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Modelling of Woven Fabric as Micro Perforated Panel as Sound Absorber

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Abstract : Woven fabrics have a micro perforation created by warp and weft yarn in x and y direction. A micro perforation in the stucture of woven fabric creates a viscos-inertial thermal effect as a basis of sound absorber. In this study, the focus is to determine diameter, space and ratio of perforation that is used in modelling of the twill woven fabric as Microperforated Panel (MPP) absorber. Maa model is used as basis for modelling. For further investigation, the geometrical properties are characterized using a digital microscope. The sound absorption coefficients are measured by an impedance tube using transfer function method. The prediction model is validated by experiment. It can be concluded that the behavior of sound absorber for certain woven fabric can be determined by the model.

Keywords: microperforated panel; modelling; woven fabric

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1. Introduction

One of the problems for human and environment is noise pollution (1-4). Indonesian government actually has a regulation according to control noise level for human and environment (5).

Woven fabric can be used as absorber material as part of noise control. Although research in woven fabrics as sound absorber have been conducted by several researcher but there are some aspects that must be carried out. The relationship between a certain densities, high pile, and structure has been carried out (6-11). Multi regression has been used to analyze the relationship between some variables and sound absorption (12). In a woven fabric, intersection between warp yarns in Y direction and weft yarns as X direction create the micro pore that useful for visko-inertial-thermal effect as a basis absorption mechanism just like resonator Helmholtz (13). Prasetiyo, etc (14) has developed a model prediction a sound absorption behavior for a plain woven fabric. Tang (15) has carried out experiment to make more smaller poros in structure of plain woven fabric with chemistry processing using facile dip-coating method to increase sound absorption coefficients.

Maa has developed absorption mechanism for absorber material as Micro-Perforated Panel (MPP). Maa has been developed a theoretical model to predict the behavior of MPP (16-18). A perforate constant k, acoustic resistance r and frequency fo are the important parameters in Maa model. Those parameters are related with pore geometry in material.

Micro porous in a woven fabrics creating a sound absorption mechanism have a specific different with another material just like acrylics, woods or metals because it was created by intersection between yarn and the way yarns intersections in a certain structures. This paper present a modelling using Maa approach to predict woven fabric for twill structure. The model is then validated by measurement.

2. Materials and Method

The yarns that used in woven fabric are TR (65% Polyester and 35% rayon) with count number Ne1 20. The structure of woven fabric is twill 3/1 with warp density 98 yarns/inch and weft density 60, 55, 50 and 45 yarns/inch.

Thickness fabrics are measured by thickness tester (Teclock) according to ISO 5084 (Textile Determination of thickness textiles and textile products). A geometry fabrics are measured using digital microscope. Absorption coefficients are measured using impedance tube (BSWA SW477) with 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). Woven fabrics with 30 mm and 100 mm diameter are used to get absorption coefficient in low, middle and high frequency. Air gap for all measurement is 15 mm. Matlab is used as Mathematic software to calculate the model.

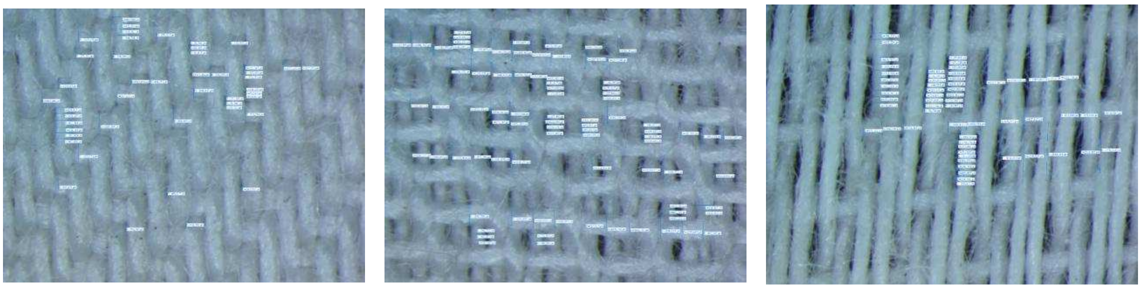

Figure 1. The geometry of woven fabric with twill structure with different weft density

3. Formulation of Micro Perforated Panel and Woven Fabric

Maa (18) stated that MPP can be seen as pores in the form of a narrow and short tube that the distance between the pores is wider than the pore diameter, but it smaller than the sound wavelength. Propagation of sound waves in the tube has been done by Lord Rayleigh and the behavior in the narrow tube has been simplified by Crandall. The acoustic impedance of the MPP is then formulated:

$$z = \frac{Z1}{(\sigma\rho oc)} = r + jxm = r + j\omega m \quad (1)$$

With:

$$r = \frac{32\,\eta\mathbf{t}}{\sigma\rho ocd^2}k_r, \quad k_r = \left[1 + \frac{k^2}{32}\right]^{1/2} + \frac{\sqrt{2}}{32}k\frac{d}{t} \quad (2)$$

$$\omega\mathrm{m} = \frac{\boldsymbol{\omega}\mathbf{t}}{\sigma c}k_m, \quad k_m = \left[1 + \frac{k^2}{2}\right]^{-1/2} + 0.85\frac{d}{t} \quad (3)$$

$$k = d\sqrt{\omega}\rho o/4\eta \quad (4)$$

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Where ⊚ is the fluid viscosity coefficient, ρo is the air density, k is the perforation constant, c is the speed of sound, ω is the angular velocity, d is the pore diameter, t is the pore thickness, and σ is the perforation ratio with a round cross section of σ = (π / 4) (d / b) 2 where b is the distance between pores.

MPP material is placed before the solid surface with air cavity D so that it behaves as MPP absorber. The magnitude of relative acoustic resistance r and mass reactance xm = ωm as shown in equation (1), while the relative acoustic reactance in air cavity is -cotωD / c. For normal incidence, the absorption coefficient can be formulated as:

$$\alpha = \frac{4r}{(1+r)^2+(\omega m-\cot(\omega D/c))^2} \qquad (5)$$

With maximum

$$\alpha_0 = \frac{4r}{(1+r)^2} \qquad (6)$$

It can be seen the most important parameter in the Maa model for predicting sound absorption behavior is pores. The pore geometry parameters included in the equation are pore diameter, distance between pores, pore thickness and ratio perforation. Furthermore, the physical property of woven fabric that has been made is characterized as shown in the table 1. Figure 2 shows the prediction model and the measurement.

Table 1. Physical properties of woven fabric Woven Fabric

Yarn	Weft Density (yarn/inch)	Diameter Perforation (mm)	Perforation Ratio (%)
60	24	0.135	4.69
55	22	0.151	5.35
50	20	0.167	5.93
45	18	0.171	6.02

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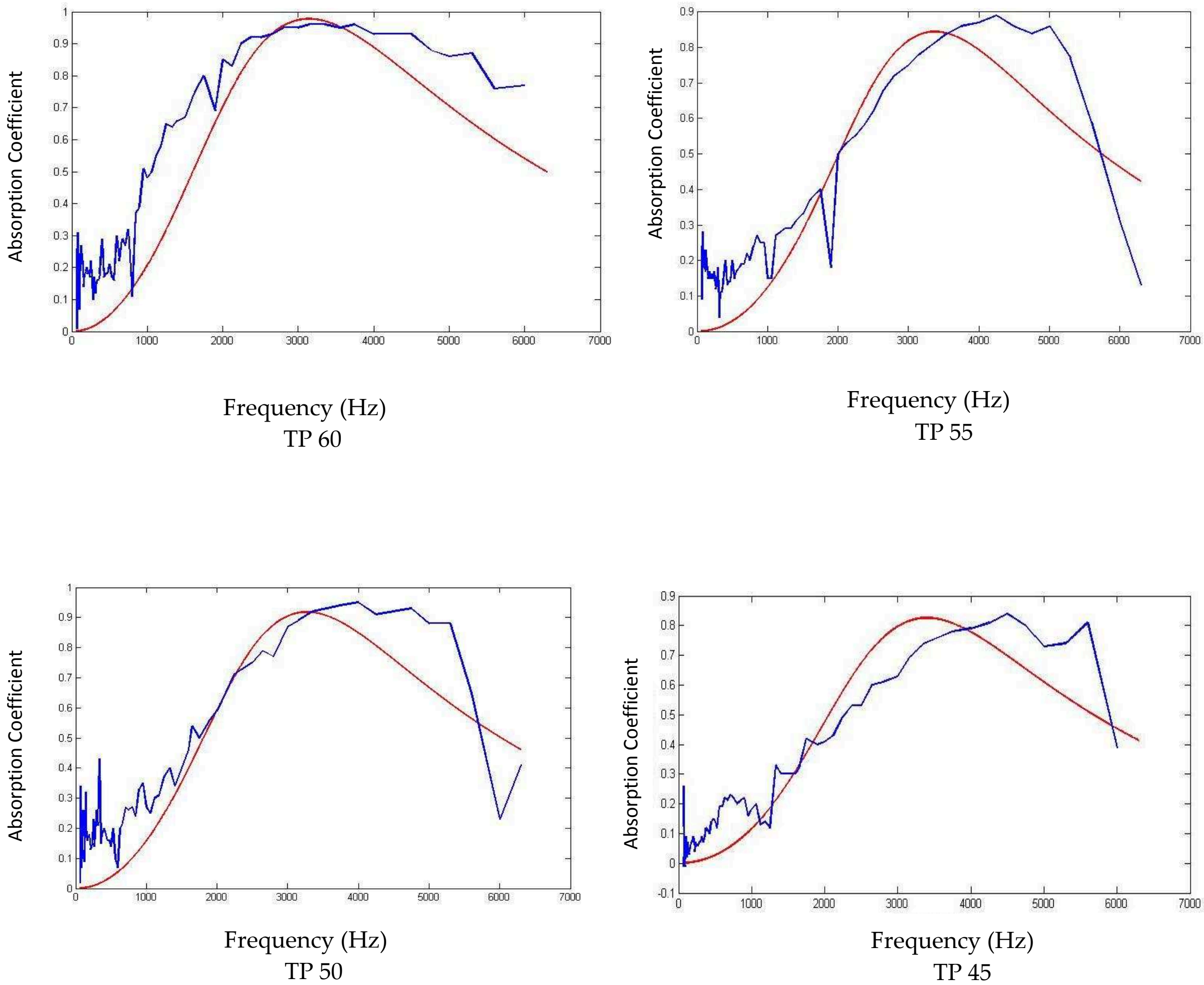

Figure 2. Sound absorption coefficients of twill woven fabric
(Red line is predicted model and blue line is measurement)

4. Discussion and Summary

Based on the development using Maa model, it can be seen that woven fabric can be approached as MPP material but it also very important to improve the model. The presence of pores in woven fabric plays an important role as the basis for sound absorption mechanisms.

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