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Recycling of Cotton/Polyester Selvedge Waste to Produced Chemical Bonded Nonwovens for Functional Thermal Insulation Materials

Meseret Bogale*, Sakthivel S

Department of Textile Technology, Textile, Apparel and Fashion Technology Division, Ethiopian Technical University, Addis Ababa, Ethiopia

Abstract

This research study reports on thermal insulation properties of six samples made from recycled Cotton/Polyester selvedge waste for automotive interior applications. The selvedge waste recycled from cotton/ polyester fibers have a possible source of raw material that can be measured for thermal insulation purposes, but its amounts are limited. In the procedure of different-layer nonwoven sheets are prepared with a chemical bonding method. The entire samples were tested for thermal insulation according to their physical properties as per the ASTM and ISO standard. The thermal insulation properties were measured according to thermal conductive in solids Principle method, thermal insulation values on over six temperatures 0,50,100,150 and 200 (TIV) were calculated. The results showed that the nonwovens were made from recycled Cotton/ polyester selvedge wastes have confirmed more than 75% of the thermal insulation application. The recycled waste cotton/ polyester selvedge nonwoven mats have satisfactory moisture resistance at high humidity situations without disturbing the insulation properties. From this research it is concluded that the nonwovens produced from 100% polyester and 50/50 C/P nonwovens shows that better thermal insulation performance.

Keywords: Thermal insulation• Recycled selvedge waste• Cotton/polyester fibers• Nonwoven• Chemical bonding

Introduction

Recycling fibrous wastes is one of the most significant for environmental tasks that face the world, to reduce environmental loading and promote the most effective use of resources [1]. Thermal insulation plays an essential role in contributing to the automotive by heat gains and losses through the envelope. And a study will reported that effective thermal insulation in the automotive interior parts. Selvedge wastes can be changed into short fibers by the application of mechanical processes. A series of processes have been undertaken in the course of a research aimed at more or less complete recycle of fibers from end-of-life textiles. First of all, selvedge waste is crushed with a grinding machine [2]. The use of recycled cotton and polyester nonwovens has many advantages compared to conventional thermal insulators, including reduced product cost, good handling, and environmental protection.

Materials were manufactured from reclaimed fibers to offer the thermal insulation application. And also introduced into a detailed manufacturing process for nonwoven materials and thermal insulation materials and interior of automotive application, so, it makes intelligence to find out the ability of the materials made from recycled selvedge wastes to thermal insulation [3]. The thermal insulation properties of materials were investigated; there were several insulation materials were made from recycled textiles with the proportion of cotton fibers and polyester fibers [2].

Zeinab et al. addressed heat passed through various kinds of nonwoven materials that was used as a thermal insulation. They studied about the dependence of the thermal physical phenomenon on the thickness and density of the insulation of materials which was made from the polyester and also the plastic fibers. They concluded that, based on the measured value of the thermal conductivity (λ = 0.033 $W \cdot m^{-1} \cdot K^{-1}$) of the recycled textile materials investigated, the selected nonwovens were suitable for use as a thermal insulation material [3].

In this research, the thermal insulation properties of nonwovens with different fabric weight, thickness, density, porosity and air permeability were investigated. The main target for choosing the nonwovens were due to their lightweight for manufacturing thermal insulation materials. In this situations, thermal insulation of different layer nonwovens with forming single and double layer were investigated. Furthermore, thermal insulation of the six samples was analyzed.

Likewise, the increase of weight of nonwovens leads an increase in thermal conductivity. According to the thermal insulation measurements, the results show that when the thickness of nonwovens increases the thermal insulation of the samples also increases' [4]. The thermal insulation material is one of the very vital properties of the textile resources for the technical textile application. And also the procedures frequently used to measure the thermal insulation values (TIV) were the le's disk method, the constant temperature method and the cooling method [5]. In this research recycled the properties of cotton/polyester nonwovens were investigated by using recycled woven selvedges wastes to produce thermal insulation nonwovens can reduce the textile waste problem and also help to reuse resources more efficiently. The main purpose of the research was to investigate the effects of the physical properties of nonwovens on the thermal insulation property of recycled cotton/polyester nonwovens. And chemically bonded nonwovens were manufactured from recycled cotton and polyester selvedge waste fibers and tested for thermal insulation performance [6].

In this study the thermal insulation affecting factors such as thickness, density, air permeability, porosity, and thermal conductivity were measured according to the ASTM and ISO Standard for the purpose of automotive industry applications. The recycled cotton and polyester fibers prepared from the selvedge wastes have the parameters like fiber length, uniformity ratio, micron are value and fiber strength which were appropriate to manufacture the fiber in to nonwovens. Chemical bonded non-woven fabrics using recycled cotton/polyester fiber have been developed and their characteristics have been critically analyzed for thermal insulation behavior in automotive application [7].

Materials and Methods

The raw materials used for this study were recycled cotton and recycled

***Address for Correspondence:** Meseret Bogale, Department of Textile Technology, Textile, Apparel and Fashion Technology Division, Ethiopian Technical University, Addis Ababa, Ethiopia, E-mail: abcdbogalemeseret@gmail.com*

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Polyester selvedge waste fibers were used for the production of nonwovens. The raw materials which were cotton and polyester selvedge wastes for this study were collected from Kanoria Africa textile PLC of weaving department around in Debrezeyit of Ethiopia for the preparation of adhesive bonded nonwoven nonwovens. First of all it was performed sorting and opening by means of mechanical Processes. The selvedges of woven fabric waste have been converted in to fiber mechanically using Lashima grinding, opening and blending machine. The input raw materials were fed manually through a rubber conveyor belt of the first grinder and opener to be automatically transferred to bottom of the spiked roller. This roller was responsible for tearing and opening the selvedge waste into fiber form.

The selvedge wastes from weaving departments were processed through the sequence of operational procedures. Firstly the wastes were cleaned, because they were containing many undesirable materials. And then cotton and polyester selvedge wastes separated carefully. Then after woven selvedge wastes were proceeded in to grinding machine. After that the fibers were processed in the mini laboratory carding machine for the preparation of nonwoven webs. During the production process of nonwovens from recycled cotton (R-cotton) and recycled polyester (R- polyester) fibers were blended with cotton and polyester with a proportion of 50/50, 70/30, 30/70 and 60/40 cotton/polyester respectively by using an electronic balance in grams of fibers. And also 100% cotton and 100% Polyester nonwovens were produced for comparison of their thermal insulation properties.

Cotton selvedge waste

The cotton selvedge wastes obtained from the shuttle less weaving loom was collected separated and cleaned manually to remove non-cotton and colored materials existing in the cotton selvedge waste out of cotton threads. The cleaned cotton selvedges were grinding and opened into fibrous form using grinding machine. The photographic images of cotton selvedge waste and cleaned cotton threads are shown in Figure 1.

Polyester Selvedge Waste

The polyester selvedge wastes obtained from the shuttle less weaving loom was collected, separated and cleaned manually to remove no polyester and colored materials existing in the polyester selvedge wastes. The cleaned polyester wastes were grinded and opened into fibrous form using grinding machine. The photographic images of polyester selvedge waste and cleaned polyester selvedge wastes are shown in the Figure 2 below.

Grinding of Textile wastes

Laroche grinding machine offers very accurate opening and blending equipment which was a very easy way to recycling the wastes used for the production of technical textiles. Like automotive industry, building construction in the form of thermal insulation application. And also textile products coming in a different forms like agro textiles, big bags, carpets, clothing, furnishings, geotextiles, nets, tarpaulin, towels, combat and personal protective equipment other applications (Figure 3).

Figure 1. 100% cotton selvedge wastes.

Figure 2. 100% selvedge polyester waste.

Figure 3. Laroche grinding machines.

Blending of Recycled Fibers

Cotton and polyester were blended with various proportions using a mini laboratory carding machine. The various proportions of recycled cotton and recycled polyester fibers used for the production of nonwoven fabrics were given in Table 1. The fiber blend was carded four times to improve the web uniformity, and also all the measures were done with an electrical balance in terms of grams (Table 1).

Table 1. Fibre blending composition and sample coding.

S.No	Fibre blending composition/proportion	C/P	Coding
1	100% recycled cotton fibers	100:00:00	S1C
2	100% recycled polyester fibers	0.069444	S2P
3	50% recycled cotton fiber and 50% recycled polyester fiber	50:50:00	S3C/P
4	70% recycled cotton fiber and 30% recycled polyester fiber	70:30:00	S4C/P
5	30% recycled cotton fiber and 70% recycled polyester fiber	30:70	S5C/P
6	60% recycled fiber and 40% recycled polyester fiber	60:40:00	S6C/P

Web Formation

100% recycled cotton, 100% polyester fibers and the blended cotton/ polyester fibers were fed into mini laboratory carding machine to gain carded web. For the period of carding process, the fiber blending was extra opened in to individual fibers and combed to be somewhat to makes parallel. The fiber blended was carded four times enhance the web uniformity. With different webs layers are superimposed one above the other to obtain required thickness in the final nonwoven fabric.

Method of Chemical Bonding

S.-M. Saaristo discussed on chemical bonding with an adhesive bonding chemical which was used to bind the web of nonwovens together. The bonding agents were polymers that are formed by emulsion polymerization. These binders were usually water-based latexes that were formed from few ingredients. The latex polymers were the most commonly used for several

Reasons. Latex binders were versatile because of their variety and can be found suitable binders for different applications and properties required. Other essential reasons were ease of application and cost effectiveness [8]. The fibrous layer from the web former was sprayed with a solution of fevicol which was made from polyvinyl acetate at a constant pressure and flow by using compressed air with a spray gun as shown in the Figure 6 below and then the fibrous layer is converted into nonwoven fabric (Figure 6).

The produced selvedge cotton/polyester nonwoven samples such as 100% recycled cotton, 100% recycled polyester fibers and within different ratios 50:50 C/P, 70:30 C/P, 30:70 C/P and 60:40 C/P on the principle of weight of recycled fibers by using electronic balance were prepared. The thickness of the preferred samples in this study ranges from 2mm to 4mm and 50cm wide and 100cm long were developed to measure the thermal insulation property as shown in figure 2.7 which shows the prepared samples of chemical bonded recycled nonwovens. The physical properties of nonwovens which affect the thermal insulation were thickness, density, porosity, air permeability, thermal conductivity were tested according to the ASTM and ISO standard. And also physical properties were tested to understand the influence on the thermal

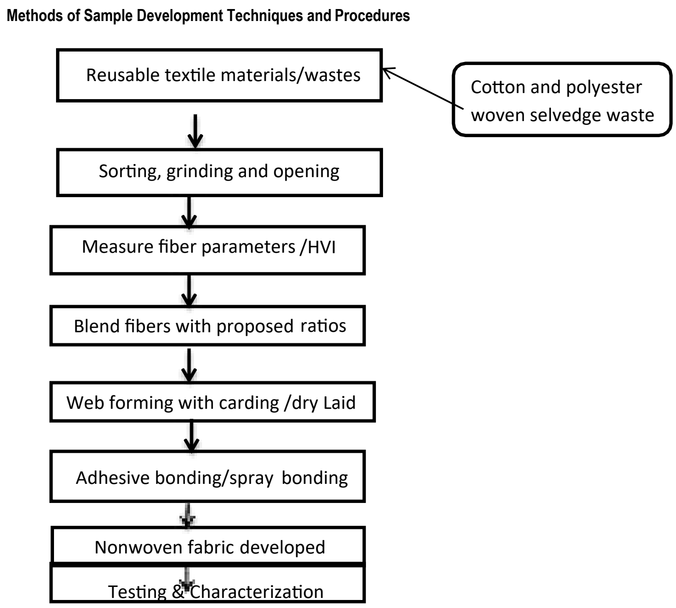

Figure 4. Method of development of chemical bonded non-woven.

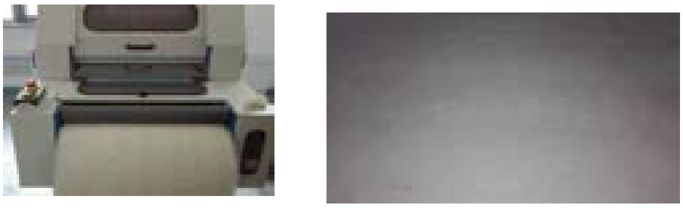

Figure 5. Mini lab card web making process

Figure 6. Adhesive bonding of recycled selvedge waste nonwovens.

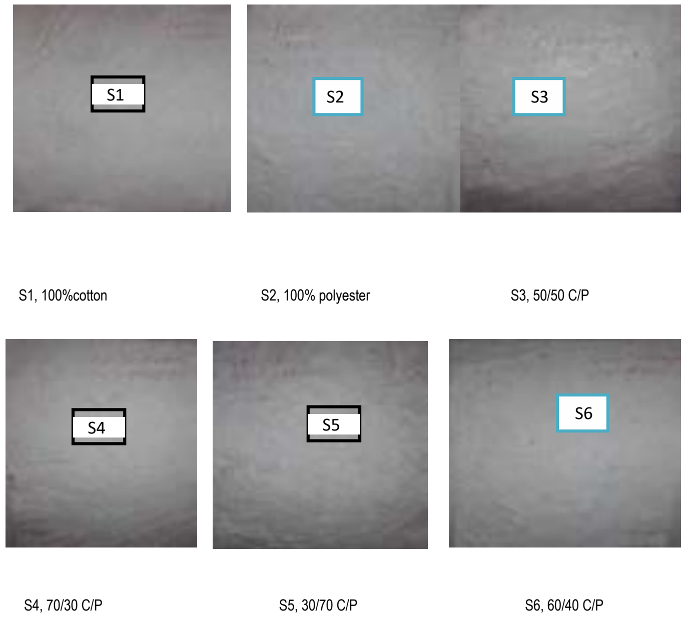

Figure 7. Chemical bonded recycled selvedge waste nonwoven samples.

insulation of recycled nonwovens (Figure 7).

Testing Methods

The recycled cotton and polyester fibers were tested according to the standard procedures of HVI and favimat with the physical properties like fiber length, fiber strength, fiber elongation and fiber micron are values. And also the nonwoven samples of recycled cotton and polyester recycled fiber from selvedge waste of weaving department produced according to required samples were tested for their thermal insulation and physical properties like thickness, areal density, Bulk density, porosity, air permeability and thermal conductivity with respect to the ASTM and ISO standard. In order to study the influence of fiber type, areal density, and porosity and air permeability on thermal insulation, the samples of recycled fiber nonwoven were produced and measured with the above parameters.

Testing of recycled fibers

The selected waste fibers were tested in terms of fiber length, fineness, elongation, diameter, fiber strength by using standard test procedures. The test was essential as the fiber characteristics directly affect the properties of developed nonwoven fabric. Before testing recycled 100% cotton, 100% recycled polyester fibers were kept in standard conditions for 24 h i.e., 21± 1°C temperature and 65% ± 2 RH. This was done to avoid deviation in results (Table 2).

Testing Methods

Testing of thickness

The thickness tester was used to measure the thickness of nonwovens. The measurement of thickness 0.001~25 mm. for measuring an accuracy of 0.001mm, the lowering speed of pressing foot was 1.72 mm/s, Area of pressing foot was 2500 mm^2 and load weight of 1000cN Pressing duration of 10s. The sample size which taken for thickness measurement is 15cm width and 30 cm length. From four random readings we have taken the mean value of the thickness was used to determine the value in (mm) and the calculated result is the average thickness of the sample under the test. The nonwovens thickness was determined in accordance with the digital thickness tester with ISO 9073 standard method (Figure 8).

Fabric Weight Measurement

GSM is the weight of fabric in one gram per square meter. And also it is the metric measurement of the weight of the fabric. Its unit is g/m^2. To measure the gram per meter square (g/m^2) of the nonwoven fabric by GSM cutter, fabric weight is one of the physical tests of the nonwoven fabrics. And by the following ways we can measure the weight of the fabrics. That are cut the nonwoven fabric with GSM cutter (g/cm^2) weight the nonwoven fabric with an electrical balance, the cut sample is 100cm^2, the Wight of the sample is multiplied by 100 or divided by 0.01 To change in meter. Then the result is the GSM of the particular fabric (Figure 9).

Testing of Bulk density

M. El Wazna, et al. defined bulk density ρ[kg/m^3] is defined as the ratio of the mass per unit area Ma [kg/m^2] and thickness [m], The fabric mass density or fabric bulk density (g/m^3) depends on both fabric weight and fabric thickness. In turn bulk density of the nonwoven fabric was calculated from the weight of nonwoven fabrics and thickness values of the nonwoven fabrics using the following equation [9,10].

$$Ma/t \quad (1)$$

Where is bulk density in kg/m^3, Ma mass per unit area in kg/m^2, t thickness of fabric in (m) And also M. Venkataraman et al. reported that fabric density [kg/m^3] is calculated as ratio of areal mass (G [g/m^2]) and thickness (h [mm]). Fabric density (kg/m^3) is calculated as ratio of areal mass (G (g/m^2)) and thickness (h (mm)) by using the following formula [11].

Table 2. Recycled cotton and polyester fiber properties.

Sl. No.	Properties	RCF	RPF
1	Length (mm)	25.50	63.4
2	Elongation (%)	5.93	18.41
3	Fiber fineness/count (dtex)	1.577	3.92
4	Fiber strength (cN/dtex)	3.29	5.02
5	Diameter (microns)	15.75	22.29

RCF= recycled cotton fiber, RPF= recycled polyester fiber

Figure 8. Digital thickness tester machine.

Figure 9. Nonwoven fabric weight testing.

Fabric Density = G/h (2)

Porosity Measurement

M. El Wazna, et al. They have been explaining the porosity can be defined as the total volume of void space contained within the boundaries of a material. In other words porosity can be defined as the set of voids of a nonwoven material. This is a physical amount that determines the flow and retention abilities of a nonwoven [9]. A theoretical, calculated value for porosity can be determined, and has been defined as the ratio of air space to the total volume of the fabric, expressed as a percentage. The terms used in this calculation are the specific gravity of the component fibers and the weight and thickness of the specimen, as indicated in the following formulas [12].

P = 100 - Pa/Pb (3)

Whereas: - Pa is the fabric density and Pb is the fiber density. Fabric density, Pa, expressed in grams per cubic centimeter (g/cc), is calculated by dividing the fabric weight (g/cm^2) by the fabric thickness (cm):

Pa = (g/cm^2)/cm (4)

Air Permeability Measurement

M. K. Ozturk, et al. on their study they have been conducted that air permeability plays an essential role for applications such as filtration, thermal and acoustic insulation. They were found that the fabric GSM was closely related to the air-permeability. The air permeability decreased with the increase in mass per unit area [13]. Air permeability of nonwoven fabric is the amount of airflow passing through perpendicularly to a known area of fabric is adjusted to obtain a suggested air pressure differential between the two fabric surfaces and it's normally articulated in terms of cm^3/s/cm^2 calculated at working conditions. From the amount of airflow, the air resistance of the nonwovens is resolute in accordance with the ISO 9237:1995 test Method. And the measurements was carried out by using 20cm^2 circular fabric with 100 Pa pressure difference for the results was expressed in cm^3/s/cm^2 by taken the average of four different measurement. The test was performed according to ISO 9237:1995 test method (Figure 10).

Thermal Conductivity

The thermal conductivity of the specimens was measured using WL 374 Heat Conduction in solids. The apparatus shown in figure 2.11 consists of two identical discs of 40mm in diameter. One of them includes an electrical heater. The specimen (nonwoven such as cotton, polyester, cotton/ polyester blend with 40mm in diameter was placed between an electrical heater and a water-cooled plate. A Dewar vessel prevents the exchange of heat with the surrounding Environment. The specimens are equipped with several temperature measuring points. The heat transfer rate is determined via the Current and voltage of the heater (Figure 11).

Scanning electron microscopy

Morphological analysis was performed as per the ASTM D 256 Standard using a JEOL SEM apparatus, on cryogenically cracked surfaces of nonwoven samples. The developed non-woven's cracked surfaces after tensile testing are tested using a scanning electron microscope (SEM) JEOLJSM-6480LV. Figure 2.12 Shown in A, B, SEM micrographs of a cracked surface of recycled selvedge waste nonwovens' tensile test [14] (Figure 12).

Figure 10. GT-C27B Automatic air permeability tester.

Figure 11. Testing of non-woven fabric Thermal Conductivity.

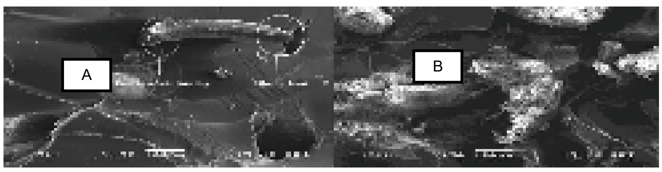

Figure 12. (A) And (B) SEM micrographs of fractured surface of recycled nonwoven's tensile test.

Results and Discussion

Six different types of nonwoven fabric samples were developed from cotton, polyester and cotton/polyester blend in different blend ratios, with different thickness, fabric GSM and density. The physical properties of the chemical bonded selvedge waste nonwovens of recycled from cotton and polyester fibers are measured and average values of samples are given in Table 3.1 samples of 100% cotton(S1 C), 100% polyester (S2 P), 50:50 cotton/ polyester (S3 C/P), 70:30 cotton/polyester (S4 C/P),30:70 cotton/polyester (S5 C/P) and 60:40 cotton/polyester (S6C/P)were tested according to the ASTM and ISO standards to determine the properties of the nonwovens in accordance with the thermal insulation applications(Table 3).

Table 3. Physical properties of chemical bonded nonwoven.

Sample code	Thickness (mm)	Fabric weight g/m²	Bulk density g/m³	Porosity %	Air permeability cm³/s/cm²	Thermal conductivity (W/(m·K)	Thermal insulation (m²·K/W)
S1C	2.11	184.3	0.323	0.769	37.67	0.137	0.77
S2P	3.49	259.5	0.497	0.919	28.75	0.166	0.84
S3C/P	3.65	306.8	0.566	0.924	26.74	0.178	0.85
S4C/P	2.95	227.1	0.412	0.891	35.27	0.147	0.80
S5C/P	3.02	265.8	0.344	0.884	33.49	0.157	0.83
S6C/P	2.02	222.7	0.239	0.894	39.65	0.127	0.75

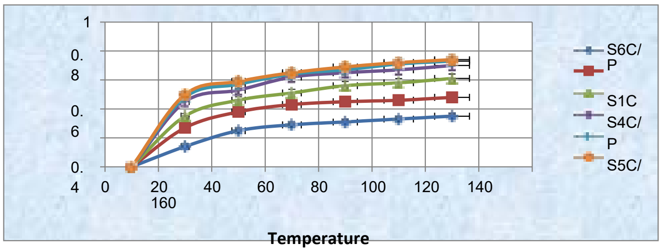

Figure 13. Thermal insulation performances of S1C, S2P, S3C/P, S4C/P, and S5C/P & S6C/P.

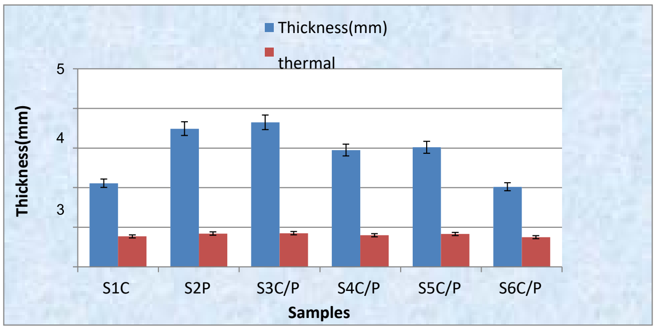

Figure 14. Influence of thickness on thermal insulation.

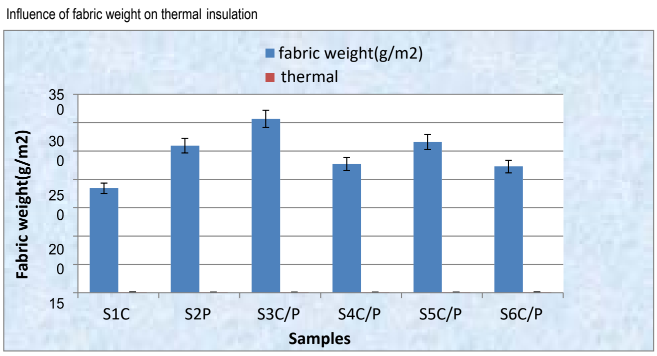

Figure 15. Influence of fabric weight on thermal insulation.

From table 3, it is observed that the S2P and S3 C/P cotton/polyester recycled fiber nonwoven shows similar results in porosity and the air permeability of the samples, S1 C, S2P, S3 C/P, S4 C/P, S5 C/P, and S6 C/P shows 37.67, 28.75, 26.74, 35.27, 33.49 and 39.65 Cm³/S/Cm² . This Comparison shows that the increase in fiber content of the nonwovens decreases the air permeability. From the table we have seen that when thickness of the nonwoven increases the fabric weight, bulk density, thermal conductivity and thermal insulation also increases (Figure 13).

From figure 13 it is observed that all developed recycled nonwoven samples indicates better thermal insulation properties in the overall temperatures (50–140˚C). Thermal insulation value of the samples in different temperature ranges were shown in Figure 13. The thermal insulation was depends upon the thickness and areal density of the nonwovens related to other factors. On the other hand recycled cotton/polyester based nonwoven samples can be showed that while temperature increases, the thermal insulation value of the samples S1C, S2P, S3C/P, S4C/P, S5C/P and S6C/P becomes increased. At the same manner while the thickness of the nonwovens increases the thermal insulation performance the nonwovens increased. So that from the figure 3.1 it is observed that sample S2P and S3C/P has best thermal insulation performance as Compared to the others.

Influence of thickness on thermal insulation of nonwovens

In this study thermal insulation in porous materials was concluded as low thermal insulation has a direct relationship with thickness. This study shows a high increase of thermal insulation value at temperatures, as the material gets thicker the thermal insulation property increases shown in Figure 14 from figure 14. It shows that the nonwoven, S3C/P, S2P and S5C/P which has 3.65, (Figure 14).

3.49 and 3.02 mm, thickness having a thermal insulation value of 0.85, 0.84, and 0.83. From this figure it is observed that with the increase of the fabric thickness its thermal insulation value also increases. So that from this it can be understood that thermal insulation mostly dependent on the thickness of the fabric (Figure 15).

From figure 15 it is observed that with the increase of the weight of the nonwoven fabrics its thermal insulation value also increases. So that thermal insulation of nonwovens is highly dependent on the weight of fabrics. And from this figure it is observed that nonwovens made from 50/50 C/P have higher fabric weight and higher thermal insulation performance as Compared to the other blending composition. It is obvious from table (3.1) and fig. 3.3) that, there is a direct relationship between fabrics weight and its ability to thermal insulation. As samples of 306.8 g/m² weight have scored the highest values of thermal insulation, this may be because the increase in weight means increase in number of fibers per unit area, so increase the compact of fabrics, this reduce the aerobic blanks between these fibers, leading to reduce the heat lost during those blanks, so thermal insulation of the fabrics increased (Figure 16).

Figure 16 shows that the bulk density of fabric increases as the thermal insulation value of the sample increases. The amount of fibers increases per unit area when the density is large. The energy losses increases as the surface friction increases, thus the thermal insulation value increases. It leads that the increase in bulk density directly increases its thermal insulation values. 50/50 Cotton/polyester selvedge nonwoven having higher bulk density with the value of 0.566 g/cm³ with increases in thermal insulation value of 0.85 m²·K/W. The amount of fibers increases per unit area when the bulk density is large (Figure 17).

Figure 17 shows that the influence of porosity on thermal insulation of recycled cotton/polyester-based upon samples values with a value of 0.769, 0.919, 0.924, 0.891, 0.884, and 0.894, the results indicates that porosity of nonwovens have direct influences on the thermal insulation properties. The thermal insulation of the porous materials was highly dependent on the permeability of the materials. Less porosity and less air permeability of the samples, thus performs with higher heat energy. The same finding was obtained by [15]. (Figure 18).

Figure 18 shows the relationship between specific airflow resistance and thermal insulation. It can be observed that air flows give better thermal

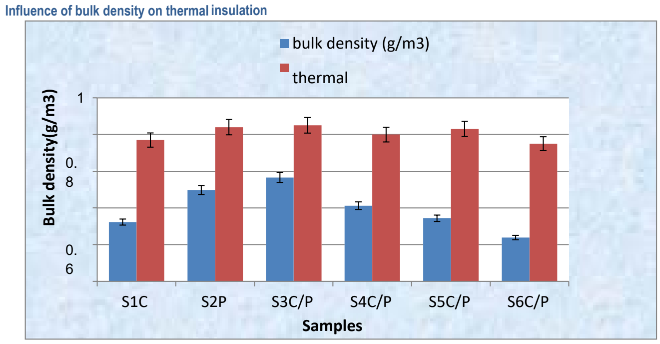

Figure 16. Influence of bulk density on thermal insulation.

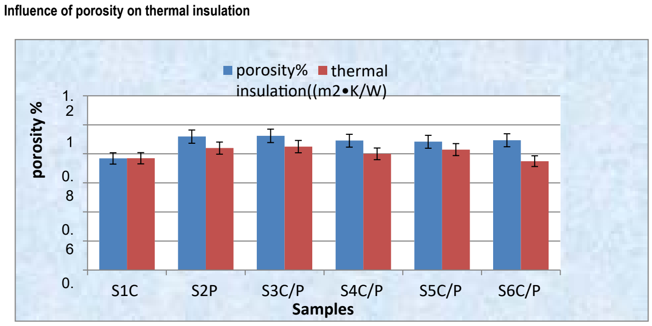

Figure 17. Influence of porosity on thermal insulation.

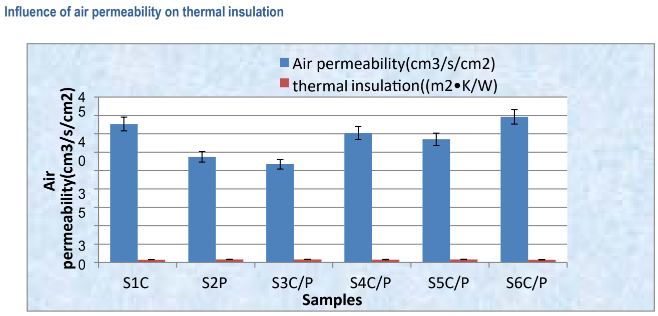

Figure 18. Influence of air permeability.

insulation values. The thermal insulation property was affected by a high increase in airflow. Highly increases of airflow resistance and increasing in density of fabric thermal insulation property also highly affected. The airflow resistance of the nonwovens is about 26.74 to 39.65cm^3/s/cm^2 with TIV of 0.75 to 0.85. It is clear that where the nonwoven fabric density increased, the airflow resistance decreased due to increased resistance to airflow produced by the consolidation of the web; therefore the samples S6 C/P sample has the highest air flow resistance value with the thermal insulation value of 0.85 which is greater than that of S1 C, S2 P, S3 C/P, S4 C/P and S5 C/P, the same result was obtained [15].

Influence of thermal conductivity on thermal insulation

The thermal conductivity of the samples was measured in terms of their thermal insulation value. The thermal conduciveness of different samples is shown in Figure 18. The thermal conductivity improved the insulation property. Low values of the thermal conductivity show higher resistance to conduction of the hotness through the material. By the increases in temperature, the thermal conductivity increases for all samples of recycled cotton fiber along with recycled polyester fiber providing one of the best insulation properties (Figure 19).

From Figure 19 the results indicates that it is potential to develop samples that show related thermal conductivity as that of 100% recycled cotton and polyester fiber. The thermal conductivity for the 50/50 c/p material is about 0.178 W/mK which has a thermal insulation value of 0.85 which is higher

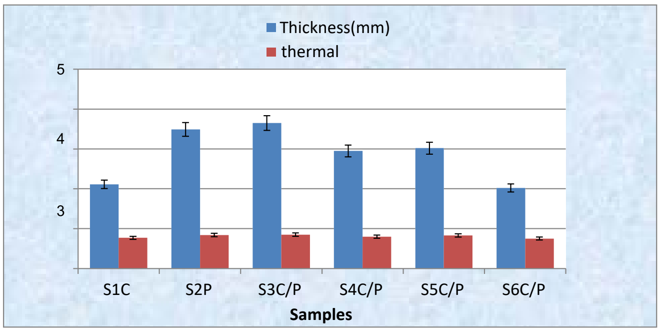

Figure 19. Influence of thermal conductivity on thermal insulation.

than that of the S1C, S2P, S4C/P, S5C/P, S5C/P, and S6C/P these samples were suitable for car interior insulation applications.

Statistical software analysis

For the data analysis, one way ANOVA in SAS software are used with 95% confidence interval and 0.05 alpha values are used. Factors that affect thermal insulation of nonwovens are statistically affected and highly significant it is confirmed with ANOVA analysis that p value is less than 0.05 at 95% confidence level, indicating significant effect on thermal insulation of the nonwovens (Table 4).

From this ANOVA table it shows that density has significant effect on thermal insulation of nonwovens with a 'p' value of less than 0.05 and R-square of 0.562703 values (Table 5). From this ANOVA table it shows that porosity has significant effect on thermal insulation of nonwovens with a 'p' value of less than 0.05 and R-square of 0.588439 values (Table 6).

From this ANOVA table it shows that air permeability has significant effect on thermal insulation of nonwovens with a 'p' value of less than 0.05 and R-square of 0.978024 values (Table 7). From this ANOVA table it shows that thermal conductivity has significant effect on thermal insulation of nonwovens with a 'p' value of less than 0.05 and R-square of 0.443566 values.

Table 4. Analysis of variance ANOVA of density.

Source of variation	df	Sum of squares	Mean squares	F Value	P-value
Model	5	0.00263204	0.00052641	3.09	<0.0001
Error	12	0.00204546	0.00017046		
Corrected total	17	0.00467750			

Table 5. Analysis of variance ANOVA of porosity.

Source of variation	df	Sum of squares	Mean squares	F Value	P-value
Model	5	0.0477450	0.00955490	3.43	<0.0001
Error	12	0.03341400	0.00278450		
Corrected total	17	0.08118850			

Table 6. Analysis of variance ANOVA of air permeability.

Source of variation	df	Sum of squares	Mean squares	F Value	P-value
Model	5	45.09777778	9.01955556	106.81	<0.0001
Error	12	1.01333333	0.0.08444444	---	----
Corrected total	17	46.1111111	---	---	--

Table 7. Analysis of variance ANOVA of thermal conductivity.

Source of variation	df	Sum of squares	Mean squares	F Value	P-value
Model	5	0.00314028	0.00062806	1.91	<0.001
Error	12	0.00393933	0.00032828	--	--
Corrected total	17	0.00707961	--	--	--

Conclusion

Six different recycled selvedge waste cotton/polyester nonwoven mats of S1C, S2P, S3C/P, S4C/P, S5C/P, and S6C/P were produced and tested for thermal insulation and influencing performance of recycled selvedge waste cotton and Polyester nonwovens showed the best thermal insulation values and S3C/P and S2P nonwovens were insulating more than 75% of the occurrence of heat (0-150 T ˚C). There were significant effects of the physical properties of chemical bonded nonwovens on the thermal insulation. From this research it is concluded that the nonwovens produced from 100% polyester and 50/50 C/P nonwovens shows that better thermal insulation performance. These cotton and polyester materials were contribute to the cost benefit as well as green automotive initiatives through the development of materials from natural and recycled resources. SAS software are used to determine the statistical importance of the variations, ANOVA tests were applied. To deduce whether the parameters were significantly affect or not, p values were examined. From the result it is important emphasized that if the p value of a parameter is greater than 0.05 ($p > 0.05$), the parameter wouldn't be significantly affect. The results of this study show that recycled fibers can be used in insulation applications without sacrificing from thermal properties. Such type of nonwoven structures can be used as insulation materials in automotive, furniture and clothing industries.

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