DETERMINATION OF THE ABSORPTION COEFFICIENT OF OPEN AND CLOSED CELL MATERIALS

by

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ABSTRACT

DETERMINATION OF SOUND ABSORPTION COEFFICIENT OF OPEN AND CLOSED CELL MATERIALS

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Faculty Mentor: Raul Fernandez

With the growing development of self-driving vehicles, the issue of passenger discomfort due to noise pollution has infiltrated the automobile industry. The computer driving these vehicles requires multiple fans to maintain optimal temperatures. To reduce the noise level created by the fans, this senior design team was tasked with developing a sound dampening solution that can be implemented to the computer superstructure while maintaining aesthetics, functionality, and accessibility for repair of the computer. This extended project was performed to investigate the sound absorption properties of open and closed cell materials that could then be used to create a solution. The sound absorption coefficients of neoprene foam, charcoal eggcrate foam, and cork were found using a self-made 2-microphone impedance tube and SimCenter Testlab. Thickness variations and material combinations were also tested. The results show that the open cell charcoal foam absorbs the most noise while the closed cell neoprene foam absorbs the least noise.

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CHAPTER 1

INTRODUCTION

1.1 Senior Design Project

May Mobility, Via Rideshare, and the University of Texas at Arlington have partnered to provide carpool opportunities in autonomous driving vehicles. In an effort to increase accessibility and inclusivity of all passengers, May Mobility is working towards incorporating a fleet of specialized Toyota Sienna self-driving vehicles that can offer rides to passengers who require the use of a wheelchair. This new fleet of vehicles utilizes the trunk of the Sienna to accommodate a wheelchair ramp and provide appropriate seating. Previously, the trunk was used to house the self-driving computer superstructure that drives the vehicle. In the subsequent improved models, the computer was brought to the front passenger seat. However, this introduced a major noise pollution issue from the computer cooling system. This senior design team was tasked with reducing the noise level inside the vehicle to provide a comfortable ride. The team must deliver a procedure which can be used to measure the noise level, select a sound dampening material, and build a working prototype of a sound dampening solution. My role in the team is to develop the sound measuring procedure and assist during testing of the prototype. I am also the “drafter” of the team as I keep notes of our meetings and help with the organization of our files. Additionally, I took the preliminary measurements for the available design space and will draft, review, and edit the proposed prototype engineering drawings.

1.2 Objective

This project explores the possible materials that could be used to manufacture a sound dampening solution. From previous testing during the senior design project, it was determined that the computer fans produce frequencies in the range of 800 to 3000Hz. The majority of the recorded frequencies were observed to be closer to 1200Hz. Considering this information, three sound dampening materials were selected as a potential solution for sound dampening and included: neoprene foam, charcoal eggcrate foam, and cork. Each material has a unique physical composition that determines whether the material is considered open or closed cell. It is expected that the charcoal foam will behave like an open cell material and provide the most noise absorption. This hypothesis was assessed by finding the sound absorption coefficient of each material. Additionally, material width and multiple variations were tested to explore the effects, if any, on the sound absorption coefficient.

CHAPTER 2

LITERATURE REVIEW

Sound dampening materials can generally be classified as open cell or closed cell. This classification is given based on physical characteristics of the material. Regardless of their classification, all materials have a unique sound absorption coefficient. An impedance tube is used to determine the sound absorption coefficient. This is a standardized test governed by standard ISO 10534-2. In this project, a self-made impedance tube was built to test open and closed cell materials for their sound absorption coefficient.

2.1 Open and Closed Cell Materials

Although commonly mistaken, sound absorption and sound blocking are two separate methods in which noise is controlled. An open cell material tends to have high porosity and relatively low density. Conversely, a closed cell material tends to have low porosity and higher density.[1] Figure 2.1 shows a material subjected to sound. As seen in the figure, all materials will allow for the incident sound wave to split into two components.

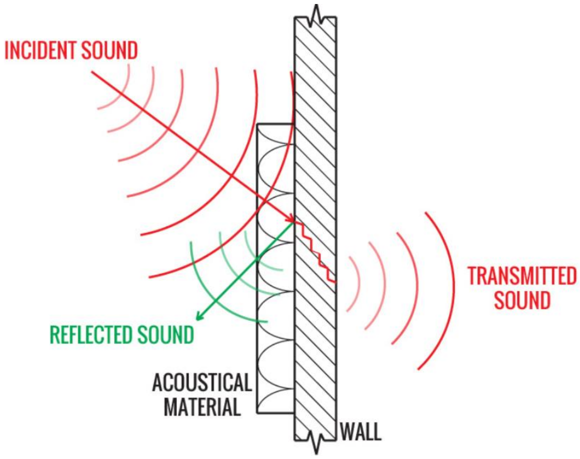

Figure 2.1: Sound Blocking vs Sound Absorption [2]

One wave component will pass through and be transmitted while the remaining component is reflected. If the sound wave is reflected, it can be concluded that sound blocking is present, due to the use of a closed cell material. If the sound wave is transmitted, sound absorption is present, as it is caused by the use of an open cell material.

2.2 Sound Absorption Coefficient

All materials used to absorb noise can be quantified by the sound absorption coefficient unique to each material. The sound absorption coefficient is defined as the ratio of sound energy absorbed to the overall sound energy reaching the surface of a given material.[3] The sound absorption coefficient, α, is mathematically found by measuring the normal incidence reflection factor, r. The relationship between α and r is shown below.[4]

$$\alpha = 1 - |r|^2$$

The normal incidence reflection factor is a complex number with real and imaginary components, r_r and r_i, and with a phase angle, $\emptyset_r$. The value of r can be found as a function of the complex acoustic transfer function, H_{12}, the incident wave transfer function, H_I, the reflected wave transfer function, H_R, the complex wave number, k_0, and the distance between the material and the further microphone location, x_1.[4]

$$r = |r|e^{j\emptyset_r} = r_r + jr_i = \frac{H_{12} - H_I}{H_R - H_{12}} e^{2jk_0x_1}$$

The complex acoustic transfer function, H_{12}, is defined as the ratio of the sound pressures p_2 and p_1 which is measured by two microphones. The inverse ratio is known as H_{21} and can be used to determine the coherence between the microphones, H_c.[4]

$$H_{12} = \frac{p_2}{p_1}$$

The incident wave transfer function, H_I, and the reflected wave transfer function, H_R, can be found as a function of the complex wave number, k_0, and the spacing between the microphones, s.

$$H_I = e^{-jk_0 s} \; and \; H_R = e^{jk_0 s}$$

2.3 Previous Sound Dampening Material Research

The standardization of sound absorption coefficient measurements alone implies there is previous research available on this topic. Recent research is focused on finding the acoustic properties of engineered polymers. For example, environmentally friendly materials were tested by Abdel-Hakim and their team in order to prove that sound dampening materials do not need to be harmful to the environment.[5] In their research, Abdel-Hakim uses recycled sawdust to manufacture sound dampening materials of varying densities and measure their absorption coefficient.

Other researchers are finding ways to provide access to material testing for acoustic properties in underfunded educational settings. Dr. Rao was able to develop an impedance tube with a budget of $1500 suitable for educational institutions in developing countries.[6] Their research consisted of first developing a 2-microphone and 4-microphone impedance tube setups, then testing EVA Barrier, Fiberglass insulation, cotton shoddy, and Ether Foam, and finally, verifying the results by testing the same material samples with a standard Bruel & Kjaer (B&K) impedance tube Type 4206. The results of their studies show that it is possible to build a cost efficient testing tube that results in minimal error when compared to a commonly used, standardized apparatus. Dr. Rao’s project was the basis of this project as there was minimal funding outside of currently available equipment in the lab such as the Data Acquisition Device and microphones used in this project.

CHAPTER 3

METHODOLOGY

This project aims to determine the sound absorbing behavior of open and closed cell materials. In order to quantify this behavior, the sound absorption coefficient of each material must be determined. Although there are no units associated with the sound absorption coefficient, this physical characteristic can be used to compare the sound absorption of each material based on a numerical value that is found by standard testing.

3.1 Approach

To measure the sound absorption coefficient, a 2-microphone impedance tube was designed and built using thrifted components. The testing parameters were carefully selected and set throughout all material testing for consistency. The impedance tube was placed inside a standard Whisper Room in order to minimize error from outside noise. It was assumed ambient noise was negligible. It was also assumed the Whisper Room was at room temperature and under standard atmospheric pressure.

3.2 Impedance Tube Design and Manufacturing

3.2.1 Impedance Tube Sizing

The main two parameters to consider when building a 2-microphone impedance tube are the inner diameter, d, and the spacing between the microphones, s. The values for these two parameters can be calculated for a given upper frequency, f_u as shown below.

$$f_u * d < 0{,}50 c_0 \text{ for } f_u = 2500hz,\ c_0 = 343\frac{m}{s} \rightarrow \mathrm{d} = 6.35cm$$

$$f_u * s < 0{,}45c_0 \text{ for } f_u = 2500hz,\ c_0 = 343\,\frac{m}{s} \rightarrow \mathrm{s} = 6cm$$

The frequency 2500Hz was selected based on the desired frequency range of 800hz to 3000Hz with special interest of the 1200Hz frequencies. 3000Hz is not a standard frequency used for this testing. The next standard frequency of 5000Hz was not used as the upper limit because this design parameter would introduce error in the measuring system. It was preferable to obtain a sound absorption coefficient at a peak frequency of 1200Hz with minimal error by excluding the 2500 to 3000Hz range of frequencies.

Because the impedance tube was built using standard American parts, the final value of d and s were selected by using the calculated value as the maximum allowable value and choosing a standard American part size closest to that value. Standard 2.5in-PVC pipe for electrical wiring was used to build the testing tube. The PVC pipe was sorted from a construction site that discarded it as waste material and came with a manufactured inner diameter of 2.46in. The final value of s was set to 2.375in because it is the closest standard inch value to 6cm that meets the standard specification. Standard ISO 10534-2 dictates that the first microphone is located at least three times the length of the inner diameter when measured from the noise generator end and the second microphone should be placed at least one diameter away from the material. Considering these specifications, as well as the spacing between the microphones, the overall length of the pipe from the speaker to the material was set as 13.375in. The pipe was cut using an electric reciprocating saw and sanded using Aluminum Oxide 150 Very Fine sandpaper. The results are shown in Figure 3.1. There are four pieces of PVC in the figure. Two of the pieces are cut PVC pipe and the other two pieces are 2.5in-PVC Pipe Couplers. The couplers were found at the same site as the pipe.

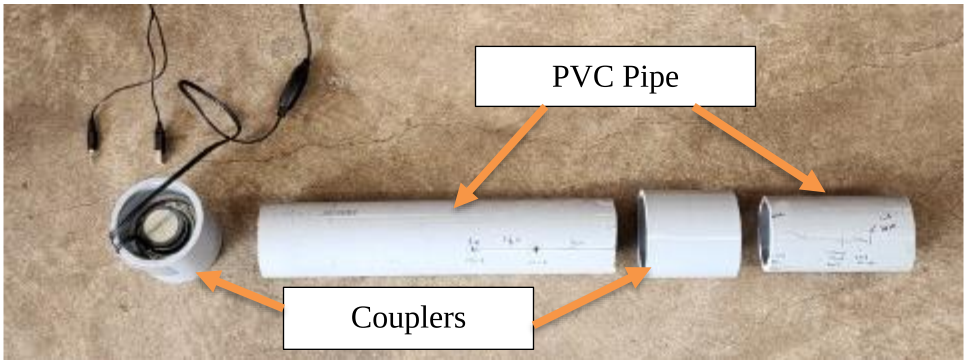

Figure 3.1: Cut PVC Pipe for Impedance Tube

3.2.2 Microphones

Once the pipe was cut to the right length, the two holes for microphone installation needed to be drilled. The microphones used in this experiment were provided by Dr. Wang. Two multi-field microphones type 4961 from Brüel & Kjær were used. The microphones have an outside diameter of 0.275in. The holes were drilled using a drill press as shown in Figure 3.2. The pipe was held using duct tape while a quarter inch drill bit was used to make an initial hole. The hole was enlarged appropriately to fit the microphones using a cordless rotary tool. This process was repeated for the second microphone hole.

Figure 3.2: PVC Pipe Installed in Drill Press for Microphone Hole Drilling

The standard specifies that the two microphones must be flush with the inside diameter of the impedance tube and must be able to be removed for microphone calibration. Rubber grommets were used in order to meet these specifications. One grommet was fixed to the PVC pipe using Gorilla Clear Epoxy adhesive. The second grommet was secured to the microphone at a set distance. The distance was determined by holding the microphone at the right location by inspection and securing the grommet in place. Figure 3.3 shows the grommets installed for both microphones. In the first attempt to secure the grommet to the microphone, cotton twine was used. However, this proved to be inefficient because the twine became loose easily. The issue was fixed by using electrical wire instead of twine.

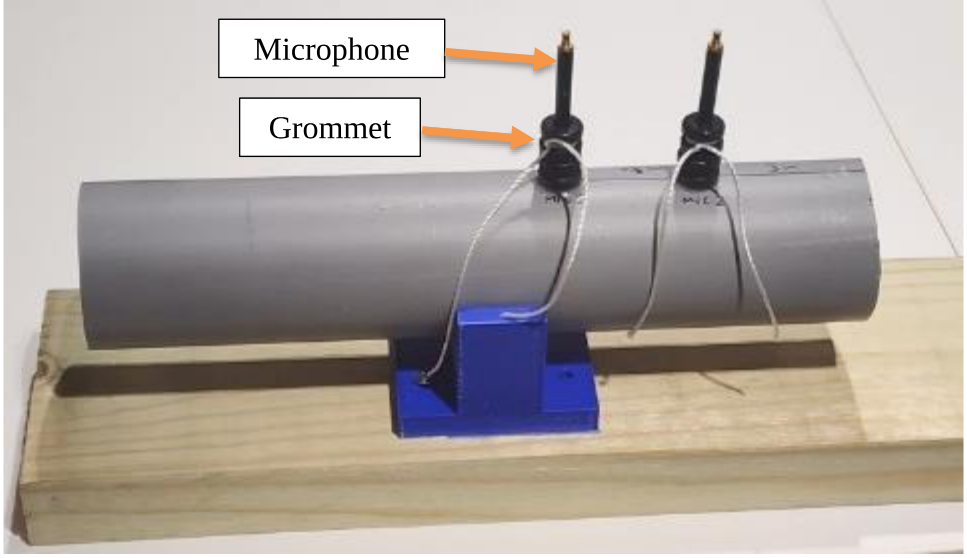

Figure 3.3: Grommets Installed in the PVC Pipe and Microphones

3.2.3 Loudspeaker

Opposite to the material holder, a loudspeaker must be held rigidly at the entry of the impedance tube. The overall surface area of the speaker should be at least two thirds of the cross section area of the tube, A. The value of A can be calculated as:

$$A = \frac{\pi d^2}{4} = \frac{\pi (2.46in)^2}{4} = 4.752in^2$$

The minimum area the speaker can have can be calculated as:

$$A_{min} = A * \frac{2}{3} = (4.752in^2) * \frac{2}{3} = 3.168in^2$$

This means that the minimum speaker diameter is:

$$d_{speaker,min} = \sqrt{\frac{4A_{min}}{\pi}} = \sqrt{\frac{4(3.168in^2)}{\pi}} = \boldsymbol{2.00in}$$

Knowing the minimum speaker diameter is 2in, a Gikfun 2" 3W Full Range Audio speaker with a 3.5mm audio cable extension volume control adapter was selected. The adapter was soldered to the speaker positive and negative leads accordingly. A Bath and Body Works candle lid was repurposed to attach the speaker to one of the PVC couplers. The lid was cut by punching various holes along the inside diameter using a screwdriver and a hammer. The outside diameter was achieved by cutting the lid with metal cutting pliers. The part was sanded down using a cordless rotary tool. The metal ring was attached to the PVC coupler using E6000 adhesive. The speaker had a square metal frame that was rounded off before adhering it directly on the metal ring with the same adhesive. The final speaker component is shown in Figure 3.4 with duct tape for cable management.

Figure 3.4: Impedance Tube Speaker End (Left:Inside, Right:Outside)

3.2.4 Material Sample Holder

The standard recommends that the material sample holder be accessible from the front and back. In order to achieve this, a piece of the same PVC pipe used for the initial length of the impedance tube was cut to 5in. This pipe was attached to the remaining coupler permanently using E6000 adhesive. The coupler was used because it can easily attach to the impedance tube while creating an air-tight seal.

3.2.4.1 Tube Termination

The standard dictates that the material samples are placed directly next to a flat, solid termination that is at least 20mm (0.787in) in depth. It is recommended that this piece is made from solid metal. For this project, the end piece was cast from epoxy resin because forming a solid piece of metal to have a circular cross section of 2.46in diameter was outside the scope of this project. Mod Podge 8oz Resin and Hardener kit was used to cast the part with a mold made by taping one end of the remaining PVC pipe used to construct the impedance tube. The mold was lubricated with Dawn dish soap to help prevent the epoxy from bonding to the PVC tube. The final cast piece is shown in Figure 3.5. The part was lightly sanded to remove rough edges and a 6in bolt was added to act as a handle.

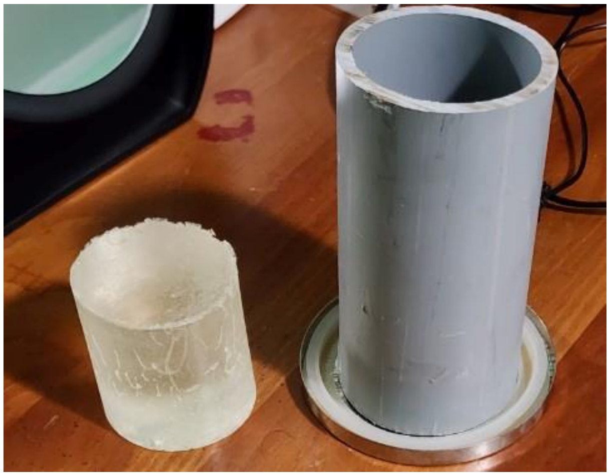

Figure 3.5: Tube Termination Cast From Epoxy

3.2.5 Additional Standard Specifications Considered

There were various specifications in the standard used to manufacture the impedance tube that were considered at the manufacturing of each component. Firstly, the tube must be straight, of uniform cross section, rigid, smooth, non-porous, and have no slits or holes. This was considered during the cutting and drilling operations of the PVC pipe to ensure the tube was not damaged. The standard also recommends the use of Vaseline to seal any parts that are removed from the main impedance tube such as the material sample holder. This was considered in the design process of the material holder because it meant that there had to be surface area where Vaseline could be applied when installing the material sample holder. Although not quite common, there are square impedance tube setups available. However, the standard highly encourages the use of circular cross section impedance tubes. This design choice needs the addition of a base that holds the impedance tube. For this project, a standard 1” x 3” wood plank and 3D printed holders were used. The dimensions of the 3D printed holder can be found in Appendix A. Figure 3.6 shows the final design of the 2-microphone impedance tube designed and manufactured for this project.

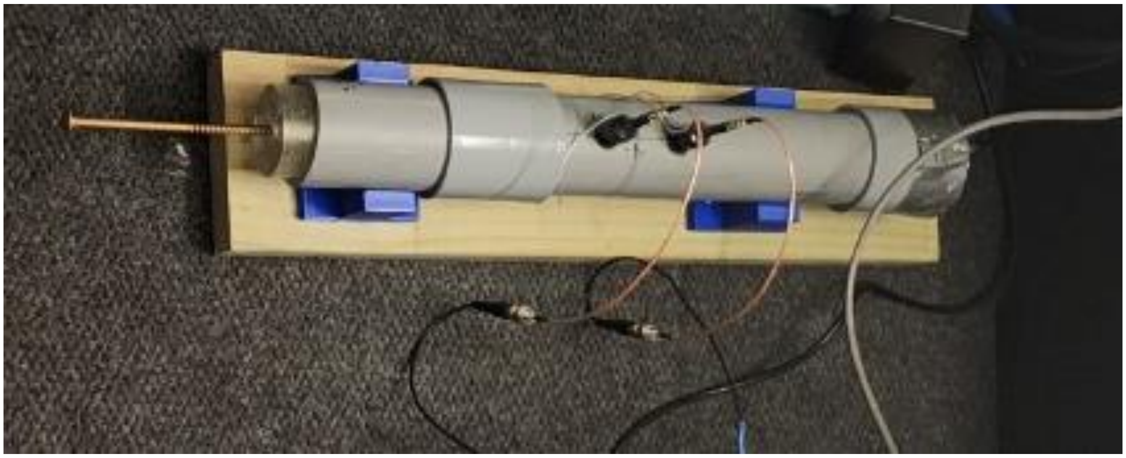

Figure 3.6: Two-Microphone Impedance Tube

3.3 Data Acquisition

3.3.1 Setup

Before data could be collected, samples of each material were cut using scissors and the PVC pipe as a guide. As seen in Figure 3.7, there were two samples of each material. The neoprene foam, charcoal foam, and cork material have a thickness of 0.5in, 1.5in, and 0.0625in accordingly. The thickness of the materials was left as per manufacturing because changing the material thickness would create additional manufacturing steps when using the materials to build a sound dampening prototype.

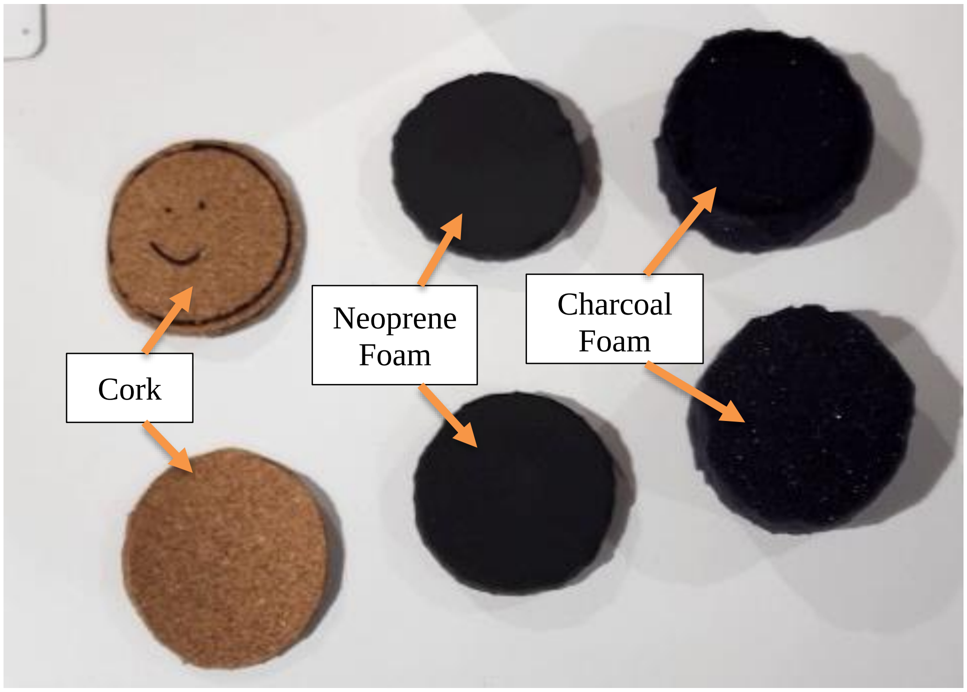

Figure 3.7: Material Samples

In addition to the material samples, a flat, random noise was created using a random signal generator function in MATLAB. The MATLAB code for the signal used is found in Appendix B. The signal was played on the speaker by connecting a laptop running MATLAB to the speaker through the USB adapter previously soldered to the speaker. The data of this experiment was collected and processed using SimCenter Testlab software. The sound pressure values measured by the microphones are obtained by the software from a Data Acquisition Device (DAQ). The DAQ is connected to a computer running the Testlab software through an ethernet cable, and to each microphone through a BNC coaxial cable. Note that the microphones have a SMB output connection, so a BNC to SMB adapter was needed.

Prior to collecting data, a project file was created for the self-made 2-microphone impedance tube. The input parameter values specific to the manufactured impedance tube were inputted as shown in Table 3.1.

Table 3.1: Testing Tube Parameters for SimCenter Testlab Software

x1 [mm]	s [mm]	d [mm]	Fmin [Hz]	Fmax [Hz]
136.53	60.33	62.48	20	2558

When setting up the Testlab project file, the microphones must be calibrated. This was done by holding each microphone to a calibrated tuning box and recording the measured value on the Testlab interface. Additionally, the reference transfer functions must be measured. The forward transfer function, H_{12}, is measured by taking a measurement under "Channel Setup." There should be no material sample installed when the transfer function is being measured. Directly after measuring H_{12}, the reverse transfer function, H_{21}, was measured similarly. Before measuring H_{21}, the microphones must be physically interchanged on the impedance tube. Once the value of H_{21} is obtained, the microphones must be switched back to their original locations. Then, the coherence transfer function, H_c, can be measured by clicking the measure value on the Testlab software interface. The file was named and saved to a directory on the computer where the data would be stored.

3.4 Procedure

Before any measurements are taken, the temperature of the impedance tube is stabilized by letting the speaker play the random noise for at least 10 minutes. The material sample holder was lightly greased using Vaseline before inserting a test sample. The materials are installed by removing the material holder and sliding the test sample with the use of the end plunger. The material should lay flush with the inner diameter of the tube without any buckling or bulging. The material samples should always start at the same location along the sample holder, but the end piece is adjusted based on the sample thickness. The software provides 3 plots every time a measurement is taken. The first plot is the Frequency Response Function (FRF) which shows the frequency profile measured by the microphones. The second plot is the coherence of FRF and provides an indication of the accuracy of the measurement. A constant value of one is desired for this plot at all frequencies. The third plot is the absorption coefficient plot over the given range of frequencies. This plot can be used to obtain the sound absorption coefficient of each material. The plots can be found in Appendix C.

The first goal of this experiment was to determine the sound absorption coefficient of each material alone. A single layer of charcoal foam, neoprene foam, and cork material was tested individually. To observe the effects of increasing the size of the material, each material was tested a second time as a double-layered material. This is equivalent to doubling the thickness of each material sample. The combinations of materials tested were as follows: neoprene to cork, neoprene to charcoal, cork to neoprene, cork to charcoal, charcoal to neoprene, and charcoal to cork. The order of the materials was assumed to be important.

3.4.1 Optimizing Cork Samples

When first testing the cork material, it was found that the cork sample when placed as a single layer could not remain flat inside the material holder. This introduced air gaps between the material and the end plunger. The data obtained from this experiment would not be consistent with the data obtained for the other two materials. To address this issue, the cork sample was designed to be tested in a manner that represents the conditions in which cork would be used to manufacture a mechanically stable structure. For this, three layers of cork material samples that had been previously cut were stacked and glued using E6000 adhesive. The glue was applied across the diameter of the sample four times, all lines crossed the centroid of the cross section approximately. The layers were then rotated to cause shearing of the adhesive and form a thin, even layer of E6000 between each layer of cork.

3.4.2 Data Post-Processing

The data was processed with a SimCenter SCADAS Mobile Data Acquisition Device and SimCenter Testlab software. Five samples of data were taken for each material and material combinations. The average of these samples was taken using the “Average” function of Testlab. All the measurements were taken in the same day over the course of two hours. The sound absorption coefficient was assumed to remain constant during this period based on assumed constant temperature, pressure, and moisture conditions.

CHAPTER 4

RESULTS

The hypothesis of this experiment is to prove that closed cell materials are less effective at absorbing noise than open cell materials. The sound absorption coefficient of selected open and closed cell materials was measured using SimCenter Testlab software. In addition to the main hypothesis, the effects of material thickness and material combinations on the sound absorption properties were tested. The data agrees with the main hypothesis and shows a clear trend of sound absorption in relationship to thickness and material placement.

4.1 Sound Absorption Coefficient Results

Figure 4.1 shows the three plots produced by SimCenter Testlab after obtaining five data samples and their average value for the charcoal foam. The top plot shows the FRF for the system. The trend of the line indicates a clear peak resonance frequency of about 460Hz. The coherence plot shown right below illustrates major error in the measurement system at this point. Although there was no further investigation, the noise seen in the coherence plot is assumed to be caused by vibration of the microphones due to the peak resonance being reached. The absorption coefficient plot shows that there is zero absorption at the zero frequency and the value begins to increase slowly until a constant number is reached. This value is taken as the absorption coefficient over the given range of frequencies. The remaining plots are shown in Appendix C.

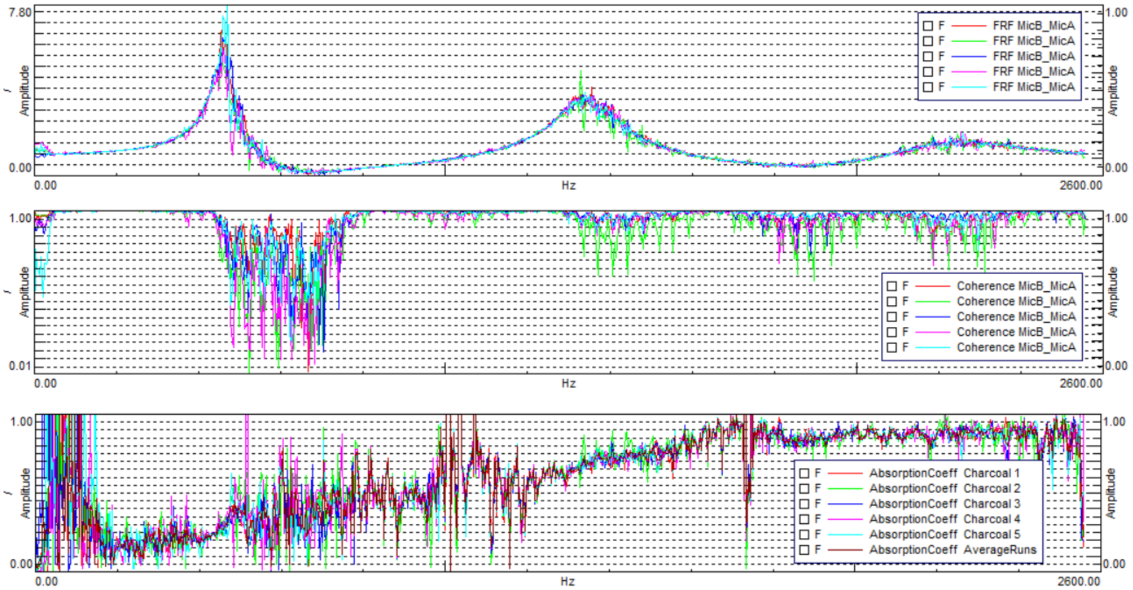

Figure 4.1: Testlab Output Plots for Charcoal Foam

The values of the absorption coefficient for the three materials tested are shown in Table 4.1. Note that a single-layered cork sample refers to the previously optimized cork sample composed of three individual cork material layers. As predicted, the material with the most sound absorption is the charcoal foam while the material with the least sound absorption is the neoprene foam.

Table 4.1 Sound Absorption Coefficient for Single-Layered Materials

Material	Neoprene	Cork	Charcoal
Absorption Coefficient	0.15	0.25	0.85

Figure 4.2 shows the average value of the sound absorption coefficient for each double-layered material. The red line shows charcoal foam, the green shows cork, and the blue shows neoprene foam. The data shows that increasing the material thickness results in each material reaching an average absorption coefficient equal to the corresponding single-layered material sound absorption coefficient. However, there is improved sound

absorption performance at the lower frequencies. For example, when looking at the charcoal double-layered sample, the peak absorption coefficient is reached at 800hz. For a single-layered charcoal sample, the peak absorption coefficient value is reached at about 1800Hz. It is difficult to draw a conclusion about the non-absorbing materials due to the much higher level of noise in the system.

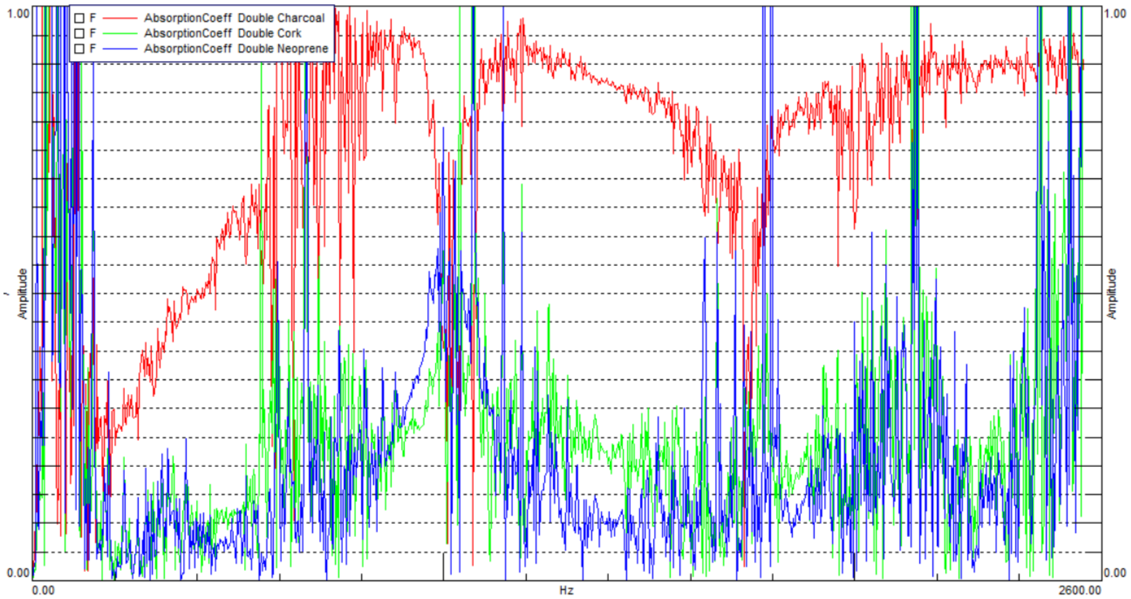

Figure 4.2: Sound Absorption Coefficient for Double-Layered Materials

The values of the coefficient of absorption for the material combinations are shown in Table 4.2. The data shows that placing a closed cell material in front of any other material renders the second material useless as very little noise can reach past the first material. The only combination that shows improvement of the sound absorption coefficient is charcoal to cork. However, the effect is minimal.

Table 4.2: Sound Absorption Coefficient for Material Combinations

Materials	Neoprene to Cork	Neoprene to Charcoal	Cork to Neoprene	Cork to Charcoal	Charcoal to Neoprene	Charcoal to Cork
Absorption Coefficient	0.15	0.15	0.25	0.25	0.85	0.87

CHAPTER 5

CONCLUSION

The data proves the hypothesis that open cell materials have a higher noise absorption coefficient than closed cell materials. The charcoal foam had higher absorption in all the tests performed, whether it was installed alone or paired with a second material. The material combinations further prove that absorption is dependent of the material that experiences the incidence noise. All of the combinations behaved closely to the single-layered material behavior of the material that was placed closer to the microphones. The coefficient of absorption was found to be influenced by the material thickness. A thicker material sample will have improved sound absorption at lower frequencies. This information can be used to design sound dampening solutions when the frequency range is known.

5.1 Recommendations

Although the hypothesis was proved true in this experiment, the experiment error sources could be considerably improved. The main limitation for this project was the manufacturing of the impedance tube using thrifted materials and readily available tools. When manufacturing the impedance tube termination, the bolt used as a handle should be inserted in the cast part while it is casting in order to remove manufacturing steps. Similarly, a better approach to attaching the speaker to the coupler should be tried as the current method yields a metal ring that may not guarantee the speaker is perfectly centered within the cross section of the impedance tube.

APPENDIX A

3D PRINTED BASE DIMENSIONS

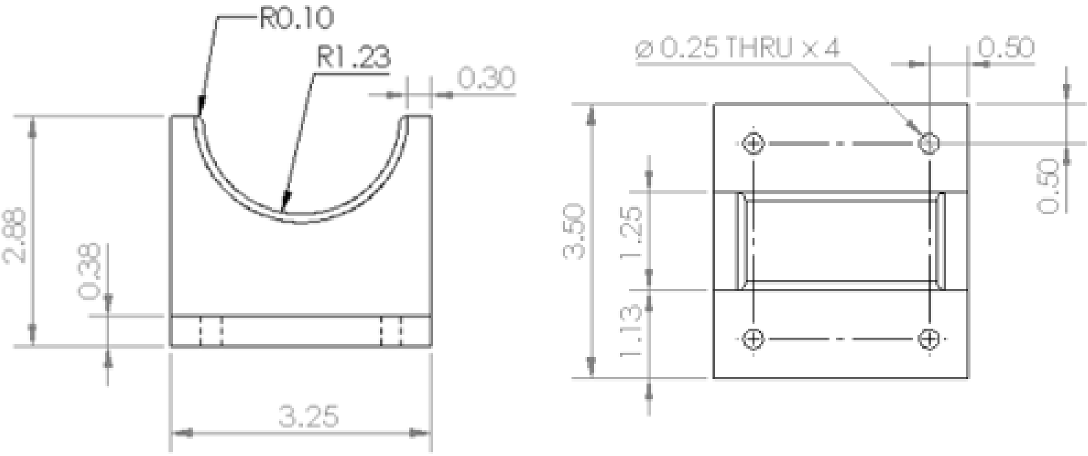

Figure A.1: Base Dimensions in Inches

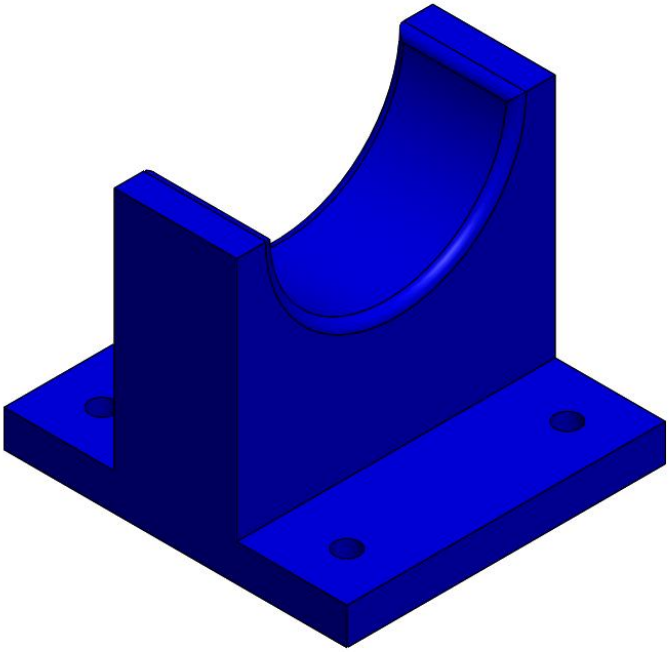

Figure A.2: Base Perspective View

APPENDIX B

MATLAB CODE FOR SIGNAL GENERATION

```
clc;clear;close all;
noise= wgn(100000000,1,-6); %Noise= white gaussian noise(m x n matrix,
                            decibel power (dBW))
sound(noise)                %Plays the generated audio on computer speakers
var(noise)                  %Gives the Watts of power for the given dBW power
plot(noise)                 %Creates a visual representation of the sound
xlabel('Samples (Volts)');
ylabel('Power density (dBW)');
```

APPENDIX C

ADDITIONAL DATA PLOTS

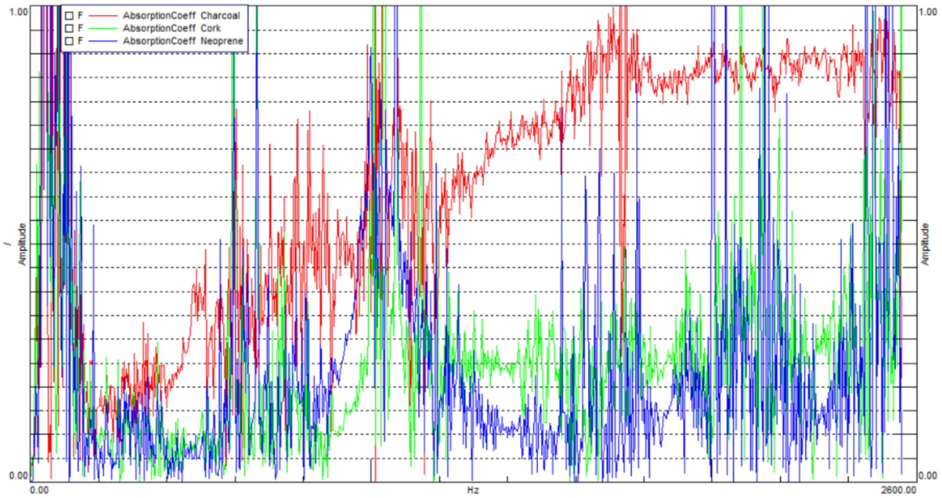

Figure C.1: Absorption Coefficient For Single-Layered Materials

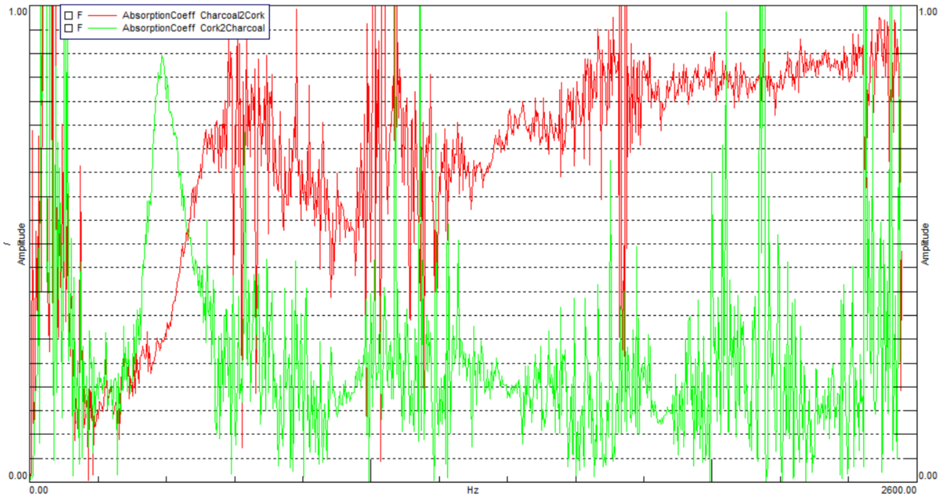

Figure C.2: Absorption Coefficient For Charcoal and Cork Combinations

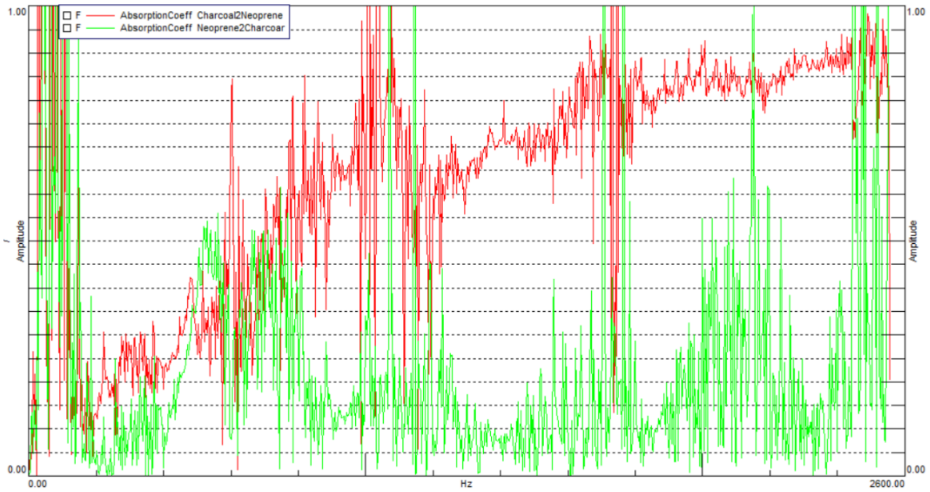

Figure C.3: Absorption Coefficient For Charcoal and Neoprene Combinations

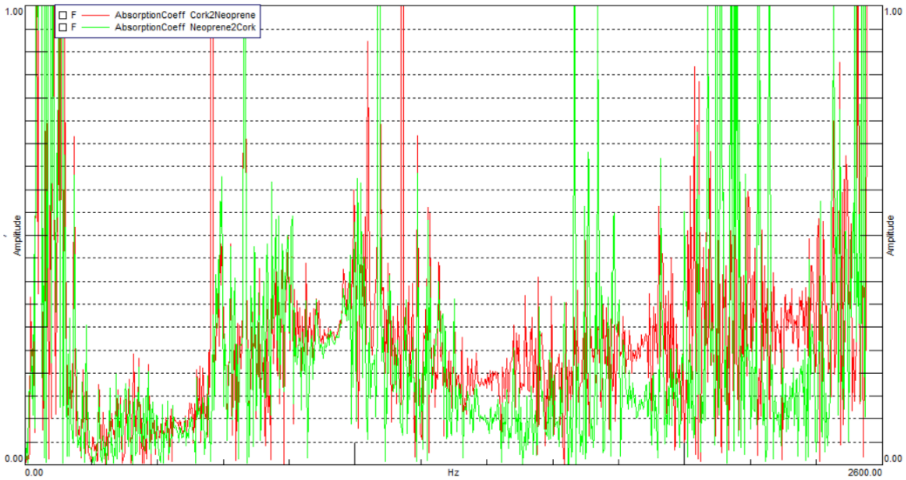

Figure C.4: Absorption Coefficient For Cork and Neoprene Combinations

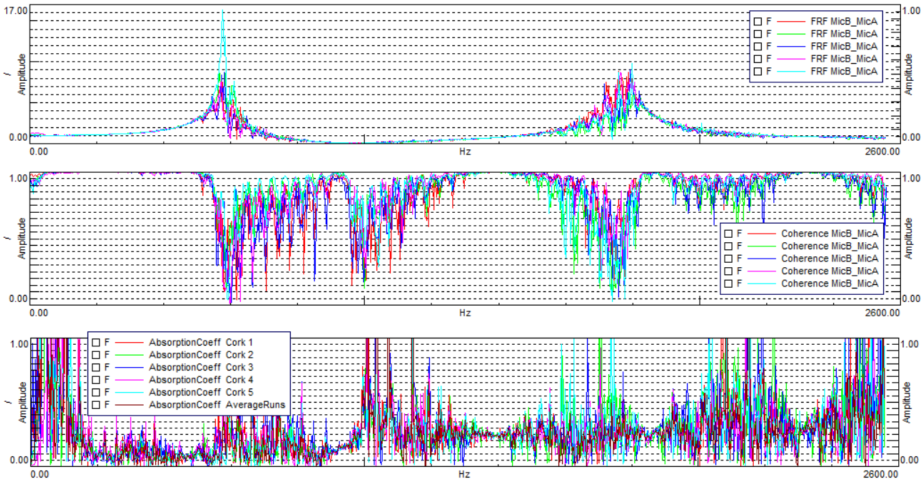

Figure C.5: Testlab Output Plots for Cork

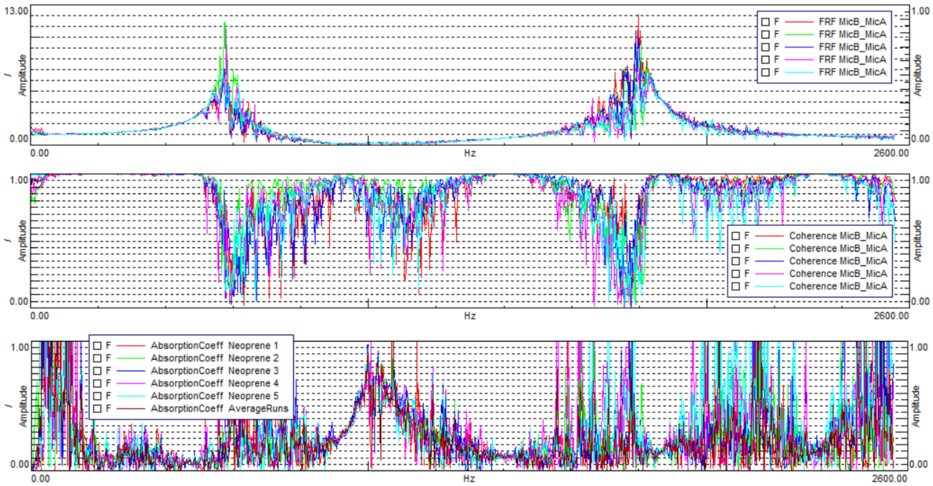

Figure C.6: Testlab Output Plots for Neoprene Foam

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BIOGRAPHICAL INFORMATION

Fernando Alejandre began his journey in engineering at North Garland High School when he took his first engineering course, Project Lead The Way (PLTW) Introduction to Engineering. In this course, he was tasked to solve quick engineering challenges such as designing and constructing a cardboard vehicle powered by a balloon. Fernando found immediate interests in this field and decided to attend the University of Texas at Arlington to earn a degree in Mechanical Engineering.

Through his time at UTA, Fernando devoted much of his time to being an Honors College Advocate. He held a Lead Advocate position for two years and helped develop a peer-mentoring program for the Honors College. At the same time, Fernando was growing his technical skills by completing Honors College Contracts that allowed him to explore topics of his interest. He completed various projects related to reverse engineering and engineering design for manufacturing. Fernando will be pursuing a career as a manufacturing engineer and potential engineer drafter.