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Sound reduction by needle-punched nonwoven fabrics

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Effect of area density, fabric type, source intensity, number of layers, distance of fabric from sound source, distance of fabric from the receiver and fibre type on sound reduction of various needle-punched nonwoven fabrics has been studied in an indigenously fabricated equipment. Nonwoven fabric shows higher sound reduction than the woven fabric. Jute-polypropylene (1:1) blend shows maximum sound reduction among jute, polypropylene, polyester and other jute-polypropylene blend (3:1 and 1:3) samples. Higher area density is responsible for higher sound reduction and there is a negative correlation between area density or bulk density of needle-punched nonwoven and sound reduction. With the increase in number of layers of nonwoven fabric, the sound reduction through the fabric increases initially but after the maximum it remains almost unaltered. Sound reduction also increases as the distance between the fabric and the sound source increases, and the source decibel decreases.

Keywords: Blended fabric, Jute, Needle-punched nonwoven, Polypropylene, Sound reduction

1 Introduction

During recent years, the subject of noise has received increasing amount of attention to the scientists, technologists and public as a whole. There is ample evidence showing that the high noise levels cause sleep disturbance, hearing loss, decrease in productivity/ learning ability/ scholastic performance, and increase in stress related hormones and blood pressure. Therefore, unwanted and uncontrolled noise should be reduced using noise barriers and noise absorbers. Properly designed textile materials may be considered as noise control elements in a wide range of applications, including wall claddings, acoustic barriers and acoustic ceilings[1]

All materials have some sound absorbing properties. Incident sound energy which is not absorbed must be reflected, transmitted or dissipated. Most good sound reflectors prevent sound transmission by forming a solid, impervious barrier. Conversely, sound absorbers are generally porous, lightweight material. Thicker materials generally provide more bass sound absorption or damping.

The sound reduction between two spaces is dependant on all of the elements of the structure separating them. The sound pressure waves cause the fibres or particles to vibrate. These movements are so small that they are not normally visible. This vibration liberates tiny amount of heat due to the friction and thus absorbed sound energy is converted to potential and heat energy. Common porous absorbers include carpet, draperies, spray-applied cellulose, aerated plaster, fibrous mineral wool and glass fibre, open-cell foam, and felted or cast porous ceiling tile. The air inside the pores acts as damper. The most effective way to increase damping is through the use of a viscous interlayer such as soundproofing mat. Bending waves, excited by the incident sound, cause shear strains within the viscous interlayer material. Because the interlayer has inherently high damping, the bending waves are transformed into heat energy. The mass law predicts that the transmission loss will increase by approximately 6 dB for doubling of the surface mass using thicker material or denser material[2].

A numerical method of calculating acoustic performance of nonwovens has been proposed in a study[3] and the noise absorption coefficient of fibre webs is shown as a function of their thickness and porosity. It has been shown[4] that the absorption coefficient is higher for the nonwoven having more fine fibres. The use of nonwoven is increasing rapidly in the automobile industry due to its sound insulation property[5]. One of the oldest applications of impregnated jute or shoddy mat is in noise damping[1,6]. The efficacy of the nonwoven materials as sound insulator has been examined by Teli *et al.*[7].

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They observed that with the increase in frequency and area density the extent of sound reduction increases by the nonwoven while with the increase in air permeability, it decreases.

Needle-punched nonwoven with jute and its blend may be used as sound insulator and absorber. However, the information regarding this is found to be scanty. Detailed study and proper quantification of various jute and jute blends is necessary for their use as sound absorbent / insulator. Keeping this in mind, in the present study an attempt has been made to investigate the sound reduction by various specially tailored jute, polyester, polypropylene and jute:polypropylene blended needle-punched nonwovens.

2 Materials and Methods

2.1 Materials

Tossa Daisee jute[8] of grade TD_3, polypropylene and polyester fibres were used separately for the preparation of needle-punched nonwoven fabrics. Jute blended with polypropylene in 3:1, 1:1 and 1:3 dry weight proportion was also used for the study. The physical properties of jute fibres taken from breaker card, polyester and polypropylene are shown in Table 1.

2.2 Preparation of Needle-punched Nonwoven

The middle portion of jute reed (after removal of root and tip portion of reed) was subjected to softening treatment. Jute batching oil (a commercial grade, hydrocarbon based mineral oil) in water emulsion was sprayed to maintain an average of 1.5% oil content and nearly 35% moisture on the weight of fibre. The reeds were then kept in bin for piling or conditioning for 24 h as commonly practiced[9] in jute mills. Then, it was processed through jute softener and breaker card. The breaker card sliver was fed to Dilo nonwoven plant comprising a card, a camel back cross-lapper and a needle loom (model number OD II/6) to prepare pre-needled web of 50 g/m^2 area density with 25 punches/cm^2 and 12 mm depth of needle penetration. The fabric area density was achieved by adjusting and needling the required number of layers of pre-needled fabric, considering area density loss due to needling.

Table 1—Physical properties of fibres

Fibre	Density g/cm^3	Staple length mm	Linear density tex	Tenacity cN/tex	Extension -at-break, %
Jute	1.46	-	2.09	31.3	1.61
Polypropylene	0.92	100	1.70	38.2	53.00
Polyester	1.38	100	0.90	35.05	32.00

To prepare blended fabric, breaker card jute sliver and synthetic fibre were opened thoroughly and then mixed in required dry weight proportion following stack mixing technique. This blend was then processed in Dilo needle-punched nonwoven plant to prepare the nonwoven fabric required for the study. Similarly, needle-punched nonwoven fabrics from synthetic fibres were prepared feeding hand opened synthetic staple fibre directly on the conveyor of card and processed in Dilo needle loom in the similar way as stated above.

For parallel-laid needle-punched fabric, instead of cross lapper in the nonwoven line circular drum has been used to collect the web from the card. Thick web from the surface of the drum is then fed to needle loom. Random laid web was prepared by air laying technique using the Callaghan Web maker consisting of a hopper feeder and two randomizers. It was then needled as stated here.

Needling density of 200 punches/cm^2 and 13 mm depth of needle penetration have been applied with 25 gauge, regular barb needles in all the cases. The actual area density was measured following the ASTM standard[10]. The constructional details along with fabric thickness and bulk density of three different fabrics are shown in Table 2. Jute woven fabric of 12 porter × 11 shots and 345 g/m^2 was procured from the market.

2.3 Evaluation of Sound Insulation

2.3.1 Fabrication of Sound Absorption / Insulation Testing Apparatus

A simple testing apparatus (Fig. 1) has been set up to measure the permeability of sound through a needle-punched nonwoven fabric. It consists of a

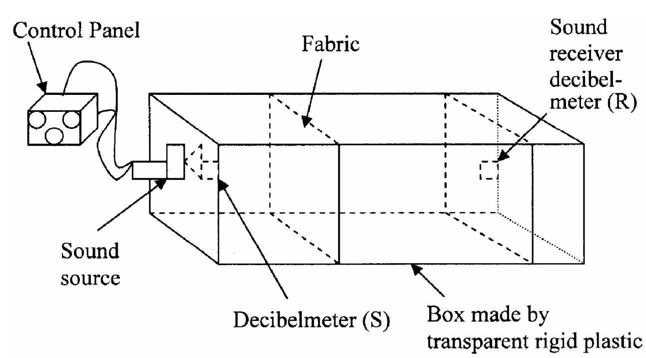

Fig. 1—Set-up for measurement of sound reduction

Table 2—Constructional details of cross-laid experimental fabrics

Sample No.	Fibre	Laying type	Proportion	Mass per unit area g/m^2	Fabric thickness mm	Bulk density g/cm^3
S1	Jute	Cross laid	100%	299	2.55	0.117
S2	Jute	Cross laid	100%	512	4.57	0.112
S3	Jute	Parallel laid	100%	706	5.60	0.126
S4	Jute	Random laid	100%	711	7.18	0.099
S5	Jute	Cross laid	100%	701	6.49	0.108
S6	Jute	Cross laid	100%	910	8.58	0. 106
S7	Polypropylene	Cross laid	100%	509	5.09	0.100
S8	Polyester	Cross laid	100%	504	4.84	0.104
S9	Jute: polypropylene	Cross laid	3:1	511	5.32	0.096
S10	Jute: polypropylene	Cross laid	1:1	502	5.64	0.089
S11	Jute: polypropylene	Cross laid	1:3	492	5.18	0.095

sound insulating box made out of thick transparent rigid plastic with removable top lid. Inside one vertical wall of this box a sound source and a decibel meter (S) are fixed. In another movable (to adjust the distance between sound source and receiver) vertical wall, a decibel meter (R) is fixed coaxially opposite to sound generator to measure the sound intensity. In between these two decibel meters, a sliding (to adjust the distance between sound source and fabric) arrangement is there to fix the fabric sample vertically. The sound intensity is controlled by an electrical panel.

2.3.2 Measurement of Sound Insulation

A sound of particular decibel is created by operating the control panel. The source decibel and the receipt decibel have been measured by two decibel meters S and R respectively without and with fabric sample. The sound reduction responsible for fabric which is expressed as the measure of sound insulation can be calculated as shown below:

$$dB_{\mathrm{F}} = \begin{pmatrix}\text{Decibel reduction}\\ \text{with sample}\end{pmatrix} - \begin{pmatrix}\text{Decibel reduction}\\ \text{without sample}\end{pmatrix}$$

$$= (dB_{\mathrm{S}} - dB_{\mathrm{R}})_{\mathrm{WS}} - (dB_{\mathrm{S}} - dB_{\mathrm{R}})_{\mathrm{WOS}}$$

where dB_F is the sound reduction responsible for fabric; dB_S, the sound intensity at source; dB_R, the sound intensity at receiver; WS, with sample; and WOS, without sample.

3 Results and Discussion

3.1 Effect of Fibre Type on Sound Reduction

Figure 2 shows the sound reduction of 500 g/m^2 needle-punched nonwoven fabrics made out of different raw materials i.e. 100% jute, 100% polypropylene, 100% polyester, and jute-polypropylene blends of 3:1, 1:1 and 1:3 proportions. The evaluation has been done keeping the fabric at 8 cm and receiver decibel meter (R) at 16 cm in the same side from the source of sound.

Different natural and synthetic fibres have different properties especially in consideration of rigidity, surface properties, elongation and resiliency. These properties control the density or air voids of nonwoven fabrics, which, in turn, affect the sound permeability through the fabric. It can be observed that jute gives the lowest sound reduction among all the samples tested because of less void area due to compact structure which is also reflected in the fabric density (Table 1). All synthetic fabrics (polypropylene and polyester) show the higher sound reduction than all jute fabric due to higher bulk, which gives damping effect to the sound energy. Jute-polypropylene (1:1) blended fabric shows the highest sound reduction due to higher damping (low density) of sound energy in the mixture of two dissimilar fibres, which may possibly arrest wide range of frequencies of sound. Hence, blends of dissimilar fibres show higher sound reduction compared to their individual performance. Figure 2 also reflects that with the increase in synthetic fibre proportion with respect to jute in the blend, the sound reduction initially increases and after attaining optimum it reduces. Jute-polypropylene (1:1) blend reduces the sound by about 27 dB.

3.2 Effect of Distance of Fabric from Sound Source

This study has been carried out with 500, 700 and 900 g/m^2 jute needle-punched nonwoven fabric. The fabric has been kept at 4, 8, 12 and 16 cm distance

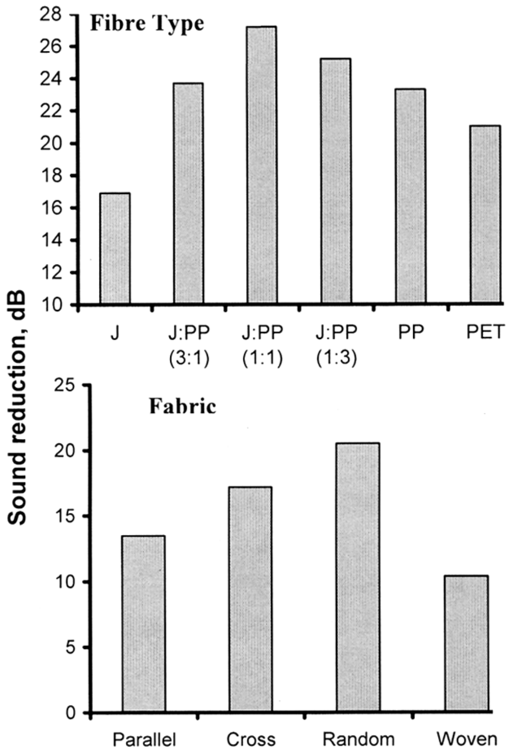

Fig. 2—Effect of types of fibre and fabric [J-jute, PP-polypropylene, and PET-polyester]

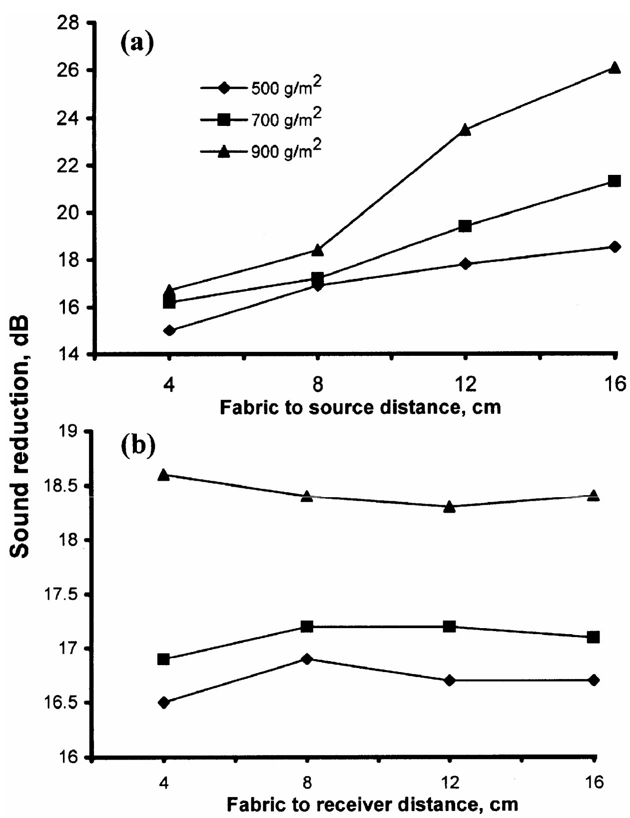

Fig. 3—Effect of (a) fabric to sound source and (b) fabric to receiver distances

from the sound source (S), whereas the distance from the receiver (R) to the fabric is kept fixed as 8 cm. It is found from Fig. 3 that the sound reduction increases as the distance of the fabric from sound source increases. This is quite obvious because as the sample moves away from the sound source, the sound pressure and intensity reduces which affects the transmission of sound through the fabric. It is also observed that with the increase in fabric area density, this effect increases.

3.3 Effect of Distance of Fabric from Receiver

This study has been carried out with 500, 700 and 900 g/m^2 jute needle-punched nonwoven fabric. The fabric has been kept at 8 cm distance from the source (S), whereas the distance from the receiver (R) to the fabric is varied as 4, 8, 12, 16 cm. It is found from Fig. 3 that sound reduction remains fairly constant with the increase in distance. But the increase in area density of fabric increases the sound reduction, as stated above.

3.4 Effect of Fabric Type on Sound Absorbency

Three jute needle-punched nonwovens of 700 g/m^2 are prepared with parallel-laid, cross-laid and random-laid web respectively, keeping other processing parameters same. In Fig. 2, their performances have been compared with 700 g/m^2 woven jute fabric. It is observed that woven fabric gives lower sound reduction than nonwoven fabric because of pores between threads. In nonwoven fabrics, random-laid sample shows higher sound reduction compared to cross-laid fabric followed by parallel-laid nonwoven. This is due to lower density of fabric which acts as damper to the sound energy.

3.5 Effect of Source Intensity on Sound Reduction

Jute cross-laid nonwoven fabric of 500 g/m^2 is tested under different source dB level and it is observed that sound reduction in lower dB source is higher due to lower energy in the source sound (Fig. 4).

3.6 Effect of Area Density of Fabric

Figure 5 shows a decrease in fabric density and a increase in sound reduction with the increase in area density. Hence, there may be a correlation between these two parameters. Figure 6 shows a good correlation having R^2 value of 0.9 with the equation $y = -420.77x + 64.002$. Therefore, it can be said that bulk of fabric or the void in the fabric plays a significant role in determining the sound reduction.

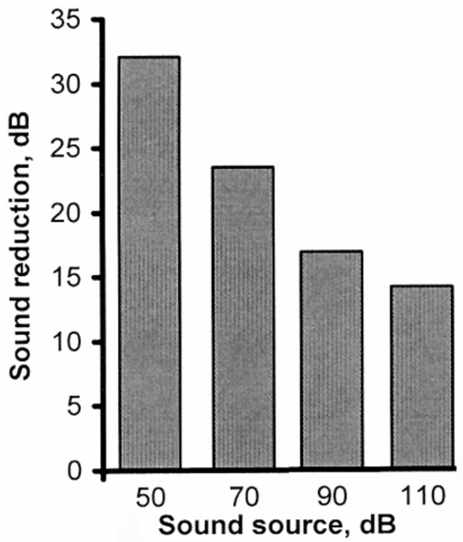

Fig. 4—Effect of intensity of sound source on sound reduction

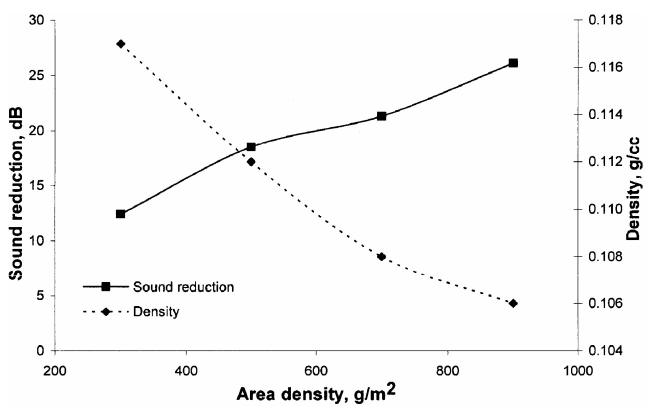

Fig. 5—Effect of area density on bulk density and sound reduction

3.7 Effect of Number of Layers of Fabric on Sound Reduction

Nonwoven fabrics having single layer area density of 500, 700 and 900 g/m^2 are tested for sound insulation in single and multiple layers. With the increase in number of layers of nonwoven fabric, the sound reduction through the samples increases initially but after the maximum it remains almost unaltered (Fig. 7). As the layer increases, it not only increases the area density of the combined sample but also introduces an air gap between the layers. At the maximum sound reduction, possibly all the frequencies of sound that can be absorbed or reflected by the said nonwoven are restricted and beyond that the effect of addition of layer is found inactive. In this case, the maximum reduction is achieved with 500

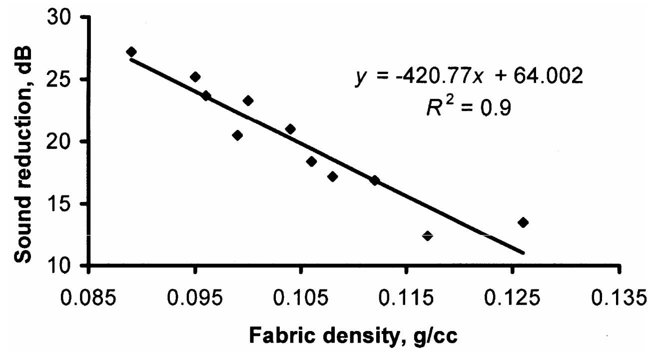

Fig. 6—Correlation between sound reduction and density of fabric

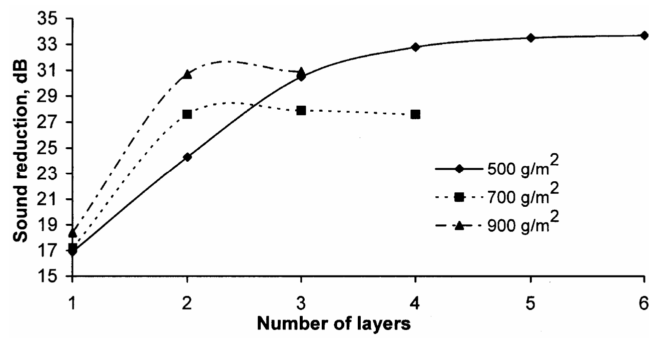

Fig. 7—Effect of number of layers on sound reduction

g/m^2 of 4 layers having total area density of 2000 g/m^2 or 900 g/m^2 of 2 layers having total area density of 1800 g/m^2.

4 Conclusions

4.1 Sound reduction is observed in the following order: jute-polypropylene (1:1)> jute-polypropylene (1:3)> jute-polypropylene (3:1)> 100% polypropylene> 100% polyester> 100% jute.

4.2 Sound reduction increases as the distance between the fabric and the sound source increases. With the increase in area density of fabric, this effect increases.

4.3 Sound reduction remains fairly constant with the increase in distance between fabric and receiver.

4.4 Sound reduction follows the following trend for jute fabric:
random-laid nonwoven> cross-laid nonwoven> parallel-laid nonwoven> woven fabric.

4.5 It is also observed that the higher the source decibel, the lower is the sound reduction.

4.6 With the increase in number of layers of nonwoven fabric, the sound reduction through the set of fabrics increases initially but after the maximum it remains almost unaltered.

4.7 There is a significant negative correlation between sound reduction and density of nonwoven fabric

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References

1 Shoshani Y & Yakubov Y, *Appl Acoust*, 59 (2000) 77.

2 Schwind David R, *Room acoustics in Acoustics: Architecture, Engineering, the environment* (William Stout Publishing, San Francisco), 1998, 69.

3 Shoshani Y & Yakubov Y, *Text Res J*, 69 (7) (1999) 519.

4 Lee Y & Joo C, *Autex Res J*, 3 (2) (2003) 78.

5 Sasile S & Langenhove L V, *J Text Apparel Technology Management*, 3 (4) (2004) 1.

6 Shoshani Y & Wilding M, *Text Res J*, 61 (12) (1991) 736.

7 Teli M D, Pal A & Roy D, *Indian J Fibre Text Res*, 32 (2) (2007) 202.

8 *Indian Standards Specification IS :271* (Bureau of Indian Standards, New Delhi), 1975.

9 Pal S N, Burman Roy U, Bhattacharya S & Samanta D, *Norms for the Jute Industry, Part I – Quality Parameters upto Spinning* (Indian Jute Industries Research Association, Kolkata, India), 1997.

10 *Annual Book of ASTM Standards,* ASTM:D 6242-98, Vol. 07.02 (ASTM Internationals, West Conshohocken), 2003, 1083.