Effect of Glass-Beads on Sound Insulation Properties of Nonwoven Fabrics

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ABSTRACT
Nonwovens are very important sound absorption materials used by the automotive and building industries. One of the most important fabric parameters that affect the sound insulation and absorption properties is the surface area. Higher surface area is often achieved by using low-diameter fibers in the insulation material. This research was done to prove that neither the thickness nor the weight of the material is as important as the total surface area of the fabric. Glass beads with 0.1mm, 0.5mm and 2.5mm sizes, which do not contribute considerably to the total surface area of the fabric, were imbedded into cross-lapped and needlepunched nonwoven structures. These beads were added in weight percentages of 25%, 50%, 75%, 100% and 200%. Sound insulation of glass bead imbedded nonwoven fabrics was tested using Clemson Boston Sound Insulation Tester. It was found that the micro-glass beads did not have a large impact on the sound insulation, as they do not contribute to the surface area of the nonwoven fabric. The samples with 0.1mm beads performed slightly better than samples with larger beads but not enough to make a significant difference. Since surface area is the major parameter that affects sound insulation, simply increasing the weight does not affect the sound insulation property of the material.

INTRODUCTION
Sound insulation is crucial for both automotive and building industries. High-density materials are able to insulate sound effectively. However, their rigid nature does not allow the sound waves to get through and therefore they reflect a majority of sound waves back into the environment. The use of the rigid structures as insulators is not practical because of their high weights and prices limit their use in automotive and building applications. [6]

When the sound meets with a material, some of the waves are reflected back, some of the waves are transmitted through the boundary, and some of the waves are absorbed by the material. The energy of the absorbed sound waves changes into vibration and heat energy that are dissipated to the environment. If the material is fibrous, then the number of boundaries of the structure will be directly proportional to the number of fibers in the fibrous material. Therefore, fibrous materials such as nonwoven fabrics are used for the acoustical insulation applications.

Acoustical insulation is mostly related to the geometry of the fabric for nonwoven fabrics. More than the fiber type, the fiber denier, fiber cross-sectional shape and fiber length in nonwoven fabrics are very important factors in sound absorption and insulation [7–10].

Sound insulation properties of nonwoven fabrics are quite similar in terms of the resistance to sound energy and air and water molecules. Parikh *et al.* [3] used natural fibers such as kenaf, jute, waste cotton and flax blended with polypropylene and polyester in automotive floor coverings. As a result, the absorption coefficients were better, when the floor covering was combined with a polyurethane underpad. The coefficients got higher as the frequency got higher. This research proved that natural fibers could be combined with synthetic polymers to produce efficient noise absorption.

Lou *et al.* [1] used recycled polyester and polypropylene selvages to make functional sound absorption composites. These selvages came from reinforced cloth for shoes. The cloth for the shoes was created by needlepunched nonwoven webs into many layers and then using a hot calendar to bond the layers. They were composed of approximately 25%

regular polyester fibers, 60% reclaimed polyester fibers, and 15% low-melt polyester fibers. The selvages were used as fillers in plastic composites so they were torn apart into pieces that fit through a 4mm hole screen. These pieces were mixed with polypropylene nonwoven pieces in a 1:1 ratio in addition to sawdust and compressed to form the composite. The composites did well at absorbing high-frequency sound waves but did not perform as well for low-frequency sound waves.

Na *et al.* [2] determined the sound absorption coefficients of micro-fiber fabrics. They used micro-fiber fabrics because of their high surface area and fine fibers. The types of microfiber fabrics used were waffle, queenscord, mesh, suede and terry. A fleece non microfiber fabric was also tested. When compared to a conventional fabric, the sound absorption ability of a micro-fiber fabric with the same thickness or weight was found to be superior.

Zhou *et al.* [4] created a sound absorption material made of polymer microparticles and polyurethane foam. The polymer particles were made via suspension, emulsion and dispersion polymerization. These particles were encompassed by the foam and the material was made to be 20mm thick. They found that the polymer microparticles had a positive effect on the absorption performance for the composite materials. They concluded that the polymer particle's vibrations combined with the sound absorption of visco-thermal loss in the spaces between the particles and in the foam, which contributed to the overall sound absorption.

Increasing the weight and the thickness of the fabric does not have enough effect on the sound insulation properties of the material if the weight and the thickness increase do not contribute the total surface area of the material. When glass beads with 0.1mm, 0.5mm and 2.5mm diameters are imbedded to the fabrics, they do not contribute enough to the total surface area of the fabric. The objective of this research is to discover if glass beads will help absorb sound energy through vibrations and provide an improvement in sound insulation without contributing to the total surface area of the material. The main reason to select the glass beads is because acoustical insulation material used for building industry is the nonwoven fabric made from glass fiber. This research will provide new data because there is no existing data on nonwoven polyester being paired with glass beads. The contribution to the literature is to prove that weight and thickness increase of the material do not contribute the sound insulation property without the surface area increase.

MATERIALS AND METHODS

Fabric Production

The nonwoven fabric was composed of a 50% 3 denier PET and 50% 4 denier co-PET fibers. These fibers were mixed with the CMC Rando Cleaner. After the fibers were mixed and opened, they were fed through a chute into the 20in Bematic Card. The resulting fiber web was fed onto a 24in Automatex cross lapper conveyer system. Then the web was needlepunched on an Automatex needle loom.

The needlepunched nonwoven webs were cut into 15in x 20in pieces. Three layers of these 250g/m² nonwoven webs were layered together with imbedded glass beads in the middle layer. The resulting weight of the control fabric without particles was around 700g/m². The middle layer was thru-air bonded at 310˚F before glass-beads were distributed. This was done so that the fabric would be more compact to inhibit the glass beads from falling through the porous material. Glass beads were distributed on to a 10in x 10in area in the middle of the fabric. The amount added was determined by the weight percent of the sample. Weight percentages of 25%, 50%, 75%, 100% and 200% glass beads were imbedded to the fabric. The three layers of nonwoven fabric were then thru-air bonded twice at a rate of 4m/min and at a temperature of 350°F. Once the samples were bonded, they were cut into 12in x 12in pieces for testing purposes.

The sizes of the glass beads are chosen to be 0.1mm, 0.5mm, and 2.5mm for the research. These glass beads increases the composite fabrics' weights and thicknesses but do not contribute much to the total surface area of the composite fabric.

Sound Measurement Apparatus

Clemson-Boston Differential Sound Insulation Tester was used to measure sound insulation of the produced nonwoven fabrics [5] as shown in *Figure 1*. The six main components are the sound signal-processing computer, the sound signal amplifier, the sound source, the sound chamber, the material sample holder and the sound detector. White noise with sound frequencies ranging from 73Hz to 20,000Hz was used for the sound insulation measurements.

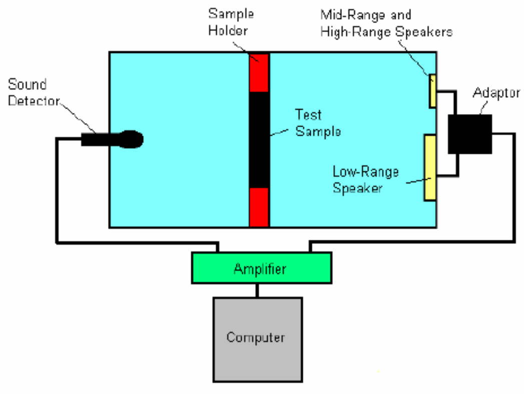

FIGURE 1. Illustration of the Clemson–Boston Differential Sound Insulation Tester [5].

The computer generates sound signals, which are amplified by the signal amplifier. These signals are then converted into sound waves via the sound source. The material being tested rests in the sample holder in the sound path. The sound passes through the sample and reaches the sound detector, which converts the received sound signals to electric signals that are then analyzed by the signal-processing computer.

When there is no sample in the sample holder, a background reference can be obtained. A background does not need to be set between samples. Each sample material was tested four times by rotating the sample 90˚ at each test. This was done because of the possibility that the glass beads may not have been distributed evenly. A total of 5 tests for each direction were done and the average was taken as the result.

The Clemson-Boston Differential Sound Insulation Tester cannot not provide an absolute measurement, but it is able to provide a direct acoustical comparison because the samples are tested under the same conditions. [5]

The results are reproducible which is verified by the fact that when tests are made with no sample in the holder the plotted results are identical to the base line when there has been initial calibration and Fourier Transformation. [5]

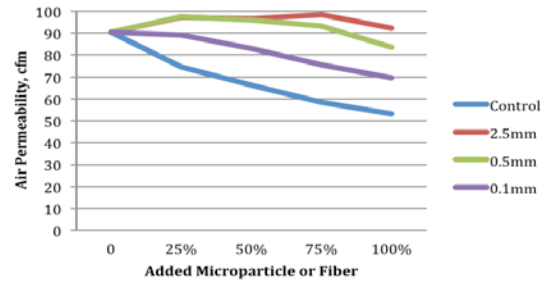

FIGURE 2. Air permeability results of glass beads or fiber added nonwovens. C: Control Fabric, 2.5mm: Particle of 2.5mm diameter added nonwoven fabric, 0.5mm: Particle of 0.5mm diameter added nonwoven fabric, 0.1mm: Particle of 100-micron diameter added nonwoven fabric.

Air permeability results of nonwoven fabrics with different amounts of glass beads added are shown in *Figure 2*. Control fabric has the same weights of extra fibers. Results show that air permeability of the nonwoven fabric with extra fiber is lower than the glass-bead added nonwoven fabrics. This result is expected because the sizes of the glass beads are much higher than the fiber diameter therefore fabric will have more opening and bigger voids in the structure. Therefore, more fiber addition makes the fabric more resistant to the air.

As shown in *Table I*, the surface areas of the nonwoven fabrics were about the same for most of the samples with glass beads added even though the weight increased dramatically. The total surface area of the glass beads was almost negligible except for the samples with 0.1mm beads.

TABLE I. Calculated Total Surface Area of Fibers and Glass Beads for Each Sample.

Sample	Surface Area of Fibers (m^2)	Surface Area of Beads (m^2)	Total Surface Area of Composite (m^2)
25% 2.5mm	10.93	0.01	10.94
25% 0.5mm	10.46	0.04	10.50
25% 0.1mm	10.63	0.22	10.85
50% 2.5mm	10.49	0.02	10.51
50% 0.5mm	10.20	0.09	10.28
50% 0.1mm	10.47	0.45	10.92
75% 2.5mm	10.15	0.03	10.18
75% 0.5mm	9.93	0.13	10.07
75% 0.1mm	10.32	0.67	10.99
100% 2.5mm	10.70	0.04	10.74
100% 0.5mm	11.40	0.18	11.57
100% 0.1mm	10.41	0.89	11.30
200% 2.5mm	11.24	0.07	11.31
200% 0.5mm	10.93	0.36	11.29
200% 0.1mm	11.50	1.78	13.29
C	10.76	0.00	10.76
C+25	13.36	0.00	13.36
C+50	17.22	0.00	17.22
C+75	18.81	0.00	18.81
C+100	22.81	0.00	22.81
C+200	33.92	0.00	33.92

RESULTS AND DISCUSSIONS

Nonwoven polyester structures were used in combination with glass beads to form sound insulation materials. The sound insulation properties of these glass-beads imbedded nonwoven fabrics were analyzed in order to determine if the glass beads had any impact.

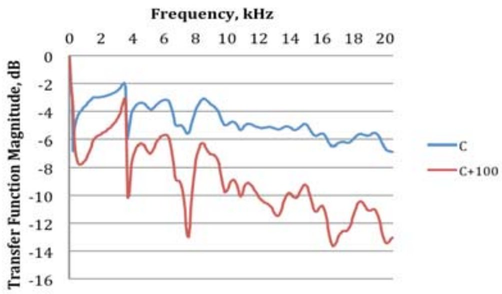

FIGURE 3. The Effect of Fiber Weight on Sound Insulation. C: Control Fabric, C+100: Double weight of control fabric.

As seen in *Figure 3*, the amount of fiber used to make the sample had an effect on the sound insulation ability. Sample C represents the control with a weight of about 700g/m². Sample C+100 represents a control of a weight of about 1400g/m². Samples C+75 and C+200 were the base weight plus 75% weight and 200% weight respectively. The more fiber the sample contained, the better sound absorption properties it had. This effect is due to the amount of surface area the sample had. The sound absorption is realized by the changing the sound energy into the vibration of the fibers. Therefore the sound absorption capacity of the material increases with increasing the fiber content in the material. *Table I* shows the surface area of the fiber in each sample. A higher surface area allows for better sound insulation because it provides more possibilities for sound waves to interact with material. Samples C+25, C+50 and C+200 followed the same trend but were left out of *Figure 3* for simplification.

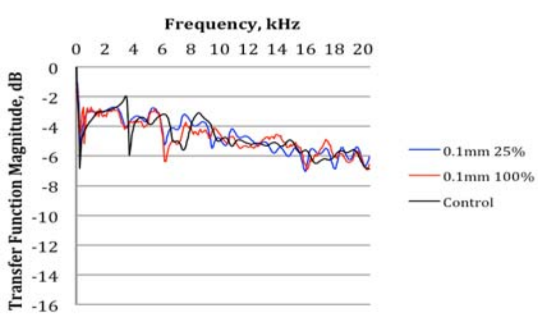

FIGURE 4. The Effect of the Amount of Glass Beads on Sound Insulation

Figure 4 shows the effect that the amount of glass beads added to the sample had on the sound insulation properties. Data was collected for all of the different weight percentages but this graph is being used as a representative because all of the samples had the same trends. The sample with 200 wt% of 0.1mm beads was able to insulate slightly better than the sample with 25 wt% of 0.1mm beads. This is again a result of surface area. In *Table II* it shows that the 0.1mm beads added the most surface area to the samples. The surface area of the beads in the 200 wt% sample was 1.78m^2 that is larger than the surface area of the beads in the 25 wt% sample which had a surface area of 0.22m^2. A higher surface area provides more area for sound waves to be absorbed. This can explain why the sample with more glass beads was able to insulate better.

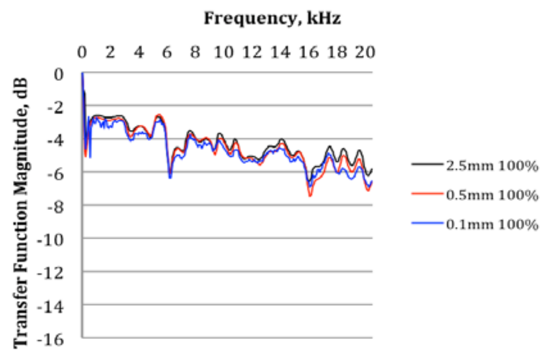

FIGURE 5. The Effect of The Diameter of Glass Beads on Sound Insulation.

As seen in *Figure 5*, the different size glass beads did not affect the sound insulation property of the nonwoven fabric. Data was collected for all of the different size beads but this graph is being used as a representative because all of the samples had the same trends. The sample with the smallest beads, 0.1mm, was able to insulate slightly better than the 2.5mm and 0.5mm beads. This can be attributed to the fact that the smaller beads provided more surface area, which can help insulate sound more.

CONCLUSIONS

The imbedded glass beads did not contribute much to the sound insulation ability. The amount of extra surface area provided was not significant enough to make a big difference. The more fibers the sample had, the better it insulated sound due to the fact that extra fibers provide extra surface area. The samples with 0.1mm glass beads did work slightly better than the samples with the bigger beads. It is possible that if even smaller beads were tested, they could have a larger impact on sound insulation as long as they were separated from each other.

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