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Research Article

Noise Reduction Performance of Recycled Polyester/Cotton Nonwoven Composite Materials

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Abstract

Recycled fibers are normally second-hand in dissimilar applications and individual important function is noise reduction. Recycled fiber nonwoven composites, currently, are in greater demands in company and their advantages such as low cost, biodegradability, acceptable mechanical & physical properties and so on. Noise reduction materials, biodegradable and environment pleasant nonwoven composites were produced using recycled cotton and polyester fibers. Nine types of recycled nonwoven composites were developed using thermal bonding, adhesive bonding and compression molding methods. The blending ratio of polyester and cotton fibers is 60:40. Noise reduction coefficient was measured by impedance tube method (ASTM E 1050). The recycled nonwoven composite physical properties are Thickness, specific airflow resistance, specific porosity, density, and air gap was determined for all the samples with respect to the ASTM standards. The results exposed that at the highest frequency of 4000 Hz. The NAC values of T WP, T CP, T CC/P, and C WP. C CP, C CC/P, TC CP, TC WP and TC CC/P are 0.39, 0.43, 0.5, 0.58, 0.6, 0.63, 0.68, 0.75 and 0.77.The performance of sample TC CC/P, C CP, TC CC/P shows equal values from 0 to 1000 Hz; this might be appropriate to the lower frequency, the small increase in thickness or fiber content of this nonwoven composites does not manipulate the noise reduction performance.

Keywords: Recycled fiber; Nonwoven composites; Compression molding; Physical properties; Noise reduction 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 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

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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

Recycled nonwoven samples were selected as the reinforced material and epoxy (resin) as the matrix. The fabrication was made by thermal & chemical bonding techniques. Nine different samples namely Thermal white polyester (TWP), Thermal color polyester (TCP), Thermal color cotton/polyester (T CC/P), chemical white polyester (CWP), Chemical color polyester (C CP), Chemical color cotton/polyester (C CC/P), Thermal & Chemical white polyester (TC WP), Thermal & Chemical color polyester (TC CP) and Thermal & Chemical color cotton/polyester (TC CC/P) were developed. The size mould of 28 cm (length, *L*) × 28 cm (width, *W*) is used. Initially, epoxy and hardener were mixed with in ratio 4:1 to form a matrix. Then, nonwoven samples were spread into the mould and covered with the matrix.

The composite materials is packed in awaiting thickness of 3 to 7 mm was achieved. The curing time of 6 hrs was maintained uniformly for the 9 composite materials at (60°C). Finally, composite materials were cut into the required specimens with respect to ASTM standard D638 and D790. The noise reduction coefficients of the nonwovens composites were tested by the impedance tube method on ASTME 1050 at Kombolcha institute of Technology, Wollo University Ethiopia. The Fabric thickness was determined in accord with ASTM D5729 standard method. The density was determined in accordance with ASTM D 6242. The porosity was determined by the nonwoven composite samples with respect to ASTM D 3776.

Results and discussion

Figure 1 shows the noise reduction coefficient of nonwoven composite materials made out of cotton, polyester, and cotton/polyester blend. From Figure.1 it can be exposed that while the frequency increases the noise reduction coefficient (NRC) of all samples T WP, T CP, T CC/P, and C WP. C CP, C CC/P, TC CP, TC WP and TC CC/P also increase.

Similarly while thickness increases the noise reduction performance also increases. At the highest frequency of 4000 Hz, the NAC values of T WP, T CP, T CC/P, and C WP. C CP, C CC/P, TC CP, TC WP and TC CC/P are 0.39, 0.43, 0.5, 0.58, 0.6, 0.63, 0.68, 0.75 and 0.77.The average SAC values of T WP, T CP, T CC/ P, CWP. C CP, C CC/P, TC CP, TC WP and TC CC/P which are 0.198, 0.243, 0.281, 0.331, 0.354, 0.376, 0.409, 0.444, and 0.465 also reveal the same. The performance of sample TC CC/P, C CP, TC CC/P shows equal values from 0 to 1000 Hz; this might be owing to the lower frequency, the small increase in thickness or fiber content of this nonwoven does not manipulate the noise reduction. The similar tendency was experimental by Walter and Mike [13]. A recycled fiber web to contain a high noise reduction coefficient, porosity should enhance next to the dissemination of the noise signal. In general, while noise enters the materials, its noise signal is reduced by roughness. The same findings were obtained by Shoshani and Yakubov [14].

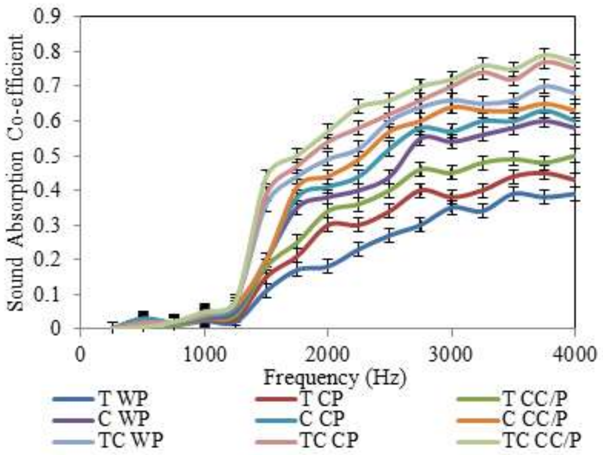
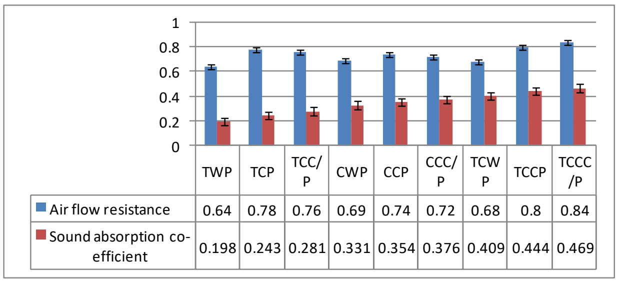


Figure 1. Noise reduction performances of nonwoven composites

Influence of specific air flow resistance

The majority analysis significant character that manipulates the noise reduction performance of the recycled nonwoven composites is the particular flow resistance/ element thickness of the composites. The typical impedance and dissemination stable, which describes the acoustical properties of absorbent materials, are presiding over to a vast amount by flow resistance of the recycled nonwoven composite materials. Fibers interconnecting in nonwoven samples are the roughness constituent that give resistance to sound signal movement. The airflow resistance / component thickness of an absorbent material is relative to the coefficient of engrave thickness of the liquid (air) occupied and differing relative to the rectangle of the typical hole size of the materials.

Figure 2 shows the connection between exact air flow resistance and average noise reduction coefficient for thin (lower curve) and thick materials (the upper curve). It can be inferred that, higher airflow resistance always gives enhanced noise reduction values but for air flow resistance higher than 1000Hz, the noise reduction have less values because difficult in movement of noise signal from side to side the materials. From the figure 2 obtained that, thermal & chemical color cotton/polyester (TCCC/P) sample has high air flow resistivity with the value of 0.84 which manipulate the high enhance in air flow resistance. The other samples like chemical white polyester and thermal & chemical color cotton (TCCC) also have moderate air flow resistivity with the value of 0.8 and 0.78 respectively. This similar tendency was experimental by Zent and John et al [3].



	TWP	TCP	TCC/P	CWP	CCP	CCC/P	TCWP	TCCP	TCCC/P
🟦 Air flow resistance	0.64	0.78	0.76	0.69	0.74	0.72	0.68	0.8	0.84
🟥 Sound absorption co-efficient	0.198	0.243	0.281	0.331	0.354	0.376	0.409	0.444	0.469

Figure 2. Air flow resistances of nonwoven composites

Influence of specific porosity

The figure, range and kind of pores are the significant factors that one be supposed to consider whereas studying noise reduction coefficient in absorbent materials. To permit noise indulgence by roughness, the noise signal has in the direction of the absorbent material. This way, there should be sufficient pores on the outer surface of the materials. The porosity of an absorbent material is clear as the ratio of the volume of the voids in the materials to its full amount volume. Thus from the above figure the sample Thermal & chemical color cotton/polyester (TCCC/P) which has the specific porosity of 0.9 and with the sound absorption co-efficient of 0.46. This shows that the increase in specific porosity materials increases the noise reduction. The samples like

TCCP, TCWP, and CCC/P also have specific porosity equal to that of TCCC/P. thus the specific porosity is increased from TWP to TCCC/P this is appropriate to the fiber pleased in between them. It also can be seen that the hole dimension, link-correlation between the hole and substance composition of materials. If an elevated amount of pores are blocked and the material has a lesser thickness of reduction. The equivalent leaning was studied by Murugan et al [15].

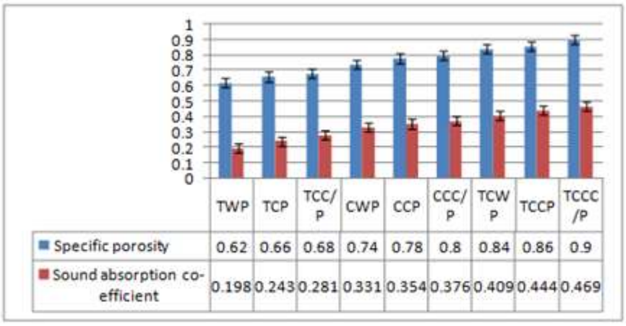


Figure 3. Influence of specific porosity of nonwoven composites

Influence of thickness

Several researches with the intention of noise reduction in absorbent materials have finished that small frequency noise reduction has direct connection with thickness. The thumb rule that has been followed is the efficient noise reduction of absorbent materials is achieved while the material thickness is in relation to one tenth of the wavelength of the occurrence sound. Hit the highest point reduction occurs at a reverberating frequency of one-quarter wavelength of the occurrence sound. This study clear that improve of noise reduction only at low frequencies, as the material gets thicker. However, at upper frequencies thickness has irrelevant effect on noise reduction.

The figure 4 reveals that thicker the material superior sound absorption values. The sample TCCC/P has the highest thickness of 6.68mm with the sound absorption coefficient of 0.469. The graph clearly shows as the thickness of the sample increases the sound absorption behavior of the sample. Moreover, the importance of thickness on low frequency sound absorption that is based on the physics – low frequency means higher wavelength and higher wavelength sound can be absorbed if the material is thicker. It found that increasing thickness obviously improved the sound absorption efficiency of the reclaimed nonwoven samples at medium and low frequency. Thickness of nonwoven is less than 3.5 mm little sound absorption is achieved, if the thickness is more 9.03mm best sound absorption is achieved. The similar findings were reported [13,16].

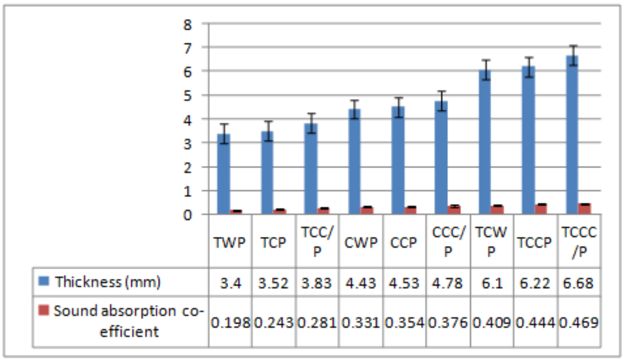


Figure 4. Influence of thickness on nonwoven composite material

Influence of density

Density of a material is often considered to be the important factor that governs the sound absorption behavior of the material. At the same time, cost of an acoustical material is directly related to its density. This study also shows the increase of sound absorption value in the middle and higher frequency as the density of the sample increased. The number of fibers increases per unit area when the apparent density is large. Energy loss increases as the surface friction increases, thus the sound absorption coefficient increases.

The figure 5 shows that the density increases the sound absorption coefficient of the sample increases. The sample TCCC/P with density of 154.3 kg/cm^3 has the highest sound absorption coefficient of 0.469 this is due to the higher fiber content and molecular fraction inside the sample. The other samples like TCCP, TCWP and CCC/P also has equivalent density and sound absorption behavior. Moreover, they showed the following effect of density on sound absorption behavior of nonwoven fibrous materials, less dense and more open structure absorbs sound of low frequencies (500Hz). Denser structure performs better for frequencies above than 2000 Hz. The above said results are in line with the bindings of Koizumi et al (2002). To make the composite structure more compact, the interconnected voids in the composites are relatively decreased with increasing composites density. The similar results were obtained by Wu et al [17].

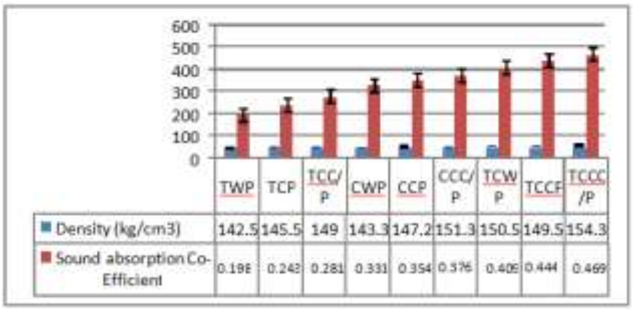


Figure 5. Influence of density on nonwoven composite material

Influence of air gap

Sound absorption measurement calculations were performed with and without an air gap of 0.4 mm and 0.6 mm between the rear of sample and the backing of the movable plunger of the impedance tube. The results for the Figure 6, states that, for the same amount of material, it is much better to have an air gap behind the layer, which coincides with the results. The creation air gap increases sound absorption coefficient values in mid and higher frequencies, in spite of showing minima at certain frequencies. There is not much difference seen between 5 mm air gap sample and 10 mm air gap sample. Moreover, maxima peak for different air gap is different (higher the air gap distance, maxima peak shift towards lower frequency). This indicates that there is an optimum value for an air gap beyond which there is not much influence seen in sound absorption properties. For a fibrous material with a given air gap this means that the flow resistance per unit thickness is inversely proportional to the square of the fiber diameter.

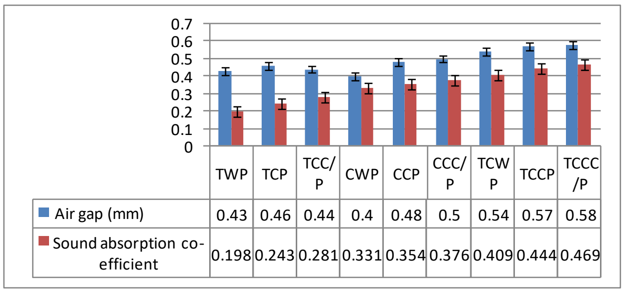


Figure 6. Influence of air gap on composite material

Conclusions

The influence of various factors of a nonwoven composite material on sound absorption is presented in this research work, the Sound absorption coefficient increased with a decrease in fiber diameter, micro denier fibers (less than 1 dpf) provide a dramatic increase in acoustical performance. 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. In general, it can be inferred that, higher airflow resistance always gives better sound absorption values but for airflow resistance higher than 1000Hz the sound absorption have less values because of the difficult in the movement sound wave through the materials. The second important quality which influences the sound absorption behavior is specific porosity; the increase in specific porosity of the sample increases the sound absorption behavior of the material this is due to the fiber content in between the samples. The influence of thickness on sound absorption at low frequencies and thicker material is higher. However, at higher frequencies thickness has insignificant effect on sound absorption. Moreover, the importance of thickness on low frequency sound absorption is based on the physics – low frequency means higher wavelength and higher wavelength sound can be absorbed if the material is thicker. The influence of density clearly shows that when less dense and more open structure absorbs sound of low frequencies (500 Hz), denser structure performs better for frequencies above than 2000 Hz. The influence of air gap increases sound absorption coefficient values in mid and higher frequencies. At the same time, creation of air gap will have minima at various frequencies for various air gap distances.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Langley KD. Recycling and reuse of mixed – fiber fabric remnants (spandex, cotton, polyester). Chelsea Center for Recycling and Economic Development (Mass). Lowell, USA: University of Massachusetts Lowell; 2000. p. 28.

[2] Wang Y. Recycling in textiles. Cambridge, UK: Wood Head Publishing Ltd; 2005.

[3] Zent A, John TL. Automotive sound absorbing material survey results. In: St. Charles IL, Editor. Proceeding of the SAE Noise and Vibration Conference and Exhibition. USA: 2007. p. 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(1):114-25.

[5] Merve KO, Banu UN, Cevza C. A study on the influence of fabric structure on sound absorption behavior of spacer knitted structure. Tex Sci. 2010;6-8:4-8.

[6] Goud G, Rao RN. Effect of fibre content and alkali treatment on mechanical properties of Roystonea regia-reinforced epoxy partially Biodegradable composites. Bull Mater Sci. 2011;34:1575-81.

[7] 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. Fibers and Textiles in Eastern Europe. 2012;20,3(92):73-7.

[8] Verma BB. Continuous jute fiber reinforced laminated paper composite and reinforcement-fiber free paper laminate. Bull Mater Sci. 2009;32:589-95.

[9] Koisszumi T, Tsujiuchi N, Adachi A. The development of sound Absorbing materials using natural bamboo fibers. In: Brebbia CA, De Wilde WP, Editor. High performance structure and composites. Southampton SO40 7AA, UK: WIT Press; 2002.

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

[11] Allard JF. Free field surface impedance measurements of sound-absorbing materials with surface coatings. Applied Acoustics. 1989;26(3):199-207.

[12] Li J, Depollier C, Guignouard. A study on the relationship between the thickness of nonwoven and sound absorption capability. Modern Applied Science. 1(4);74-79:2007.

[13] Walter F, Mike H. Textiles in Automotive Engineering. Cambridge, UK: Wood Head Publishing Ltd; 2001.

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

[15] Murugan D, Varughese S, Swaminathan T. Recycled polyolefin based plastic wastes for sound absorption. Poly Plastic Technology Engineering. 2006;45 (7):885-8.

[16] Shoshani Y. Studies of textile assemblies used for acoustic control. Tech Textiles Int. 1993;2:32-4.

[17] Wu HC, Lim YM, Li VC, Foremsky DJ. Utilization of Recycled Fibers in Concrete. In: Chong K, editor. ASCE Proc. Materials Eng. Conf. 1996;Nov 10-14; Washington DC; 1996. p. 799-808.

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