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Development of Stiffened Sandwich Vibrating for Plane Speakers

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Abstract The main purpose of this paper is developed the membrane, produced exciter, selected surround, optimal design method to manufacture gamut planar loudspeakers. Used nano-carbon tubes and foam board to combine the sandwich membranes which are applied the large planar loudspeakers. The optimal sandwich membranes which are including the stiffed pattern, minimum weight and stiffness are affected high frequency sound quality and sound pressure curve. Because of the sandwich membranes such as high stiffness and strong, and has received much attention as a new material for industrial applications. This creation of flat-panel speakers has the properties of light weight, thin exciter, and broad response of frequency, and also has the live sound quality and clear. The optimal programs are used finite element analysis and Fortran software to search optimal design parameters which are optimal sound quality and smooth curve of sound pressure at the 20Hz ~ 20KHz. Therefore, the optimal manufacturing parameters are manufactured sandwich planar loudspeakers which are measured experimental sound pressure curves to compare theory values.

Keywords Sandwich Membrane, Manufacturing, Nano-Carbon Tubes, Sound Pressure Curve

1. Introduction

This article mainly introduces that sandwich planar loudspeakers are invented with the sound pressure emulation analysis, optimal design, assembly and measurement of entities. The simulation analysis and design optimization of the sound pressure curves of the sandwich planar loudspeakers are discussed firstly in this article. Utilize the optimization to assemble the components and entities of the planar loudspeakers and measure of the sound pressure curves. At last, the sound pressure curves of experimental measurement and simulation analysis should be compared and confirmed to ensure the consistency the simulation data and experimental data.

The literature of the calculation and optimization method of the sound pressure curves, Morse drove the sound pressure equations through audio source in air delivery. Takeo cited the sound pressure equations of the finite elements. Jia-hong Wu (2005) applied finite-element method to the Rayliegh's sound pressure equation and to sound pressure analysis of the vibrating plates of the planar loudspeakers. Particle swarm optimization (PSO) was brought up by Eberhart and Kennedy (1995). Pisano (1997) applied optimal method to solved the piezoelectric engineering, Chang(1999) and Smits (1194) developed new material for electro-elastic haracteristics, Zhang (2004), Xu(2001) and Kulkarni(2003) used finite element modeling to analyzed stresses. In the application of algorithm, Mingsian and Bowen's (2004) manipulation of genetic algorithms in the development of the effectiveness of full frequency range of planar loudspeakers not only earned optimal manufacturing parameters but also had a better effectiveness on the planar loudspeakers.

2. Research Procedure

The main entity manufacturing in the first part is the spring system; second part is the vibration plates and the final part is the exciter production. The illustrations of flat-panel speakers processing are as follows:

2.1. The production of the spring system

The main function of the spring system is to support the vibration of the vibration plates and stick the vibration plates to a fixed position; the irregular swings won't occur when vibration motion happens; besides, the spring system has to be stable under the vibration of the maximum power. In this way, the fo value of the first resonance could be reduced.

The illustrations of the spring system processing are as follows.

Step 1: Cut three kinds of the springs into the size of the speaker you need.
Step 2: Put the springs into model, place them in the oven and bake them at 100 degree Celcius for 40 minutes.
Step 3: After step 2, place the model in the shade, cool the mold naturally.
Step 4: After cooling, take the springs out and trim them. Cutting is done.
(Figure 1).

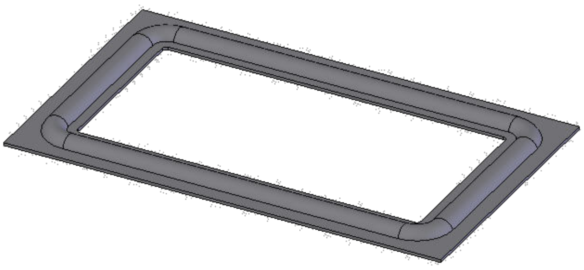


Figure 1. Illustrations of the forming of the springs

2.2. The production of the Vibration Plates of the Composite Sandwich Material

Two kinds of processing of the vibration plates forming can be seen in this article. One is that the foam board is used to be the substrate; the foam board testing is cut into the dimension 265 mm×18 mm×1.8 mm and then the prepreg carbon fiber is cut into the dimension 265 mm×18 mm×1.8 mm; the top and bottom side of the prepreg carbon fiber is pressed by steel plates and put it into the oven. After baking, apply the AB silicone to the foam board evenly; attach the prepreg carbon fiber to the foam board and the production is completed after pressed for two hours by weight. (Figure 2)

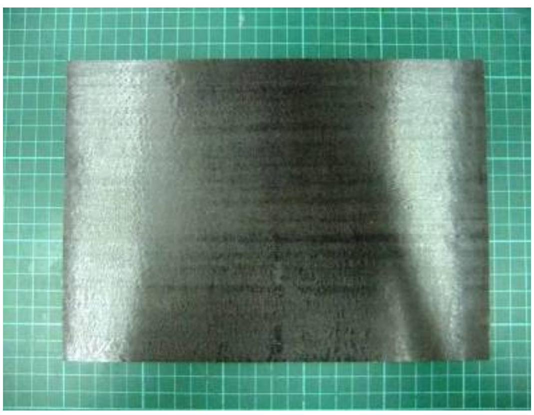


Figure 2. Completion of vibration plates of carbon fiber

Step 1: The carbon nanotube is mixed into epoxy resin, and after stirring by an agitator for about 20 minutes to blend them uniformly, and then add hardener of appropriate proportion to stir uniformly.

Step 2: Bind a mesh screen, place the balsa wood, and cover the mesh screen over the balsa wood.

Step 3: Coat the prepared carbon nanotube onto the mesh screen, use a scraper to coat the carbon nanotube uniformly to and fro.

Second production method is mainly for coating Balsa, using nano carbon tubes and epoxy resin as hardening material. The steps of coating nano carbon tubes are as follows:

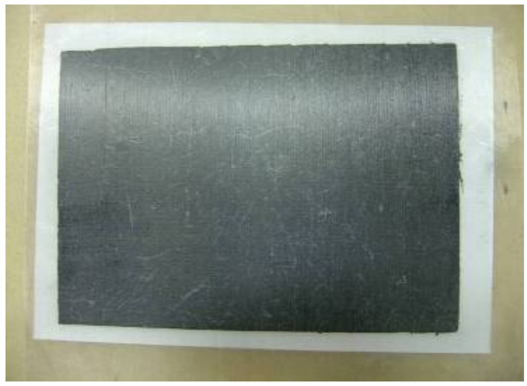


Figure 3. Completion of vibration plates of nano carbon tubes

2.3. The Production of the Exciter

A exciter is mainly made up of voice coil and exciter plates. The material of a exciter has to be high-temperature-proof and unfragile. The material of the exciter plates is woven carbon fiber prepreg. Because of the preferable mechanical properties of high stiffness and lightweight, the exciter is light in weigh and strong but easily damaged.

The illustrations of the production and the position of a exciter are as follows:

Step 1: Place a layer of woven prepreg on the flat and press it forcefully. Then put it in the oven, bake it at 120 Celsius degree for 60 minutes.
Step 2: After the woven prepreg is cooled, the exciter is complete. After pressed woven prepreg is taken out and trimmed.
Step 3: Use AB silicon to adhere coil to the exciter.
Step 4: Scrape the exterior paint of the coil, solder the wire and apply AB silicon to fix the wire to the exciter. (Figure 4).

Figure 4 Completion of the exciter

2.2. Planar-loudspeaker entity assembled

First, twin adhesive is adhered to the four-side interior of a spring, and apply the resin to the spring; vibration plates are attached to the inside of the spring; then magnets are plugged into the frame. Chisel two small holes close to the magnet frame (thread using) and attach the springs and vibration plates to the frame. Apply the silicon to the junction of the frame and the spring. After the silicon dried, bond the exciter and vibration plates with AB silicon. For sticking the exciter to the center precisely, measure the central point before sticking it. Position the magnet frame exactly in order that the coil won't scratch the magnet and keep equal distance between two ends. After positioning is done, apply silicon to the junction of the magnet frame and exterior frame. The planar loudspeakers are set up after all junctions are checked and one-day solidification. Figure 5 shows the assembly.

2.3. Measurement of a planar loudspeaker

The surroundings must be in anechoic chamber, measurement must be with spectrum analyzer of sound pressure of CLIO, and measured distance is 50cm when the sound-pressure curves of the sandwich material are measured.

Step 1: Start the CLIO, and connect the microphone and the two voltage terminals (Red and black).

Step 2: Set the voltage, bandwidth and number of points (Figure 6).

Step 3: Save picture files and data files.

Step 4: Align the microphone with the center of the membrane. The distance of measurement is 50cm (Figure 6).

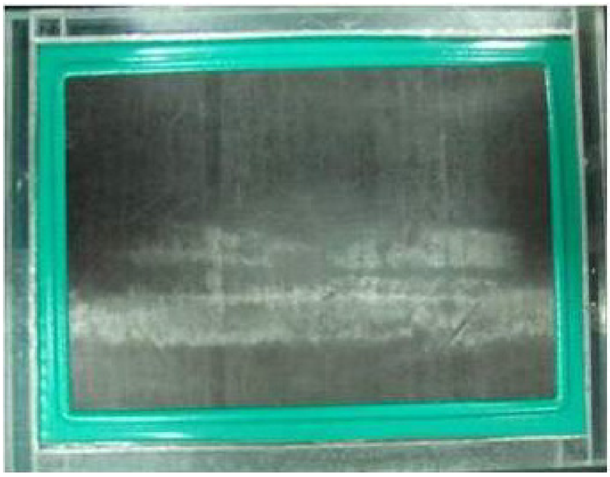


Figure 5. Completion of a planar – loudspeaker entity

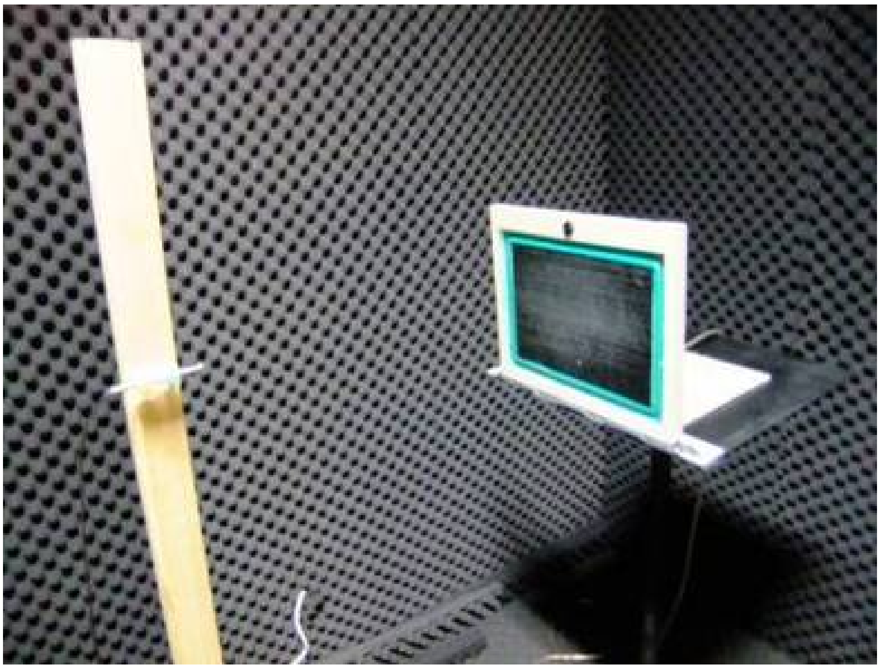


Figure 6. A illustration of the measurement of a planar loudspeaker

3. Result and Discussion

3.1. Convergence analysis of finite element model

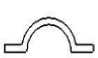
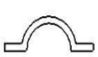
The membrane of this loudspeaker consists of two materials and two stiffed materials. The base material is very light but stiffness is insufficient. The stiffed material has a strong stiffness and a light mass. The sound pressure simulation of the planar loudspeakers is analyzed by using ANSYS to build a finite element model. The boundary conditions and relevant parameters are set to find out a more appropriate simulation method so as to verify the correctness of the experiment and the analyzed data.

The stiffed material is the carbon fibrous composite. Parameters of carbon nanotube are listed in table 1. Used nano-carbon tubes (or prepreg carbon fiber) and foam board to combine the sandwich membranes which are applied the large planar loudspeakers. The material of spring system can be effect the first resonance frequency (f_o) value in the speakers which used the differential K value, such as PVC, rubber and leather material to manufacturing spring systems. The three parameters(three differential material) of surround materials are listed in table 2.

Table 1. Parameters of stiffed material

Materials / Parameters	Nano-carbon tube	Prepreg carbon fiber
E1	8.46GPa	147.503GPa
E2=E3	8.46GPa	9.223GPa
v12=v13	0.3	0.306
v23	0.3	0.25
G12=G13	3.25 GPa	6.8533GPa
G23	3.25 GPa	1.1229GPa
ρ	1053.86Kg/m^3	1747Kg/m^3

Table 2. Parameters of surround material in the spring systems

Shape of spring	Material of spring	K value (N/m)
	PVC	39613
	rubber	59431
	leather	37500

The foam board substrate and carbon fiber are used together in this paper, and the surround material uses polyurethane to make the mesh convergence curve. In this paper, the line cutting is used to make mesh so as to prove that the convergence of the mesh cutting analyzed by ANSYS. The line cutting consists of 4 types, like 0.01, 0.007, 0.006 and 0.005. 0.006 cutting size is a good sound pressure curve. Therefore, the size 0.006 will be used to conduct analysis in the future. The number of elements is listed in table 3, and the convergence condition is as shown in figure 7.

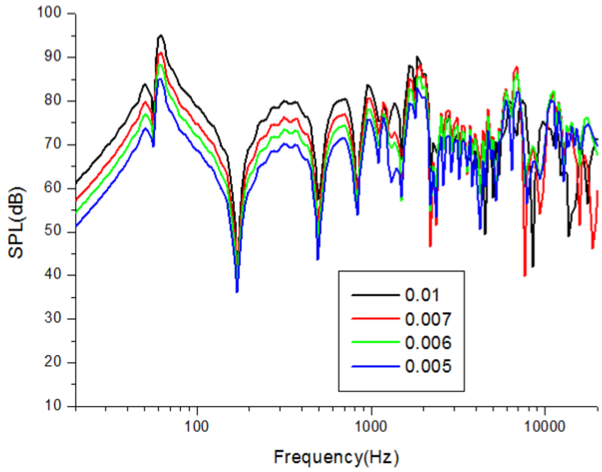


Figure 7. Sound pressure curve of mesh convergence

Table 3. Cutting size and element quantity

Cutting size	**Element quantity**
0.01	486
0.007	988
0.006	1350
0.005	1908

In order to verify the correctness of theoretical analysis of sound pressure curves, PVC is used to produce spring system, foam boards and coating nano- carbon tubes are adopted to make vibration plates, and planar loudspeakers with dimension 265mm×180mm×1.8mm (LxWxT) of composite sandwich material are assembled. Figure 8 compares the experiment and analysis of the sound pressure s curves, and the fo value of the experiment and analysis of the sound pressure curves is very close. Accordingly, the model of theoretical analysis is feasible.

3.2. Experimental measurement and comparison of initial solution and optimal solution

A planar loudspeaker with sandwich structure is respectively made by using the initial manufacturing parameter and the optimal manufacturing parameter obtained according to the simulation analysis, and the sound pressure curve is measured and the difference is compared, as shown in figure 9.

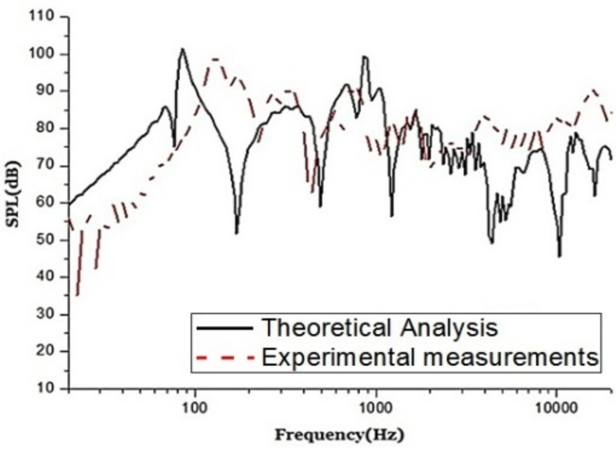


Figure 8. Verification of the experimental and analytic sound curves

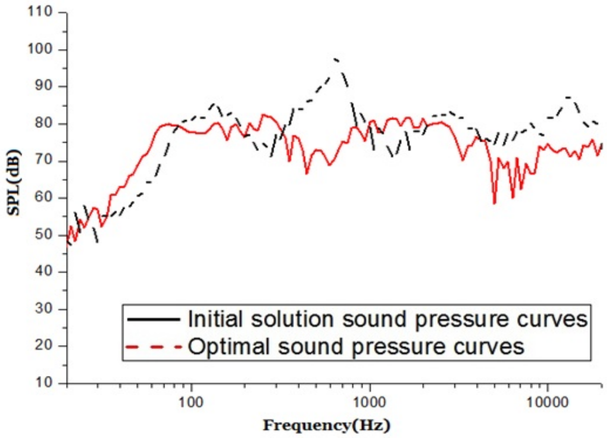


Figure 9. Comparison between the initial solution and optimal sound pressure curves

From figure 10, we can know that there is an evident noise on the initial sound pressure curve, namely the sound pressure is too high at intermediate frequency (about 670Hz). The measurement shows that the difference between the peak and the valley is about 30dB. However, a shrill sound is clearly heard when actually listening. As for the low frequency, the bass effect is better when the optimal sound pressure curve, *fo,* is at 60Hz. As for the variance, the variance of the optimal solution is 75.35, and the variance of the initial solution is 118.33. Therefore, the smoothness of the optimal sound pressure curve is better, and there is no higher noise.

3.3. Application of Planar Loudspeakers with Sandwich Structure

As for as the application of planar loudspeakers with sandwich structure is concerned, it is mainly to put the loudspeakers in planar ornaments like a photo frame or painting so that the space is beautified and music can be played, and people not only can enjoy the beautiful painting but also can listen clear and loud songs (Figure 10).

Figure 10. Application of planar loudspeakers with sandwich structure

4. Conclusions

By synthesizing all simulation analyses, experiments and measurements, and from comparison of the sound pressure measuring curves, simulation analyses and experiments, conclusions are as follows:

1. As for computer-aid analysis, the simulation value and the experimental value of the sound pressure curve tend to be consistent, and can simulate the model to verify the correctness, i.e. the simulation can be used to change design demands to reduce analytical time, and can seek out the optimal processing parameter together with the optimization.
2. By comparing the optimally analyzed sound pressure curve with the experimentally measured sound pressure curve, we can know the experimentally measured sound pressure curve is smoother, but the trend of the sound pressure curve is the same, and the *fo* efficiency of the analyzed curve is higher.

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