hz) because it has excellent acoustical damping performance due to its hollow structure inside kapok fiber which was the main reason for its good absorption properties and its absorption coefficients of kapok fibers are essentially impacted by the density, thickness and pact of kapok fibers however but less subjected to the fiber length. As such the results of all the three samples demonstrate that kapok fiber is a promising light and environment-friendly sound absorption material and this large hollow structure is beneficial for acoustical energy dissipation. The higher the ɑ value better will be the sound absorption property. The reason can be attributed to the fact that the large and straight hollow structure increases the frictional resistance between sound waves and kapok fibers resulting in energy dispersion of the waves and makes air vibrations of the waves transfer to fiber vibrations more easily. Also the kinetic energy of the incident sound wave gets converted to low level of heat energy when it passes through a thicker structure. In case of lower thickness, path lengths available for the propagation of the sound wave were not enough to cause sufficient amount of frictional loss (Kucuk and Korkmaz 2012) [14]. Sample A (0.14ɑ) and Sample B (0.29ɑ) both exhibit good sound absorption coefficient measurement. Sound absorption coefficient (ɑ) of the samples in various frequency ranges are shown in the table respectively. The sound was higher at low frequencies (50-1000 Hz) and reduced from medium (1000-2000 Hz) to high recurrence range (2000-5700 Hz) for all the three samples. From the table it was found that the lowest value of for sample A was 0.14 and for sample B was 0.29 which was highest and this distinction was huge (50-5700 Hz). In the case of sample B, as it is a smooth fiber without presence of any scales and hence the sound absorption in the similar frequency range was lower. Sample B showed higher ɑ values than sample A and C in overall (50-5700 Hz) as well as individual frequency ranges due to the presence of longer fiber length of Kapok in sample B which may result in creating a more uniform pore structure for the passage of sound. Therefore it could be said that sample B (0.29ɑ) has good sound absorption coefficient with highest ɑ value in account to the thermal insulation property.

4.3 Thermo Gravimetric Analysis (TGA)

The results of TGA of all the three nonwoven mats A, B and C are presented in the Table 3 and Figure.1;

Table 3: Thermo Gravimetric Analysis (TGA)

Sl. No	Sample	Temperature (Celsius)	Decomposition (%)
1.	A	22.3	98.1
2.	B	24.2	99.9
3.	C	23.7	102.4

From the Table III and Figure 1, it is obvious that the temperature required for the decomposition was highest in the Sample B with 24.2 °C followed by the Sample C with 23.7°C and Sample A with 22.3 °C respectively. The decomposition percentage was highest in the Sample C with 102.4% followed by the Sample B with 99.9% and Sample A with 98.1%. According to Subramaniam *et al*. (2018) [15], the rate of decomposition depends on the heating rate. More the rate of heating, the more will be its decomposition temperature. The curves for nitrogen show only slight differences in the degradation temperatures however they do not change systematically but they do decrease with the number of extrusion cycles again due to the scission of the polyethylene chains, which become shorter and prone to thermal degradation at lower temperatures. Therefore, it was concluded that the systematic decrease in degradation temperature under nitrogen atmosphere might be due to presence of polypropylene chains and as such sample A has slight decreased degradation temperature whereas sample B has a higher degradation temperature which means that there is no presence of propylene chains.

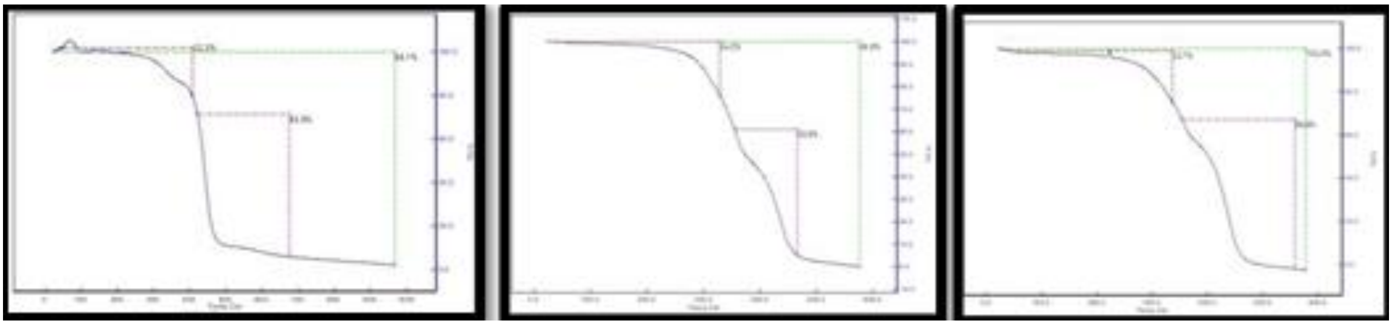

Fig 1: TGA Graph of Sample A, B & C

4.4 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR helps to identify any mix fibers that are used in nonwoven as well as woven fabric. These peaks above-mentioned are the indications that there is a good chemical interaction between polyester nonwoven fabrics and can also be utilized for many functional purposes. The results of FTIR spectra of the three nonwoven mats A, B and C was found that the three needle punched nonwoven mats A, B and C comprised of functional groups namely Alkanes, Bromides and Iodides which means that these samples exhibit good chemical bonding.(Figure 2.).

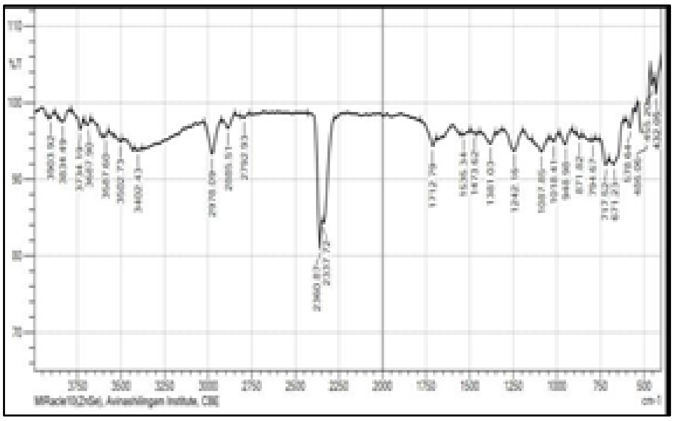

Fig 2: FTIR-Sample A, B&C

4.5 Abrasion Resistance

The results of abrasion resistance of all the three nonwoven mats A, B. and C are expressed in Table 4;

Table 4: Abrasion Resistance

Sample	Initial Weight (g)	Final Weight (g)	Abrasion Mass loss Percent (%)
A	22.060	21.710	1.58
B	13.030	12.180	6.97
C	14.040	11.380	18.9

With reference to the abrasion resistance, the values of needle punched nonwoven samples A, B and C was found to be 1.58%, 6.97% and 18.94% respectively. The lesser the abrasion mass loss percent of tested samples, the better will be the abrasion resistance. As shown in Table IV, the abrasion mass loss of sample C was 18.9% after 50 times of abrasion. Besides it was observed that the appearance was damaged after multiple times of abrasion, almost thoroughly losing the material elements of the nonwoven mats. However, sample A could withstand more than 50 times of abrasion against the load with relatively low abrasion mass loss of approximately 1%.This strong abrasion resistance may improve the Sound and Thermal insulation properties and will prolong the service life of the nonwoven mats. Therefore, it can be concluded that sample A plays an essential role in abrasion resistance activity.

4.6 Flammability

The results of fire properties of all the three nonwoven mats A, B and C are shown in Table 5.

Table 5: Flammability

Sample	Melting characteristics	Smoke generation (sec)	Ignition time (sec)	Continuous burning time (sec)
A	Shrink and melt	5	3.4	42
B	Shrink and melt	5	2.3	60
C	Slightly burnt	5	9.4	0

From the Table V, it is found that sample A and B got shrank first and then melted whereas sample C was burnt slightly. Sample C showed better fire properties followed by sample A than that of sample B. Sample C took a bit longer time to ignite in comparison to that of sample A and B. This was due to inherent fire retardant properties of waste wool and kapok blended samples which helped to delay the burning. Sample A and B showed similar fire properties and expected a bit longer burning time which may be because of the presence of wool in the sample. All the samples were not combustible at the onset of fire; first they melted, generated smoke and then burnt at higher temperatures. When combined with waste wool fibers they inherent good fire properties and also exhibit a bit longer burning time because wool is naturally flame retardant and does not ignite easily. It burns with a self-extinguishing flame. Wool does not melt and despite the fact that it consumes more oxygen that is available in the atmosphere to ignite and has cross- cell connected cell layer structure which get swelled when heated to the point of combustion forming an insulating layer that prevents the spread of flame. (Zhang, 2010) [16]. Therefore it was concluded that sample C has good fire resistance properties and can prevent any immediate fire hazards. The prepared nonwoven samples are shown below in the figure 3, 4 & 5 respectively;

Fig 3: Sample A

Fig 4: Sample B

Fig 5: Sample C

5. Conclusions

In this research work, three nonwoven mats were being made by using Needle Punched techniques of which the samples A, B and C comprises of Kapok &Wool respectively of blended ratios of 100 and 50-50% to form mats and as such sample A exhibited more weight, thickness, abrasion resistance whereas sample B exhibited good insulating properties with reference to sound absorption coefficient measurement. While considering sample C it has good thermal conductivity, sound absorption coefficient. Thus, the result shows that sample C has the best combination with good thermal and sound insulation properties and these samples can be used in various applications such as acoustic boards, automobiles, home furnishings, civil engineering, geo-textiles and industrial filters also. Therefore, nonwoven thermal and sound absorption mats are taking up the pace and will grow more advanced in coming future.

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