A STUDY ON THE INFLUENCE OF FABRIC STRUCTURE ON SOUND ABSORPTION BEHAVIOR OF SPACER KNITTED STRUCTURES

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Abstract
Textiles are widely used in the automotive industry to provide both comfort to the passengers and an aesthetic appearance to the automotive interior. They can also be used to reduce automotive interior noise, which can make automotive travel safer and more comfortable. This paper investigates 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. Fabrics were designed with using SDS ONE Knit&Paint program and knitted on a seven-gauge Shima Seiki flat bed knitting machine. The fabric has two layers which are interconnected through a series of tucks. The sound absorbencies of fabrics which were measured with a two-microphone impedance tube method. The aim of this study is to design and produce a knitted spacer fabric having relatively good acoustic behavior and determine the influence of the modification of the knit structure on sound absorbency of fabric with keeping the yarn structure and fiber type constant.
Key words: automotive interior noise, knitted spacer fabric, sound absorbency, impedance tube method

1. Introduction

Noise refers to the irregular and chaotic sound which disturbs people’s work and impairs people’s health. In recent years, with rapid development of modern industry and transportation, noise pollution has become increasingly prominent, and has become a major cause of environmental pollution and personal unhealthiness. There are two main methods to control the noise pollution. One is the control of the noise sources, that is, to make the big vocal sound inaudible through a small device or equipment; the other one is to use a variety of noise reduction materials with special structures [1]. Very high density materials, such as steel, can be used as noise reduction materials. They can insulate sound very effectively, but these rigid materials reflect most of the sound back to the environment, which causes sound pollution. In addition, these high density, rigid materials are also very heavy and costly, they can not be used efficiently for sound absorption in automotive industries. Textile materials also have potential to reduce interior noise in an automobile due to their porous fibrous structures. Because they are both less expensive and lighter than steel like materials and additionally environment-friendly materials, they are mostly used in interior parts of automobiles [2]. Nonwoven structures have also been used, but they have less aesthetic appearance and drapability compared with knitted structures. Knitted fabrics are mostly used for noise reduction in automotive industry due to their superior drapability properties.
Acoustic behaviors of textile fabrics were also studied by some researchers before. In a study on sound absorption of plain knitted structures, fabric was knitted from 430dtex PE yarn and it was found that sound absorbency of fabrics was higher when they had low pore size, stitch size and high thickness [3]. In another study which determined sound absorption coefficients of fabrics with different structures knitted using 80/20 pet/nylon micro-fiber and % 100 pet conventional fibers, it was found that sound absorbency of fabrics were directly proportional to fabric thickness at low frequencies. Micro-fiber fabrics absorbed all sound frequencies better than a conventional fabric because their fibers have a higher surface area than those of regular fiber fabrics, resulting in higher flow resistance [4]. Tilak Dias and his friends investigated sound absorption of thick knitted spacer fabrics knitted from covered elastomeric yarn in their study. The results of their study showed better noise absorption when there is a thicker air gap between the front and fabric layers of the spacer fabric and/or a thicker face layer [5]. In another study of Tilak Dias and his friends, they analyzed sound absorption of

tuck spacer fabrics. Top and bottom layers were plain fabrics. These two layers were interconnected with a mesh of yarn oriented at an angle. They found that sound absorbency of these fabrics increased with both airflow resistivity and thickness. The porosity is inversely proportional to the airflow resistivity of the fabrics, therefore the sound absorbency of fabrics decreased with porosity. The fabric whose top and bottom layers knitted from textured polyester multifilament yarn had optimum sound absorbency [6]. The effects of basic weight, thickness and constructions of upholstery fabrics on acoustic properties of fabrics were analyzed and found that from all these parameters thickness had the highest effect on sound absorbency [7]. A study on acoustic behaviors of carpets obtained the result that pile structure, pile weight and pile height influence sound absorption coefficient of carpets [8].
This paper studies the sound absorbency of a novel spacer fabric, which has reasonable sound absorption properties. It is light in weight, flexible and can be knitted with any design to suit automotive brand requirements. These fabrics can be used in automotive upholstery, parcel shelf, headliner and door panels, to provide both comfort and noise reduction to the automotive interior. The fabric is superior over other textile structures used in the automobile in terms of flexibility and ease of manufacture. However, its drapability is reduced in comparison to a simple knitted fabric [6]. The aim of this study is to determine the influence of the modification of the knit structure on sound absorbency of fabric with keeping the yarn structure and fiber type constant.
Most of the research in the literature used two methods for measuring acoustical properties of fabric materials: the impedance tube method (ISO 10534-2) [9] and acoustic chamber method. The impedance tube method uses very small test samples (approximately 10cm diameter). On the contrary, large reverberation rooms and large test samples are used for the acoustic chamber method. In this study, two microphone impedance tube method was used to measure the absorption coefficients of spacer fabrics. The obtained results are evaluated and then discussed.

2. Fabric Samples

2.1. Fabric sample construction

For designing of the spacer fabrics, SDS ONE Knit and Paint program was used. The spacer fabrics were developed and knitted on an E7-gauge Shima Seiki flat bed knitting machine. The fabrics were steam treated. The front and back layers of the fabrics have been knitted with the yarns indicated in table 1. These two layers are then interconnected through a series of tucks of 321.43 denier polypropylene multifilament yarn.
The pictorial view of a spacer fabric is shown in figure 1.

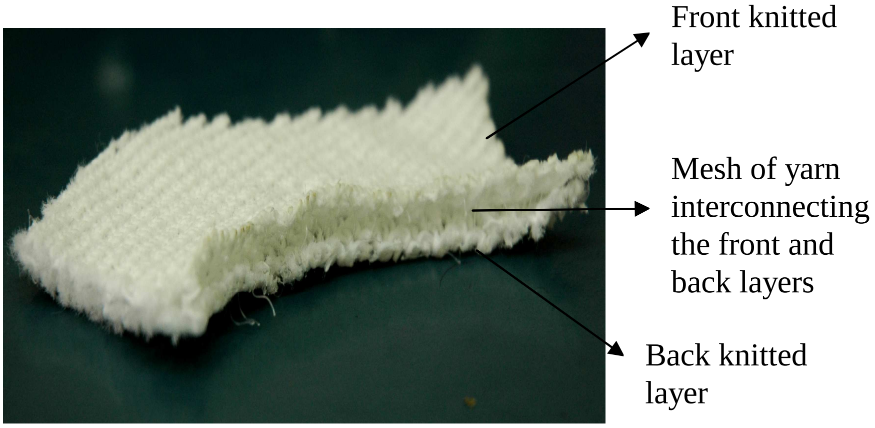

Figure 1. Pictorial view of a spacer fabric

The details of the fabric structures developed are given in the figures below. As it may be seen from the figures, number of miss stitches was changed in fabrics I, II and III. Fabric I has one miss stitch per three loops, fabric II has three miss stitches per three loops and fabric III has five miss stitches per three loops on front and back faces. Multifilament yarn connects two face layers in same number of points. In all fabrics there is one connection point per two loops. In fabric I.I, II.I and III.I mini-jacquard knit was used instead of plain knit. Fabric codes were arranged according to details of fabric structures. ".I" indicates mini-jacquard knit.

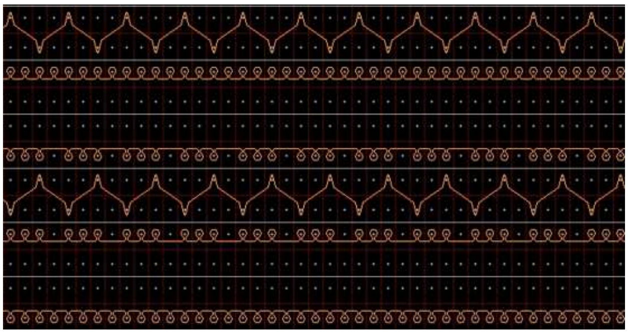

Figure 2. Structure of Fabric I

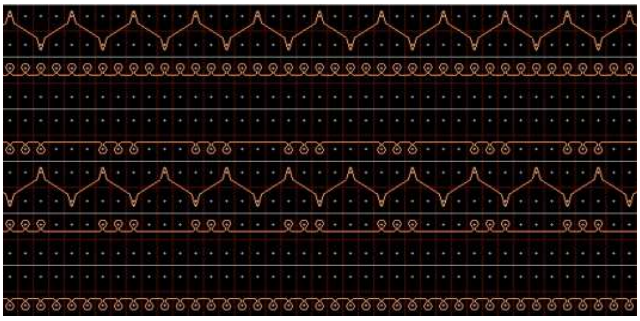

Figure 3. Structure of Fabric II

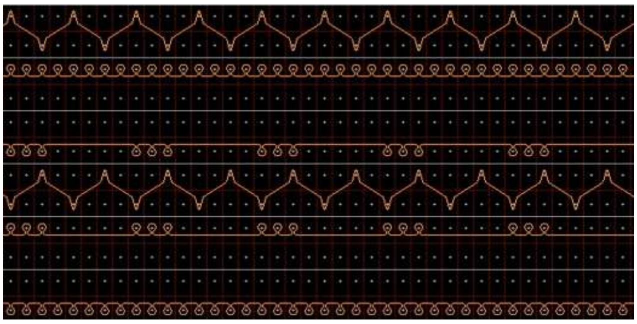

Figure 4. Structure of Fabric III

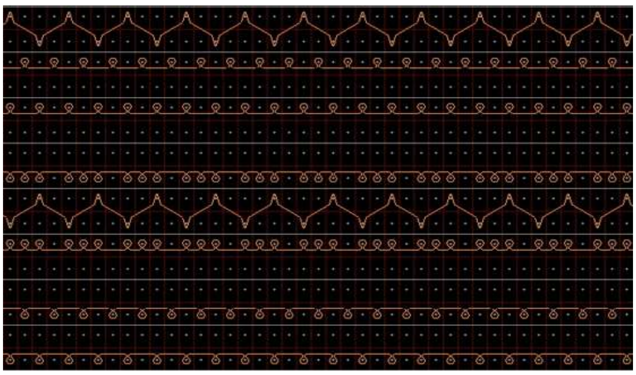

Figure 5. Structure of Fabric I.I

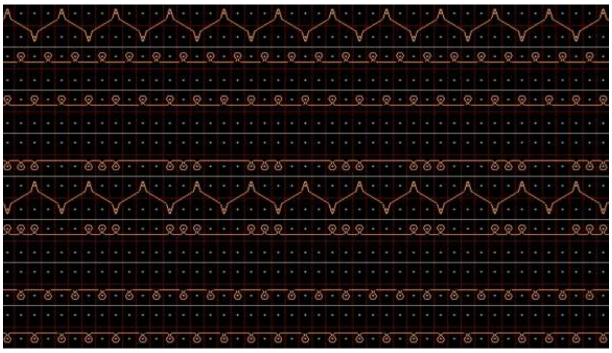

Figure 6. Structure of Fabric II.I

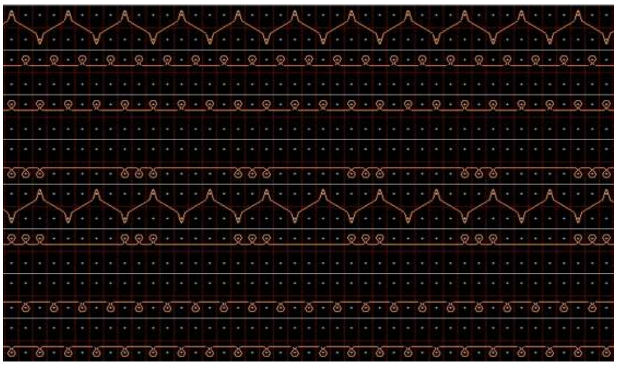

Figure 7. Structure of Fabric III.I

2.2. Fabric sample details

The details of the yarns used for the fabrics are given in table 1. Some dimensional properties of the fabrics are given in table 2.

The raw material and yarn properties were kept the same for all the fabrics developed to determine the influence of the modification of the knit structure on sound absorbency of fabric.

Table 1. Yarn properties

	Yarn Type	Yarn Count	Yarn Twist (rev/m)		
			Single ply	Double ply	Three ply
For both layers of the knitted fabrics	100% Cotton	Ne 2.16 (Nm 3.67)	848.8	601.6	243.2
Interconnecting Yarn	100% Polypropylene multifilament	321.43 denier (Nm28)	-		

Table 2. Dimensional properties of knitted spacer fabrics

Fabric Code	Wale and Course density (1/cm^2)		Fabric Density (kg/m^3)	Fabric Thickness (mm)
	Front	Back		
I	19	19	231.148	4.48
II	20	20	231.442	4.75
III	19	19	252.455	4.88
I.I	19	19	248.222	5.03
II.I	20	20	247.678	5.68
III.I	19	19	279.065	5.60

3. Measurement of some dimensional properties and noise absorption coefficient of spacer knitted fabrics

Before the fabrics were tested for determining their dimensional and noise absorption properties, they were steam treated.

3.1. Measurement of the total fabric thickness

The thicknesses of the fabrics as indicated in table 2 were measured with the use of a James H. Heal thickness tester. A 5 g/cm^2 pressure was used for this purpose. (BS 2544 standard)

3.2. Measurement of the fabric density

The weights of samples were measured in grams and the average was taken. The samples were cut in circular area of 100 cm^2. This value is then divided by 100 to obtain the mass per unit area (*M*) for the fabric in g/cm^2. This value and the measured thickness (t) of the fabric from table 2 are used to obtain the density of the fabric. The results are given in table 2.
The density of the fabrics can be determined by the equation 1.

$$\rho_f = \frac{M}{t} \qquad (1)$$

3.3. Measurement of noise absorption coefficient

To validate the mathematical prediction of the NAC of spacer knitted fabrics a measurement of the NAC was done using a standard two-microphone tube provided by Bruel&Kjaer. Two-microphone impedance method is based on measuring sound pressure in an impedance tube at two flush-mounted microphone positions. It determines the acoustical characteristic quantities such as the absorption coefficient, reflection coefficient, surface impedance and surface admittance for small size objects exposed to plane waves at normal sound incidence, referring to the figure 8 [10].

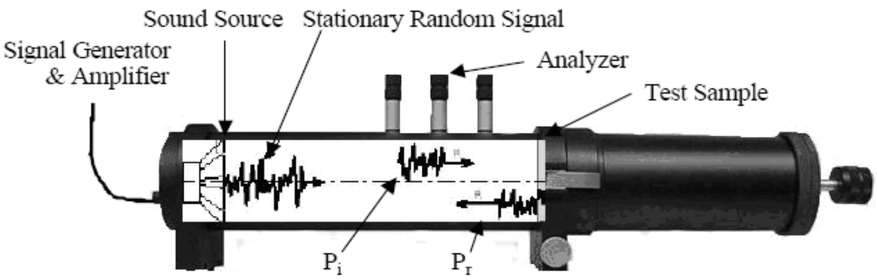

Figure 8: Conceptual drawing of two-microphone impedance method

PULSE Material Testing is the complete and fully integrated system for acoustic measurements on small material samples in the 50 Hz to 6.4 kHz frequency range. The white noise signal required by the impedance tube is generated by software in PC, which is fed to the tube with a National Instruments data device. The A and B microphone signals are fed to the PC with this device. The sound absorption software in PC calculates the NAC from 50 Hz to 6.4 kHz. As per ISO 10534-2 standard, NAC measurements were done on three identical samples taken from different regions of the fabric under test and their average taken [3].

The system configuration of Material Testing is shown in figure 9 [11].

Figure 9: System configuration of acoustical material testing using two-microphone method

Sound absorption coefficient can be determined by the equation 2.

$$
\begin{aligned}
\alpha_n &= \frac{\text{Sound energy absorbed by a surface } (I_i - I_r)}{\text{Sound energy incident in that surface } (I_i)} \\
\alpha_n &= 1 - \frac{\text{Energy reflected } (I_r)}{\text{Energy incident } (I_i)} \\
&= 1 - (p_r/p_i)^2
\end{aligned} \tag{2}
$$

Coefficient varies from zero (0) to one (1). Sound absorption performance is a function of frequency and is performed generally with the increase in frequency. Performance improves with the increase in thickness. Material thickness should be at least 1/10 wavelength of sound to justify the use (i.e., offer any benefit) and ¼ wavelength of sound to be effective.
Sound absorption coefficient is affected by parameters of material such as porosity, thickness, density, airspace between the absorber and the wall, perforation and facing.

4. Results and discussion

A comparative study of the sound absorption results of the fabrics I, II and III showed that Fabric III has the highest sound absorption coefficient value when compared with Fabric I and II (see fig. 10). In the knitting structure of Fabric III, the number of miss stitches on both front and back layers is more than that of Fabric I and II. With reference to Figure 10, sound absorption coefficient of fabrics increases with the increase in the number of miss stitches in knitted structure, because the total thickness of fabric increases. After the steam treatment, it was the Fabric III that had the highest stitch density and porosity of this fabric was observed to be lower than the porosity of Fabric I and II. Higher stitch density and relatively lower porosity improved the sound absorption performance of the fabric. Effect of porosity and density on α is seen clearly at frequencies higher than 1.6 kHz. Figure 11, 12 and 13 on the other hand reveal the effect of technical back thickness on sound absorbency of fabric. Unlike the fabric types I, II and III in which plain knit is utilized in the technical back, the thickness of the fabric increases when mini-jacquard knit is employed in the technical back of the fabric. To analyze the effect of thickness on sound absorbency, the sound absorbencies of the fabrics I-I.I, II-II.I, III-III.I were compared. Sound absorption coefficient increases with thickness. Effect of fabric thickness on α is seen clearly at frequencies higher than 1 kHz.

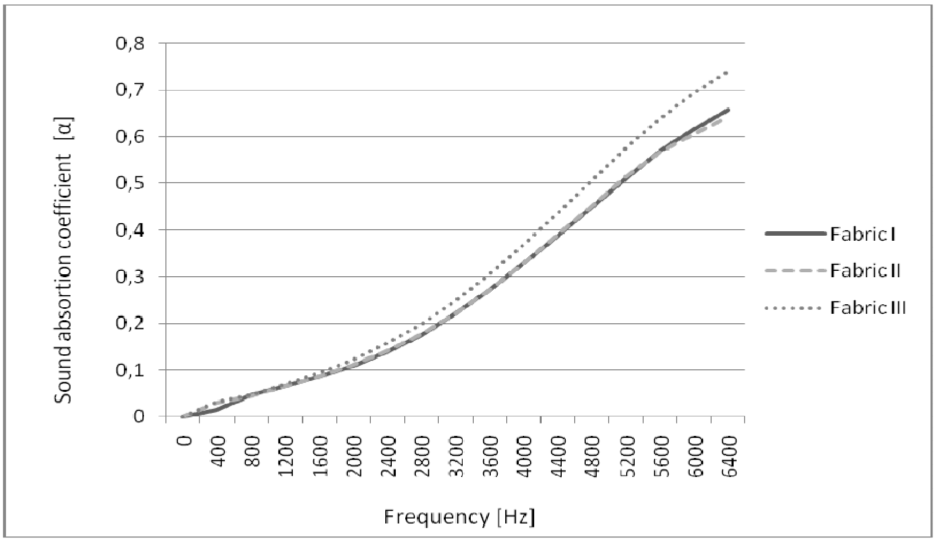

Figure 10: Comparison of absorption coefficients of Fabrics I, II, III

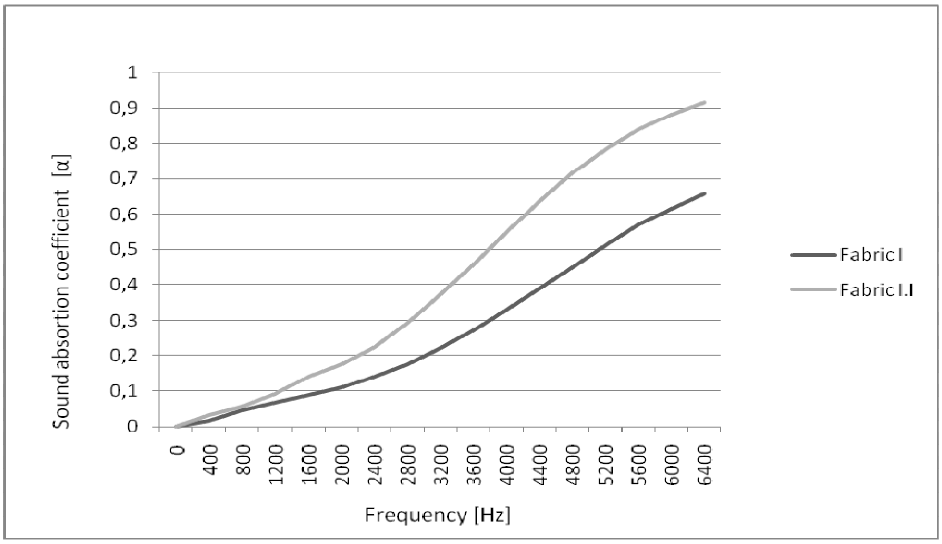

Figure 11: Comparison of absorption coefficients of Fabrics I and I.I

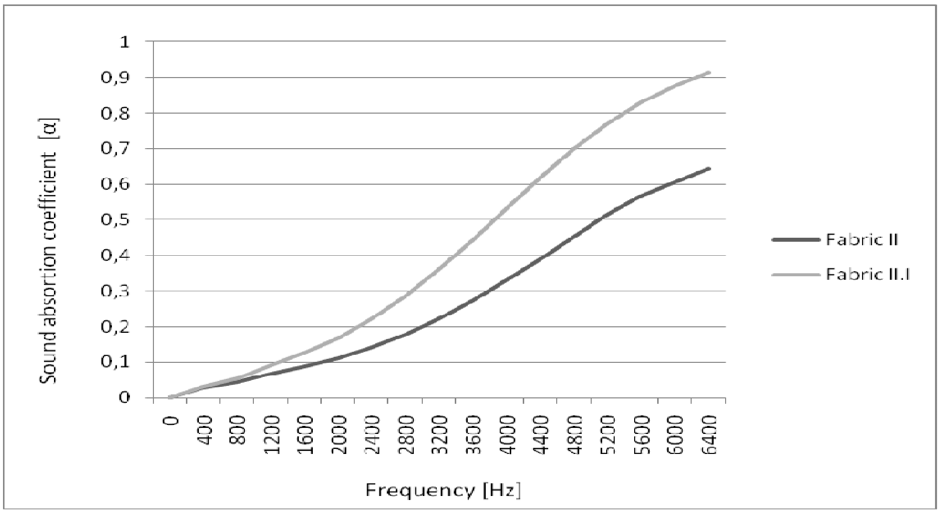

Figure 12: Comparison of absorption coefficients of Fabrics II and II.I

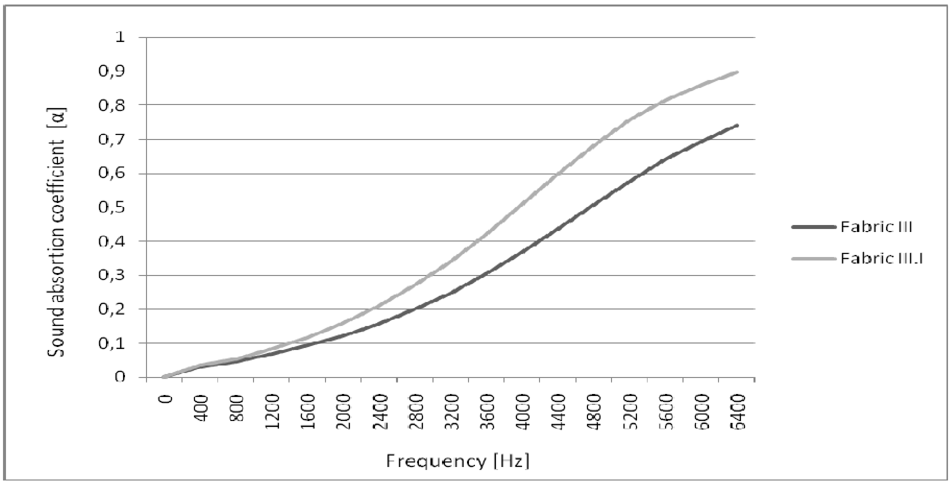

Figure 13: Comparison of absorption coefficients of Fabrics III and III.I

5. Conclusion

The sound absorbencies of the spacer knitted fabrics were measured with a two-microphone impedance tube according to the ISO 10534-2 standard. The effect of density, porosity and total fabric thickness parameters of the spacer knitted fabrics on their sound absorbencies are analysed in this study. The results showed that better noise absorption coefficient values can be achieved by using mini-jacquard knit instead of plain knit structure due to thicker face layer and consequently thicker spacer fabric. Besides, density has positive effect on sound absorption property of fabric. The sound absorbency of the fabric increases with the reduction in its porosity. This type of a knitted structure is a promising material for use in automobile interiors as headliner, parcel shelf and door panel liners due to their good sound absorption property and aesthetic appearance. The sound absorbency of the spacer fabrics developed is generally effective from 4000 Hz upwards when its noise absorption coefficient (NAC) is greater than 50%. Therefore, future work on these fabrics will be directed at the improvement of its sound absorbency in the region less than 4000 Hz.

5. References

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