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Research Article

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Manufacture of Reclaimed Fiber Non-Woven for Sound Absorption

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Abstract

Recycling is the process of making or bringing out new products from a product that has originally served its purpose. The use of non-woven for noise reduction is based on two major advantages of these materials, namely low production costs and small specific gravity. Through this thesis, an attempt was made and implemented an innovative technique of developing stitch bonded non-woven by using recycled fiber. Knitted wastes were collected from cut and sew knitwear factories and recycled by using fabric opening machine in Adey abeba textile factory. The opened fibers are carded by mechanical carding machine by varying the number of layers. Six nonwoven samples are manufactured by stitching the web structure with core spun yarn. The manufactured reclaimed fiber stitch bonded nonwoven sound absorption coefficients were measured according to ASTM E 1050 standard by an impedance tube. The results revealed that the sound absorption coefficient increased with increasing frequency level of 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz and 3000 Hz. Factors influencing sound absorption of nonwoven materials such as fabric thickness, areal density, air permeability and thermal conductivity were tested. The results revealed that while thickness increases the sound absorbing performance also increases. Low frequency sound absorption has direct relationship with thickness. However, at higher frequencies thickness has insignificant effect on sound absorption. Less dense and more open structure absorbs sound of low frequencies. Denser structure performs better for frequencies above 2000 Hz. Air permeability of the stitch bonded nonwoven decreases the sound absorption performance increases. The mechanism of sound absorption was conversion of sound energy in to heat but the effect of thermal conductivity of stitch bonded nonwoven structure was very small.

Keywords: Acoustics; Sound absorption; Absorption coefficient; Non-woven; Reclaimed fiber; Stitch bonding; Air permeability

Introduction

The concern over the environment induced a large numbers of companies to start developing manufacturing process using alternative materials for their products and seeking new markets. With the significant production of waste fibrous materials, different companies are looking for applications wherein waste materials may represent an added-value material [1-3].

There are many compelling reasons for the recycling of waste from textile products and processes. They include conservation of resources, reduction of the need for landfills and paying the associated tipping fees, and provision of low-cost raw materials for products [4-6].

Association of the Nonwoven Fabrics Industry defines Nonwoven fabrics are sheet or web structures bonded together by entangling fibre or filaments by perforating films mechanically, thermally, or chemically [7-9]. Nonwovens are used in automotive industry for a variety of purposes due to their advantages: lightweight, sound efficiency, flexibility, versatility and easily tailored properties, mouldability (easiness to conform to irregular shapes), recyclability, low process and materials costs as well as attractive cost/performance ratio [10-15].

Knitted waste can be converted into short fibers by the application of mechanical processes. Series of trials have been under taken in the course of a research project aimed at a more or less complete reuse of fibers from end-of-life textiles. First of all, knitted waste is crushed with a shredder. The design of those fiber shredders requires sharp cutting edges and a tight gap between the cutting blades and the feeding bed to avoid wrapping [1].

Recycled fiber products that add improved noise control, weight reduction, durability, and design versatility to the toolbox of the noise control engineer are now available. The performance envelope of fiber materials has been expanded using engineered fiber constructions [16-19].

The use of recycled polyester nonwovens has many advantages compared to conventional sound absorbers, including reduced product cost, good handling, and environmental protection. The sound absorption coefficient of the recycled polyester nonwovens were determined by a two-microphone impedance measurement tube; the determination of the noise absorption coefficient is nothing more than the absorption energy rate of the material against the incidence energy. They have determined the relationship between the acoustic absorption values measured and the nonwoven parameters including fibre properties and web properties [20].

A study was conducted on the sound absorbency of a novel knitted spacer fabric which can be applied to automotive interior parts and have the potential for greater sound absorbency than conventional plain knitted fabrics [21,22].

The influence of fabric structure on sound absorption behavior of spacer knitted structure has been studied with its good sound absorbing efficiency [23].

The use of recycled materials in nonwovens provides alternatives for the production of ecologically friendly acoustic products for the automotive industry [19]. Recently noise absorbent textile materials, especially nonwoven structures or recycled materials, have been widely used because of the low production costs and their being aesthetically appealing [17,24].

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New developments in highly durable non-woven fiber constructions allow these materials to be used in interior applications. The multiple uses of recycled fiber products are presented to show how they are moving out of their traditional role as sound absorbers and into new applications and new markets [10,25].

Studies have also been conducted to compare the sound absorption of thermo-bonded and needle punched non-woven fabrics and it was observed that these structures did not show any significant difference in the sound absorption performance [26].

The absorption of sound mainly results from the dissipation of acoustic energy due to viscosity and heat conductivity of the medium. Differences in pore structure due to different fiber orientation, random arrangement of fibers produce samples with small pores and a higher number of fiber to fiber contact points which ends in better sound absorption properties [25,27].

In this study stitch bonded nonwoven were manufactured from reclaimed fiber and tested for the sound absorption performance. The sound absorption influencing factors such as thickness, areal density, air permeability and Thermal conductivity were tested.

Materials and Methods

Materials

The raw materials used in this study are ‘cut and sew’ knitwear production waste materials. The waste materials were collected from knit wear producing garment companies then segregated depending on their colors and prepared for recycling to process in recycling machine. These wastes are then fed into the re-used fabric opener machine to obtain reclaimed fibers. The recycled fiber is then converted in to web structure with different areal density by using mechanical carding process in carding machine. The manufactured carded web structured samples are finally bonded by using stitching machine to form a nonwoven structure.

The first step in developing non-woven is web structure formation and bond together by entangling fibers by mechanical processes known as stitch bonding. Nonwovens are engineered fabrics that can form products that are disposable, for single or short-term use or durable, with a long life, depending on the application.

Figure 1 shows the method of developing stitch bonded nonwoven samples.

Web formation: This process was done on Marzoli C60 carding machine and the settings are as shown on Table 1.

The card clothing is comprised of fine metallic teeth embedded in a metallic foundation. The cylinder is partly surrounded by an endless belt of a large number of narrow, cast iron flats positioned along the top of the cylinder. The top of the cylinder was covered by alternating rollers and stripper rolls in a roller-top card. The spacing between the cylinder and flat was 0.4 mm to individualize the reclaimed fibers.

Stitch bonding: Stitch bonding is a method of consolidating fiber webs with yarn to interlock the fibers. In many applications stitch-bonded fabrics are taking the place of woven goods because they are faster to produce and, hence, the cost of production is considerably less.

Testing methods

Methods of testing physical property of nonwovens

Fabric thickness: Fabric thickness tester is a specialized equipment to determine the thickness of fabrics. Latest model MESDAN *LAB* thickness tester equipment was employed with modern facilities like modern aesthetics, maximum capacity 10mm and accuracy 0.01mm and portable and handy to carry anywhere (Table 2).

Areal density: To determine the areal density of samples first prepare samples by cutting 5cm by 5cm using scissor. Weighing the mass of each by using electronic weighing balance and values are recorded in gram. Finally the areal densities were calculated by the following equation (1):

$$\text{Areal density} = \frac{\text{mass}(\text{g})}{25\ \text{cm}^2} * 10000 \tag{1}$$

Air permeability: Air permeability is the rate of air flow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material. FX 3300 Air Permeability Tester III was used for fast, simple, and accurate determination of the air permeability of all reclaimed fiber nonwovens.

Thermal conductivity: Thermal conductivity coefficient of specimens was measured using Lee’s disk method Principle [28]. Figure 2 shows about the disc consist of two identical discs of 4 cm in diameter. One of them includes an electrical heater. The specimen with 4 cm in diameter was placed between the discs (A) and (B). The heat is supplied between the discs. Temperature of (A) and (B) discs were measured using two thermocouples. The temperature of the ambient was also measured. The rate of supply energy was also measured.

When the discs were assembled they are vanished to give them the same emissive and the whole apparatus was suspended in an enclosure of constant temperature. Total heat can be obtained in terms of supply energy q by using eqn. (2), since the total heat supplied must be equal to that given up by the various surfaces [28].

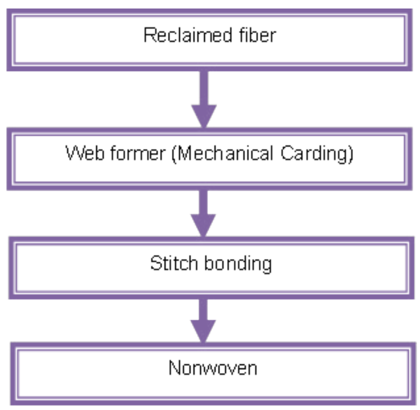

Figure 1: Method of developing stitch bonded nonwoven.

No.	Machine parts	Setting	
1	Licker-in	Diameter, mm	250
		Revolution per minute, rpm	1000
2	Cylinder	Diameter , mm	1290
		Revolution per minute, rpm	600
3	Doffer	Diameter , mm	700
		Revolution per minute, rpm	60
4	Flat	Speed ,cm/min	16
		No. of flat	75

Table 1: Carding machine parameters and settings.

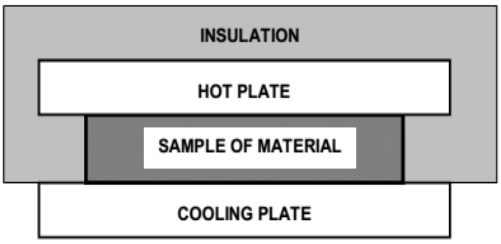

Figure 2: Scheme of guarded hot plate.

No.	Test type	Testing tools	Standard
1	Thickness	Fabric thickness tester	ISO 5084
2	Areal density	Fabric GSM tester	ASTM D6242
3	Air permeability	Fx3300 air permeability tester	ASTM D 737
4	Thermal conductivity	Fabric thermal conductivity tester	ASTM D 6343-10

Table 2: Tests for physical property of nonwovens.

The quantity of transferred heat q is given by the following equation:

$$q = \frac{Q}{A}\left[W / m^2\right] \quad (2)$$

Where

Q ---is quantity of heat passing through a base area of the sample [W]

A --- Base area of the sample [m^2]

Thermal conductivity λ is given by formula:

$$ë = \frac{q * d}{T1 - T2}\left[W / mK\right] \quad (3)$$

Where

q--- Is quantity of heat passing through a unit area of the sample in unit time [W/m^2]

d ---distance between two sides of the sample [m]

T1 ---temperature on warmer side of the sample [K]

T2--- temperature on the colder side of the sample [K]

The average of 5 measurements was taken for each specimen to minimize the possible errors.

Sound absorption coefficient by impedance tube method: A sound source or loud speaker was mounted at one end of the impedance tube and at the other end the nonwoven was placed. The loud speaker generates broadband, stationary random sound. This sound propagates as planner waves in the tube, hits the sample and gets absorbed. Thus a standing wave interference pattern results due to superimposition of forward and backward travelling waves inside the tube. The sound pressure at two fixed location was measured and by using the two-channel digital frequency analyzer [29,30]. From the results reflection coefficient, the sound absorption coefficient and the normal acoustic impedance of the non-woven samples were determined by the impedance tube method on ASTM E 1050 standard. Tube setup with 30 mm diameter measures the parameter of sound in the frequency range from 500Hz to 3000 Hz. In this study the frequency level range will be 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz and 3000 Hz.

A sound of particular decibel was created by the sound source and the receipt decibels were measured by the decibel meter with and without sample. The sound insulation by the fabric samples can be calculated by the following equation (Figure 3).

$$SR\,\% = \frac{dBwos - dBws}{dBwos} * 100 \quad (4)$$

Where,

SR – Sound reduction

dBwos – Sound level without sample and

dBws – The sound level with sample.

Result and Discussion

Nonwoven sample

Samples were produced having different areal density 296, 340, 420, 552, 612 and 675 GSM by using layering technique of the fiber sheet. Stitched nonwoven materials were made by joining fibers into the fabric, which is moving through a stitching machine. Sheet-stitched nonwoven materials are made by stitching a textile sheet with core yarn.

Stitching yarn: The yarn is used to keep all fibers to form the nonwoven structure. The yarn used in this thesis is polyester/cotton core spun sewing threads having 60 Tex count. This thread has a continuous filament polyester core wrapped in cotton fibers, which produces a strong thread with excellent sew ability. Core spun threads have good elasticity and a high resistance to heat and shrinkage, but cost more than regular threads because they have to be dyed twice, first for the polyester core and then for the cotton wrap. An advantage of core-spun threads is that finer threads can be used due to the superior strength of the polyester core.

Stitch density: Is kept constant at 10 stitches per inch (SPI) with x and y directions within one centimeter difference of fabric surface and which improves the structure and properties of the nonwoven fabric.

Base fabrics: Are used on the back to improve the property of the sheet and the fiber sheet will be stitched by using stitching warp yarns with x and y directions. The base fabric used in this study was plane manufactured woven structure to hold and improve the property of the nonwoven (Figure 4).

Physical Property of nonwovens Test result

The physical properties mostly influencing the manufactured stitch bonded nonwoven from recycled fiber (Table 3).

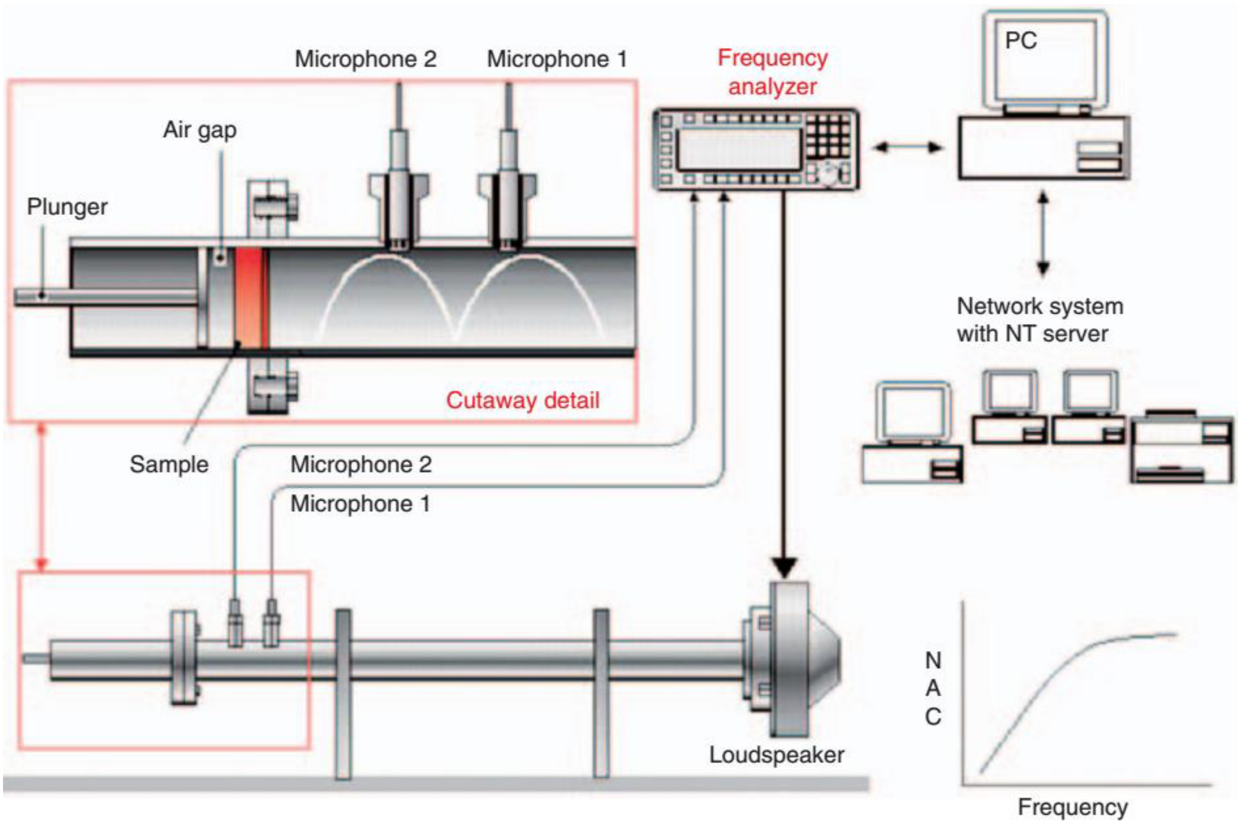

Figure 3: Schematic sketch of an impedance tube set up.

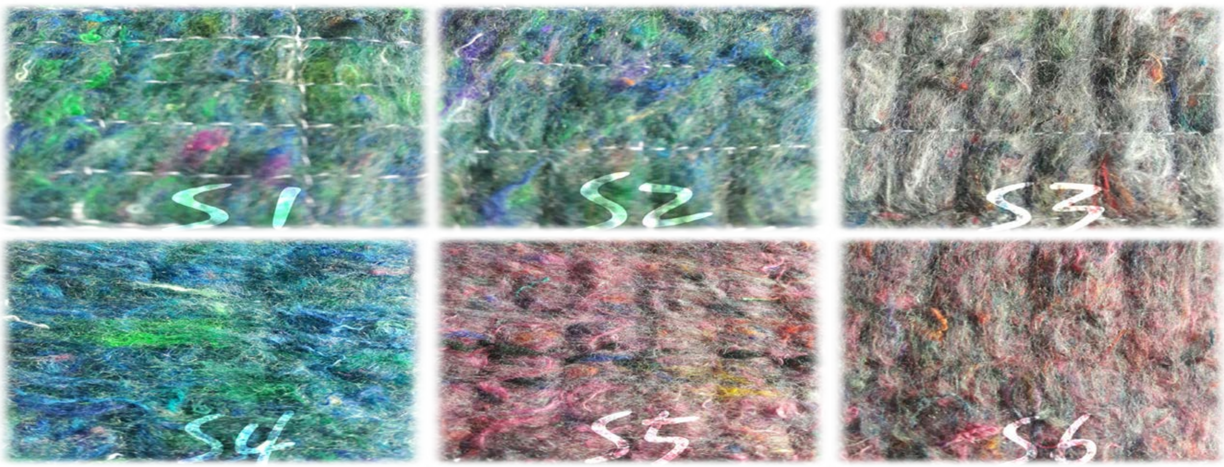

Figure 4: Manufactured stitch bonded nonwoven samples from reclaimed fiber.

No.	Samples code	Thickness, mm	Areal density, g/m²	Air permeability, l/m²/s	Thermal conductivity, W/mK
1	S1	2.32	296	66.4	0.190
2	S2	2.59	340	55.6	0.161
3	S3	2.97	420	44.5	0.154
4	S4	3.64	552	32.3	0.146
5	S5	5.03	612	26.9	0.138
6	S6	5.24	672	24.5	0.132

Table 3: Physical property of nonwovens test result.

Sound absorption performance of samples in different frequency level by impedance tube test method

Figure 5 shows the sound absorption coefficient of recycled fiber stitch bonded nonwoven with various frequency levels. From Table 4 and Figure 5 it can observe that while the frequency increases the sound absorption coefficient of all manufactured samples also increases. Similarly while thickness increases the sound absorbing performance also increases.

The sound absorption value ranges from 0 to 1, If the sound absorption coefficient value is 0.5 this means 50% of incident sound waves are absorbed, If the coefficient is zero there is no incident sound wave absorption and If the sound absorption value is 1 this means 100% of incident sound wave is absorbed.

Influence of physical properties on sound absorption performance of reclaimed fiber nonwoven

Influence of thickness: In this study sound absorption in porous materials were concluded as low frequency sound absorption has direct relationship with thickness. This study shows high increase of sound absorption at low frequencies, as the material gets thicker the sound absorption property decreases as shown in Figure 6. However, at higher frequencies thickness has insignificant effect on sound absorption.

Figure 6 reveals that thicker the material better sound absorption values on the middle value of thickness of the sample.

Influence of fabric areal density: Figure 7 shows that the density increases the sound absorption coefficient of the sample increases. This is due to the higher fiber content and friction inside fiber of the sample. Moreover, the result showed that effect of density on sound absorption behavior of nonwoven fibrous materials, less dense and more open structure absorbs sound of low frequencies 500 Hz. Denser structure performs better for frequencies above than 2000 Hz.

Influence of air permeability: Figure 8 shows the relationship between specific air flow resistance and sound absorption coefficient. It can be inferred that, higher airflow resistance always gives better sound absorption values. The sound absorption property was influenced by high increase in air flow. With high increase of air flow resistance and increasing in areal density of fabric the sound absorption property also highly affected.

Influence of thermal conductivity: Fiber surface geometry determine the air volume distribution within the fabric, influencing the openness of fabric structure, which strongly affects the permeability and thermal properties through the influence on heat transfer phenomena across the fabric.

In Figure 9, the figure representation shows the influence of thermal conductivity on sound absorption. The thermal insulation value shows increasing with the increase in the recycled non-woven fabric weight.

Conclusion

With the continuing development of new technologies, particularly the trend towards faster, more powerful machinery, environmental impact of noise is a matter of increasing concern, and considerable efforts are being made to finding effective means of noise abatement. The use of textiles for noise reduction is based on two major advantages of these materials, namely low production costs and small specific gravity. The manufactured stitch bonded nonwovens were tested for acoustic absorption by ASTM E 1050. It was observed that while frequency increases sound absorption property of all stitch bonded sample

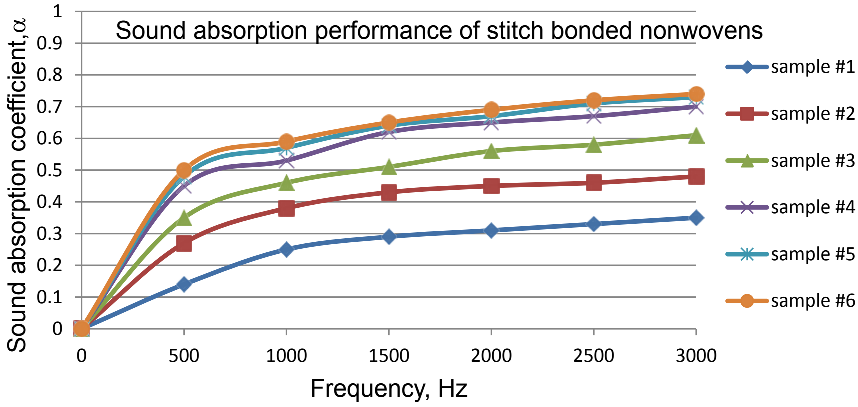

Figure 5: Sound absorption performance of stitch bonded nonwoven samples.

No.	Sample Code	Sound Absorption coefficient of stitch bonded nonwovens						
		0 Hz	500 Hz	1000Hz	1500Hz	2000 Hz	2500 Hz	3000 Hz
1	S1	0	0.14	0.25	0.29	0.31	0.33	0.35
2	S2	0	0.27	0.38	0.43	0.45	0.46	0.48
3	S3	0	0.35	0.46	0.51	0.56	0.58	0.61
4	S4	0	0.45	0.53	0.62	0.65	0.67	0.70
5	S5	0	0.48	0.57	0.64	0.67	0.71	0.73
6	S6	0	0.50	0.59	0.65	0.69	0.72	0.74

Table 4: Sound absorption coefficient of samples in different frequency.

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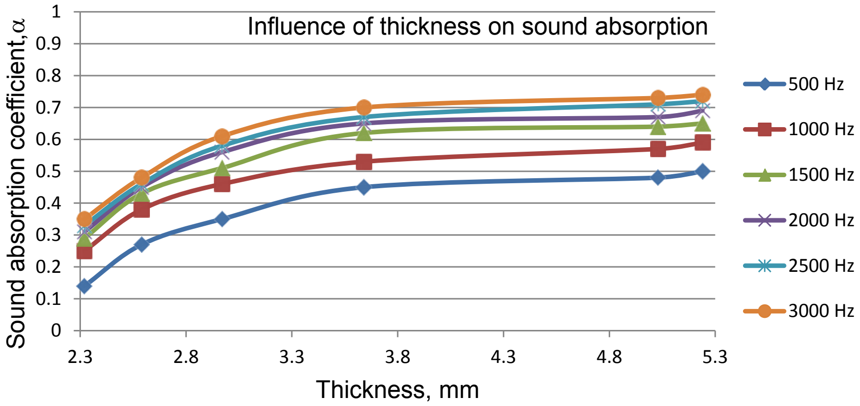

Figure 6: Influence of thickness.

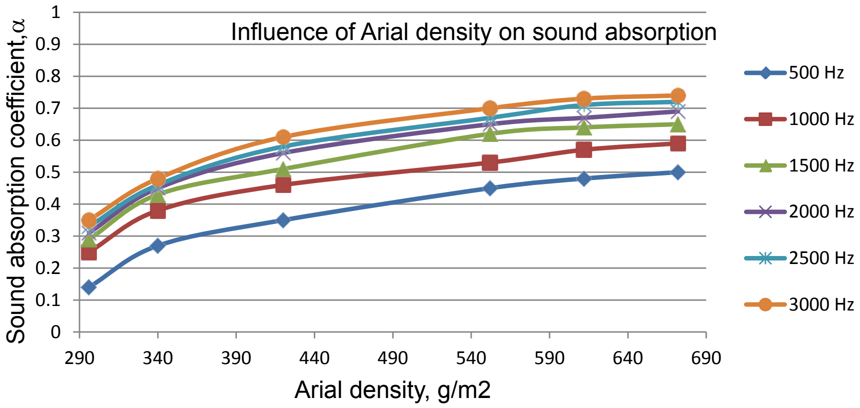

Figure 7: Influence of fabric density.

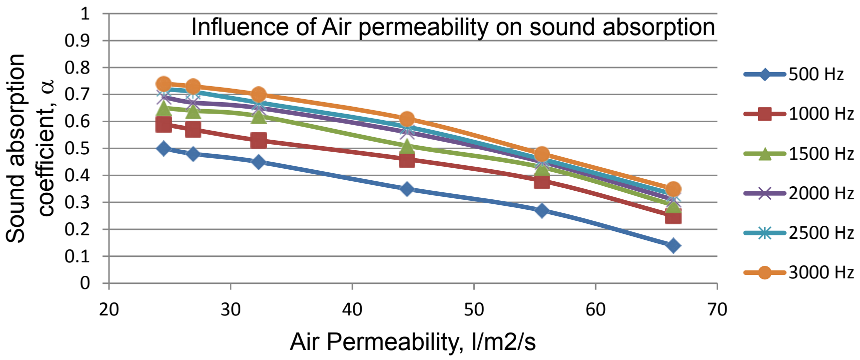

Figure 8: Influence of air permeability.

increases. Similarly while thickness increases the sound absorbing performance also increases. Low frequency sound absorption has direct relationship with thickness. The increase of sound absorption only at low frequencies, as the material gets thicker. However, at higher frequencies thickness has insignificant effect on sound absorption. The number of fibres increases per unit area when the apparent density is large. Energy loss increases as the surface friction increases, thus the sound absorption coefficient increases. Less dense and more open structure absorbs sound of low frequencies (500 Hz). Denser structure performs better for frequencies above than 2000 Hz. As shown in the result when the air permeability of the stitch bonded nonwoven decreases the sound absorption performance increases because fibres interlocking in nonwovens are the frictional elements that provide resistance to acoustic wave motion. In general, when sound enters these materials, its amplitude is decreased by friction as the waves try to move through the tortuous passages. Thus the acoustic energy

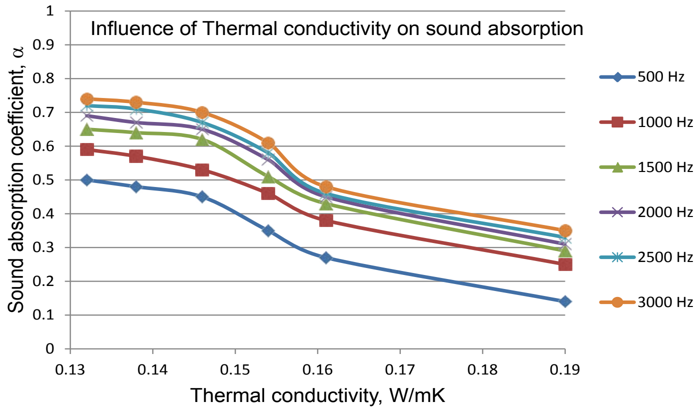

Figure 9: Influence of thermal conductivity.

is converted into heat but the effect of thermal conductivity of stitch bonded nonwoven structure was very small.

References

1. Bartl A, Hackl A, Mihalyi B, Wistuba M, Marini I (2005) Recycling of fibre materials. Process Safety and Environmental Protection 83: 351-358.
2. Roznev A (2011) Recycling in textiles. Supply chain Management, pp: 1-20.
3. Bhatia D, Sharma A, Malhotra U (2014) Recycled fibers: an overview. International Journal of Fiber and Textile Research 4: 77-82.
4. Vasile S, Van Langenhove L (2004) Automotive industry a high potential market for nonwovens sound insulation. Journal of Textile and Apparel, Technology and Management 3: 1-5.
5. Bartl A, Marini I (2008) Recycling of apparel.
6. Bartl A (2009) Fiber recycling: potential for saving energy and resources.
7. Russell SJ (Ed.) (2006) Handbook of nonwovens. Woodhead Publishing.
8. Chapman R (Ed.) (2010) Applications of nonwovens in technical textiles. Elsevier.
9. Horrocks AR, Anand SC (2015) Handbook of Technical Textiles: Technical Textile Processes. Woodhead Publishing.
10. Teli MD, Pal A, Roy D (2007) Efficacy of nonwoven materials as sound insulator.
11. Fung W, Hardcastle JM (2000) Textiles in automotive engineering (Vol. 13). Woodhead Publishing.
12. Parikh DV, Chen Y, Sun L (2006) Reducing automotive interior noise with natural fiber nonwoven floor covering systems. Textile Research Journal 76: 813-820.
13. Pieren R, Heutschi K (2015) Predicting sound absorption coefficients of lightweight multilayer curtains using the equivalent circuit method. Applied Acoustics 92: 27-41.
14. Shishoo R (Ed.) (2008) Textile advances in the automotive industry. Elsevier.
15. Thilagavathi G, Pradeep E, Kannaian T, Sasikala L (2010) Development of natural fiber nonwovens for application as car interiors for noise control. Journal of Industrial Textiles 39: 267-278.
16. Jordeva S, Tomovska E, Trajković D, Popeski-Dimovski R, Zafirova K (2015) Sound insulation properties of structure designed from apparel cutting waste. AUTEX2015_Proceedings.
17. Gulich B (2006) Development of products made of reclaimed fibres. Recycling in textiles 50: 117.
18. Seddeq HS, Aly NM, Marwa AA, Elshakankery MH (2013) Investigation on sound absorption properties for recycled fibrous materials. Journal of Industrial Textiles 43: 56-73.
19. Stanciu MD, Curtu I, Cosereanu C, Lica D, Nastac S (2012) Research regarding acoustical properties of recycled composites. In 8th International DAAAM Baltic Conference Industrial Engineering.
20. Lee Y, Joo C (2003) Sound absorption properties of recycled polyester fibrous assembly absorbers. AUTEX Research Journal 3: 78-84.
21. Liu Y, Hu H (2010) Sound absorption behavior of knitted spacer fabrics. Textile Research Journal 80: 1949-1957.
22. Dias T, Monaragala R, Needham P, Lay E (2007) Analysis of sound absorption of tuck spacer fabrics to reduce automotive noise. Measurement Science and Technology 18: 2657.
23. Ozturk MK, Nergis BU, Candan C (2010) A Study on the Influence of Fabric Structure on Sound Absorption Behavior of Spacer Knitted Structures. In 7th International Conference-TEXSCI.
24. Sakthivel MS, Ramachandran T, Archana MG, Ezhilanban J, Sivajith Kumar VMS (2012) Sustainable Non Woven Fabric Composites for Automotive Textiles Using Reclaimed FIBRES. International Journal of Engineering Research and Development 4: 11-13.
25. Wyerman B (2010) New Frontiers for Fiber-Based Noise Control Solutions. Sound and Vibration 44: 14.
26. Carvalho R, Rana S, Fangueiro R, Soutinho HFC (2012) Noise reduction performance of thermobonded nonwovens. In 12th World Textile Conference AUTEX, pp: 597-600.
27. Ogunbowale WO, Banks-lee P, Bello KA, Maiwada S, Kolawole EG (2011) The Effects of Fiber Type and Layering Structure on the Acoustical Absorptive Properties of Nonwoven. Continental J Applied Sciences 6: 19-30.
28. Bozkurt E, Kaya E, Tanoğlu M (2007) Mechanical and thermal behavior of non-crimp glass fiber reinforced layered clay/epoxy nanocomposites. Composites Science and Technology 67: 3394-3403.
29. Taşcan M (2016) Acoustical Test Methods for Nonwoven Fabrics. Acoustic Textiles, Springer pp: 115-141.
30. Takahashi Y, Otsuru T, Tomiku R (2005) In situ measurements of surface impedance and absorption coefficients of porous materials using two microphones and ambient noise. Applied Acoustics 66: 845-865.