The Effect of Thickness and Density to Acoustic Parameters for Fabric Reinforced Composite Structures Produced From Rachis Material

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Abstract

Only some of the chicken feathers obtained as a by-products in white meat production are used for protein meal production, construction industry and composite panel production for different purposes. These wastes are also harmful to the environment. The chicken feather fibers obtained by cutting and separating from rachis part are universal and have multipurpose usage. The rachis material, which predominantly forms the half of the chicken feathers, is important with its light weight, high strength and other interesting properties. In these study, porous sandwich composite structures were developed using different matrices from rachis and their acoustic properties were measured according to the impedance tube method. Sound absorption coefficients of structures made from rachis show high values at high frequencies and show low values at medium and low frequencies. When the density of material increases, there is a noticeable improvement in the sound transmission loss value of material. Acoustic parameters improved with increase of layers in material. Because of the outer layers are composite, better results at low frequencies were obtained in terms of sound transmission loss. Acoustic parameters of sandwiched structures produced with conventional sound absorbing materials such as glass wool, rock wool and felt have caused significant increases in all frequencies due to rachis composites. In terms of acoustic comfort, it is thought that the composites produced from rachis are futuristic material.

Keywords: Rachis, chicken feather, composite material, sandwiched structures, sound insulation

1. Introduction

The noise which is defined as uncomfortable noise has become an increasingly important issue because of evolving technology, mechanization, increasing of public habitats, heavy traffic and motor vehicles become indispensable elements of our social life. It is an important field of study that scientists are interested in to combat noise that affects human health negatively from psychological, physiological and psychosocial aspects. When look at the literature studies, there are many traditional materials that can be used in sound insulation. However, scientists are looking for new materials that will perform better and cost less. One of those materials can be chicken feather.

In every year, millions of tons of feathers appear a fall-out in our country and in the world. More than half of these feathers cannot be evaluated in any way, they are burnted or buried. In both cases serious damage is given to the environment. By producing a product with added value, this waste material will result in an economic gain and the health of the environment. In our studies in Erciyes University, we have produced composite materials which have a very high acoustic parameters by using special machines and processes. In this study, we analyzed how the thickness and density of composite materials produced from chicken feather rachis material affected the sound absorption and sound transmission loss value.

2. Material and Method

2.1. Material

Rachis material

The chicken feathers which were obtain from Gaziantep ‘Tad Piliç’ company were washed, dried and disinfected for cleaning in the Erciyes University, Textile Engineering Department Laboratories. The feathers were washed with sodium hypochlorite at 40ºC in order to remove from the dirt and grease at the first stage, than dried at 40ºC in a specially designed feather dryer and disinfected for 12 minutes at 70ºC [Paşayev et al.,2017; Paşayev, 2017; Kocatepe and Paşayev, 2018]. After the cleaning process, the chicken feathers were processed in a special machine to obtain fiber and rachis material [Paşayev and Erol., 2018].In Figure 1, obtained chicken feather fiber and rachis material can be seen.

Bonding polymer

In the production of composites, Ethylenevinylacetate (EVA) and Low Density Polyethylene (LDPE) as a powder form, Polyvinyl Acetate (PVA) and Polyacryl (PAKR) binders which dispers in water were used. This polymers were used because of we wanted to keep the process temperature as low as possible. In Table 1 and Table 2, some properties of the selected bonding materials are given.

Table 1. Some properties of the bonding materials

Properties	**Low Density Polyethylene (LDPE)**	**Ethylenevinylacetate (EVA)**
Density in 23ºC	0,92 g/cm^3	0,93 g/cm^3
Melting temperature	120ºC	80ºC
Process temperature	130ºC	90ºC

Table 2. Some properties of the bonding materials

Properties	**Polyvinyl acetate (PVA)**	**Polyacrylic (PAKR)**
Appearance	White dispersion	White dispersion
Solubility	In cold or warm water	In cold or warm water
Density in 20ºC	1,25g/cm^3	1,78g/cm^3
pH	6-7	4-5
Thermal drying	90-100	90-100

Figure 1. Fiber and rachis materials obtained from chicken feather fibers

Composite Production

Hot pressing method has been applied in the production of composites and used as press equipment of Gülnar Plastic Machines. Metal molds which has a internal dimensions of

16cmx16cmx0,5cm were used. Using these molds, samples with different bulk densities were produced by keeping the amount of raw material thickness and pressing pressure constant. The rachis material, amount of binding material and type of binding material were accepted as independent variables in the production and sample sizes were kept constant.

Experimental plans showing the mixing ratio of rachis material and binding material were prepared in Table 3 and Table 4 and samples were produced according to these plans. In Figure 2, the mold used in sample production, the composite samples can be seen.

In the composited produced by using EVA and LDPE, the amount of rachis was 33gr and 50gr, amount of binding material were twenty percent of rachis material and forty five percent of rachis materials. (Table 3).

The mixture of the rachis particles and the dry binding material was molded onto the teflon film. A teflon film was laid on top of the prepared mixture and put in to press machine. Press machine temperature was adjusted according to the process temperatures written in Table 1 and Table 2. The pressing time was determined according to the internal temperature of the structure and fixed at 120ºC as 90ºC for dry binding material.

Table 3. Plans of composite production which incledes EVA, LDPE and rachis material

Experimental number	Raw material amount, gr	Binding material, gr	Binding material type
1	33	8,25	EVA
2	50	12,5	EVA
3	33	14,85	EVA
4	50	22,5	EVA
5	33	8,25	LDPE
6	50	12,5	LDPE
7	33	14,85	LDPE
8	50	22,5	LDPE

PVA and Polyacryl (PAKR) binding materials are used in water as an emulsion. According to the results of the preliminary studies, appropriate binding material rations have determined.

For 40gr and 50gr weights of rachis material, the solution was prepared so as to be treated with binder at 30% and 50%. After the solution was mixed homogeneously together with rachis material, the mixture was molded, then pressed at 120ºC for 220sn. After cooling, the mixture was removed from the mold. In a total, 32 samples were produced as given in the production plans (Table 3 and Table 4).

Table 4. Plans of composite production which incledes PVA and Polyacryl (PAKR)

Experimental number	Raw material amount, gr	Binding material, gr	Binding material type
1	40	12	PVA
2	50	15	PVA
3	40	20	PVA
4	50	25	PVA
5	40	12	PAKR
6	50	15	PAKR
7	40	20	PAKR
8	50	25	PAKR

Figure 2. Composite production

In order to see the effect of thickness and density on the acoustic parameters in layered composites, the measurements of layers were made by combining with six different fabrics and graphs were drawn for the obtained results. For the sample production, fabrics encoded as K1, K2, K3, K4, K5 and K6 and composite plates coded as C1, C2 were used and brief information about their content are given in Table 5.

Table 5. Content of fabric codes and composite

Kod	**Malzeme içeriği**
C1	50gr rachis-12,5gr EVA
C2	50gr rachis-12,5gr EVA
K1	Chenille upholstery (17 density)
K2	Chenille upholstery (19 density)
K3	Woolen cloth
K4	Raw linen fabric
K5	Nonwoven (Cleaning fabric)
K6	Tricot fabric made from acrylic yarn

Measurement of Acoustic Parameters

The sound insulation parameters of the composite plates produced were measured with the BSWA TECH branded impedance tube (Figure 3). For this purpose, two specimens of 10cm and 3cm in diameter were cut from each produced sample.

Measurements were made according to standart of the ISO 10534-1: 1996 Acoustics-Determination of sound absorption coefficient and impedance in impedance tubes-Part1: Method using standing wave ratio ve ISO 10534-2: 1998 Acoustics-Determination of sound absorption coefficient and impedance in impedance tubes-Part2: Transfer function method.

Figure 3. Impedance tube

3. Findings and Discussion

The acoustic properties of the produced composite samples were measured and compared, the structures produced by using EVA exhibit better performance.

The change graphs of sound absorption coefficient and the sound transmission loss value of the single layer composite samples produced in Figure 4 are given. Composite samples were produced according to the test plans in Table 3 and Table 4 by using binding polymers at different densities and weights. In the curves of Figure 5, it can be seen that how the increase of sample thickness and density affects the acoustic parameters.

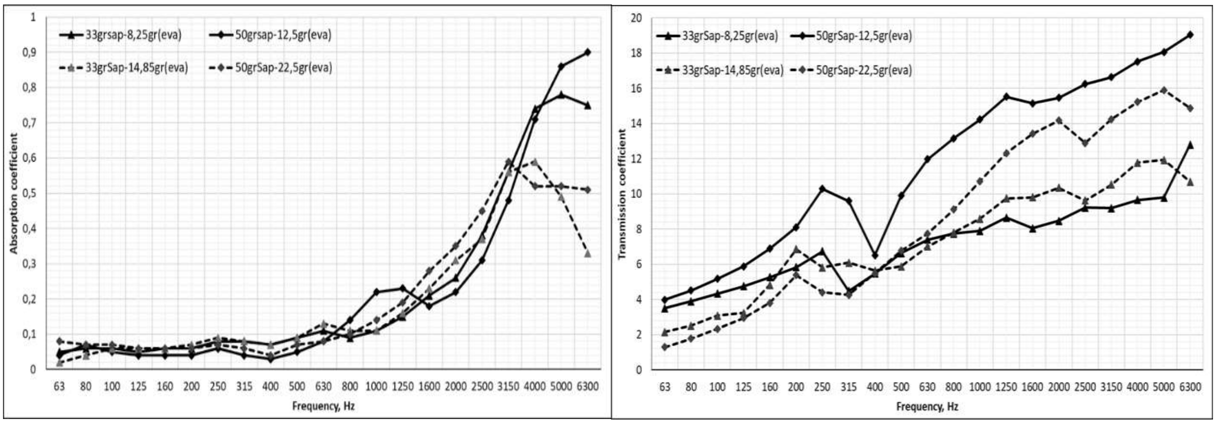

Figure 4. The effects of density and binding material to the sound absorption and sound transmission value in single-layer composite structure

When the thickness and amount of binding material are kept constant, the sound transmission loss coefficient has increased considerably due to the increase in density. This caused lower sound absorption at mid frequencies. On the other hand, as the amount of binding material used in the composite increases, the sound absorption coefficient decreases in all cases because of the pore closes. Similar results can be said in terms of sound transmission loss (Figure 4).

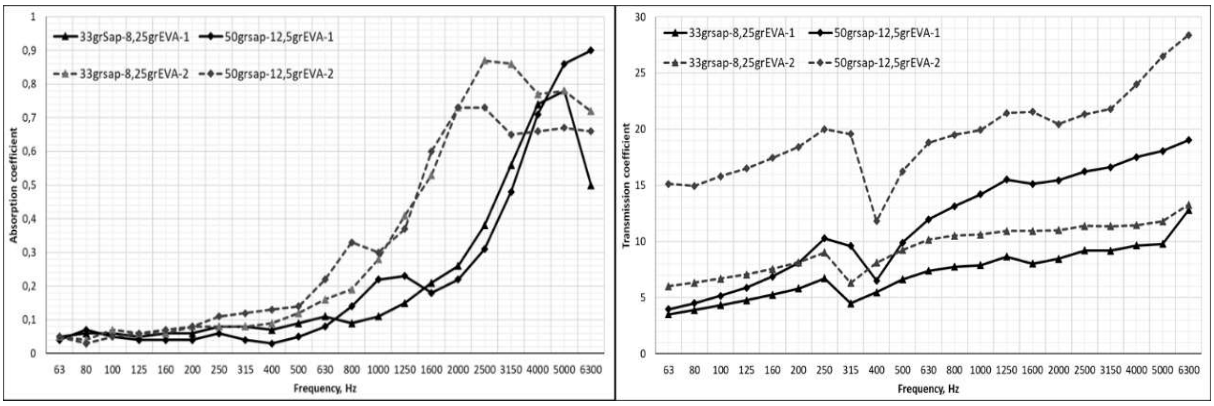

Figure 5. The effects of thickness and density to the sound absorption and sound transmission value in composite structures

As can be seen from graphs, when the thickness of sample are double layer, sound absorption values are significantly increasing in low and medium frequencies. When the thickness and density increase in all scale, the sound transmission loss value increase (Figure 5).

In Figure 6, graphs which shows how the results of the impedance tube measurements of samples coded as C1 K1, K2, K3, K4, K5, K6, are changed depending on the frequency are presented. Figure 7 shows how the sound absorption coefficient and the sound transmission loss coefficient values of the samples which are produced by adding a third composite layer to this produced two-layer structure according to the frequency.

As a results of the producing the two-layer samples which were produced with composite contain chicken feather rachis and fabrics have a different specialties, it is seen that curves of sound transmission loss of two-layered samples shows great similarity. But for the sound absorption coefficient, this situations change according to the structure and specialties of fabrics. At medium and high frequencies, it is seen that the when the knitted fabric of 1.5mm thickness produced from K6 coded acrylic yarn is used, the higher sound absorption has obtained. At the lower frequency, when the K5 coded fabric is used, the higher sound absorption has obtained in sample. In another structure used with another fabrics, close results has obtained in nearly every frequency.

When the present structure is supported by a third C2 composite layer, it is clearly visible that the curves are going the left and upward for every frequency in all samples in terms of sound absorption. It has been seen that in the structures with more voluminous and thick fabrics, much better sound absorption is achieved, especially at low and medium frequencies. Thickness, porosity and density are very important for sound absorption. When look at the curves related to the sound transmission loss, it has observed that significant increases in all samples were observed due to the increase in thickness.

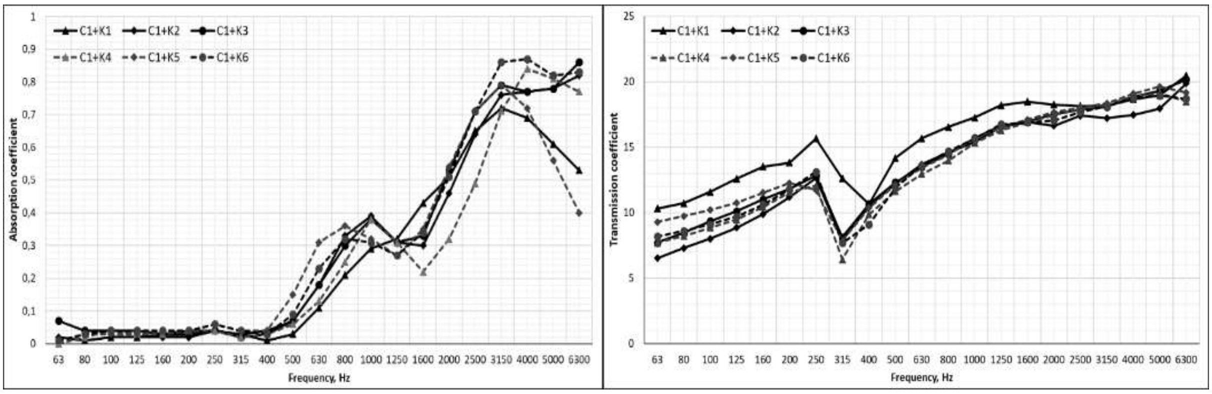

Figure 6. Effect of composites produced by combination with fabrics which have a different properties on sound absorption coefficient and sound transmission loss values

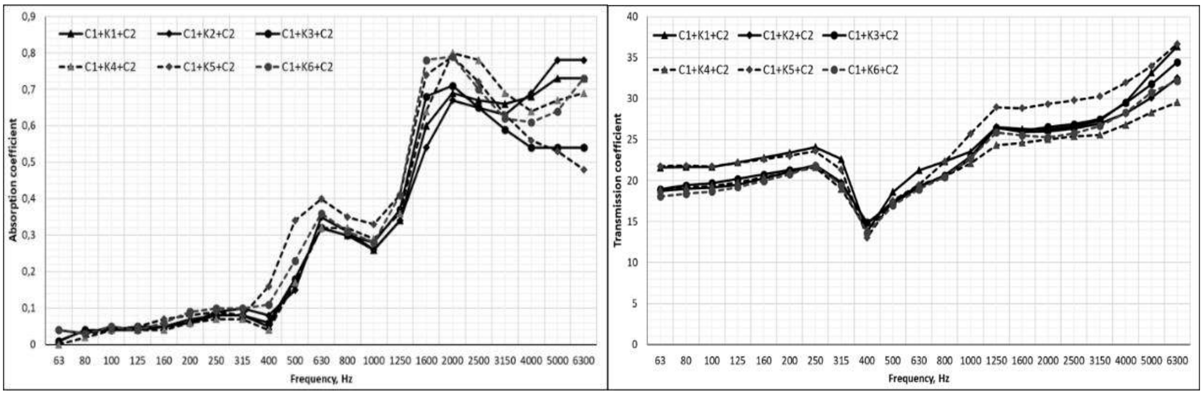

Figure 7. The effects of thickness increase on the acoustic parameters of composite structures obtained by the addition of composites in combination with the fabrics of different properties

4. Conclusions and Recommendations

It has been seen that there are significant changes in the acoustic parameters due to the variation of thickness and density of the composite plates produced according to the thermal bonding method using different binders from chicken feather rachis material. When the thickness and the amount of binding material are kept constant, the sound transmission loss coefficient has increased. This caused lower sound absorption at mid frequencies. On the other hand, as the amount of binding material used in the composite increases, the sound absorption coefficient decreases in all cases because of the pore are closed. It has been found that in a single layer structure, a low density structure at low frequencies and a high density structure at medium-high frequencies have better noise transmission loss coefficients.

When the second layer is added to a single layer composite sample with a thickness of 5mm, it is found that there is a significantly increase for sound absorption values at all low and mid frequencies. The sound absorption coefficient of 0,38 at the 2500Hz frequency rises to a high value of 0,87 when it is two layer. In the sound transmission loss coefficient, an increase was observed due to the increase in thickness and density throughout the whole scale.

It has been found that there is not important difference in sound transmission loss of the samples which produced as a two-layer at the end of the combine the chicken feather rachis and six different fabrics. But it is seen that that structure has higher performance at all frequencies from one-layer structure and the material construction is insignificant for sound transmission loss. It can be said that use of structures that are more voluminous and porous in two-layer structure gives better results at low and high frequencies in terms of sound absorption coefficient.

As a results of the combine of the present construction with a third composite layer, the sound absorption coefficient curves dramatically shift to left and right at all frequencies due to the thickness and density rise of fabrics in structures. It can be said that the properties such as thickness, weight, density and porosity of layers in layered composite structures are important properties for acoustic parameters.

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