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Characterization of woven fabrics for development of micro perforated panel absorbers

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ABSTRACT

Woven Fabrics are potentially to be developed as a sound absorber system because of the presence of micro perforation on their surface. By introducing air cavity backing the woven fabrics up, such system can undergo Helmholtz resonator mechanism as found in micro-perforated panel absorber. The micro perforations in a woven fabric are formed by yarn in x (weft) and y (warp) direction. The perforations can create a viscos-inertial effect when interact with sound fields that is useful as a basis for sound absorption mechanism. In this study, we focused on investigating the relationship of woven fabric material and manufacturing technique properties to associated sound absorption characteristics. For this, natural, semi-synthetic and synthetic fibers-based yarn are used to produce woven fabrics. For further investigation, the geometrical and physical properties of the yarns and fabrics are characterized. The geometrical properties are characterized using a digital microscope while the physical properties are measured using a fabric air permeability, fineness yarn, and other textiles testing devices. Meanwhile, the sound absorption coefficients are evaluated by an impedance tube using transfer function method. From this study, it can be concluded that the sound absorption coefficients of woven fabric are affected by material and manufacturing technique properties. It is expected that the results can be beneficial for developing design procedure of development woven fabric based on micro perforated panel absorber system.

Keywords: woven fabric, micro perforation, sound absorption, natural, semi-synthetic and synthetic yarns.

1. INTRODUCTION

Noise pollution is one of the problem for human and environment [1, 2]. Woven fabrics as acoustic absorbers have been used as an absorber material. The relationship of some parameters on woven carpet to sound absorption has been investigated by many researcher [3, 4, 5, 6]. Several experiments have been carried out by varying the structure and density of woven fabric with absorption coefficient below 0.6 [7, 8]. Multiple regression has been used to analyze sound absorption on woven fabric [9]. The combination of woven fabric with other material such as non-woven, felt, foam, knitted fabric, membrane, etc. has been carried out to improve sound absorption [10, 11, 12]. Some prediction models have been developed related to the woven fabric material [13, 14, 15]. Prediction sound woven fabrics have been formulated based on JCA formulation [16].

In further development, it is important to improve woven fabrics by exploiting the perforation in that presence inherently on woven fabric. Because of the presence of micro-perforation on the surface, woven fabric has a basis for a viscos-inertial effect that is important as a micro-perforated panel [17] Some effort have been carried out to exploit perforation to have micro size. The application of facile dip-coating method was carried out to improve micro-perforated on woven fabric [18]. Textile composite material was drilled into micro sized to have a benefit on structure and sound absorption properties [19].

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Maa has developed theory and model to predict sound absorption on micro-perforated panel (MPP) [20, 21, 22]. The most important parameter is the perforate constant *k,* acoustic resistance r and frequency f_o. Maa also suggests to make minute holes 01-0.3 mm for having wide-band absorption up to 3-4 octaves and for low–frequency absorption with a cavity of depth small compared to the wavelength.

In this experiment, woven fabric was developed by variation on yarn and manufacturing technique properties to improve perforation to be smaller in micro size. Yarns were varied based on yarn counts and fiber type (natural, semi-synthetic and synthetic. The purpose of the research is to investigate the relationship between yarn and weft density on absorption coefficient that is very important in developing micro-perforated panel. Maa's model was used to compare between measurement and prediction.

2. MATERIAL AND METHODS

2.1 Materials

There were 8 combination fabrics from different yarns based on natural, semi-synthetic and synthetic fibers. Table 1 shows yarn properties of woven fabric that use as weft yarn (x direction). TR (Rayon 35% - Polyester 65%) yarns with count number Ne_1 20 were used for all warp yarns (y direction).

In the manufacturing process, the density of woven fabric consists of the number of warp and weft yarns in inch. The warp density for all woven fabrics are 98 yarns/inch. The weft density were varied from 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 and 70 yarns/inch. The structure for all woven fabrics were Twill 3/1.

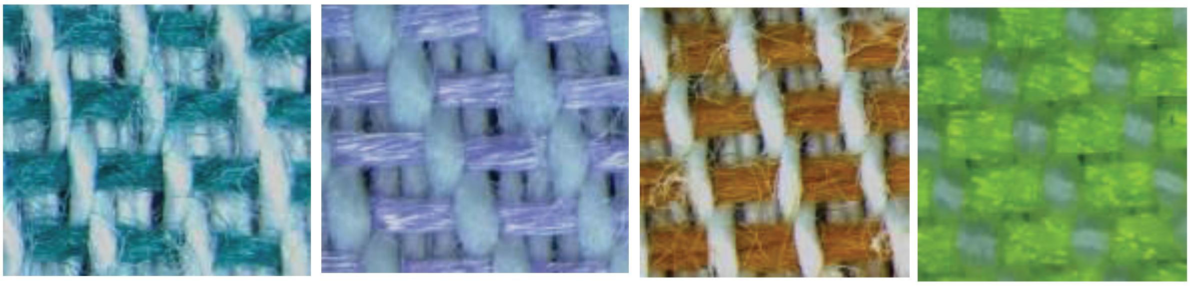
Table 1 - Yarn properties

Yarn	Category Fiber	Yarn count	Diameter (mm)
Cotton	Natural	Ne_1 32/2	0,488
Wool	Natural	Nm 30/2	0.667
Nylon	synthetic	210 D	0.670
Acrylic	synthetic	Nm 32/2	0.587
PE (Polyester spun)	synthetic	Ne_1 10	0.424
PE (Polyester spun)	synthetic	Ne_1 20	0,352
Polyester (filament)	synthetic	75 D	0.429
TR (65% Polyester 35% Rayon)	Semi-synthetic	Ne_1 20	0.357

2.2 Methods

The air permeability was measured using a fabric air permeability instrument (Textest FX 3300 LabAir IV) according to ISO 9237 (Textile Determination of the Permeability of fabrics to air). The thickness was measured using a fabric thickness tester (Teclock) according to ISO 5084 (Textile Determination of thickness textiles and textile products). The geometrical properties are characterized using a digital microscope. Figure 1 shows magnification image sample woven fabric by a digital microscope.

Absorption coefficient was measured was measured by impedance tube (BSWA SW477) using transfer function method according to ISO 10534-1:2001 (Acoustics-Determination of sound absorption coefficient and impedance tubes-Part 1; Method using standing wave ratio). The circular woven fabrics with a diameter of 30 mm and 100 mm were measured to obtain coefficient absorption at low, medium and high frequency. The air gap was 15 mm for all measurement.



(a) Cotton (b) Polyester (c) Wool (d) Nylon

Figure 1-Magnification of image sample woven fabric by digital microscope

3. RESULTS AND DISCUSSIONS

3.1 Effect of yarn on acoustic absorption

Figure 1 shows acoustic absorption of woven fabrics with natural, semi-synthetic and synthetic fiber-based yarn with the same number density of 20 weft yarn/cm (x direction) and 40 warp yarn/cm (y direction). Woven fabric from natural fiber-based yarn has a good sound absorption. From low until mid-frequency, wool fabrics have the highest absorption coefficient with the lowest diameter perforation of 0.05 mm. At the frequency of 3000 Hz wool fabrics have the highest absorption coefficient 0.96 and then gradually decrease until reach the absorption coefficient of 0.29 at the frequency 6300 Hz. Meanwhile, cotton woven fabric has also good performance of the sound on absorption. Cotton woven fabric has the highest absorption coefficient of 0.96 at the frequency of 4250 Hz.

Table 2 – Physical properties of woven fabrics with 20 weft and 40 warp density

Fabric	Weight (g/m^2)	Diameter Perforation (mm)	Air Permeability (cm/s)
Cotton Ne_1 32/2	208	0.17	68.2
Wool Nm 30/2	288	0.05	29.1
Acrylic Nm 32/2	292	0.05	10.2
Nylon 210 D	295	0.08	44.7
Polyester 75 D	184	0.17	100.0
PE Ne_1 10	258	0.15	78.1
PE Ne_1 20	189	0.17	79.4
TR Ne_1 20	187	0.17	87.7

Nylon woven fabric as synthetic yarn has the highest absorption from mid until high frequency than the other woven fabrics. Nylon woven fabric has the highest absorption coefficient of 1.00 at the frequency of 3350 Hz and 3550 Hz. Although the absorption coefficient of nylon fabric after the mid frequency gradually decreases, but it still has the absorption coefficient of 0.73 at the frequency of 6300 Hz. Polyester woven fabric has the lowest sound absorption than the others. Semi-synthetic TR woven fabric, based polyester and viscous fiber, has medium performance. It has the highest absorption coefficient of 0.86 at the frequency of 4500 Hz.

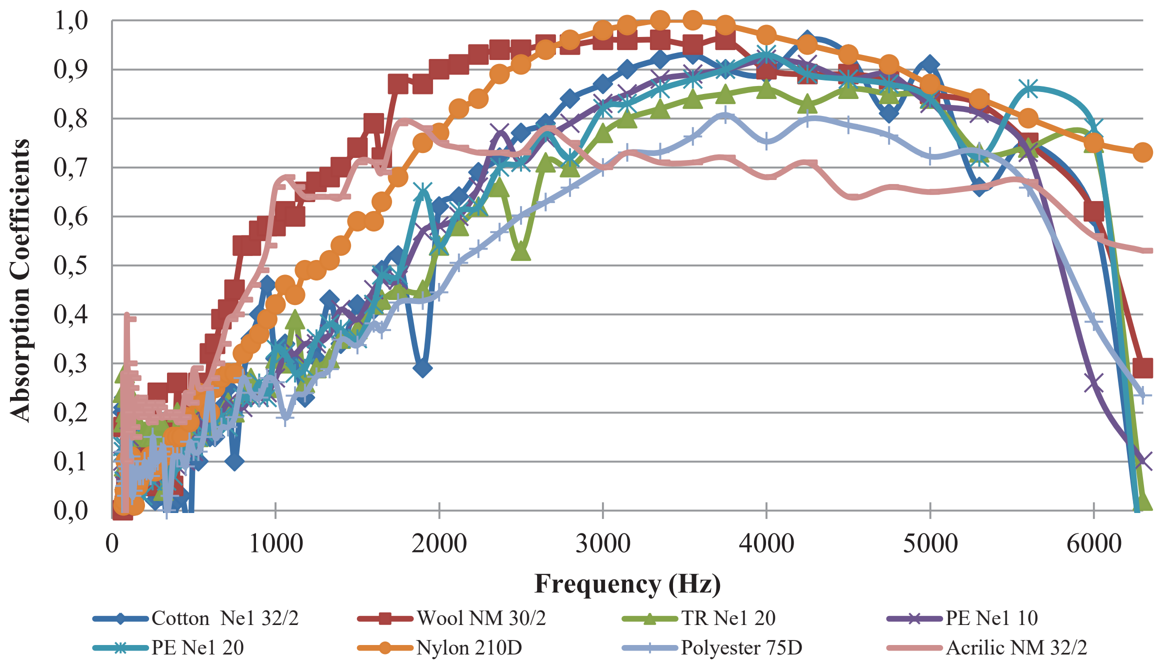


Figure 2- Effects of yarn count and fiber based on sound absorption characteristics

The other property of yarn that is also important in the manufacturing of woven fabric is yarn count. Figure 2 shows the absorption coefficient of woven fabrics from the same polyester yarn (PE) with different yarn count. Yarn count indicates the mass per unit length or the length per unit mass. It expresses the fineness or coarseness of yarn. It can be seen from low until high frequency absorption coefficient between yarns almost the same. At the frequency of 5000 Hz, the absorption coefficient of both yarns are 0.83 and 0.84. The sound absorption of both yarns show the difference after the frequency of 5000 Hz. Woven fabric with yarn count Ne_1 20 has higher absorption coefficient than Ne_1 10. The higher the yarn count the finer the yarn is.

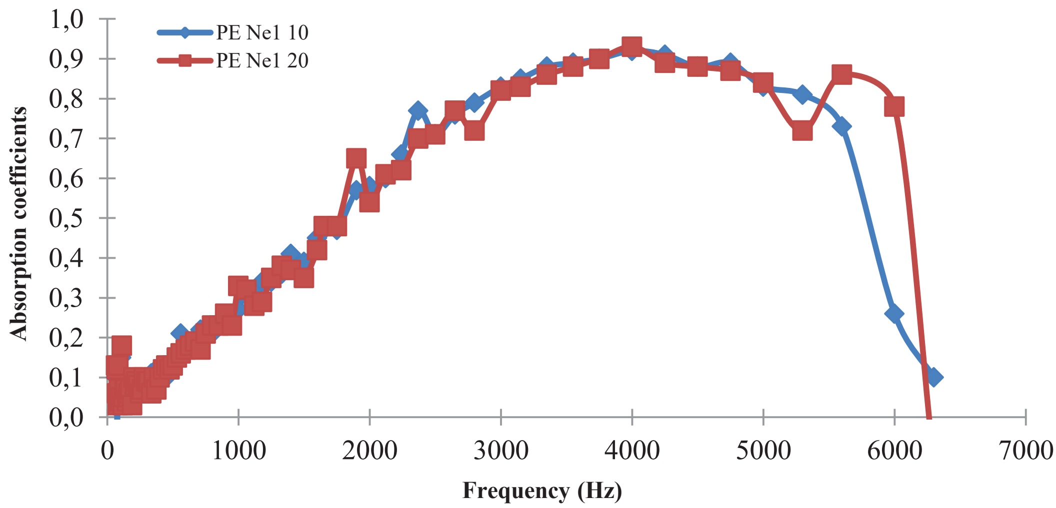


Figure 3-Sound absorption polyester woven fabrics with different yarn counts

It is also interesting to show different yarns with the same yarn counts. Figure 3 shows the absorption coefficient of woven fabrics from the same yarn counts, Ne_1 20, with different fiber. It can be seen that woven fabrics from synthetic yarn of 100% Polyester (PE) has a slightly higher sound absorption than the semi-synthetic yarn of 65% Polyester 35% Rayon (TR) especially at 2000 Hz until high frequency. This effect must be further investigated more detailed to have better understanding the significance and the properties of yarns that contribute to the absorption coefficient.

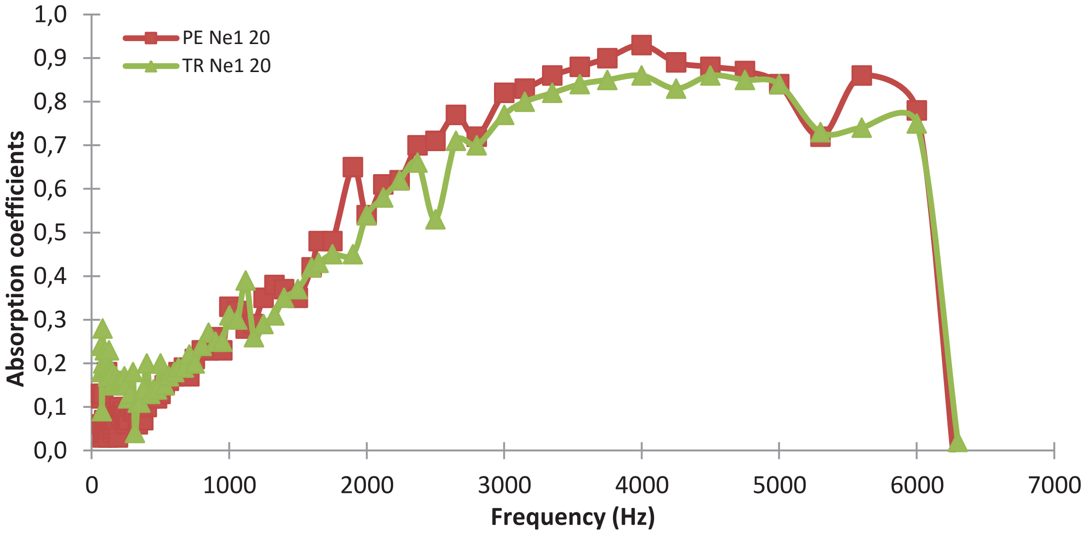


Figure 4-Sound absorption woven fabrics with different fiber

3.2 Effects of weft density on acoustic absorption

The geometry woven fabric can be affected by the yarn density in the structure of woven density. Yarn density is a number of weft and warp yarn in square (cm). In this experiment, warp density is constant of 40 warp yarn per cm but weft density (TP) was varied. Figure 4 show effect weft density on acoustic absorption in TR woven fabric. The form of sound absorption all woven fabric are curve. It can be seen that the increasing of the weft density results in increasing sound absorption. In the mid-to-high frequency, weft density TP 65 has the highest curve sound absorption and the lowest for weft density TP 20. The highest absorption coefficient 0.98 was obtained at frequency 3750 Hz by weft density TP 65. It is also interesting althought the weft density TP 70 is the highest weft density but in mid-to-high frequency performance sound absorption under weft density TP 65.

Table 3 – Material properties of woven fabric TR Woven Fabric

Fabric	Weft density (yarn/cm)	Diameter Perforation (mm)	Weight (g/m^2)	Air Permeability ($m^3/m^2/s$)
TP 20	8	0.342	144	3.3750
TP 25	10	0.292	153	2.7970
TP 30	12	0.240	160	2.3200
TP 35	14	0.218	166	1.8780
TP 40	16	0.200	172	1.4770
TP 45	18	0.171	180	1.1090
TP 50	20	0.167	187	0.8774
TP 55	22	0.151	195	0.634
TP 60	24	0.135	203	0.4348
TP 65	26	0.121	210	0.3572
TP 70	28	0.103	219	0.2221

Variation in weft density will change the perforation. Perforation in woven fabric is formed by the intersection between weft and warp yarn. When weft density increases, it makes perforations smaller. The smaller perforations create more a viscos-inertial effect when interacting with sound fields that are useful in sound absorption mechanism.

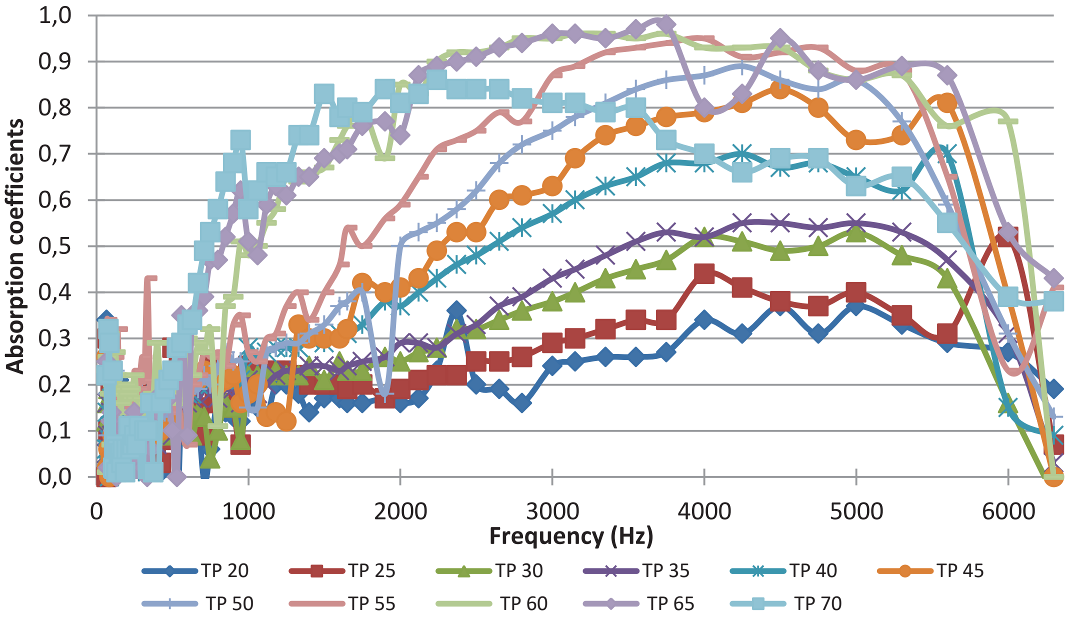


Figure 5-Effect weft density on sound absorption woven fabric

3.3 Prediction by Maa's model

Maa's model is used to analyze the sound absorption of woven fabrics. Table 3 shows the diameter and perforation ratio as input parameter in Maa's model. Figure 5 shows the measurement and prediction by Maa's model for TR 20 Woven Fabric with air cavity 15 mm. It can be seen from the figure that for TP 70 Maa's model can well predict behavior of absorption coefficients, but for TP 65 there are a slightly gaps between measurement and model. Further development must be carried out to solve the gap. Overall this result is important as a basis to develop of woven fabrics based on micro perforated panel absorber system.

Table 3 – Physical properties of woven fabric TR Woven Fabric

Fabric	Weft density (yarn/cm)	Diameter Perforation (mm)	Perforation Ratio (%)
TP 65	26	0.121	4.12
TP 70	28	0.103	3.33

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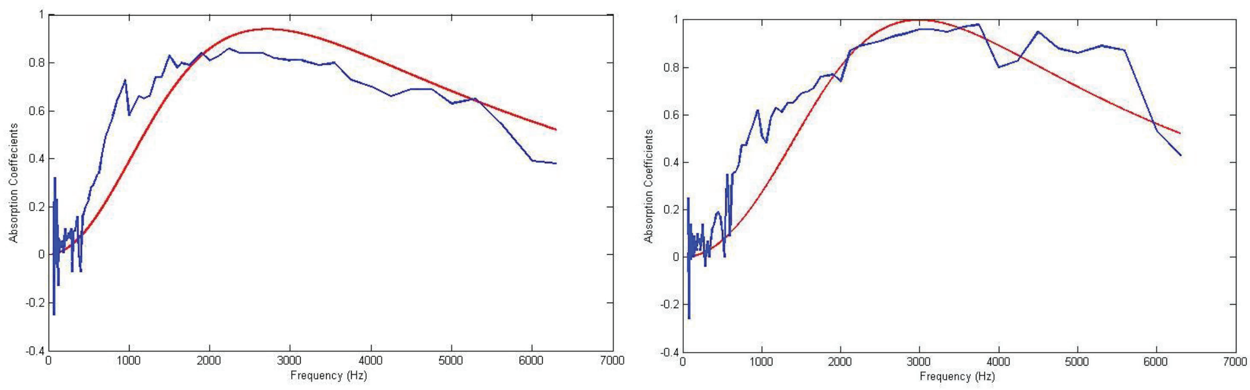

(a) Weft density TP 70 (b) Weft density TP 65

Figure 6- Validation results using Maa's model Prediction (--) and Measurement (--)

4. CONCLUSIONS

In this study, it can be concluded that yarn and weft density affect to the sound absorption coefficients of woven fabric. Overall, woven fabrics have a potential as absorber based micro perforated panel system. It is important to have a range for amplitude and bandwidth in which the yarn and material come into play. The development of MPP based on woven fabrics is rather different from that of the conventional from solid material. Moreover, Maa's model is not always successful to predict its behavior. Hence, it is suggested to improve the model.

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