Using Nonwoven Hollow Fibers to Improve Cars Interior Acoustic Properties

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ABSTRACT

This research aims to produce nonwoven fabrics that can be used in car interior components (head liners, doors, side panels and trunk liners) to prevent noise from reaching the passenger compartment and therefore achieving comfort in the car interior. Two kinds of fibers were used, polyester and hollow polyester fibers, both of 6 denier, to produce three different fabrics of 100% polyester fibers, 75% polyester/25% hollow polyester fibers, and 55% polyester45% hollow polyester fibers. Four fabric weights were produced: 300, 400, 500 and 600 g/m^2. All samples were bonded using thermal bonding technique. More results were reached and most samples have achieved the expected results for example, samples produced with high percentage of hollow fibers have recorded the highest rates of sound absorption whereas samples produced with 100% polyester fibers have recorded the lowest rates. It was also found that there is a direct relationship between weight per m^2 and sound absorption efficiency. Samples produced with 55% polyester/45% hollow polyester fibers and 600 g/m2 have achieved the best results.

Keywords: Nonwoven Fabrics, Hollow Fibers, Cars Interior Acoustic Properties, sound Insulation

1. Introduction

When talking about textiles, most people think of clothing, home textile and the like. Only few think about the automotive industry (Wilkens, 2005).

In fact, automotive textiles are considered one of the most important markets in the technical textiles sector (Mukhopadhyay, 2000).

Over the last decades, the field of non-conventional textiles has been witnessing a material revolution which has resulted in improved and economical products (Tilgul, 1990).

The automotive industry has become so competitive that manufacturers are reluctant to divulge precise details of their process for fear that textiles are widely used in transportation vehicles and systems, including cars, trains, buses, airplanes, and marine vehicle (Fung and Hardcastle , 2001) automotive textiles are growth markets in terms of quantity, quality and product variety (Parikh et al., 2002).

it could be helpful to their competitors. Industrial Motor vehicle remains an important means for individual transport worldwide. The interior of transportation vehicles is receiving more attention these days. Acoustical insulation products are frequently used in automotive interiors to reduce heat levels (Imfeld et al.) as customers expect more comfort, better safety, good appearance (both externally and internally), high performance and good fuel mileage (Mukhopadhyay, 2000).

Textiles make a major contribution towards realizing customers’ expectations due to their advantages which made textiles a preferable material because of their high capacity to take moisture, adjustable porosity, high-pile fibrous surface, low-cost recycling, and the flexibility and diversity in combining textiles with other materials. (Bottcher, 2005). Due to the diverse product range, automotive textiles can be classified into upholstery and carpeting (Desai ,2005) which have a decisive influence on acoustic comfort (Laser, 1997) interior components such as head liners, and doors and side panels (Desai, 2005) which are foam backed components to achieve easier installation and improve acoustical properties (Waugh, 1986) and tyres, safety devices (such as seat belts and airbags), filters and engine compartment items (Desai, 2005).

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1.1. Noise in Cars

Noise has become serious environment pollution in our daily life and is an increasing public health problem, as noise can cause serious health effects such as hearing loss, sleep disturbance, tiredness, cardiovascular and psychophysiologic problems and performance reduction. It is very important to control or reduce noise from traffic, and in factories, offices and houses (Lou et al., 2005).
Car noise is essentially caused by the unit sound, the exhaust system noise, the air suction, noise, rolling and wind noises (Helmer, 2002).
Today, the dominant approach to achieving interior quietness relies to a large extent upon the ability to create impermeable enclosures around vehicle occupants through the use of several heavy interior layers (sound transmission loss), but recently a new concept has been emerged suggesting that sound can be reduced by replacing reflection (sound transmission loss) with dissipation (interior sound absorption area) by eliminating heavy barrier layers with light weight porous materials (Buskirk & Middleton, 1999).
Nonwoven is employed as fabrics for different kinds of interior applications. The numerous applications of nonwoven in cars can be classified into functional and aesthetic but there is a third category that of substitutes for other materials. Nonwoven can be made in a wide range of densities and different forms; the use of nonwoven is increasing because it offers great versatility and cost effectiveness (Adanur, 1995).
Each vehicle requires about 20 m2 of nonwoven materials (Lou et al., 2005) which are used specially for insulation, noise dissipation and as filter materials. Woven and knitted fabrics are also used in producing automotive fabrics but to a lesser extent compared to nonwoven fabrics (Hilden, 2002).

1.2 Hollow Fibers

Hollow fibers are polymeric fibers that have a continuous hole running down the middle, which is created by the introduction of air or other gas (nitrogen) in the polymeric solution (in the wet spinning process) or by melt spinning through specially designed spinnerets (**Hoechst** Celanese Corporation , 1990).
Hollow fibers provide greater bulk with less weight; they are therefore often used to make insulation fabrics (Tortora & Phyllis, 2002).

2. The Experimental Work

2.1 Specification of Samples Under Study

In order to produce samples under study, the nonwoven technique was applied using cross-laid fiber orientation. Two kinds of textile materials were used: polyester and hollow polyester fibers, both of 6 denier, to produce three different fabrics of 100% polyester fibers, 75% polyester and 25 % hollow polyester fibers and 55% polyester/ 45% hollow polyester fibers. Four fabric weights were also produced: 300, 400, 500,and 600 g/m2 .All samples were bonded using thermal bonding technique (hot air method (by adding a small proportion of low–melting point polyester fibers (about 15% and melting point of 110°C). Tables (1) and (2) illustrate the specification of all sample production.

2.2 Tests Applied to Samples Under Study

In order to evaluate the performance properties of the produced samples, the following tests were carried out.
Test 1: Sound absorption coefficient, this test was carried out according to the ASTM - E 1050-1982. The sound (noise) absorption values (%) of samples under study were measured at 6 different frequencies: 125, 250, 500 Hz (low frequency tube) and 1000, 2000, and 4000 Hz (high frequency tube).
Test 2: Air permeability, this test was carried out according to the (ASTM-D 4491-92)
Test 3: Fabric thickness, this test was carried out according to the (ASTM- D -1777).

Table 1. Specification of samples production

Sample No.	Property	Specification
1	Fiber type	Polyester and hollow polyester fibers
2	Fiber count	6 denier
3	Fiber length	64 mm
4	Fabrics material	100 % polyester fibers ,75 %polyester /25 % hollow polyester fibers and 55 % polyester / 45 % hollow polyester fibers.
5	Web formation	Cross-laid
6	Fabric weight (g/m^2)	300,400,500 and 600
7	Bonding technique	Thermal bonding

Table 2. Specification of all samples under study

Sample no.	Fabric weight (g/m^2)	Fabric material
1	300	100% polyester fibers
2	300	75% polyester /25% hollow polyester fibers
3	300	55% polyester /45% hollow polyester fiber
4	400	100% polyester fibers
5	400	75% polyester /25% hollow polyester fibers
6	400	55% polyester /45% hollow polyester fiber
7	500	100% polyester fibers
8	500	75% polyester /25% hollow polyester fibers
9	500	55% polyester /45% hollow polyester fiber
10	600	100% polyester fibers
11	600	75% polyester /25% hollow polyester fibers
12	600	55% polyester /45% hollow polyester fiber

Table 3. Results of all tests applied to samples under study

Tests	Sound absorption (%)						Air permeability (cm3/cm2/sec)	Thickness (mm)
	Frequency (Hz)							
Sample no.	125	250	500	1000	2000	4000		
1	0.003	0.030	0.065	0.100	0.228	0.320	212	3.3
2	0.003	0.033	0.080	0.141	0.362	0.485	196	4.5
3	0.003	0.033	0.076	0.132	0.323	0.421	195	4.9
4	0.003	0.034	0.075	0.130	0.320	0.398	195	6.1
5	0.004	0.037	0.088	0.169	0.426	0.542	182	7.7
6	0.004	0.036	0.085	0.161	0.400	0.513	160	7.8
7	0.004	0.038	0.086	0.167	0.414	0.524	152	9.8
8	0.004	0.037	0.039	0.196	0.493	0.646	148	9.9
9	0.004	0.038	0.092	0.191	0.463	0.585	129	10.1
10	0.004	0.039	0.098	0.221	0.524	0.666	127	11.4
11	0.004	0.039	0.099	0.220	0.521	0.677	122	13.6
12	0.005	0.041	0.106	0.247	0.596	0.727	108	15

3. Results and Discussion

Results of the experimental tests carried out on samples under study are presented in table (3). Results were also statistically analyzed for the data listed and relationships between variables were obtained.

3.1 Sound Absorption Efficiency Test

It is clear from results that the increase in fabric weight improves the sound absorption efficiency of fabrics at both low and high frequencies. This is mainly because of that the increase in fabric weight means increasing in number of fibers per unit area and also increasing in fabric volume and so the interconnected voids will be increased which absorb the sound waves rather than reflecting them, if the fabric was compacted, the sound absorption efficiency will be increased.

It is also obvious from figures (1) to (3) that there is a direct relationship between the increase in hollow fibers percentage in the fabric and its sound absorption efficiency. This is probably due to the structure of hollow fibers which have air inside their lumen, which increases the air volume in the fabric and increase its ability to absorb sound waves but not reflecting them.

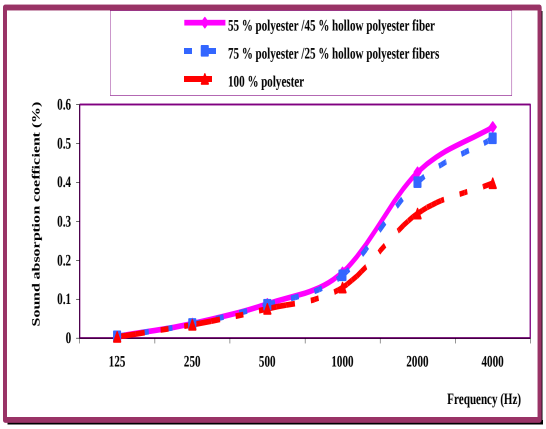

Fig. 1. Effect of fiber type on fabric sound absorption at weight 300 g/m^2

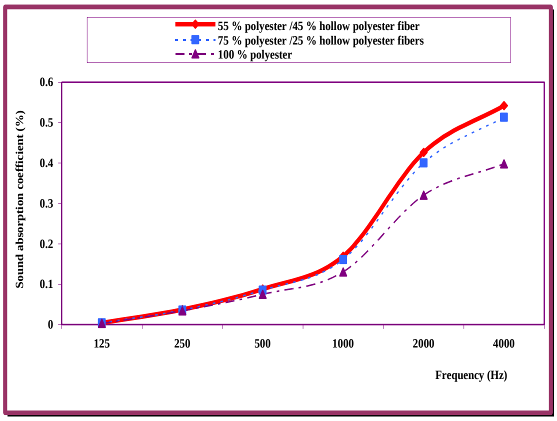

Fig 2. Effect of fiber type on fabric's sound absorption ,at weight 400 g/m^2

Table 4. Regression equation and correlation coefficient for the effect of fiber type on fabric's sound absorption at weight 400 g/m^2

Fiber type	Regression equation	Correlation coefficient
100% Polyester	Y=7.78871 X +0.027875	0.97704865
75% Polyester/25% hollow fiber	Y=0.0001233 X +0.029083	0.96701712
55% Polyester/45% hollow fiber	Y=0.0001055 X +0.033416	0.9624999

Table 5. Regression equation and correlation coefficient for the effect of fiber type on fabric sound absorption at weight 500 g/m^2

Fiber type	Regression equation	Correlation coefficient
100% Polyester	Y=0.00013317 X +0.039376	0.95556476
75% Polyester/25%hollow fiber	Y=0.0001495 X +0.0420416	0.954627931
55% Polyester/45%hollow fiber	Y=0.000166 X +0.0345	0.961916708

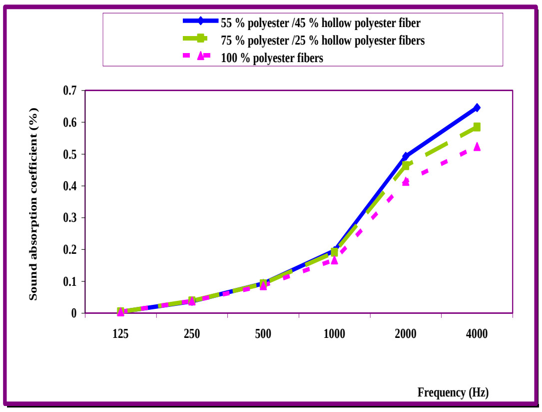

Fig. 3. Effect of fiber type on fabric's sound absorption at weight 500 g/m^2

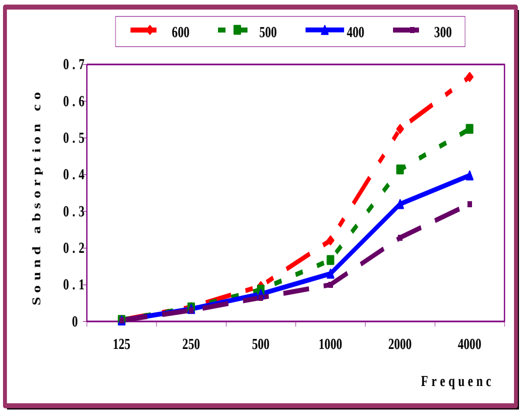

Fig. 4. Effect of weight /m^2 on fabric's sound absorption at 100% polyester

Table 6. Regression equation and correlation coefficient for the effect of weight g/m^2 on fabric's sound absorption at polyester 100%

Weight /m^2	Regression equation	Correlation coefficient
300	Y=8.1626 X +0.17199	0.976762
400	Y=0.0001044 X +0.02288	0.957373368
500	Y=0.0001387 X +0.023338	0.9609214
600	Y=0.000178 X +0.0246766	0.96088684

Table 7. Regression equation and correlation coefficient for the effect of weight g/m^2 on fabric sound absorption at 75% polyester/25% hollow fiber

Weight g /m^2	Regression equation	Correlation coefficient
300	Y=0.000127784 X +0.0162835	0.9706377
400	Y=0.000143 X +0.022208	0.9618994
500	Y=0.000172321 X +0.186616	0.966878
600	Y=0.000127784 X +0.016283	0.9706377

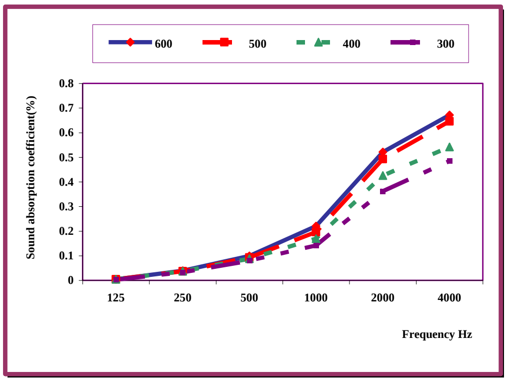

Fig. 5. Effect of weight /m^2 on fabric's sound absorption at 75% polyester/25% hollow fiber

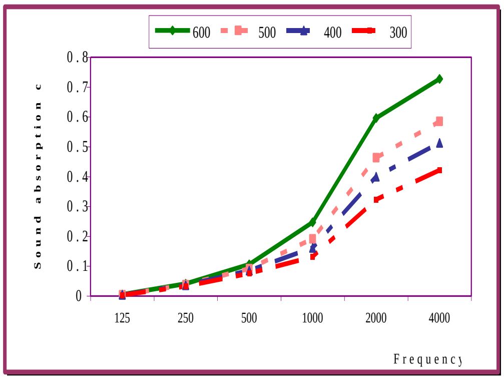

Fig. 6. Effect of weight /m^2 on fabric's sound absorption ,at 55% polyester/45%/hollow fiber

Table 8. Regression equation and correlation coefficient for the effect of weight g/m^2 on fabric's sound absorption at 55%polyester/45% hollow fiber.

Weight /m^2	Regression equation	Correlation coefficient
300	Y=0.00011024 X +0.01996517	0.9660334
400	Y=0.00013567 X +0.02176619	0.963322316
500	Y=0.00015565 X +0.02454228	0.960252268
600	Y=0.0001956 X +0.03019403	0.952865124

3.2 Air Permeability Test

From table (3) and figure (7), it can be seen that there is an inverse relationship between fabric weight and its air permeability properties. We can state that the increase in fabric weight increases the number of fibers per unit area and therefore free spaces in the fabric will be decreased, delaying the free passage of air through the fabric.

The effect of heat bonding technique also facilitates this because of the melting of fibers (polyester fibers of low melting point) which causes pore spaces of the free area between fibers to be decreased, resulting in the decrease in fabric air permeability.
It can also be noticed from figure (7) that that the more the hollow fibers, the less air permeability the fabrics become for the same weight. This is because the increase in the number of hollow fibers increases the air volume in the fabric as the air is entrapped in the fibers and so the free spaces into the fabrics will decrease because of fabric bulkiness and so the ability of air flow to be passed through the fabric will be decreased.

3.3 Fabric Thickness Test

It is obvious from table (3) and figure (8) that there is a direct relationship between fabric thickness and its weight. This is because of the fact that the increase in fabric weight means an increase in number of fibers per unit area, which leads to the increase in fabric thickness.
It is also clear from table (3) and figure (8) that the increase in hollow fibers percentage in the fabric increases its thickness. This might be due to the structure of hollow fibers which has air in the internal voids increasing the volume ratio of fibers and leading to the increase in fabric bulkiness and thickness.

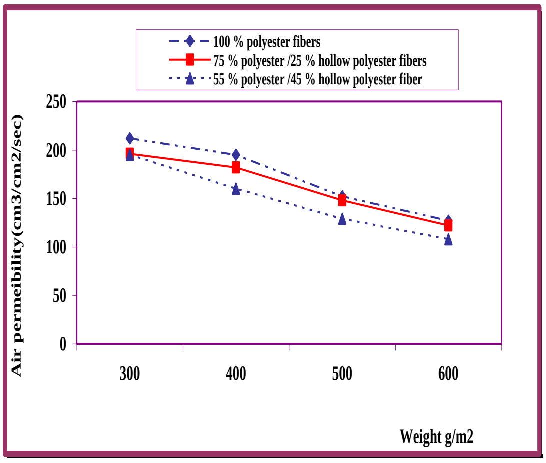

Fig. 7. Effect of weight g/m^2 and fiber type on fabric's air permeability

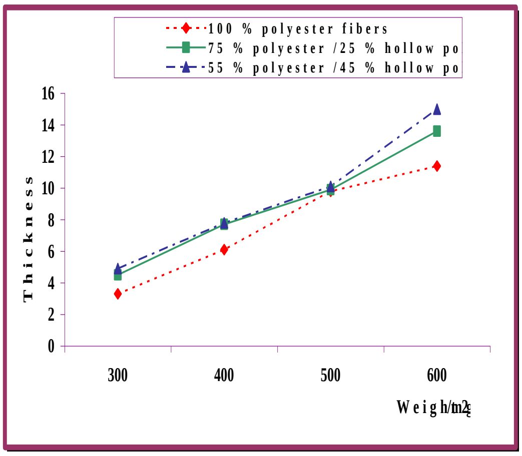

Fig. 8. Effect of weight g/m^2 and fiber type on fabric thickness

Table 9. Regression equation and correlation coefficient for the effect of weight g/m^2 and fiber type on fabric's air permeability.

Fiber type	Regression equation	Correlation coefficient
100% Polyester	Y=-0. 34 X +328	-0.9885229
75% Polyester/25% hollow fiber	Y=-0.26 X +262.33h33	-0.9938927
55% Polyester/45% hollow fiber	Y=-0.3 X +300.666	-0.997050141

Table 10. Regression equation and correlation coefficient for the effect of weight g/m2 and fiber type on fabric thickness.

Fiber type	Regression equation	Correlation coefficient
100%Polyester	Y=0. 28 X +4.95	0.989825773
75%Polyester /25%hollow fiber	Y=0.0295X + 4.36	0.995418547
55%Polyester /45%hollow fiber	Y=-0.36 X -7.03333	0.9789502

4. Conclusion

Over the past decade, improvements in both functional and appearance durability of automotive trim have been significant. Technology applied in the form of better polymers, stabilizers and testing procedures has contributed to these functional and appearance improvements. Fabrics provide comfort and better appearance in car interiors while still meeting the performance and consistency requirements. These fabrics, used in car interiors, must also meet the needs of fashion function and durability required by the automakers. This research is an attempt to produce fabric used in sound insulation in automobiles.

In this study the researchers have developed fabrics used in car interior components to prevent noise from reaching the passenger compartment and so achieving comfort in the car interior. Two kinds of fibers were used: polyester and hollow polyester fibers, both of 6 denier, to produce three different fabrics of 100% polyester fibers, 75% polyester /25% hollow polyester fibers, and 55% polyester/45% hollow polyester fibers. Four fabric weights were produced: 300, 400, 500 and 600 g/m^2. All samples were bonded using thermal bonding technique. More results were reached concerning structures and materials used in the research; for example, samples produced with high percentage of hollow fibers have recorded the highest rates of sound absorption whereas samples produced with 100% polyester fibers have recorded the lowest rates. It was also found that there is a direct relationship between weight per m^2 and sound absorption efficiency also samples produced with high percentage of hollow fibers had recorded the highest rates of sound absorption whereas samples produced with 100% polyester fibers have recorded the lowest rates. It was also found that there is a direct relationship between weight per m^2 and sound absorption efficiency. All samples have achieved the expected results and samples produced with 55% polyester/45% hollow polyester fibers and 600 g/m^2 have achieved the best results.

REFERENCES

[1] Adanur, S. 1995, *Wellington Sears Handbook of Industrial textiles*, Willington Sears company technomic Publishing company, Inc., Lancaster, Pennsylvania.

[2] ASTM - E 1050-1982, '*Standard test method for measuring sound absorption coefficient'*.

[3] ASTM D 1777, '*Standard test method for measuring fabric thickness*'.

[4] ASTM-D 4491-92, '*Standard test method for measuring air permeability*'.

[5] Bottcher,P. 2005, 'Automotive Textiles : Current Situation and New Trends', *Technical Textiles*, vol. 48, March, pp. 30.

[6] Buskirk, J.V. & Middleton, P. 1999, ' Rieter Automotive: Lightweight Noise Protection', *Technical Textiles*, vol. 42, August , pp. 45.

[7] Desai, A. 2005, 'Textiles for Automotive Industry: Safety Devices', *The Indian Textile Journal*, July, pp. 73.

[8] Fung,W. & Hardcastle,M. 2001, Textiles in Automotive Engineering, The Textile Institute , Wood Head Publishing Limited.

[9] Helmer,A. 2002, 'Application of Nonwoven and Fiber Structure in the Car and Their Acoustic Performance', *Melliand International*, vol. 8, March , pp. 60.

[10] Hilden,J. 2002, 'Textiles in Automobile Manufacture ', *Industrial Fabrics Bulletin* ,vol.3, pp.43.

[11] Hoechst Celanese Corporation, 1990, Dictionary of Fibers and Textile Technology,

6 th edition ,Hoechst Celanese Corporation, pp.77.
[12] Imfeld, S. M., Richard H. Brandon et al., ‘Thermoplastic Adhesive films for Automotive Interior Trim Applications’, *The Dow Chemical Co.*
[13] Laser, J. 1997, ‘Moulded Automotive Carpets – Influence on Interior Noise’, *Technical Textiles*, vol. 40, August, pp. 44.
[14] Lou ,C. W. Lin ,J. H. & Su, K.H. 2005, ‘Recycling Polyester and Polypropylene Nonwoven Selvages to Produce Functional Sound Absorption Composites’, *Textile Research Journal*, vol.75 ,no.5, pp. 390.
[15] Mukhopadhyay,S. K. 2000,‘Automotiv Textiles-1’, *Textiles Magazine*, vol. 29, no.3 , pp. 5
[16] Parikh,D. V. Calamari,T. A. et al. 2002, ‘Thermo - formable Automotive Composites Containing Kenaf _and Other Cellulosic Fibers’, *Textile Research Journal* , vol. 72, no. 8, pp. 668.
[17] Tilgul,V. M. 1990 ‘Nonconventional Textiles’, *The Indian Textiles Journal* , August ,vol. 100 ,no. 11, RS 30
[18] Tortora , phyllis,G. 2002 , ‘ Understanding Textiles’ , July.
[19] Waugh ,S. 1986, ‘Automotive Fabrics’, *Industrial Fabrics Products Review*, August , pp.55
[20] Wilkens, C. 2005, ‘A Survey of Car Production in Eastern Europe and Interior Automotive Textiles’, *Technical Textiles*, vol. 48, March, pp. 38.