International Journal of Industrial Engineering, 2018;2(3):82-88.
ISSN: 2456-8449.
http://ijie.gjpublications.com

Research Article

Development of Thermal Bonded Non-woven Fabrics Made from Recycled Cotton and Polyester Fibers for Sound Absorption

S. Sakthivel, Eyasu Ferede, Bezaneh Eshetu, Tewolde Mulu

Department of Textile Engineering, Kombolcha Institute of Technology,
Wollo University, Kombolcha, Ethiopia-208.

*Corresponding author's e-mail: sakthi.texpsg@gmail.com

Abstract

Recycled fibers are commonly used in different applications and one of the most important applications is sound absorption. Recycled fiber non-woven, currently, are in greater demands in industries because of their advantages such as low cost, biodegradability, acceptable mechanical & physical properties and so on. Sound absorption materials, renewable and eco-friendly thermal bonded nonwoven have been developed using recycled cotton and polyester fibers. Six types of recycled nonwovens samples were developed using thermal bonding and air compression methods. The blending ratio of cotton and polyester fibers was 60:40. Sound absorption coefficient was measured by impedance tube method (ASTM E 1050). The recycled fiber non-woven samples were characterized for their physical properties such as areal density, bulk density thickness, porosity, air permeability and thermal resistance was determined for all the samples according to the ASTM standards. The results exposed that recycled cotton/polyester nonwoven samples with its physical properties showed, superior sound absorption at 4000Hz, lower thermal resistance, lower air permeability, then compared with recycled cotton/polyester are corresponding to the achieved level but it was lower in recycled cotton/ polyester non-woven samples. But at superior frequencies (4000 Hz), there was a decrease from the achieved level in all the nonwoven samples which might be enhanced by increasing the thickness of the nonwovens. The average sound resistance percentages of these three decibel values were calculated and compared for all the samples.

Keywords: Recycled fiber nonwoven; Thermal bonding; Air compression; Physical properties; Sound absorption coefficient.

Introduction

The recycled fiber prepared from the waste fabrics has the parameters like span length, uniformity ratio, fineness value and tenacity which are suitable to fabricate the fiber into nonwoven. Thermal bonded non-woven fabrics using recycled fiber have been developed and their characteristics have been critically analyzed for the sound absorption. The recycled fibers non-woven base fabrics combine materials with different properties, acquiring new functions and attaining a higher performance which cannot be achieved by a single material [1].

During the bonding conditions below the peak, fabric failure occurs by bond disintegration because of insufficient fiber fusion or "under-bonding". At temperatures above the maximum optimal bonding temperature, the failure occurs by fiber breakage at the bond edge, leaving the bonds intact. The fabrics bonded at the high and optimal temperatures are referred to as over-bonded and well-bonded, respectively [2]. During point bonding, the bond points and the bridging fibers develop distinct properties, different from those of the virgin fibers, depending on the process variables employed [3].

Thermally bonded carded webs were produced, using these fibers, and characterized in order to understand thermal bonding behavior of fibers with different morphology. The fibers with different morphology differed significantly in their bonding behavior [4]. While obtaining these measurements, primary air pressure, die-to-collector distance (DCD), collector speed and collector vacuum were varied and these

Received: 18.03.2018; Received after Revision: 22.03.2018; Accepted: 22.03.2018; Published: 31.03.2018

measurements were used to formulate a conceptual model of fly production based on aerodynamic drag and fiber entanglement [5].Thermal bonding can use three types of fibrous raw material, each of which may be suitable in some applications but not in others. First, the fibers may be all of the same type, with the same melting point. This is satisfactory if the heat is applied at localized spots, but if overall bonding is used, it is possible that all the fibers will melt into a plastic sheet with little or no value. Second, a blend of fusible fiber with either a fiber with a higher melting point or a non-thermoplastic fiber can be used [6].

The performance of sound absorbing materials is particularly being evaluated by the sound absorption co-efficient (α). Alpha (α) is defined as the measures of the acoustical energy absorbed by the material upon incident and usually expressed as the decimal value varying from 0 to 1.0. If 55% of the incident sound energy is absorbed, the absorption co-efficient of that material is said to be that absorbs all the incident sound waves will have a SAC of 0.55. The maximum material co-efficient is 1. The sound absorption co-efficient α depends on the angle at which the sound wave impinges upon the material and the sound frequency values are usually provided in the standard frequencies of 125, 250, 500, 1000 and 2000Hz. Sound reflection Coefficient: Ratio of the amount of total reflected sound intensity to the total incident sound intensity. Acoustic Impendence: Ratio of sound pressure acting on the surface of the specimen to the associated particle velocity normal to the surface [7]. A porous laminated recycled non-woven material by developing of premix, pre heating and lamination exhibited a very high acoustic coefficient property on the frequency range of 500 to 2000 Hz [8]. Two stages of air compression of recycled polyester nonwovens packing wastes along with plastic coated aluminum coated foils, expanded polyester and coir pith offers sound absorption properties compared to recycled cotton fibers [9]. Sound absorption with combination of nonwoven fabrics produced in recycled fibers showed higher performance than that of natural fibers [10].

The possibility of using recycled fiber as sound absorbent materials. The results of sound Absorption Coefficient of recycled fibers were superior to conventional fibers with same thickness or weight and the recycled fiber density was found to have more effect than fabric thickness or weight on sound absorption [11]. The surface area of the fabric directly related to denier and cross sectional shape odd the fabrics in the fabric. Smaller deniers yields more fibers per unit weight of the material, the higher total fiber surface area and greater possibilities for a sound wave to interact with the fiber in the structure. The fabric density also affects the geometry and the volume of voids in the fabric structure [12].

Materials and methods

Materials

The materials for the development of thermal bonded nonwoven fabric are a kind of knitted waste from garment industries. Recycled fibers are from a secondary cycle of processing. To obtain them, fabric-type or thread-type textile waste is mechanically broken down as far as of fibers. The recycled fibers cotton, polyester; cotton polyester blended is segregated in the form of color and white.

Methods of bonding

Thermal bonding nonwovens

The air or random laying techniques allows fabrics with range of mass per unit area to be produced, in which fiber orientation can be made much more random than in the case with traditional web layering. Short fibers can be processed easily, allowing textile waste materials to be used in nonwovens. Through this method (Figure 1), the non-woven samples are developed from the air laid webs of cotton (color and white), polyester (color and white), and cotton polyester blend (color and white) (Figure 2). A hot air bonding machine was used for the thermal bonding which was set to an air temperature of 220°C at the feeding speed of 0.6 m/min and 30 cm bonding area for the development of thermal bonded non-woven samples. The preferred samples proportions 6-8 mm thick, 80 mm wide and 200 mm long were developed to measure the sound absorption coefficient. The nonwoven produced by this technique is soft and bulky. Six varieties of web were produced such as color cotton, white cotton, color polyester, white polyester, color cotton polyester blend and white cotton polyester blended materials.

Methods of testing

The nonwoven samples of recycled cotton, polyester and cotton/polyester blend were tested for the standard test procedure followed for determining the physical properties of the nonwoven samples are ASTM D 5736 for thickness of the fabric, ASTM 6242 is for a real density and bulk density in grams per square meter, ASTM D 737 is for its air permeability, ASTM D 6343-10 standard methods are for the thermal conductivity and ASTM E 1294-89 for Porosity. In order to study the influence of fiber type, number of layers, areal density, porosity and air permeability on sound absorption, the samples of recycled fiber nonwoven were produced and measured with the above parameters. The sound Absorption coefficient of the material is measured using impedance tube method based on ASTM 1050. Sound resistance or insulation by then on-woven fabric samples can be calculated by using the derivation of sound insulation formula [13,14].

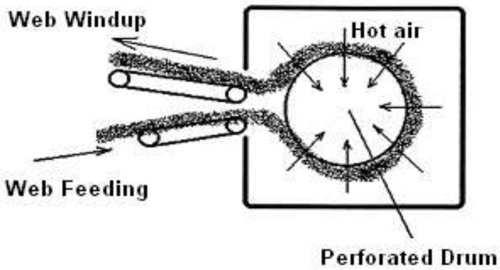


Figure 1. Schematic representation of thermal binding nonwoven

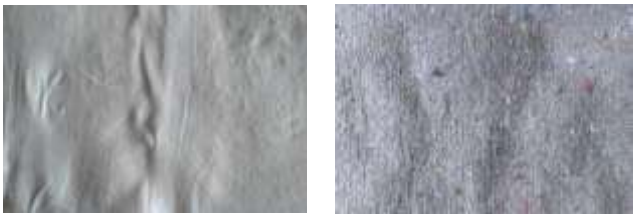


Figure 2. White and color thermal bonded non-woven samples

Results and discussion

The physical properties of the thermal bonded nonwoven of recycled cotton, polyester and cotton polyester blend fabrics are measured and average values of samples are given in table 1. The sample of white cotton (WP), color cotton (CC), white polyester (WP), color polyester (CP), white cotton/polyester (W C/P), color cotton/polyester (C C/P). From table 1, it is observed that the white cotton, polyester and cotton/polyester recycled fiber nonwoven shows similar results in porosity. When the color fibers are used the porosity is increased. This may be due to increase in the thickness and areal density of the fabrics. While comparing the air permeability of the samples, WC, CC, WP, CP, W C/P and C C/P shows that CC has more air permeability value of 38.7CC/S/C m^2this may be due to the fiber properties and their bonding behavior. These comparisons reveal that the increase in fiber content of the nonwovens decreases the air permeability.

Table 1. Physical properties of thermal bonded nonwoven

Sample	Thick-ness (mm)	Areal density (g/m^2)	Bulk Density (g/cm^3)	Fabric Porosity	Air permeability (CC/S/C m^2)	Thermal conductivity (W/mK)
WC	3.2	323.11	0.139	0.394	30.5	0.13
CC	3.3	330.50	0.141	0.387	38.7	0.29
WP	3.4	648.03	0.155	0.356	35.6	0.125
CP	3.5	653.03	0.157	0.335	33.5	0.123
W C/P	3.35	953.00	0.157	0.378	37.8	0.126
C C/P	3.4	980.77	0.151	0.365	6.5	0.127

Sound absorption performance of WC, CC, WP, CP, W C/P & C C/P.

Different recycled fiber of natural and synthetic fiber has different properties especially in consideration to the surface and inner bonding properties. These properties influence the density of the nonwovens, which in turn affect the sound absorption by the fabric. Figure 3, shows the sound absorption coefficient of recycled fiber thermal bonded nonwoven made out of cotton, polyester, and cotton/polyester blend. The evaluation has been done with the white and color samples. From figure 3 it can be observed that while the frequency increases the sound absorption coefficient (SAC) of all samples WC, CC, WP, CP, W C/P, and C C/P also increases. Similarly, while thickness increases the sound absorbing performance also increases. At the highest frequency of 4000 Hz, the SAC values of

WC, CC, WP, CP, W C/P, and C C/P are 0.39, 0.6, 0.35, 0.56, 0.48 and 0.64. The calculated average SAC values of WC, CC, WP, CP, W C/P, and C C/P which are 0.123, 0.253, 0.15, 0.281, 0.203 and 0.328 also reveal the same. The performance of sample CC, CP, C C/P shows equal values from 0 to 1000 Hz; this may be due to the lower frequency, the small increase in thickness or fiber content of this nonwoven does not influence the sound absorption. For a fibrous material with a given porosity, this means that the flow resistance per unit thickness is inversely proportional to the square of the fiber diameter.

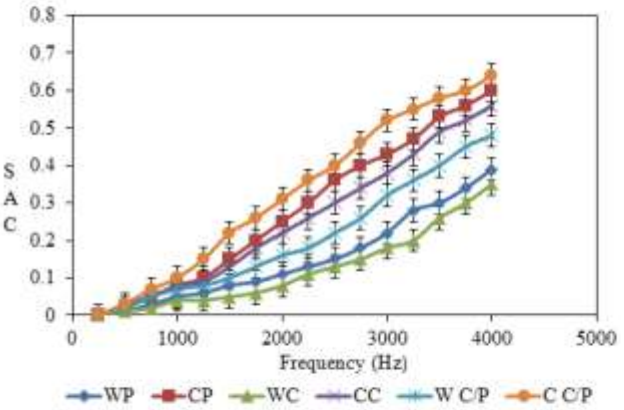


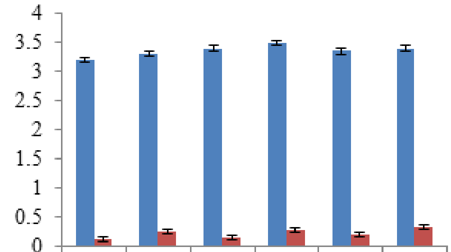
Figure 3. Sound absorption performances of WC, CC, WP, CP, W C/P & CC/P

Influence of thickness on sound absorption

From figure 4, it is observed that the nonwoven WC, WP, W C/P which has 3.2 mm, 3.4mm, and 3.35mm thickness is having SAC of 0.123, 0.15, and 0.203; whereas with the increase of 0.1 mm, 0.1 mm, and 0.5 mm thickness CC, CP, C C/P shows increase SAC of 0.253, 0.281 and 0. 328. The color Cotton/polyester blend nonwoven C C/P with the thickness of 3.4 mm results with average SAC of 0.328 which is higher than WC, WP, CP, W C/P nonwoven fabric. The result reveals that the increase in thickness of the nonwoven fabric increases the sound absorption. The result reveals that the increase in thickness of the nonwoven fabric increases the sound absorption.

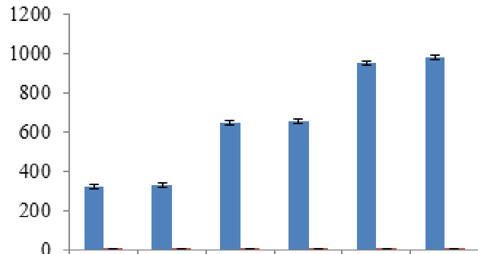
Influence of areal density on sound absorption

Figure 5, shows when there is an increase in areal density there is an increase in sound absorption coefficient for cotton; polyester and cotton polyester blend nonwovens. The colored materials have more density than white material due to the dying molecule content in the colored material. The Color Cotton/polyester nonwoven C C/P with the density of 980.77 g/m^2 results with average SAC of 0.328 which is higher than WC, WP, CP, W C/P nonwoven fabric. The result reveals that the increase in bulk density directly increases the SAC. Density of material is often considered to be the important factor that governs the sound absorption behavior of the material at the same time, the cost of an acoustic material was directly related to its density. The increase of sound absorption values in the middle and higher frequency as the density of the samples were increased.



	WC	CC	WP	CP	W C/P	C C/P
Thickness (mm)	3.2	3.3	3.4	3.5	3.35	3.4
Sound absorption co-efficient	0.123	0.253	0.15	0.281	0.203	0.328

Figure 4. Influence of thickness on sound absorption

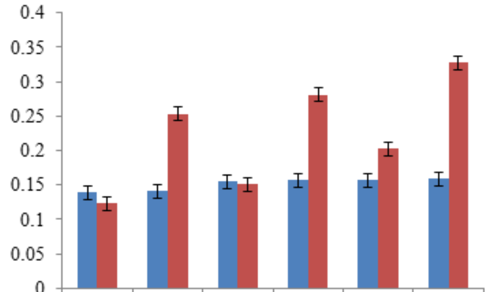


	WC	CC	WP	CP	W C/P	C C/P
Areal density (g/m2)	323.11	330.5	648.03	653.03	953	980.77
Sound absorption co-efficient	0.123	0.253	0.151	0.281	0.203	0.328

Figure 5. Influence of areal density on sound absorption

Influence of bulk density in sound absorption

The influence of bulk density on SAC of nonwovens as shown in the figure 6 reveals that increase in bulk density directly increases the SAC. Colored nonwoven which has the difference in bulk density of 0.022 g/cm^3 with the white nonwoven depicts 18% increase in SAC. Color and white polyester nonwoven having the difference in bulk density of 0.013g/cm^3 with depicts of 28% increase in mean SAC. Cotton/Polyester nonwoven having the difference in bulk density 0.002g/cm^3 increases in mean SAC of 0. 328..It is clear that where the non-woven composites bulk density increased, the air permeability decreased due to increased resistance to air flow caused by the consolidation of the web, but also increases the short fiber content which will occupy the air voids. The result reveals that the increase in bulk density directly increases the SAC.

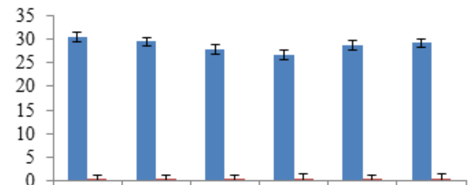


	WC	CC	WP	CP	W C/P	C C/P
Bulk density (g/cm3)	0.139	0.141	0.155	0.157	0.157	0.159
Sound absorption co-efficient	0.123	0.253	0.151	0.281	0.203	0.328

Figure 6. Influence of bulk density in sound absorption

Influence on air permeability on sound absorption

While increasing thickness of nonwoven fabrics of recycled color and white cotton, color and white polyester, and color and white cotton polyester blended, the air permeability decreases as in figure 7.



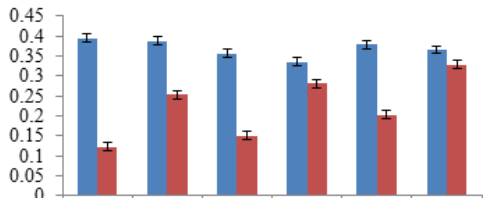
	W C	CC	WP	CP	W C/P	C C/P
Air permeability (cc/s/cm2)	30.5	29.5	27.9	26.7	28.7	29.2
Sound absorption co-efficient	0.123	0.253	0.151	0.281	0.203	0.328

Figure 7. Influence on air permeability on sound absorption

The figure 7 refers the air permeability of cotton, polyester and cotton/polyester based upon the color and white samples. The deviation among the materials can be tested clearly based upon the fiber type and color type. The air permeability of the color nonwoven is about 26.7 – 29.2 cc/s/cm^2 with SAC of 0.253 to 0.328. The graph also shows that polyester has less air permeability than cotton non-woven materials. It is clear that where the fabric density increased, the air permeability decreased due to increased resistance to air flow caused by the consolidation of the web. The C C/P has the highest air permeability value with the SAC of 0.328 which is greater than that of WC, CC, WP, CP, and W C/P. One of the most important qualities that influence the sound absorbing characteristics of a fibrous material is the specific flow resistance per unit thickness of the material. The characteristic impedance and propagation constant, which describes the acoustical properties of porous materials, are governed to a great extent by flow resistance of the materials. Fibers interlocking in nonwovens are the frictional elements that provide resistance to acoustic wave motion.

Influence of porosity on sound absorption

Similar to air permeability lower level the porosity higher level the sound absorption must be. From the figure 8, it is observed that the nonwoven WC, WP, W C/P, CC, CP,C C/P which has 0.394, 0.356, 0.378, 0.387, 0.335 and 0.365 porosity is having SAC of 0.123, 0.151, 0. 0.203, 0.253, 0.281 and 0.328. Less porosity and less air permeability of the samples permit the sound frequency lesser amount at low frequency level, but at higher frequency, the sound enters the fine pores and experience friction between the fibers and bond thus performs with higher absorption of sound energy. It also can be seen that the pore size, link-correlation between the pore and chemical composition of materials studied have a significant influence on the absorption properties If a high percentage of pores are closed and the material has a smaller thickness the absorption.

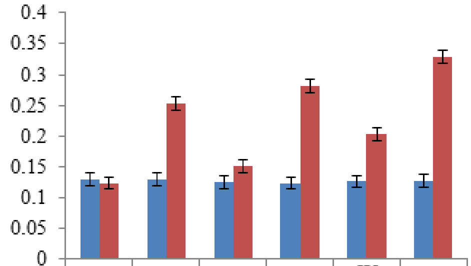


	W C	CC	WP	CP	W C/P	C C/P
Porosity	0.394	0.387	0.356	0.335	0.378	0.365
Sound absorption co-efficient	0.123	0.253	0.151	0.281	0.203	0.328

Figure 8. Influence of porosity on sound absorption

Influence of sound absorption on thermal conductivity

In the figure 9, the graphical representation shows the influence of sound absorption of the thermal conductivity. There is difference among the thermal conductivity for various thermal bonded non-woven samples. Cotton (color and white) non-woven material and polyester (color and white) non-woven material were assessed for thermal insulation property. The thermal conductivity for the white cotton material is about 0.13 W/mK which has SAC of 0.123 which is higher than that of the CC, WP, CP, W C/P, and C C/P.

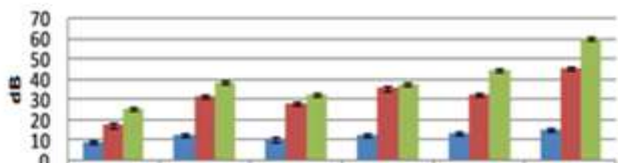


	WC	CC	WP	CP	W C/P	C C/P
Thermal conductivity (W/mK)	0.13	0.129	0.125	0.123	0.126	0.127
Sound absorption co-efficient	0.123	0.253	0.151	0.281	0.203	0.328

Figure 9. Influence of sound absorption on thermal conductivity

Sound resistance performance of the thermal bonded nonwovens

The thermal bonded nonwovens while tested for the sound resistance with 30dB to 60dB showed that when the number of layer increases the sound resistance value of the material is also increases (Figure 10). The average sound resistance percentage values for the three decibel values were shown in figure 8. The nonwoven of recycled color and white cotton, polyester and cotton polyester blend approximately 21, 22 and 28% sound resistance with fabric to source distance of 25, 50, and 75 cm. The nonwoven of cotton, polyester and cotton/polyester blend showed approximately 15, 30, and 38% sound resistance with fabric to source distance of 25, 50, and 75 cm. These results also reveal that the sound resistance increases at the distance between the fabric and the source increases.



	WC	C C	WP	CP	WCP	CCP
25cm	9	12	10	12	13	15
50cm	17	31	28	35	32	45
75cm	25	38	32	37	44	60

Figure 10. Sound resistance performances of the thermal bonded nonwovens

Conclusions

The automotive and building interiors made up of recycled fibers are in potential market growth. The recycled fiber nonwoven as acoustic absorption material is developed by using the fibers recycled from the waste fabrics of cotton (color and white), polyester (color and white) and cotton polyester blend (color and white) collected from the garment industries. The nonwoven is tested for acoustic absorption by ASTM E 1050. It is observed that polyester fiber nonwoven has the highest absorption coefficient in lower frequency levels and higher frequency levels. The recycled polyester nonwoven fabric is having high total surface area, which is influenced by the denier and cross sectional structure of the fibers in the nonwoven fabrics. Similarly, while thickness is increases sound absorbing performance of polyester samples WP, CP and C C/P also increases, at the highest frequency of 4000 Hz. Hence it is concluded that the nonwoven made of recycled polyester with its closer structure and higher sound absorbing percentage of 72% is much suited for interiors in building and auto motives. The cotton (color and white), polyester (color and white) and cotton polyester blend (color and white) are also having sound absorption percentage of 73% is much suited for interiors in sound absorption of 76% and 82% at 4000 Hz. The Color cotton/polyester nonwoven C C/P with the thickness of 3.4 mm has the higher sound absorption of 0.328 SAC. The recycled fiber nonwoven exhibits higher efficiency of sound absorption due to the following factors: effect of fiber diameter, shortened length of fibers, and variable pore geometry of the fabric. The average sound absorption values of C C/P are 0. 328. Where there is an increase in areal density there is an increase in sound absorption. The influence of bulk density on SAC of nonwoven reveals that the increase into bulky density directly increases the SAC. Similar to air permeability, lower the porosity level higher the sound absorption. Sample with highest thermal conductivity shows lesser sound absorption behavior. The samples reveal that the sound resistance also increases at the distance between the fabric and the source increases. The major application of these recycled nonwoven products may be suggested for floor covering and wall coverings.

Conflicts of Interest

The authors hereby declare that they have no conflict of interest.

References

[1] Langley KD, Kim YK, Lewis AF. Recycling and reuse of mixed–fiber fabric remnants (spandex, cotton, polyester). Chelsea Center for Recycling and Economic Development, University of Massachusetts Lowell, USA: 2000.

[2] Wang Y. Recycling in textiles. Woodhead Publishing, UK: 2006.

[3] Zent Z, Long JT. Automotive sound absorbing material survey results. SAE Technical Paper, 2007. https://doi.org/10.4271/2007-01-2186.

[4] Lin JH, Huang CH, Lin CW, Lou CW. Manufacturing Technique of Heat-Insulating and Flame- -Retardant Three-Dimensional Composite Base Fabrics. Journal of Engineered Fibers and Fabrics. 2013;8:14-25.

[5] Fedorova N, Verenich S, Pourdeyhimi B. Strength optimization of thermally bonded spunbond nonwovens. Journal of Engineered Fibers and Fabrics. 2007;2:38-48.

[6] Ozturk MK, Nerg BU, Candan C. A study on the influence of fabric structure on sound absorption behavior of spacer knitted structure. 7th Textile Science conference, Liberec, Czech Republic: 2010.

[7] Govardhan G, Rao RN. Effect of fibre content and alkali treatment on mechanical properties of *Roystonea regia*-reinforced epoxy partially Biodegradable composites. Bulletin of Materials Science. 2011;34:1575-1581.

[8] Mirjalili SA, Mohammad-Shahi M. Investigation on the Acoustic Characteristics of Multi-Layer Nonwoven Structures, Part 1-Multi-Layer Nonwoven Structures with the Simple Configuration. Fibres and Textiles in Eastern Europe. 2012;20:73-77.

[9] Verma BB. Continuous jute fiber reinforced laminated paper composite and reinforcement-fiber free paper laminate. Bull Mater Sci. 2009;32:589-595.

[10] Koizumi T, Tsujiuchi N, Adachi A. The development of sound Absorbing materials using natural bamboo fibers. High performance structure and composites. WIT Press, Southampton; UK: 2002.

[11] Ingard KU. Notes on sound absorption technology. Poughkeepsie, Noise Control Foundation. NY, USA: 1994

[12] Allard JF, Depollier C, Guignouard P. Free field surface impedance measurements of sound-absorbing materials with surface coatings. Applied Acoustics. 1989;26:199-207.

[13] Li J. A study on the relationship between the thickness of nonwoven and sound absorption capability", Modern Applied Science. 2007;1(4):74-76.

[14] Shoshani Y, Yokubov Y. Numerical assessment of maximal absorption coefficients for nonwoven fiber webs. Applied Acoustics. 2000;59:77-87.

****

