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Influences of Thickness and Fabric for Sound Absorption of Biopolymer Composite

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Abstract. Biopolymer foam was prepared by the reaction of bio-monomer based on vegetable oil with commercial Polymethane Polyphenyl Isocyanate (Modified Polymeric-MDI). The acoustic study of biopolymer foam was examined by impedance tube test according to the ASTM E-1050 and laminated with three types of textile such as polyester, cotton and single knitted jersey. It was revealed that the thicker the fabric the higher the sound absorption coefficient (α) at medium frequency level. The higher the number of layers or thickness of the fabric, the sound absorption through the fabric increases at medium frequency but after the maximum it remains almost unaltered. Three layer of cotton fabric gives maximum α approximately equal to 1 which is 1.104 mm thickness at frequency level of 3000-3500Hz and single knitted jersey gives maximum α at 4^{th} layer of 2200-2700Hz. Meanwhile , the α of biopolymer foam laminated with polyester fabric approximately equal to 1 at lower frequency level of 2000-3000Hz with lower thickness that is 0.668mm. Polyester fabric with lowest thickness shows better α at lower frequency level due to the structure of the fabric. The relationships among the fiber properties such as fiber density, fiber diameter, and fibrous material layer were considered as a factor that influences the sound absorption property.

Introduction

Noise control issues and the emergence of sound quality is becoming very important in an automotive product design, acoustic material and is increasingly relevant to engineers, designers and manufacturers from a broad image of industries. Sound absorptive materials are generally used to counteract the undesirable effects of sound reflection by hard, rigid and interior surfaces and thus help to reduce the reverberant noise levels [1].

For automotive industries, sound absorption is the important issue where sound insulation developed should be efficient by means of getting the sound reduced and in economically ways of producing sound absorbing material which is cheap, user friendly and moderate sound absorbent coefficient. The absorption is desired at lower frequencies, thickness and weight. Sound absorber with different specific airflow resistance can be used to achieve desirable results. One method of increasing flow resistivity is the addition of a flow resistant scrim or film layer. Scrim means a fibrous cover layer with finite flow resistance and film means a plastic cover layer with infinite flow resistance [2].

Textiles are widely used in the automotive industry to provide both to the consumer comfort and an aesthetic appearance to automotive interiors. This material has potential to reduce interior noise in automotive due to the textile structure and diameter size of fiber porous as a sound insulating and sound absorbing material [3]. The property of textile is lightweight and less expensive as compared to steel like material and additionally environmental-friendly materials was enhances highest consumption in interior part of automotive industry. The cotton and polyester fabric were characterized as a nonwoven fabric with less aesthetic appearances as compared to single knitted jersey. Knitted fabrics are mostly used for noise reduction in automotive area due to their superior drapability properties [4].

The porous material such as textile mainly being used to investigate the sound absorption behavior based on energy dissipation behavior of sound waves while it's traveling through the media. Sound absorption of textile materials were design such as porosity was increased along the propagation of the sound wave and porosity should be maximum value in the middle of material [4]. Sound absorbing materials absorb most of the sound energy striking them and making them very useful for the control of noise. Organic and inorganic lamination on the absorbing material may also help in increase the sound absorption coefficient as compared to the product without laminated [5]. The lamination will help and improved the efficiency and the performance of the sound absorber due to its lamination of foam, and gives highly versatile acoustic foam.

Experiment Study

Materials. Bio-monomer; Polymethane Polyphenyl Isocyanate (Modified Polymeric-MDI) (viscosity at 25^{o}C = 120 – 160cps, specific gravity at 25^{o}C = 1.18 – 1.20g/ml, NCO Content, % wt = 26.3 – 27.3) ; Polyester fabric (warp density = 40 end/cm, weft density = 40 pick/cm, thickness = 0.167mm); Single knitted jersey fabric (warp density = 22 end/cm, weft density = 8 pick/cm, thickness = 0.45mm); and Cotton fabric (warp density = 13 end/cm, weft density = 13 pick/cm, thickness = 0.368mm);

Foam Production. Bio-monomer based on waste cooking oil from Small Medium Entrepreneur (SME's) was prepared beginning with a preparation of the catalyst to generate the epoxides from unsaturated fatty compound and comprised the acid-catalyst ring opening of the epoxides to form polyols [6-9]. There are three types of textile fabric such as cotton, polyester and single knitted jersey were used and laminated with biopolymer. The biopolymer foam was prepared by manual open casting method. The biopolymer foam was fabricated by stirring the bio-monomer with a *Philips multiple speed hand* in a cup for 1 minute. The isocyanate was poured into bio-monomer and stirrer again for about 10 minutes. The mixtures were then immediately poured into plastic containers before the biopolymer foam is expanded out. The reaction was occurred when the mould became warm and reacted with air to develop foam. It was left for 12 hours to fully cure at room temperature.

Characterization Methods. The sound absorption coefficient was carried out using Impedance Tube Test; type SSC 9020B/K, according to ASTM E1050 and ISO 10534-2 which is for horizontally mounted orientation sensitive materials for the frequency range of 100-6300 Hz. The Impedance tube is used to test sound absorption coefficient of biopolymer foam at low frequency level by 100 mm diameter, while sound absorption coefficient at high frequency were determined by using 28 mm diameter at 10 mm of thickness. The biopolymer foam was laminated with three types of textile such as cotton, single knitted jersey and polyester fabric. The testing was conducted with different layer of fabric to obtain the sound absorption performances at low and high frequency level.

Result and Discussion

Fig. 1 shows the ability of the biopolymer foam to act as sound absorbing materials in the frequency range 100-6300 Hz. At low frequency level where human sensitivity to noise is high, biopolymer foam exhibit gradually increasing of α from low frequency level up to high frequency level. By examining the curve, the highest ability for normal incident α is approximately equal to 0.87 at 5430Hz. The α of 0.87 indicated only 87% of the incident sounds waves are absorbed by the noise absorbing material whereas all of the sound waves are absorbed when the coefficient reaches a value of 1 [10]. The biopolymer foam was able to give high α at high frequency level suitable for high noise of automotive applications; hence the sound absorption property was modified via laminated textile to enhance better absorption performance at medium and low frequency level. Table 1 shows the summary of three types of fabric for sound absorption performance laminated via biopolymer foam.

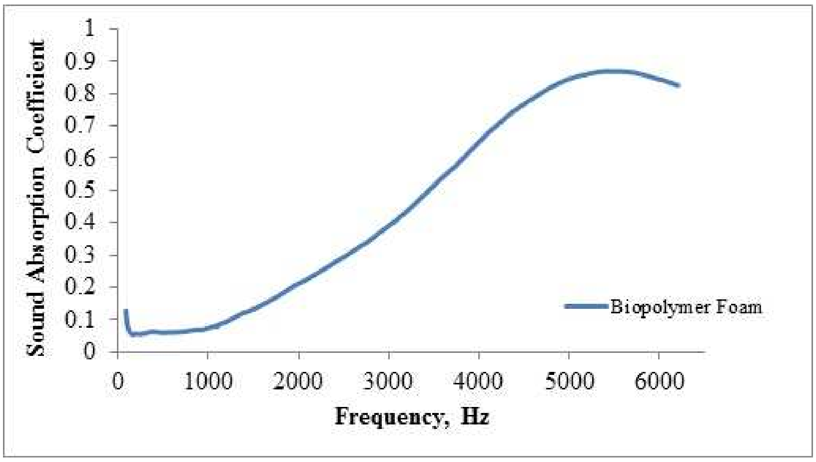

Fig. 1: Absorption coefficient (α) of biopolymer foam

Table 1 : Properties of textile for sound absorption performance

Types of textile	Warp density (end/cm)	Weft density (pick/cm)	Thickness (mm)	Maximum (α)	Maximum laminated layer
Cotton fabric	13	13	1.104	3000-3500Hz	3rd layer
Single knitted jersey fabric	22	8	1.800	2200-2700 Hz	4nd layer
Polyester fabric	40	40	0.668	2000-3000Hz	4nd layer

The ability of a textile material to absorb unwanted noise is based on dissipation of the sound wave energy upon passing through material and on conversion of some of the energy to heat. The amount of original energy less the remaining unabsorbed energy compared to the original energy leads to the measurement referred to as the absorption coefficient [10]. Referring to Fig. 2 increasing layers of cotton fabric gives maximum α at medium frequency level of 3000-3500Hz to biopolymer foam at high frequency level at 5000Hz. Besides, α was increased initially for the 1st layer and 2nd layer but at certain thickness of 3rd layer it remains almost unaltered. Hence, it is observed that the optimum thickness of cotton fabric is 1.104 mm to gives a good sound absorption approximately 1 at the range of 3000 to 3500Hz. As the layer increases, the samples introduce an air gap between the layers and influence the sound coefficient level [11].

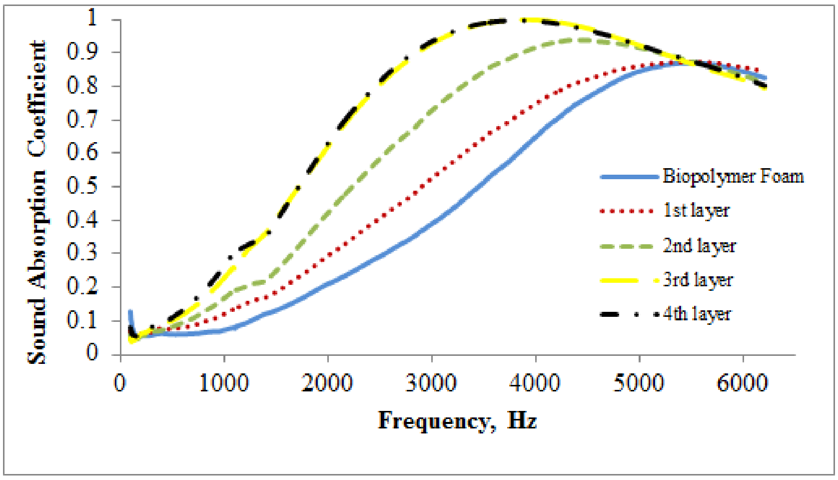

Fig. 2: Absorption coefficient (α) of biopolymer foam of laminated cotton fabric

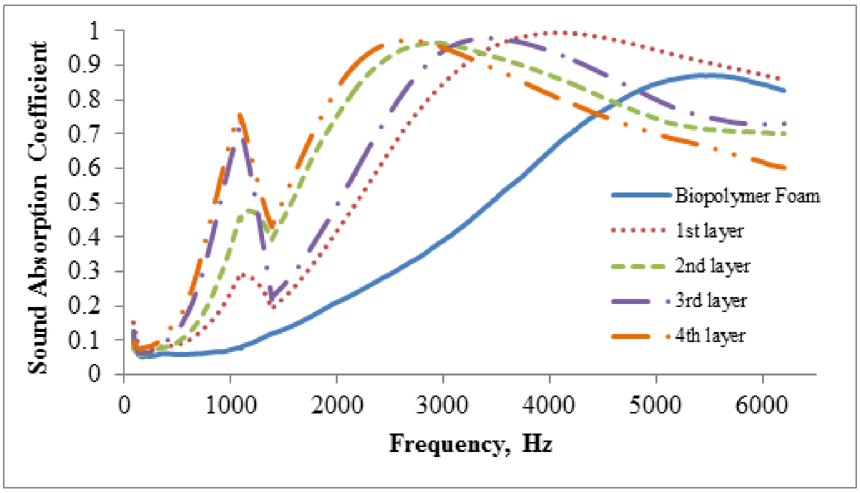

Fig. 3: Absorption coefficient (α) of biopolymer foam of laminated polyester fabric

Fabric density was affected the sound property of laminated biopolymer foam with polyester fabric with increasing layer and thickness. Polyester fabric has the higher warp density of 40 end/cm and weft density of 40 pick/cm as compared to cotton and single knitted jersey fabric as tabulated in Table 1. By examining the curve of Fig 3, the α gives a gradually increased at lower frequency level and proportional with increasing of laminated thickness of fabric. The highest α is approximately equal to 1 with laminated by polyester fabric as compared to others. The α is the highest at 2000Hz to 3000Hz indicates additional of thickness laminated layer with polyester fabric of highest warp and weft density. Hence, the maximum thickness of polyester fabric was observed up to 4th layer was achieved the α of the highest. The α increases due to ability of porous material to convert the incident sound energy into the heat energy and other types of energy by vibration, friction and air viscosity [5] in which polyester fabric has higher density and revealed that the pore size of fabric is smallest as compared to cotton and single knitted jersey fabric.

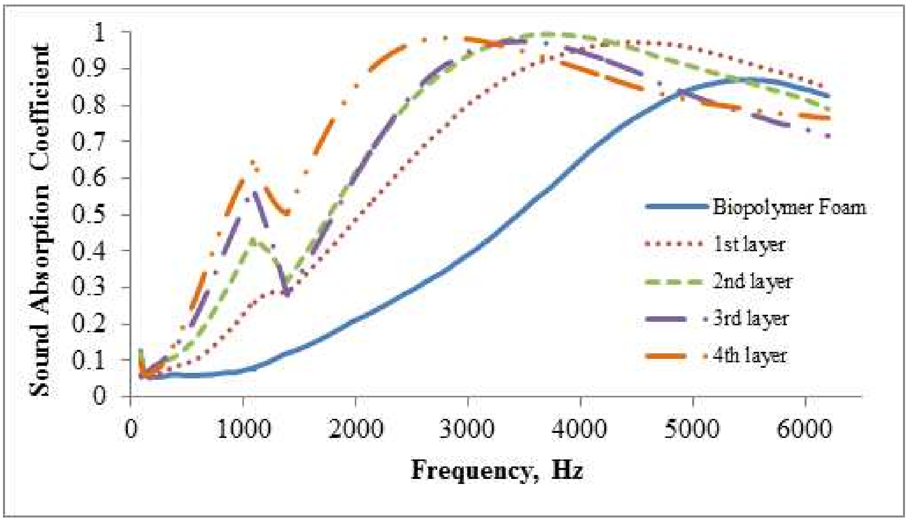

Fig. 4: Absorption coefficient (α) of biopolymer foam of laminated single knitted jersey fabric

The α increases with the smaller fiber diameter in such a way the impermeable size is much smaller as compare to sound wavelength. The change from the sound energy to heat energy will increase due to the vibration of friction of air particle [12]. Therefore, thickness of a fabric is often considered to be the important factor that governs the sound absorption behavior of the material. The consideration of biopolymer foam laminated with single knitted jersey fabric whereby gives an increase α with the increasing number of layers and thickness of fabrics. The α shows maximum at 4nd layer of single knitted jersey fabric in which approximately equal to 1 at range 2200 to 2700Hz. Hence, the suitable thickness was observed by laminating with single knitted jersey fabric at range of 1.8 mm. The characteristic of sound absorption of porous material are totally depended on the important factor which is thickness of fabric, size and type of pores. When the sound wave has to enter the porous material, there should have enough pores on the surface of the material for the sound to pass through and get dampened [13].

Conclusion

The sound absorption coefficient of the three types of textile were measured with a two microphone impedance tube according to the ASTM E1050 and ISO 10534-2 standard. The effect of number of laminated layer and fabric thickness with biopolymer foam were analyzed and shows highest α of polyester fabric at 2000 to 3000Hz approximately equal to 1 due to lesser thickness and high warp and weft density as compared to cotton fabric and single knitted fabric. The laminated cotton fabric for biopolymer foam improved the acoustic behavior based on sound absorption performance approximately equal to 1 at medium frequency level of 3000 to 3500Hz due to lesser laminated layer as compared to polyester and single knitted jersey. The technique lamination of multilayer textiles gives improvement of the absorption property to reduce sound absorption coefficient at lowest frequency for automotive applications.

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