Biomechatronics Laboratory Fume Hood

Final Proposal

Talal Alshammari

Zachary Bell

Bryce Davis

Shirley Hatcher

2020

Project Sponsor: Dr. Zachary Lerner

Faculty Advisor: Dr. David Trevas

DISCLAIMER

EXECUTIVE SUMMARY

A laboratory fume hood is commonly used to eliminate health hazards to those working with dangerous materials. Carbon fiber is a material with many beneficial properties such as its high strength and lightweight properties. Sanding operations are a necessary procedure to shape or manipulate the material into a more useful form. These sanding operations produce particulates and epoxy fumes that have been proven harmful and potentially fatal to individuals exposed to these byproducts. Laboratory Fume Hoods are devices that are specifically designed to eliminate the hazards of working with dangerous materials. The Fume hood designed for this application consists of the fume hood box connected to an exhauster with an attached filter. The fume hood box is the working space where the sanding operations will take place. The exhauster is attached to the top of the fume hood box, drawing the air flow into the exhauster which will be expelled out of the system. The filter is attached to the top of the fume hood box to extract the carbon fiber particles from the air flow before entering the exhauster.

The design process included many consultations with the client, Dr. Lerner, to determine the most efficient way to implement the lab fume hood into the Biomechatronics lab. The team decided to have an air filter on the exhauster intake to collect carbon fiber particles. This will allow the client to change out the air filter once it becomes too full and the air flow is no longer sufficient. The testing being done will involve pressure differential measurements as well as flow rate measurements. The pressure drop will increase and the flow rate will become more steady as the filter collects the carbon fiber particles. The shape of the fume hood also had to be determined by the team to maximize the flow rate without producing any dead zones.

The design solution for the team was to implement a filter in the system and have an Arduino Uno board measure the differential pressure. The device will permanently be attached to the fume hood and display the measurements as a reference to when to change the filter. The shape of the fume hood was determined to be a box with a pyramidal top to direct the air flow directly into the filter and through the exhauster, as shown below.

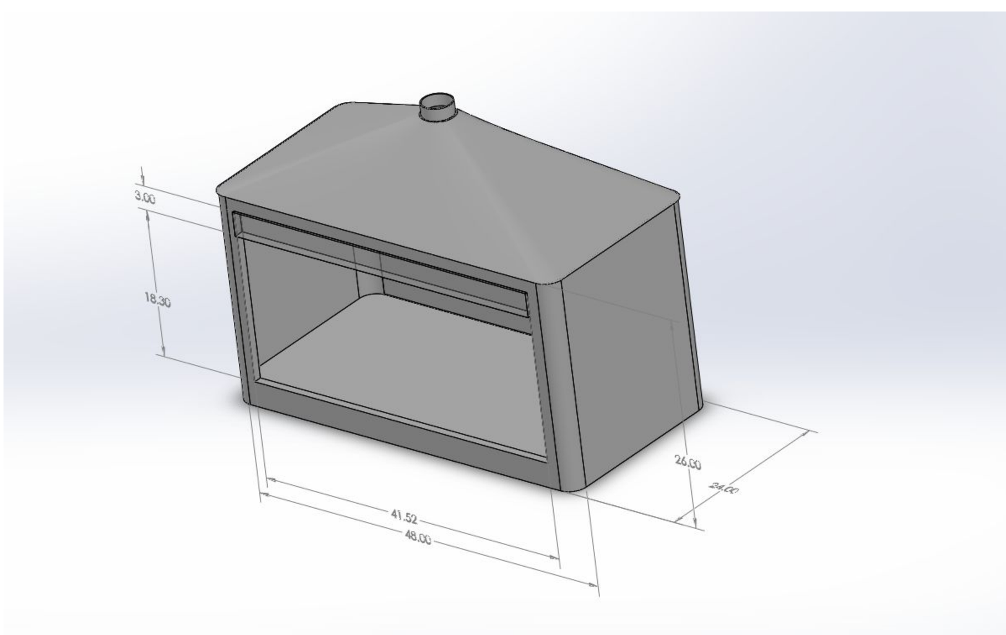

TABLE OF CONTENTS

Contents

1 BACKGROUND

1.1 Introduction

NAU's Biomechatronics lab would benefit from developing carbon fiber parts in house rather than outsourcing for fabrication. These parts will be vital to creating exoskeletons for people inflicted with mobility impairment. Carbon fiber is hazardous to work with due to the emission of epoxy fumes and fine particles contamination. A previous capstone team has successfully produced an exhauster that we are expected to use as part of our design. A working Lab fume hood would provide a safe and effective environment to cut and sand carbon fiber components while eliminating the threat to human health.

1.2 Project Description

The initial consultation with the client, Dr. Lerner, gave the team initial design parameters and requirements. The fume hood designed should be portable within a building and desktop sized, roughly having dimensions of 4ft wide by 2ft deep by 3 ft long. The flow rate through the hood should be consistent and should not contain any dead zones of stagnant air. Stagnation points could potentially cause a collection of carbon fiber particulates which could present a hazard to those working in the fume hood. A filter was an essential component outlined by the client which will be attached to the exhauster. The filter will collect the carbon fiber particulates, so they are not expelled into the atmosphere by the exhauster. Additional features will be added to the fume hood to increase the safety and effectiveness of the final product. A pressure transducer will be attached to measure the pressure drop across the filter to determine the filter life. A visual display will be mounted to the fume hood to provide operational data to those actively working with the system.

2.0 REQUIREMENTS

Several consultations with Dr. Lerner provided clear customer requirements which the team was able to relate to engineering requirements. The Biomechatronics Lab needed a portable fume hood to sand and fabricate carbon fiber in a safe manner. There are some safety precautions in place now, but a Lab Fume Hood would be more beneficial and provide greater safety measures. An exhauster was purchased and anything that was to be built must be compatible with existing equipment.

2.1 Customer Requirements (CRs)

1.Safe to Operate - The final product must meet all OSHA standards and be safe to routinely use in a lab setting.

2.Reliable Design - The design must be efficient and effective. The fume hood will be in regular use and must be in a functioning and reliable state.

3.Compatible - The fume hood design must be built around the existing exhauster already owned by the Biomechatronics Lab. The team can not propose changing the exhauster.

4.Durable - Materials and filter types must be chosen to be durable, the carbon fiber being removed should not cause severe damage to the fume hood.

5.Portable - The fume hood and exhauster should be portable within a lab setting, the design should not be permanently fixed or unable to be moved.

6.Combined Weight - The combined weight of the final product should remain under 60 lbs.

7.Filter Assessment - Filter life readings should be available to lab workers to maintain a safe operational level.

8.Eliminate Epoxy Fumes - The fume hood and exhauster should effectively remove the threat of epoxy fumes which can be harmful to human life.

9.Remove Fine Carbon Fiber Particulates - The fume hood and exhauster should eliminate the threat of fine carbon fiber particulates which can be harmful to human life.

10.Within Budget - The budget is flexible but should remain around $400. Client updates and communication will be necessary in determining the final budget.

2.2 Engineering Requirements (ERs)

The client clearly specified the dimensionality of the fume hood. The volume, weight, usability and maneuverability of the device were numbers given to us by Dr. Lerner. The volumetric flow rate and air velocity were determined through research of the exhauster given to us. The durability is based on existing fume hood designs and the material strength of plastics used currently. The pressure drop, filter assessment, and particulate capture are all determined experimentally and through independent research of the team. Engineering requirements are tabulated in table 1 below.

Table 1: Engineering Requirements

Engineering Requirements	
Requirement	Units of Measure
Dimensionality	2 x4 x3 feet
Weight	<80 lbs
Volumetric Flow Rate	300-395 CFM
Air Velocity	4000 FPM
Pressure Drop	< 2 kPa
Maneuverability	Transportable within building
Durability	200 Kpsi
Filter Assessment	Seconds
Usability	Compatible with EBR 50 Exhauster
Particulate Capture	0-80% Max capacity (lb/ft^3)

2.3 Functional Decomposition

The primary purpose of this capstone team is to provide a safe and efficient fume hood exhaustion system for NAU's Biomechatronics lab. This requires the use of a fume hood with compatible exhauster fan which had been pre-purchased in another capstone designation. Our goal for this team is to manufacture and apply prior projects to our current need. We were able to determine the primary functions of the fume hood apparatus to include first containing the toxic fumes and harmful particulates to within the confines of the fume hood, exhausting both the fumes and carbon fiber particulates safely away from the users, and all while maintaining a high level of safety standards which help avoid any possible accident to the user. Figure 1 below depicts our functional decomposition on the overall system level. Our subsystem functional decomposition will be expounded upon further in section 2.4.2.

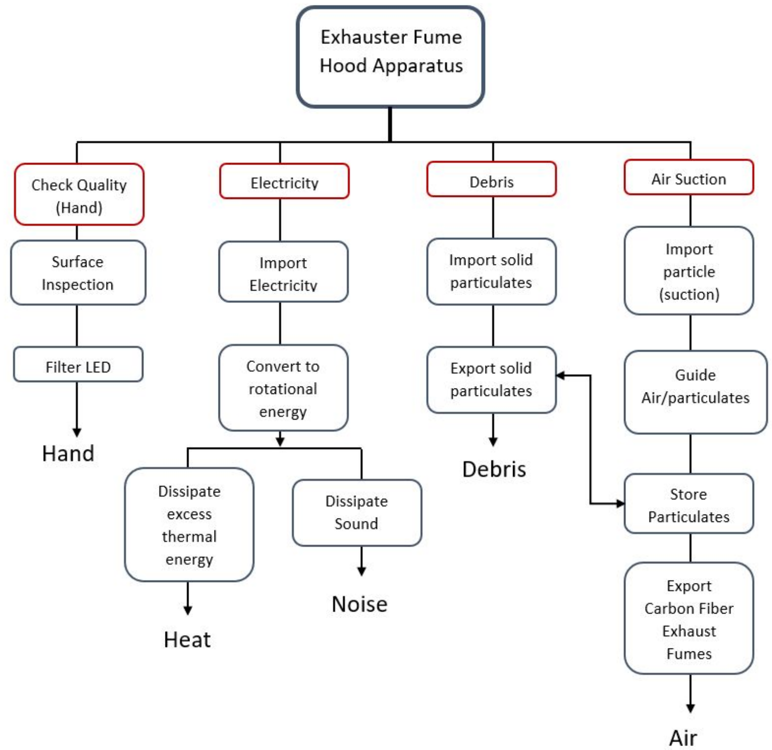

Figure 1: Overall System Functional Decomposition

2.3.1 Black Box Model

Our black box model shows both input and output functions of the fume hood exhaustion system This model relates the functional decomposition inputs and outputs to one another on a simplified basis. It relates the input of materials, energies, and signals to their respective outputs as the system operates. Our signals include a simple on off switch on the exhauster. Energy includes electrical energy provided by the wall outlet. While materials include hands, exhaust fumes, and harmful particulates. This model is visualized in figure 2 below. This model helped the team to visualize the ins and outs of the design project. With this information we were able to further breakdown the system functional decomposition to included subsystems within the apparatus.

Figure 2: Black box model of fume exhaustion system

2.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

As mentioned, previously we broke apart our functional decomposition into a full system decomposition and a subsystem decomposition that helped the team better visualize the task at hand. Our subsystem functional analysis model illustrated three different points in the exhaustion system. those points consist of containing harmful fumes and carbon fiber particulates, exporting those harmful particulates, and maintaining an elevated level of safety standards when operating the system. We determined these three subsystems to be vital to the operation and performance of the exhaustion system. Figure 3 typifies our subsystem functional decomposition.

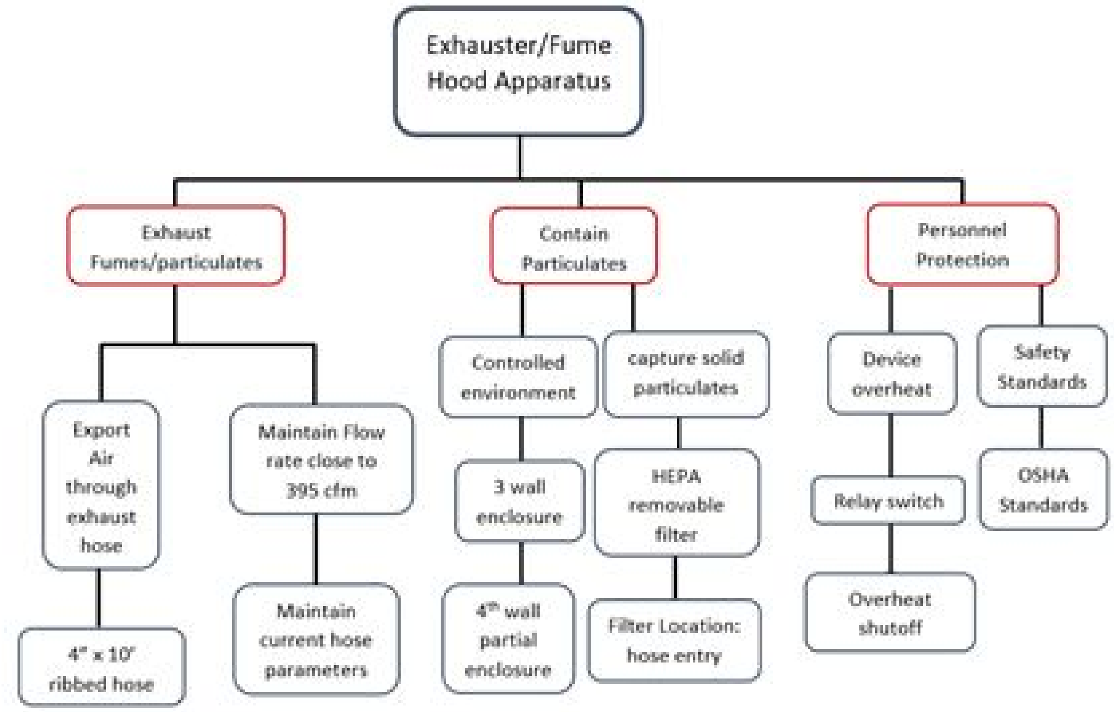

Figure 3: Subsystem functional decomposition of fume hood exhaustion system

2.4 House of Quality (HoQ)

FUME HOOD (HoQ) Customer Needs	Weight	Volumetric Flow Rate (lb/ft^3)	Device manuverability/portability	Dimensional area (ft^2)	Weight (Lbs.)	Ventilation velocity (ft/min)	Particulate Fume Capture (lb/ft^3)	Useability	Filter change assessment time (seconds)	Pressure Drops across device (SPWG)	Durability/Fracture toughness (ft-lb/in^2)
1. Table Top Fume Hood	5	1	3	5	5	3	5		3	3	3
2. Compatible with Exhauster	5	3				5	5	5	3	3	
3. Hepa Filter	4					1	5	5	3	3	1
4. Particulate Export	4	5	1	1	1	5	3	3		3	3
5. OSHA	5						5		3		
6. Reliability	4						5				
7. Minimize Inlet Pressure Drop	2	1				3	5			5	
8. Filter Light Indicator	1								5		
9. Extended Hose	2	1	1		1	1		1		3	
10. Durability	3										5
Absolute Technical Importance (ATI)		44	21	29	31	72	137	59	62	70	46
Relative Technical Importance (RTI)		7	10	9	8	2	1	5	4	3	6
Target ER values		0.75	N/A	25	100	4524	0.75	N/A	N/A	5.3"	N/A

Figure 4. HOQ

2.5 Standards, Codes, and Regulations

The engineering standards that have been made by national and international committees is a very useful tool when designing and building any device. This is because the standards that they provide gives the team a starting place when designing the project and a guideline to adhere to while in the design and implementation process and beyond. The two most important standards for this project are the standards provided by OHSA in relation to chemicals and ISO for the selection of a proper filter. These are important as the device is designed to increase safety of the user while working with hazardous materials. OSHA standard 1910.1450[1] thoroughly details the laboratory safety measures that need to be in place while someone is working with any chemical or material. This is to minimize exposure to dangerous materials without proper equipment as well as prevent a worker from getting injured while interacting with any sort of hazardous material. The standards that the team has been using is in a tabulated form below, table 2.

Table 2: Standards of Practice as Applied to this Project

Standard Number or	**Title of Standard**	**How it applies to Project**

Code		
OSHA 1910.1450	Occupational exposure to hazardous chemicals in laboratories	Helps in the design of the user-device interface.
ISO 16890	Air filters for general ventilation	Helps with selecting the correct filter for use in the device.
ASTM D543	Standard Practice for Evaluating the Resistance of Plastics to Chemical Reagents	Helps with testing the device to ensure that the device will not have any adverse reactions to the particulates and epoxy fumes.
IEEE 829-2008	IEEE Standard for Software and System Test Documentation	Helps with testing the electronic additions to the device to ensure that they will work consistently.

3. Testing Procedures (TPs)

In this section, a number of testing on the fume hood parts will be discussed and explained. The testing procedure will include a detailed description of each engineering requirement testing process to indicate whether it has been satisfied or not.

3.1 Testing Procedure 1: Hepa filter

It is important to test the hepa filter when attached to the exhauster to see the efficiency of it after the attachment installation. This test can be done by using colored powder to clearly see the efficiency of the work. This test will prove the satisfaction of the hepa filter's importance and reliability in the design.

3.1.1 Testing Procedure 1: Colored Powder - Hepa filter testing.

For the hepa filter testing, colored powder will be used to determine whether the filter is working in stopping the colored particles from going through to the exhauster. In addition, a pressure drop sensor will be used to calculate the pressure drop after attaching the filter to prove the hepa filter's efficiency.

3.1.2 Testing Procedure 1: Resources Required

For this test, one of the resources needed is the colored powder, which will be used in testing the filtering ability for the hepa filter. In addition, Arduino Uno will be used along with the pressure sensor to calculate the pressure drop after attaching the hepa filter.

3.1.3 Testing Procedure 1: Schedule

This test would take approximately 3-5 hours to be prepared and analyzed. The testing will be done on july 20th - 21st according to our plan along with the other testing procedures. However, for the completion of this testing procedure, the hepa filter, the Arduino Uno, and the pressure sensors need to be purchased in advance.

3.2 Testing Procedure 2: Pressure drop and Flow rate

Testing flow rate and pressure drops on the system after attaching the exhauster is needed to prove that the operational environment is safe. This can be done by using Arduino Uno and pressure sensors attached in different places and angles in the hose. Furthermore, the flow rate is going to be calculated from its relationship with the pressure drop.

3.2.1 Testing Procedure 2: Pressure drop and Flow rate testing details.

The Arduino Uno will be used along with the pressure sensor to calculate the pressure drop along different angles in the hose after installing the exhauster to the fume hood. Then using the Eq.1 to relate the flow rate to the pressure drop that appears after the installation. This testing is done to verify and prove that the operational environment is going to be a safe zone to do the carbon fiber experiments on.

Flow rate = Nozzle Area $\times\sqrt{\Delta p}/\sqrt{(\text{Density of Air})}$

3.2.2 Testing Procedure 2: Resources Required

The recourses needed to complete this test are the Arduino Uno, Pressure sensors, and data collectors' software. Those recourses need to be prepared and used so that the analysis and flow rate calculation can be done.

3.2.3 Testing Procedure 2: Schedule

This test would take approximately 10 - 15 hours to be prepared and analyzed. The testing will be done on July 20th – 23st according to our plan along with the other testing procedures. However, the resources provided need to be purchased and tested a time before this testing procedure.

4 Risk Analysis and Mitigation

For our fume hood design we came up with a rather helpful risk analysis and mitigation factors that helped in narrowing down a final design for the fume hood system. We determined the major potential within the system and then came up with ways to help mitigate those potential failures. We are lucky enough to have a rather simple design for our fume hood and naturally were able to avoid major catastrophic errors within the device. On the opposite side of that spectrum, the simplicity of the device also made it rather difficult to come up with a large number of potential failures. We completed a full FMEA and then simplified it into the top ten potential failures based on RPN values. We analyzed our four subsystems and the results are listed as follows in section 3.1 of this report.

4.1 Critical Failures

4.1.1 Potential Critical Failure 1: Abrasive Wear of Worm Drive Clamp

This potential failure within the fume hood relates to the worm drive clamp that holds the hose onto the fume hood itself. This worm drive clamp provides tension and security to the hose to ensure all particulates and epoxy fumes begin to transfer through the filter. If the worm drive were to fail the hose would detach and particulates and fumes would enter the atmosphere in the room. This failure could be caused by a faulty clamp or excessive vibration on the fume hood which would cause the clamp to come loose. This failure would be remedied by ensuring that the clamp is firmly secured and tightened before using the fume hood system.

4.1.2 Potential Critical Failure 2: Electrical Power Loss from Exhauster Plug

This mechanical failure comes from the necessity for electrical power to operate the exhauster fan. If the electrical plug were to be spliced or otherwise compromised the entire operation would come to a halt. Without the necessary electricity the entire device would be inoperable until the electrical plug was either plugged back in or replaced if broken. This failure is mitigated by properly plugging and unplugging the fume hood when necessary and ensuring that the plug does not come into contact with sharp objects.

4.1.3 Potential Critical Failure 3: Abrasive Wear on the HEPA Filter

The HEPA filter that accompanies our device is quite possibly one of the most important pieces of our entire system. The primary goal of the filter is to capture and retain the carbon fiber particulates that are sucked up through the exhaust hose. Without this filter, particulates would enter into the exhauster fan and cause clogging and internal damage to the blower and the inner workings of the exhaust fan. We determined that abrasive wear would cause the most damage within this system. the sharp edges of the particulates would have a tendency to cut the filter and over time we would begin to see larger and larger rips in the filter, which would allow particulates to escape through the filter and into the exhauster fan. This failure can be mitigated by using a durable filter that reduces the risks for ripping and tearing. We also recommend washing and cleaning the filter on a regular basis.

4.1.4 Potential Critical Failure 4: Plastic Deformation of the Filter Slide

The filter slide is a plastic component that acts as a tray for the filter. This plastic tray holds the filter in place at the bottom of the hose, where it meets the fume hood, and can be easily removed by sliding the tray out and away from the system. This tray allows for easy access and removal of the filter for cleaning and replacing. We examined the potential failures of this tray and determined that it would be susceptible to cracking and deformation due to poor care and maintenance. If the tray were to drop or be inserted incorrectly into the system we foresee the plastic cracking. This would be remedied by using a stronger plastic and ensuring that the users are taking care to correctly remove and re-insert the slide into its housing location.

4.1.5 Potential Critical Failure 5: Abrasive Wear of the Ribbed Exhaust Hose

Our exhaust hose is the means of suction for this device. The characteristic parameters of the hose help to determine the flow rate and face velocity from the exhauster to the hood chamber. The longer the hose the less suction efficiency we would see within the fume hood chamber. If particulates were to escape past the filter they could potentially present a problem for the exhaust hose. The sharp particulates could, over time, rip and tear the hose which would result in velocity, pressure, and flow rate losses within the hose. We plan to mitigate this potential problem by ensuring that the filter is securely tightened and operational. We are also looking into exchanging our current 10 foot ribbed plastic coated air ducting for something stronger. We are looking into a smooth walled hose that resists rips and tears and that also eliminates the ribs.

4.1.6 Potential Critical Failure 6: Thermal Fatigue of the Exhauster Fan

The Exhauster fan is the driving force in this capstone project. Without it we would not be able to successfully meet our design ideas and goals. We determined that one of the biggest potential failures in our design had to do with the exhauster fan and the possibility of overheating. We assume that overheating would occur if the device were to run for many hours a day for consecutive days. Overheating the fan would cause major problems for this system. Overheating has a tendency to cause a very minor degree of permanent damage to the system and over time with additional overheating the device would entirely be considered inoperable. To avoid this probable failure we have designs in place to install an arduino relay system that shuts the power to the fan off when it reaches a certain threshold of temperature. The power would remain off until the device cools down to a safe operating temperature. We still need to further test the theory that a similar system already exists within the fan. In the event that there is no override relay system already in place we plan to install and test our arduino relay system.

4.1.7 Potential Critical Failure 7: Galvanic Corrosion of the Hood Chamber

The hood chamber is, in essence, the box that holds all the particulates and carbon fiber pieces that are being worked on at any given time. This chamber has 3 fully enclosed walls with a 4th partial enclosure on the front. This component gives a workable space in which to safely and successfully extract carbon fiber and epoxy fumes and particulates. This biggest failure to note with respect to this hood chamber is Galvanic Corrosion. Galvanic Corrosion is an electrochemical process that involves two or more metals in contact with one another. In this process one metal (Carbon Fiber) erodes the other metal [1]. Since Carbon Fiber is naturally electrically charged it has an increased chance to errode other materials within this corrosion process. If the fume hood were designed out of something that erodes in contact with carbon fiber our system would be compromised. With this corrosion we would allow toxic fumes and particles to escape through the corrosions and into the open atmosphere which defeats the purpose of the entire system. To mitigate this potential failure we determined some alternative materials to design our hood chamber out of. The best carbon fiber friendly materials are titanium with its alloys or stainless steel. The issue of stainless steel is another type of corrosion [1]. Plastics could also be a viable alternative due to their cost and ease of use.

4.1.8 Potential Critical Failure 8: Abrasive Wear of the Exhauster Fan

We were able to identify a couple of different potential failures within the exhauster fan with our current design and system. We determined that the fan and more specifically the internal blower motor to be susceptible to abrasion wear from particulates. We assume that if particulates were to reach the internal components of the fan that they would lodge themselves in inopportune places in the motor. We assume that tiny particles are not intended to penetrate the inner workings of the fan but would cause issues if they were to penetrate into those areas. To mitigate the risk of these particles entering the motor and clogging the system we plan to ensure that the filter is continually operable without tears and rips which would allow particles to bypass the collection in the filter.

4.1.9 Potential Critical Failure 9: Galvanic Corrosion of the Exhauster Fan

Similar to the abrasive wear of the exhauster fan we can assume that Galvanic Corrosion has the potential to occur within the exhauster blower fan as well. In continuation of the previously mentioned failure (3.1.8) we assume that the filter had already failed thus allowing particles to enter into the inner portions of the blower and causing electrochemical corrosion processes in those regions of the device. This would ultimately, over an extended period of time, render the device useless if the inner workings were to corrode away.

4.1.10 Potential Critical Failure 10: Wear of Arduino Unit Relay Apparatus

The arduino unit relay system is a design idea that would prevent the exhauster fan from overheating and causing damage to the system. This relay system holds the power to exhauster off once the internal temperature reaches and exceeds a safe operating temperature that has been previously set forth by our team. However, there is still the possibility for failure within the relay system. Potential failures for this portion of the system would be normal wear and tear of the unit. If the arduino unit were to be dropped or crushed in any manner it would render the overheating system in-operable. The entire system would still be considered operation ready but would be vulnerable to overheating. This apparatus is intended to prevent other potential failures within the system but also must be analyzed for its own potential failures.

4.2 Risks and Trade-offs Analysis

A majority of these parts/functions depend on the success of the filter. If the filter were to fail in any manner it would make the entire system vulnerable to the harmful effects of carbon fiber and epoxy fumes. If failures within the filter were to be successfully mitigated it would also positively affect the mitigations in the other components as well. As such we focused primarily around the filter and came up with the best solution that we could have in order to mitigate potential failures from that point onward. We determined it best to use an Levoit lv-h132-RF HEPA filter that was able to successfully capture and retain all vacuumed particles. This filter is durable and reusable which helps cut recurring costs from the system. We chose to use a PVC plastic for the majority of our materials which help mitigate the potential failures that stem from corrosion. We did not however, have any potential mitigations that made other components harder to accommodate. As stated before, the fume design is rather simplistic in nature and therefore does not demand high risk for any real type of failure. Our final design with our risk mitigated components can be found in the next section of the report.

5 DESIGN SELECTED – First Semester

This section is for discussing the final design that was selected. The discussion is going to cover changes in the design from the preliminary report by using 3D models, air flow calculations and previous research that the team has done. Additionally it will cover the implementation plan for prototyping and creating the final product.

5.1 Design Description

The original design used from the preliminary report was a basic cuboidal shape with an open front. The design was used as a starting platform for the team to work from due to its simplistic shape and ease of changing over the course of the design phase for the project. Since then, the design has had significant changes based on research and air flow calculations. The current design has a rectangular base and sides that transition into a pyramidal top with a short cylindrical pipe at the center allowing for an easy connection point to the extraction tubing. The edges of the design have been rounded to allow for more efficient extraction of the carbon fiber particulates and the epoxy fumes. The front of the design has a small shield to help limit the amount of particulates and fumes from escaping towards the user of the device. The device alongside its dimensions can be seen in figure 5.1.

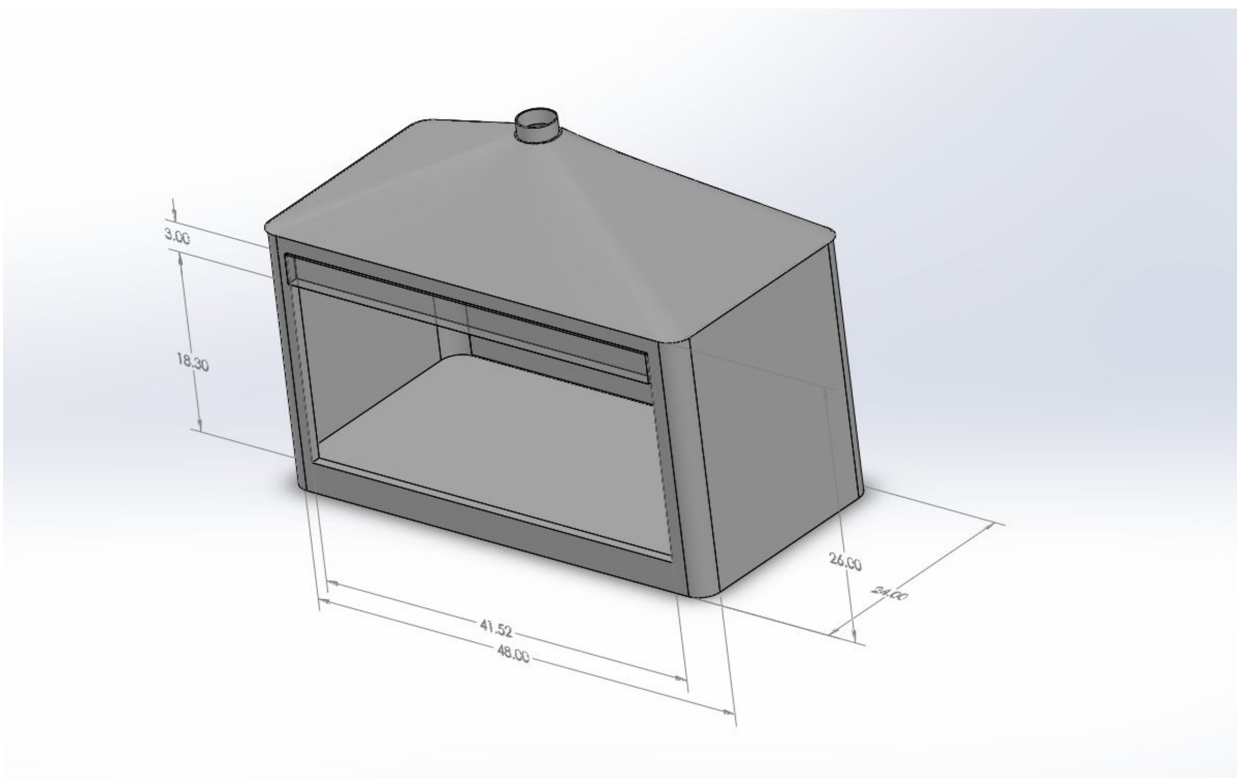

Figure 5.1: Dimensioned 3D model

The air flow calculations done were to make sure that the device would have sufficient airflow moving through the device to remove the carbon fiber particulates and epoxy fumes. Starting from the Volumetric flow rate of the exhaust system the team was able to find that the device is able to meet all of the air flow requirements for removing the particulates and fumes from the working area.

5.2 Implementation Plan

Due to the COVID-19 pandemic and subsequent quarantine, the team was unable to produce a prototype. The implementation plan for the following term now needs to include time for manufacturing a prototype and conducting tests on the prototype along with building and manufacturing the final product. At the start of the next term, the team will spend 2 weeks building a prototype model, as inexpensively as possible, that can be tested for design flaws and additional analysis on the current design. Moving forward from prototyping, the team will be in contact with the client, Dr. Lerner, to gain information on the materials he would like us to use for implementing the final design. Moving forward from this point the team will be working to manufacture the product as efficiently as possible. After the final product has been manufactured, the team will conduct tests on the device to ensure the safety and quality of the product. From this point moving forward the team will work on improving the design based on the tests that were conducted from the initial manufacturing of the product. Afterwards the team will finish testing the product and work with Dr. Lerner to implement the product in the biomechatronics lab. This can be seen from the gantt chart in figure 5.2.

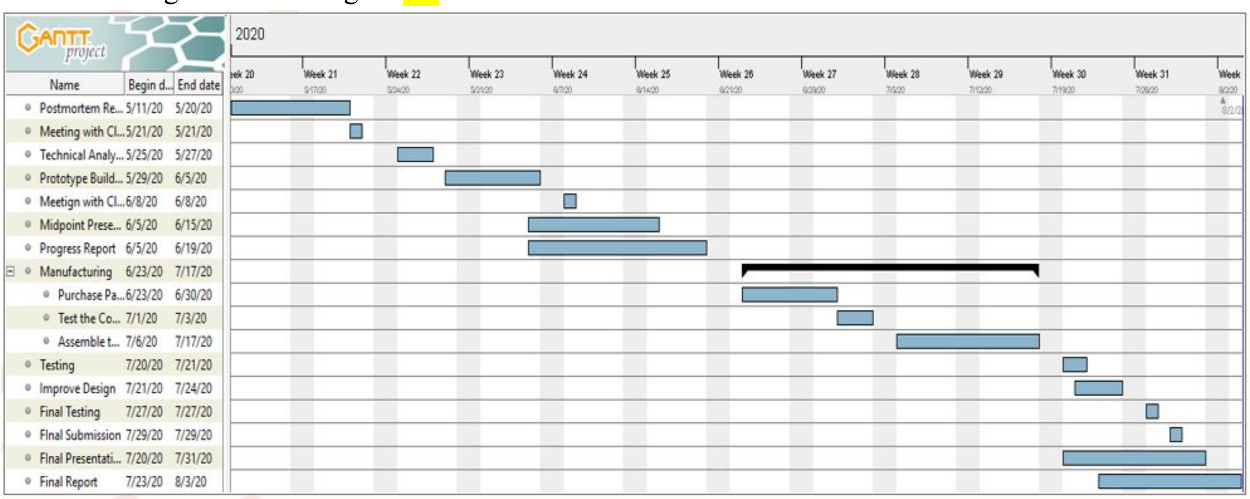

Figure 5.2: Gantt Chart for second Term Capstone

The current 3D model of the design can be seen above in figure 5.1. The drawing for the 3D model can be seen below in figure 5.3.

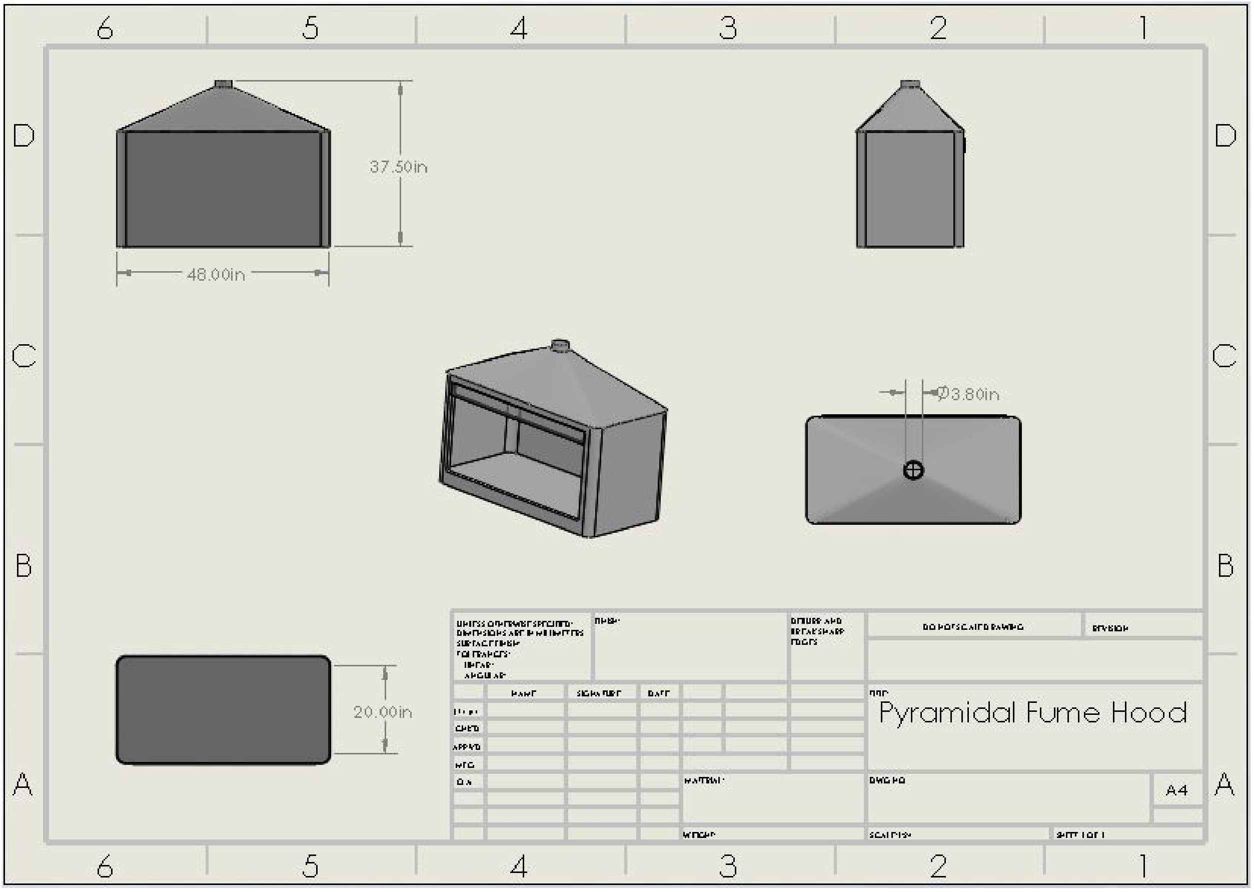

Figure 5.3: Drawing for the 3D model

Lastly the finalized bill of materials for the design can be seen in table 5.1. With the current materials that the team is anticipating purchasing to make the device it gives the team $174 to use on the prototype and any changes that occur during the testing of the prototype and final design.

Table 5.1: Finalized Bill of Materials for the project

Component	Cost per unit ($/unit)	Amount per unit	Total Material Cost	Purchase location
Levoit lv-h132 filter	$30	1	$30	Amazon
Arduino Uno Rev 3	$22.00	1	$22	Store.Arduino.cc
.187x24x96" PVC sheet	$72.48	1	$72.48	eplastics
0187x48x48 PVC Sheet	$72.48	1	$72.48	Eplastics
Buffalo tools dolly 1000lb rated	$18.32	1	$18.32	Home Depot
Pressure transducer	donated		$0	Dr.Trevas
LED Arduino light	$0.26	3	$0.78	Store.Arduino.cc
Photo resistor	$0.95	6	$5.70	Store.Arduino.cc
10 Kohm resistor	$0.036	10	$0.36	Store.Arduino.cc
221-ohm resistor	$0.27	1	$0.27	Store.Arduino.cc
4" worm drive clamps	$1.71	2	$3.42	Home Depot
Total Costs			$226	

6 CONCLUSIONS

In conclusion, a laboratory fume hood is commonly used to eliminate health hazards to those working with dangerous materials. Carbon fiber is a material with many beneficial properties such as its high strength and lightweight properties. Sanding operations are a necessary procedure to shape or manipulate the material into a more useful form. These sanding operations produce particulates and epoxy fumes that have been proven harmful and potentially fatal to individuals exposed to these byproducts. Laboratory Fume Hoods are devices that are specifically designed to eliminate the hazards of working with dangerous materials. The Fume hood designed for this application consists of the fume hood box connected to an exhauster with an attached filter. The fume hood box is the working space where the sanding operations will take place. The exhauster is attached to the top of the fume hood box, drawing the air flow into the exhauster which will be expelled out of the system. The filter is attached to the top of the fume hood box to extract the carbon fiber particles from the air flow before entering the exhauster.

The fume hood system will be tested using colored smoke and woodchips. The smoke and woodchips will simulate the carbon fiber epoxy fumes and particles being produced during sanding operations. Additionally, an Arduino Uno board will be connected as a pressure differential measurement system. The values of the pressure drop across the filter will be displayed to inform the lab when the filter should be replaced. This should ensure the operational safety level of the system. The implementation of our device is impending yet the team should be able to produce an effective CAD model and implementation plan for when COVID ends.

REFERENCES

[1] "Determining Which Fume Hood Design is Right for Your Research Application," 4th March 2018. [Online]. Available: https://www.labmanager.com/lab-health-and-safety/determining-which-fume-hood-design-is-right-for-your-research-application-2370.

[2] C. Manik and P. Jingpeng, "High Performance Low Flow Fume Hood Design," Singapore.

[3] "Lab Design Basics for Fume Hoods," [Online]. Available: https://www.nationallaboratorysales.com/blog/lab-design-basics-for-fume-hoods/.

[4] B. Panjwani and J. E. Olsen, "Design and modelling of dust capturing system in thermally stratified," *Building and Environment,* pp. 1-12, 2019.

[5] S. Pietrowicz, P. Kolasinski and M. Pomorski, "Experimental and numerical flow analysis and," *Chemical Engineering Research and Design,* pp. 1-17, 2018.

Talal's References

[1] C. Shema, "Fume Hood Design for the 21st Century: Workshop Report", available [online], https://acsdchas.files.wordpress.com/2015/03/fume-hood-design-workshop-report1.pdf

[2] Z. Alexander, "Principles of Air and Contaminant Movement Inside And Around Buildings", 2001, available [online], https://www.sciencedirect.com/topics/engineering/hood-design

[3] M. Chandra, "High Performance Low Flow Fume Hood Design", available [online], http://www.escoglobal.com/resources/pdf/high_performance_low_flow_fume_hood_design.pdf

Design Selection References

[4] US Air Purifiers, "How Long Do Air Purifier Filters Last?" https://www.citethisforme.com/cite/journal/autocite

Zach's references

[1] EMW, "Filter Classes According to EN 779 and EN 1822," EMW, [Online]. Available: https://www.emw.de/en/filter-campus/filter-classes.html. [Accessed 5 March 2020].

[2] Environmental Protection Agency, "Air Pollution Control Technology Fact Sheet," [Online]. Available: https://www3.epa.gov/ttncatc1/dir1/ff-hepa.pdf. [Accessed 11 March 2020].

[3] G. Wijbenga, "European Air Filter Test Standard," 14 June 2012. [Online]. Available: https://www.airah.org.au/Content_Files/Divisionmeetingpresentations/QLD/PPQLD_13

-06-2012-GW.pdf. [Accessed 9 March 2020].

[4] American society for testing and materials, "Standard Practice for Sampling and Counting Airborne Fibers, Including Asbestos Fibers, in the Workplace, by Phase Contrast Microscopy (with an Option of Transmission Electron Microscopy)," *Book of Standards,* vol. 11.07, no. ASTM D7201-06(2011), 2006.

[5] Occupational Safety and Health Administration, "Toxic and Hazardous Substances - Cotton Dust," [Online]. Available: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1043. [Accessed 21 February 2020].

Shirley

[1] Dielectric Manufacturing, “Material Properties of Polyethylene (PE) Thermoplastic - Polymer,” *Dielectric Manufacturing*, 20-Jan-2020. [Online]. Available: https://dielectricmfg.com/knowledge-base/polyethylene/. [Accessed: 13-Mar-2020].

[2]“The Definitive Guide to Polypropylene (PP) ” *Polypropylene (PP) Plastic: Types, Properties, Uses & Structure Info*. [Online]. Available: https://omnexus.specialchem.com/selection-guide/polypropylene-pp-plastic. [Accessed: 13-Mar-2020].

[3] “A Complete Guide to Polycarbonate (PC) ” *Polycarbonate (PC) Plastic: Properties, Uses, & Structure - Guide*. [Online]. Available: https://omnexus.specialchem.com/selection-guide/polycarbonate-pc-plastic. [Accessed: 13-Mar-2020].

[4]”1/16 in. x 4 ft. x 8 ft. Plastic Panel-63003,” *The Home Depot*. [Online]. Available: https://www.homedepot.com/p/1-16-in-x-4-ft-x-8-ft-Plastic-Panel-63003/202090190. [Accessed: 14-Mar-2020].

[5] “Suntuf 26 in. x 12 ft. Polycarbonate Roofing Panel in Clear-101699,” *The Home Depot*. [Online]. Available: https://www.homedepot.com/p/Suntuf-26-in-x-12-ft-Polycarbonate-Roofing-Panel-in-Clear-101699/100049922. [Accessed: 14-Mar-2020].

[6] Bossard, "Galvanic Corrosion in Carbon Fiber Materials," 19 December 2014. [Online]. Available: https://provenproductivity.com/galvanic-corrosion-carbon-fiber-materials-2/#. [Accessed 24 April 2020].

[7] OSHA, “Occupational exposure to hazardous chemicals in laboratories,” OSHA, DC, 2012.