Interim Design Report: Prototype Machine for Coating Stabilized Lithium Metal Powder

Team Number: #16 ME/ #18 ECE
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Professors: Dr.Helzer & Dr.Gupta
Advisors: Dh.Shih, Dr.Zheng, & Dr.Frank
Submitted To:
Mechanical Engineering Department

Authors:

Marcos Leon	ml10s
Vannesa Palomo	vp09
John Shaw	jcs09e
Maria Sanchez	ms13
John Magner	jjm10n
Ben 'Bj' Tinsley	bjt11

Team Members:

Vannesa Palomo: Co-Team Leader

Vannesa Palomo is a senior of Mechanical Engineering at FSU/FAMU College of Engineering. She is the co-leader of the prototype machine for coating stabilized lithium metal powder project. Vannesa has minors in mathematics, physics, and hospitality management. She is fluent in four languages: English, Portuguese, Spanish, and Italian.

John Shaw: Co-Team Leader

John Shaw is a senior in the Mechanical Engineering Student at the FSU/FAMU College of Engineering. He is co-Leader of Group #16 and the lead CAD designer. He has interned for a chemical insurance agency, conducting loss control surveys. He has also interned at FI-DE machine, as a intern working under a professional machinist.

Marcos Leon: Treasurer

Marcos Leon is a Senior Mechanical Engineering student at Florida State University with a focus on Mechanics and Materials. Marcos serves as the treasurer of Group 16. He holds membership in the Society of Hispanic Professional Engineers (SHPE), allowing opportunities for networking. His plans are to graduate in May 2015 with my BS and then work in product development.

John Magner: Presentation Leader

John Magner is a senior Electrical Engineering student at Florida State University with minors in Physics and Mathematics. Over previous summers, he has worked as an Electrical Apprentice for Intercostal Electric Inc. in Lake Worth, Florida. In 2014, he interned with Duke Energy in Winter Garden, Florida, in the Power Quality, Reliability, and Integrity department.

Maria Sanchez: Electrical Engineering Liaison

Maria is a Senior in the Electrical Engineering department at the FSU/FAMU College of Engineering. Her title for this project is Electrical Engineering liaison for group #16. She has previously worked in academic research and published a journal article. She has had an internship in the power distribution and management for URS Corporation, contracted at Kennedy Space Center.

Benjamin Tinsley: Webmaster

Benjamin Tinsley is a senior Mechanical Engineering student at FSU. His specialization track is magnet science, however his main interests lie in thermal fluid studies. In 2011, he participated in a pre-engineering internship with the USF's biomedical engineering department where he developed and tested controls for a sailboat designed to enable a paraplegic to command the sailboat individually.

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Abstract—

A formal structured plan to build a Stabilized Lithium Metal Powder (SLMP) coating machine is presented in this report. This project plan outlines the design and analysis, risk and reliability assessments, detailed design and design manufacturing, procurement, communications, environmental safety and ethics, and future work. Using the dry method proposed, SLMP particles will be loaded on top of a copper sheet (electrode), with a loading range of ~0.5-3 mg/cm^2. The goals describe the ideal objectives and properties of uniformly coating the electrode. There are several constraints that need to be meet in order to realize our design. These designs are discussed as function analysis, design concepts, and evolution of design. The functional analysis incorporates both the mechanical and electrical design components that can be implemented and tested. Varying the funnel nozzle size and/or the mesh shape can improve the results of loading the SLMPs. The effectiveness of the design will be determined by addressing the risks and uncertainties. The methodology to implement our design is determined by a schedule of workload and resource allocation. Future work on the project scope is detailed to demonstrate schedule for prototype building.

I. INTRODUCTION

Lithium ion batteries and super-capacitors are the newest frontier of modern day technology. The company FMC Lithium has developed a new stabilized lithium powder that has been tested and proven to improve battery capacity and energy density. Our sponsor, General Capacitors is currently working on implementing this new development on pre-existing lithium-ions batteries and super-capacitors.

A. Objective

The objective of this project is to develop a Stabilized Lithium Metal Powder (SLMP) coated anode electrode. In addition, the investigation of other components in Li-ion batteries and Li-ion super-capacitors will be conducted. These components include conventional carbons (e.g. graphite and hard carbon) and the high specific capacity silicon (Si) and other alloys [1]. A prototype machine that can uniformly coat SLMP on a flat battery electrode is to be developed. The stabilized lithium metal powder (Li/Li_2CO_3) is a relatively new product created by FMC Lithium Corporation. The SLMP particles are a form of lithium metal based on a core/shell concept[4]. The CO_3 reacts with the lithium metal and forms a shell layer on the surface of unexposed lithium metal[4]. According to the safety data sheet for SLMP, exposure to elevated temperatures above the melting point (180.5°C/357°F)[2] as well as contact with humid air, can result in spontaneous ignition The main application of this metal powder is to be used in existing lithium ion batteries. The methodology improves the capacity of the Li-ion battery by 5 to 15% [2]. Another application of the SLMP is in Li-ion super-capacitor to improve the energy density by 2-4 times [2].

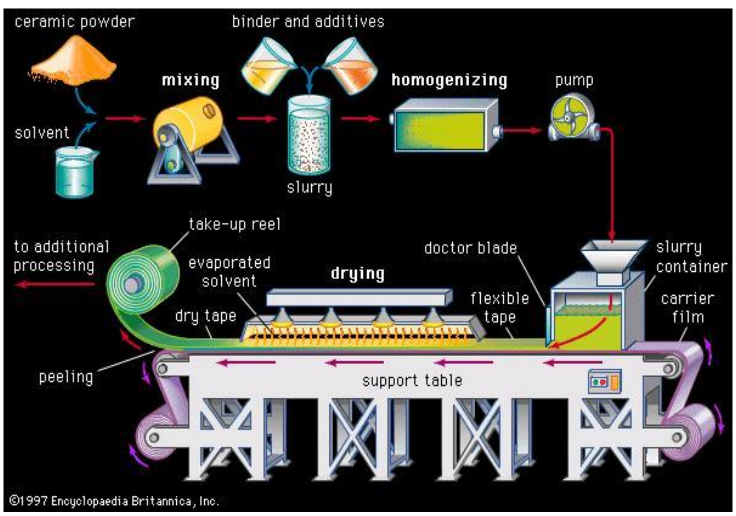


Figure 1. Illustration of a doctoring blade taken from Britannica.

In order to achieve the conditions necessary to result in battery improvement and live longevity, the SLMP should be coated on the anode electrode uniformly. One specification that will be met includes, semi-automatically coating a flat battery electrode with the SLMPs. More specifically, the range for the loading of the SLMPs should be ~0.5-3 mg/cm^2. The uniformity of the coating should be expected to be better than 20% and the coating area of the electrode is variable from 5-12 cm (width) and 5-250 cm (length). The coating time process is expected to be less than ~10 minutes. The hardware for the coating machine is expected to be within a $2,000.00 budget, to furnish the machine with motor, stainless steel plates and rods for the frame.

B. Background

Stabilized Lithium metal powder is a newly developed product, thus the experimentation and search for methods of application have only just begun. There are two main types of dispersion methods available with SLMP, dry dispersion or wet dispersion. As of current the only method that has been attempted is the wet dispersion.

Previous research describes a standard slurry procedure to lithiate electrodes with stabilized lithium metal powder. Various documents describe methods to apply SLMP on to anode electrodes. For example, in the journal of power sources, states the process of adding the SLMP slurry by film casting using a doctor blade [10]. The slurry production process involves the mixing of the SLMP and a solvent to make a homogenous mixture. Then the slurry material is pumped into the slurry container and enters the film casting procedure. A doctor blade, which is the edge of a smooth knife, spreads the slurry onto the anode film. As shown in the Figure.1, the slurry making process, along with an added drying time, makes the whole method long and costly. This process we are suggesting, Dry Method, would require no drying time and no slurry would produce. The SLMPs would be solely loaded onto a copper sheet to form the required electrode. The lithiated electrode could easily be activated by pressing the SLMP and breaking the particle shell [11].

The slurry method shown in Figure.1 consists of a large storage container, which will contain both the SLMP and a solvent that will not react with the SLMP such as Benzene. Since SLMP is very light, it is necessary to vigorously mix the solution to keep it homogenous during this slurry process. This method allows for the solution to be applied to the electrode and then dried which will evaporate the unwanted solvents leaving only the SLMP coated on the electrode.

II. Project Definition

Our approach to the application of SLMP on anodes will be focused on dry dispersion, specifically a surface application method. The advantages of attempting a dry dispersion method are it will be cost effective, will not require the use of harmful or potentially dangerous liquids/solvents, quicker application time, and no dry time period.

A. Need Statement

Group 16 is sponsored by General Capacitors, which is located in Tallahassee, FL. The sponsor is Harry Chen, the chief technology officer at General Capacitor LLC., however our main liaison and advisor is Dr. Zheng whom is their top research engineer and professor at FSU. The current project calls for group 16 to develop a coating machine. This machine will apply a uniform layer of stabilized lithium metal powder to the anode electrode of a Li-ion battery and to a Li-ion super-capacitor. This material and process application is newly developed. So group 16 is researching and developing a mechanism that can be scaled up to a production level. There are other coating machines on the marketplace, however none for this specific type of application. Due to the hazardous nature of the lithium metal powder, group 16 will develop a safe and productive way to meet our mechanisms requirements.

"A coating machine for this specific application is non existent"

B. Goal Statement and Objectives

The goal of this project is to develop an electrode with a uniform coating of stabilized lithium metal powder. To achieve this goal we must be able to reach the following objectives: Uniformity of roughly 20% for a thickness of 150μm, ability to apply a sufficient coat onto the electrode, ability to apply a coat in less than 10 minutes, ability coat electrodes of varying sizes, and a process that is semi-automatic.To execute this process, our intent is to design a prototype machine that will handle the lithium metal powder safely while applying a coat of specified thickness to the surface of a metal sheet that will be later cut into an anode.

C. Project Constraints

A prototype machine for coating copper anodes with stabilized lithium metal powder (SLMP) will be made by May 2015. General Capacitors LLC. is providing the Senior Design group 16 with a budget of $2,000. There are a couple of possible prototypes, every tentative prototype, however, will must meet the constraints listed below. Thorough research on powder metallurgy will be done to be able to understand and reproduce experimentation on the SLMP.

- The budget given by General Capacitors is $2,000
- The lithium powder is to cover the total surface area of the flat battery's anode
    - The anode dimensions will vary from 5-12 cm (width) and 5-25 cm (length)
- Lithium coat must have a uniform layer of 150μm with 20% fluctuation in thickness
- One coating process under 10 minutes
- The metallic lithium content of the powder needs to be at least 98%
- Working with the lithium powder must be done in a dry environment
    - AME dry room is 0.5% humidity
    - Lithium reacts explosively to H_2O

III. Design and Analysis

The designs have been created focusing on a dry dispersion method, specifically a surface application on pre-existing anodes. Each has 3 main steps: dispersion, coating, and pressing. The method used for these may vary from concept to concept.

During this section of the paper detailed calculations and all designs conceptualized will be discussed chronologically from the initiation of the project until the final design selection. The initial designs will be discussed briefly while the final design will be discussed in more detail. Each design will also have a CAD drawing that will show a 3D model of the proposed design.

A. Functional Analysis

1) Mechanical Components

The mechanical components in majority of the system designs will consist of a funnel, a conveyor belt, 3 meshes, and a rolling press system. To disperse the SLMP, there are a few choices of funnels that will be tested to determine the optimum choice. All designs will have a similar entrance area of 300 cm by 300 cm square and similar storage volume (300x300x350 cm^3). The difference is the exit shape, which will either be an oval shape that is 2 cm. wide by 250 cm long or a square shape that has an exit area of 3 cm. wide by 250 cm long. We also will be testing which material will best work for our funnel and will not react or have any adverse effects on the SLMP.

Consistent mass-flow is the critical component to ensure a uniform coating of SLMP. The mass-flow of granular materials through a funnel with a long-slot type orifice can be approximated by:

$$\dot{m} = 1.03\rho\sqrt{g}(L - 1.5d)(B - 1.5d)^{\frac{3}{2}}$$

Eq.1

where, ρ is the density of the granualar material, g is gravitational acceleration, L is the length of the orfice, B the width of the orfice, and d is the diameter of the granular material.

The average diameter of SLMP is about 50 micrometers. We performed the calculation for a 12cm by 3cm orifice and the approximated flowrate is $6.008 \cdot 10^{-8}\,\frac{g}{s}$. The equation used, however, is applicable only for unobstructed flow. Consequently, operating under the assumption that the flow through our mesh will be equavelent to 5% of the unobstructed flow. Therefore the approximated flow rate through a 12x3cm orifice with mesh is $3.004 \cdot 10^{-9}\,\frac{g}{s}$. This value will be used for reference. In the end, the vibrational oscillation frequency will be manipulated experimentally to determine the optimal frequency in order to induce uniform droprate onto the electrode for our particular funnel and meshes.

To coat the anode we will be utilizing meshes to drop down SLMP at a uniform rate. This is done to ensure a constant thickness throughout. The ideal meshes will also require a series of testing. SLMP is a spherical particle with a very small diameter that ranges from 30-60 microns. We will need a series of multiple meshes to control the flow rate of the powder. Possible mesh shapes are square, circular, and diamond all with a mesh range of ~(0.053mm-0.088mm) as seen in figure 6.

Using equation 2, we can narrow down the available options for the meshes. This equation calculates the mesh count, MC, needed for a specific particle size, PS, where tw is the thickness of the mesh's wire.

$$PS = \frac{1}{MC} + tw$$

Eq.2

We determined that the mesh count, MC, will have to be less than or equal to 16.67 assuming a minimum wire thickness of 0.01mm and a particle size of 50 microns.

To press the anode coated with SLMP, our design will include a pressing system. There are some designs, which included a press incorporated in the mechanism. The roller used to move the electrode will have a length of 250 cm and a diameter of 8 cm while empty. However the press roller will have a smaller diameter of ~4 cm. and will have a length of 255 cm to ensure that the entire electrode is being coated and pressed to uniformity. There are other designs that will be coupled with a pre-existing press roller system.

2) Electrical Components

Many components of our coating machine will require power or will need to be controlled. Therefore it is important that we begin with an adequately sized power supply as determined using Table 1.

The design will need to power two motors that are being used to roll the electrode through the coating machine; potential rollers that we are looking into are 80W stepper motors as seen in Figure.2. It will also need to have motors controlling the mechanisms that will determine the flow rate and limit the coating size. The amount of motors and size of these motors are still to be determined but can easily be changed or increased once we begin testing our final design. However, at this time it is likely that we will use two 50W DC motors to control this mechanism.

There will also be six actuators that will be used to vibrate the meshes, which will allow for the SLMP to flow through the meshes when activated. These actuators will consumer roughly 25W each. One of the advantages of the Dura Vibe actuator that we have selected is that it allows for a range of voltage to be applied and the vibration amplitude changes with the voltage, which allows for testing to be done and modifications to be made if the first trial is not successful.

Figure 2. Image of an 80 W stepper motor.

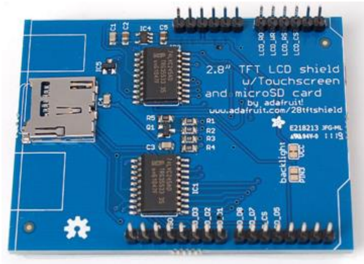


Figure 3. Image of the Arduino MCU that will be utilized.

A MCU will be used as well to control the entire machine and to allow for to user and machine to communicate such that a user can turn the machine on and off and control certain functions such as coating thickness, quality, speed, etc. A MCU controller, as seen in Figure 3, will allow for complete control over the system including all switches, the display screen, the vibrating frequency, and the input/output from the motors and their respective sensors. There will be a 12 key keypad and a two buttons to allow for the user to select the designed coating size and input choices that will be communicated through a 16X2 character display screen. The MCU we are going to use is the Arduino Uno R3, which will allow for a 7-12VDC input via USB or from a power supply. We have decided to go with this MCU because it is relatively inexpensive, there is a large amount of open source code online, and it has 20 different input output ports, which allows for us to control many components at once.
Therefore a 1000W 12V DC Power supply would be sufficient for our design allowing some design changes and room for error without getting overloaded, as seen in figure 4.

Table 1.Tabulation of electrical components and the sum of power needed by the mechanism.

Component Name	Power Needed (W)
2 Conveyor Motors	150
Funnel Motors	100
4 Actuators	100
2 Limit Switches	50
Character Display, MCU, Switches	1
Total	421 Watts

Figure 4. Image of the cosair 1,000 W 12VDC power supply.

B. Design Concepts

In this section of the report, all designs will be discussed to show the progression of concept design along with their advantages and disadvantages. Some parts of each design share similar components so these components will be discussed here. The first component to be discussed will be the funnel displayed in Figure.5. This funnel is essential to our design since it holds the SLMP powder being dispersed onto the anode. This funnel was designed to hold a premium amount of powder to limit the need of refills during the coating process. The funnel's most effective cross-sectional shape will be determined after researching and experimentation, but on this design we will be using one with a large square outlet. The next part that will be discussed is the wire meshes that will be placed below or within the funnel itself, presented below in Figure.6. The wire meshes are even more important than the funnel because it limits the flow rate and speed of the dispersion of the SLMP powder on the anode surface. All designs have a mesh combination of 3 layers of differently shaped meshes, diamonds, squares, and hexagons, which can be seen in, figure 6. Due to the size of the SLMP being <50 micros we have selected meshes that can allow a constant flow rate. This leads us to our decision of testing 0.053 mm - 0.088mesh range. This allows for the passage of 53-88 microns. Since we are only given that the SLMP is <50 microns it will be required to test a variety of mesh sizes to make sure no clogging will occur during the spreading of the SLMP.

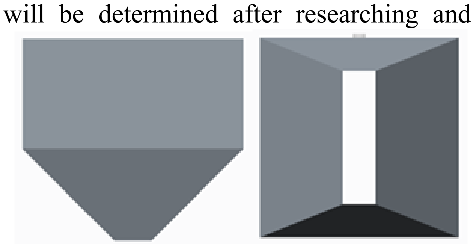


Figure 5. CAD drawing of the design proposed for the funnel.

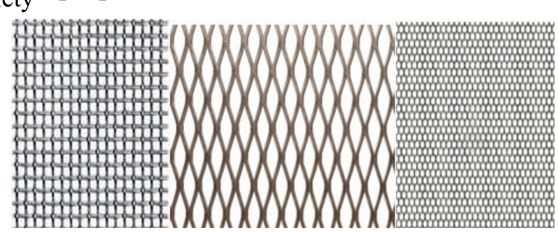


Figure 6. Image of the various meshes under consideration.

1) Design #1:

A copper electrode sheet will be continuously pulled by a conveyor belt. The prototype being created to coat a copper electrode sheet consists of three major parts. The first major part is a funnel dropping the SLMP onto the copper electrode sheet. The SLMP is dropped by shaking the funnel with an actuator. The funnel's nozzle is a controlled cross-section in order to evenly coat the electrode sheet, as seen in figure 7. This funnel uses a series of meshes inside the funnel to help resist the flow rate of the SLMP through the coating process. After the SLMP is sieved through the meshes and the particles dropping downward onto the anode, there is a roller that will lightly press the SLMP onto the electrode sheet to better bond it to the electrode surface. The roller design, found in figure 7, was chosen because it is typically utilized for the fast and constant pressing of sheets. Speed is the primary attribute of the roller. The use of bearings will ensure that the roller can cover a large amount of area in a given time. The roller will start with a minimum load and if need be will be loaded until the precise loading pressure is determined to ensure the SLMP sticks to the anode rather than the roller. Lastly there will be a punch, as depicted in Figure.3 to cut out the desired shape out of the electrode sheet. The punch's head will be interchangeable to vary in length and width depending on what size of anode is being coated. Excess copper and lithium powder will be collected by the base, which acts both as a container and a support for the whole mechanical system. This base is flat with a couple added features to smooth out the coating process. The most noticeable feature being the holes on the side of the plate. These holes will allow for excess SLMP balls to roll off and not affect the pressing of the SLMP onto the anode. Thus allowing for the coating to be uniform throughout the layer of applied SLMP. The next feature you will notice is the two-rod holders at each end. These will both hold a role of the anode material, most likely copper. This will also supply the force to move the material throughout the process by using a motor on the back cylinder roller, the elevated roller. This will pull the roll of anode material through the coating process.

Figure 7. Assembled view of Design #1 in CAD.

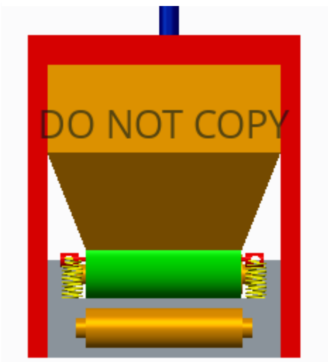


Figure 8. Assembled side view of design #1 in CAD.

This design's advantages are that it will be affordable to construct, that it will be safe for the user to operate, and that it will be simple to operate as well as to repair. Its weakness are that it will consume more power than any of the other designs, that it is not very durable based on the types of components it is made of, and that the roller used to stick the stabilized lithium metal powder onto the electrode wont supply enough pressure to break the carbon coating of the SLMP powder. This roller also has the possibility that it may slip leading to a non-uniform coating.

2) Design #2:

This design is a slight variation of the dry method for coating SLMP onto the electrode sheet, as seen in figure 9 and 10. This design still uses the three main components: funnel, roller, and punch. Instead of fixed position components design #2 uses a slider coupled with the components in order to move the components of the system. The electrode sheet would remain stationary and the components themselves would move over the electrode sheet. Only one component would be used at a time. For instance if the funnel was running then the roller and punch would be stationary at the opposite end of the funnel. The track would have gear teeth and the slider would have gears on bearings in order to move. The sliders have small motors powering the gears. The electrode sheet in design #2 is manually moved, no conveyor belt is used.

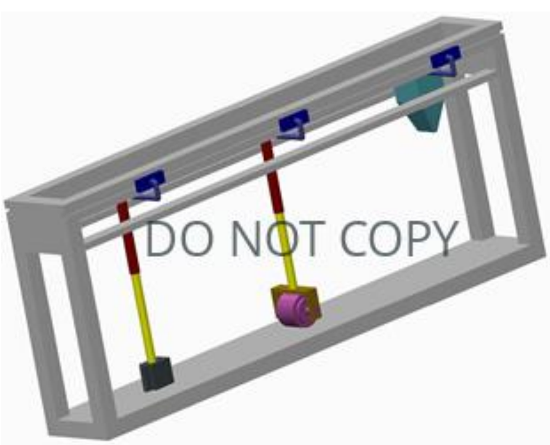


Figure 9. Assembled CAD drawing of the concept proposed for design #2.

As in design #1 a long rectangular funnel is used in design #2. Design 2's components move in a 1-D motion. The funnel needs to be wide enough for the maximum width of the electrode sheet, 12cm, thus the width of the funnel is 14cm. The excess of the SLMP not falling onto the electrode sheet is collected and is deposited back to the SLMP reservoir. The speed of the slider mechanism will constrain what the height of the funnel opening needs to be. If the funnel system is not able to move at a certain speed then the opening of the funnel will need to be narrowed and use a variety of meshes to help resist flow. What will also be needed is a mechanism to close the funnel nozzle when SLMP flow is not needed. The funnel volume will be designed for the number of full applications of SLMP desired in a batch. For example, a full funnel may be able to coat 5 electrode sheets before needing to be refilled.

The roller and punch are both operated by similar coupling mechanisms. They are driven not only by an identical slider mechanism but also an arm coupled with the slider mechanism. This arm is a hydraulic arm and can be extended in order to provide the needed force onto the electrode sheet. The punch will need a more powerful hydraulic arm, making it the only difference.

The roller's job is to break the SLMP beads and create a flat, uniform layer on top of the electrode sheet. The roller's contact with the SLMP means that some of the SLMP could stick onto the roller surface. Accumulation of SLMP on the roller surface causes irregularity of the surface and can then cause uniformity of the SLMP layer to diminish. Lubricant is be dripped on the roller while the roller is running to prevent accumulation of the SLMP. The lubricant comes from a feed through the hydraulic arm.

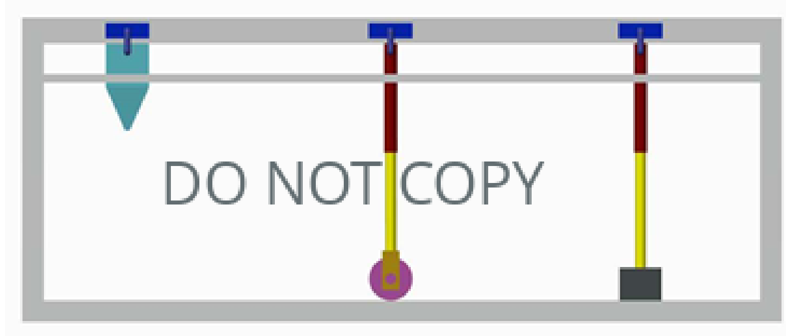


Figure 10. Assembled CAD drawing of the side view of design #4.

A sharp metal puncher is used to cut out the desired shape of the electrode as in the process of design#1. The punch is made from steel and is detachable from the hydraulic arm. By using a punch, production of the electrodes is faster and more efficient than cutting by hand.

This design is safe at a distance. Its components are moving constantly and rapidly, until a process is done and a new electrode sheet is introduced. The design is open and exposed; this means a person close to the machine could be covered with SLMP if not careful. Human fingers will need to avoid the roller and especially the punch. Many parts are needed to build design #2, which drastically increases the cost of the system. The more parts also mean more possibilities of a component breaking driving the maintenance cost higher. Repairs will take longer the more parts there are to a system. The system will be automated and only the movement of the electrode sheet is manual, making design #2 easy to use. Most of the prototype machine will be aluminium and steel. Metal has a high wear coefficient, components will last for many cycles. Power consumption is high for this machine; every component has a small motor. Pumps for the hydraulic arms and lubrication feed all require electrical power. The prototype machine can be easily moved between work sites. Every component can be removed from the system's body for storage or workstation changes. The true drawback is the complexity of using a system that uses a mechanism with three separate moving parts. The cost of this device along with possible repairs makes this design not optimized for our use.

3) Design #3:

This design forgoes complexity and is a simple funnel, drop, and roll system. The funnel is similar to the other designs' funnels however this one is fed onto a ramp at a 45-degree angle with the horizontal in order to add to the feeding process. The ramp includes edges along the sides to prevent SLMP from slipping off the side. The reasoning behind the ramp is hopefully it could improve the consistency of the drop rate of SLMP while also slowing the flow rate of the funnel.. While the SLMP is dropping, a conveyor belt will be moving the electrode at a constant speed into the roller and out the other end. This roller is to be a full roller, ideally with a pressure sensor/actuator to allowing for negligible pressure on the lithium powder to avoid sticking.

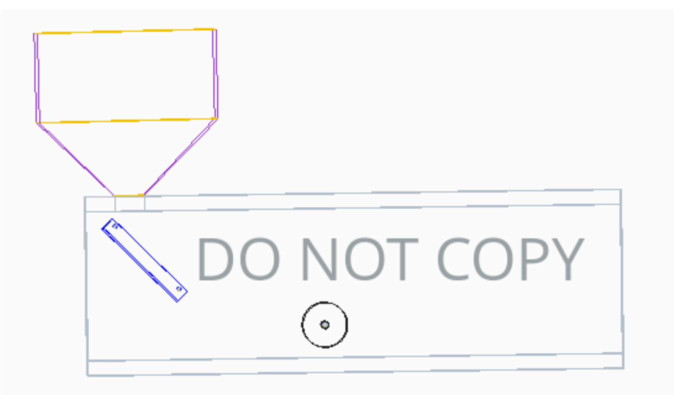


Figure 11. Assembled CAD drawing of design #3, made transparent to show the simplicity of the concept.

The internal structure of the machine is held by horizontal rods of quarter inch diameter. Such a simple structural support was chosen due to its simplicity to interchange and replace internal parts. If, for some reason, down the line we decide to remove the ramp, it is a simple matter of pushing out those associated support rods and perhaps lowering the hopper. As one can see, there is no punching device in the back of the case, which is fairly empty. For this design, the user of the machine would have to manually punch the electrode after coating. The reason the case is not consequently shortened is that the extra length provides some balance to aid in the offset mass caused by the funnel and leaves more room for future additions.

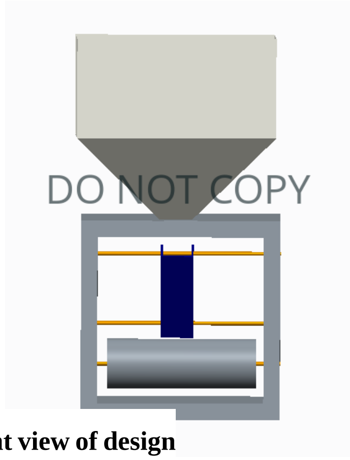


Figure 12. Front view of design #3.

The funnel shape and mesh size are key aspects to this design that will drastically affect the flow rate of the SLMP and, consequently, how evenly the SLMP is coated onto the electrode. For convenience the funnel is shown as a square funnel..

Overall, one can see that this is a very minimalistic or simple approach. There's a lot of room in the case yet, which leaves room for further customization in the future. The advantages of this design are it is inexpensive, easy to make, and further customizable. The disadvantages of this design is that it requires more manual input than the rest of the designs and will likely not be as consistent in the coating process. Another disadvantage is that the whole mechanism is enclosed. While this is beneficial to the safety of the mechanism. It also hinders the accessibility of the components of the mechanism. Hence why this design didn't get off the drawing board.

4) Design #4:

Design #4 is just a modification of design #1. It still has the same funnel, conveyor system, rollers, and press as discussed above. However in this design a dispersion device, called a rotary metering roller, is placed below the funnel, as seen in figure 13. This is similar to that of the propulsion of a riverboat. It is placed with a slight offset so it can collect the falling SLMP without rotating the opposite direction. This ideally would allow the SLMP to be dispersed more evenly thus giving a more uniform coating on the copper anode. A similar contraption can be seen in figure 14 below. However this design is similar to that of a spiral staircase or slide. This would be used instead of the one already placed in the assembly in figure 13. This ideally would also disperse the SLMP more evenly on the anode while also resisting the flow rate of the funnel. This design was deemed not functional after collaborating with our advisors. It was determined that it didn't add any benefits over the use meshes. Also the spiral funnel would collect the SLMP in the center, thus not dispersing the material in the manner desired. They suggested simplifying the design and getting rid of any excess parts that could over complicating our design.

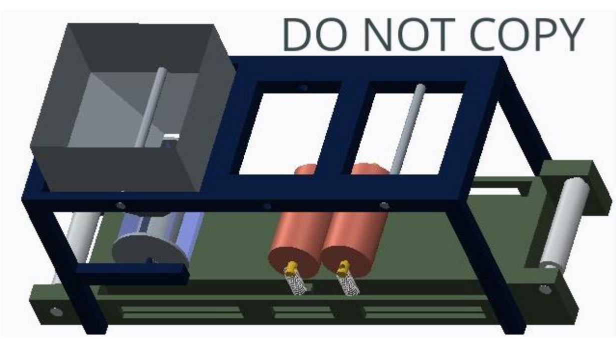


Figure 14. Angled Aerial view of concept #4. This view allows for all components to be visible.

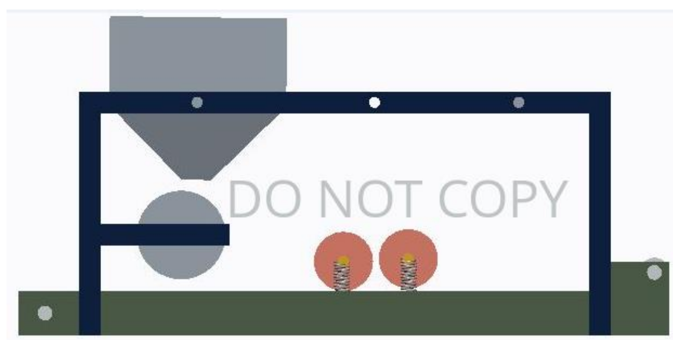


Figure 13. Side view of assembled CAD drawing of concept #4.

5) Design #5:

After consulting with our advisors it was determined that some of the components had to be redesigned to simplify the mechanism, while also building the mechanism as soon as possible. Doing so will allow ample amount of time to test. This is because the ideal set up and performance of the design won't be known until ample testing is conducted. So as result let's discuss the features of our final design.

The first component that will be discussed is the conveyor belt system. This conveyor belt is being out sourced through Dorner Manufacturer, shown in figure 16. Our current selection is precision move conveyor belt. The main reason this particular product was chosen was due its belt material, silicon rubber, and that is reinforced with a polyurethane bed to reduce friction. Silicon rubber is desired due to its nonreactive nature toward the very reactive SLMP powder. This rubber will also prevents slipping thus ideally making a uniform layer of SLMP powder balls before it goes through the press. As you can see above the roller press and punches have been deleted from the design. This was done because the punches are an afterthought since our main purpose is to coat a uniform layer on the copper anode. The roller we designed also wouldn't exhibit enough pressure to break the carbon coating of the SLMP. Thus our advisor, Dr. Zheng, is supplying a press that was can exert the amount of pressure.

Figure 15. Image of MTI corporation electrical 4" wide rolling press with dual micrometer.

This rolling press is the Electric Precision 4" width rolling press with dual micrometers. This press has the ability to exert 500lb/cm^2 of pressure, and is manufactured by MTI Corporation, shown in figure 15.

As seen in the past designs the same funnel and meshes are used, shown in figure 17. However the optimum design will be determined after the testing process is concluded. This essentially means that a variety of shapes and flow rates of funnel along with different mesh size sand shape will be tested intently to find the optimum package for SLMP flow. Another aspect that will be tested will be the location of the meshes. The CAD seen in figure 17 and 18 shows the meshes below the funnel, but the meshes will also be placed inside the funnel and tested. The solutions to the location and sizes of these components will be determined after testing is concluded. Springs are used on the meshes to dampen any vibrations that make effect the frame.

Due to safety concerns exhibited by the use of SLMP plexiglass will be put on the top, back, and front of the frame. This will help protect the operator due to the combustibility of the powder itself. The glass on the top and front will be able to be opened so an operator can adjust the mechanism. The top will especially be used to load more SLMP into the funnel. Both of these opening will have locking features to aid in the safety of the machine. Another safety feature was added to stop the flow of the SLMP completely. It's a plate that will cover the exit of the funnel by using a small motor and a power screw to place the plate in the correct position.

Another feature that is shown in the figures below is the bridge that will move the anode with SLMP powder into the MTI electric precision 4" rolling press.

Figure 16. Image of precision move conveyor belt as fabricated by Dorner Manufacturing.

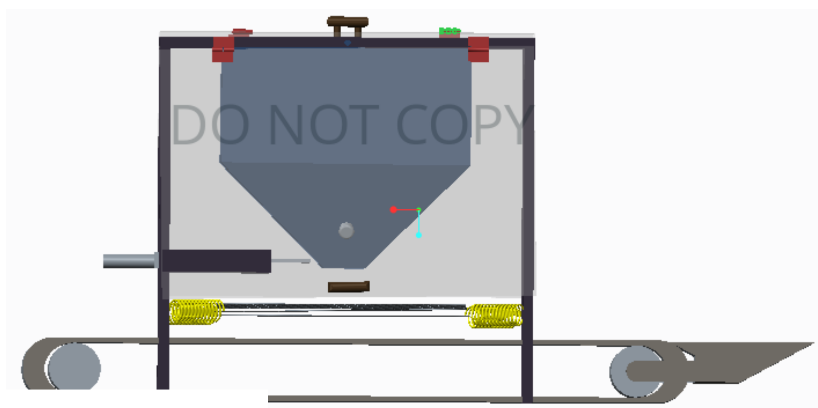


Figure 17. Side view of Assmebled CAD drawing of design #5.

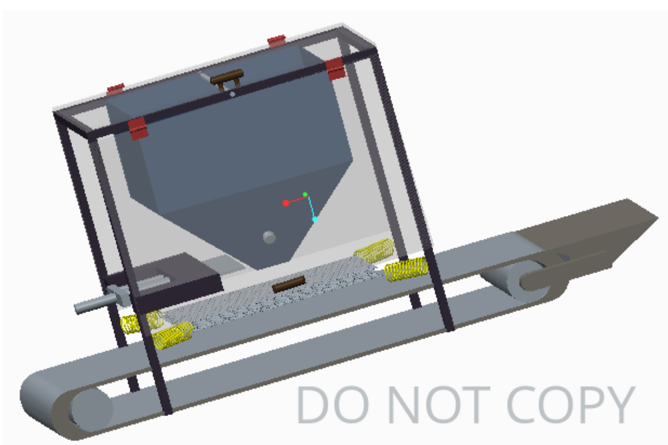


Figure 18. Angled Aerial view of design #5 to show all components incorporated.

C. Evaluation of Design Concepts

Based on the layout, various components, strengths, and weakness of each design as discussed above in section III.B. the design concepts will be given a score of 1-10(10 being the best) in eight different selection criteria. The score is then multiplied by a weight factor determined by the relevance of the selection criteria defined. The design with the best overall weighted total will then be selected as our optimum design. Below in table 2, are the results of our decision matrix comparing our concepts.

Table 2: Decision Matrix used to make a design concept selection. Score is 1-10, 10 being the best. The weight score will determine the best design.

			Design Concepts				
		Weight	Design 1	Design 2	Design 3	Design 4	Design 5
Selection Criteria	Safety	20%	8	6	7	7	9
	Affordability	20%	8	6	10	6	8
	Ease to use	10%	8	7	6	5	9
	Ease of repair	10%	8	5	9	5	9
	Durability	10%	6	7	5	6	6
	Power consumption	5%	6	5	7	7	6
	Portability	5%	7	7	4	8	9
	Powder Dispersion	20%	8	8	6	6	8
Total			59	51	54	50	67
Weighted Total			7.65	6.5	7.15	6.15	8.15

1) Criteria, Method

The selection criteria used to determine the optimum design is divided into eight categories: safety, affordability, ease to use, ease to repair, durability, power consumption, portability, and powder dispersion. These eight criteria are subdivided further into major and minor categories. Each category highlights a specific need in the system's design that will be crucial to a successful concept.

Safety is one of three major categories. Our project revolves around the use of stabilized lithium metal powder, as mentioned above in section I, lithium is an extremely reactive and flammable element that must be handled with the utmost care and attention. Our designs must ensure that that the lithium will not be exposed to humidity or to anything that may cause it to ignite. Our concept must always guarantee the user's wellbeing. Safety has a weight factor of 20%.

Affordability is another major category. Since each project is allocated a specific budget at the beginning of our team assignments, it is necessary to be realistic with each concept. Some ideas will incorporate unique and intrinsic components that require manual labor and a significant amount of money. Although innovation and original design is important and favored, if the concept is out of reach, the concept remains only an idea. Our budget must be able to cover any expense, such as raw materials, payment for labor for machined components, various meshes, funnels, rollers, wires, and a number of electrical components. Affordability will be a major factor in whether a design can be constructed, this criteria has a weight factor of 20%.

Ease to use is how simple a design is to operate for a user. This criterion has a weight factor of 10%. Although ease to use is not what a design is focused on, it is still an important part to be taken into consideration in the selection process. Although we are currently making a prototype machine if we wish for our mechanism is to be used in a fabrication line, its ease of use is a factor that will be needed and expected.

Ease of repair is the category that ranks a design's maintainability. Whether or not a design uses standard parts that can be purchased in bulk for maintenance or if the part has to special order to be fabricated. The weight factor for ease of repair is 10%.

Durability is directly related to the precedent category ease of repair. This category ranks a concept's cyclic life, thus its weight factor is 10%. Our customer expects a machine that will function for a reasonable period of time before any issues arise. Our concepts must be well thought out to ensure that it will function properly each cycle as well as a certain cycle life.

Power consumption is a necessary criterion to know how much power will be needed to sustain our prototype machine's operations. Each design has different components that will rely on certain electrical devices that will need power to run. This category clearly shows which designs will require more power supplies, thus essentially cost more to operate. This criterion has a weight factor of 5%.

Portability is another minor category. This ranks the design's ability to be moved as well as its relative weight. A design's portability is not crucial in the prototype stage, but if the design is to be mass-produced it can be an issue. Portability has a weight factor of 5% as of current, but in subsequent stages of fabrication this may change.

The last selection criteria is powder dispersion, this is the third major category. Our project is centered on the ability of our mechanism producing a layer of stabilized lithium metal powder onto an anode. The ability of a design to disperse this lithium metal powder is critical to our goal. If a design is unable to disperse an acceptable amount of lithium then the design is essential deemed a failed design. This criterion has a weight factor of 20%.

2) Selection of Optimum

Table 3: This table shows the ranking of each design with their weighted totals.

Concept Selection		
Design Concept	Ranking	Weighted Total
Design #1	2nd	7.65
Design #2	4th	6.5
Design #3	3rd	7.15
Design #4	5th	6.15
Design #5	1st	8.15

Based on the result from the decision matrix in table 3, the optimum selection was determined to be design #5. It was scored a nine in safety; this is based on the fact that this design was sized to be operated within dry room to ensure user safety. Also the frame design in this specific concept captured excess SLMP particles within the plexiglass encasing so that the user would not be under the risk of inhaling or ingesting SLMP. In the criteria of affordability the design received a score of eight. The overall cost of this design has been estimated to be within our general budget thus can be considered as our optimum choice in terms of affordability. For the criterion of ease to use, the design was given a score of nine. It will be directly controlled using the MCU controller, discussed in section III.A.2, that will allow for any input necessary to operate the machine. In terms of ease of repair, the design received a score of nine. Most of parts that are necessary to construct this mechanism are standard parts that can be store bought and are available at a number of locations. This directly correlates to the scored given for durability, six. Although this mechanism uses standard part it is not indestructible, meshes can be easily broken a motor can burnout after being in operation for such long periods of time. This design was determined to have a score of six in power consumption due to the number of motors and electrical components that will be necessary to power the machine. For portability this design received a nine. It is sized to be used within a dry room, thus it is relatively compact and will be easy to transport. In the final criterion, powder dispersion, the design scored eight. The total of the design was determined to be 67. Its weighted total was determined to be an 8.15 out of 10.

This design scored highly in the selection criteria of: safety, affordability, ease to use, ease of repair, portability, and powder dispersion. Although it did not score as well in durability and power consumption, we determined that this design concept was the most reasonable selection. It is an economical design that will keep the user safe during the coating process. The fact that it has a large projected use of power is outweighed by the fact that it is simple to operate and quick to repair outweigh its repair that means that it can be fixed quickly without any major damage to operation timelines.

D. Programming needs and Controls

We have decided to use the Arduino UNO R3 as our MCU in this project. This micro-controller will allows us to control all elements of our project. However we need to program this controller to tell it what we want it to do. Arduino is open source meaning that there is a large amount of sample code online that we can use as a reference. Even though there are a lot of resources we will still have a relatively large amount of programming to do in order to make our machine semi-automated. We will need to start by initializing all variables and then waiting for the on/off switch to be flipped on. Once on we will print a message on the screen such as "enter coating length" and the program will wait for an input. Once the user enters their desired length the program will print, "enter coating width" and wait for an input. Once length and width is inputted the program will then communicate with the machine the machine will then prepare to coat the user's desired length. Once the MCU detects that the machine is ready to coat the MCU will tell the conveyor belt to begin turning. A limit sensor will be turned on and will measure the length of the electrode and the program will then check to see if these values match. If they do not match the machine will stop moving and ask the user to re-enter their desired coating length. Once the machine verifies that the electrode is the correct length the machine will continue to turn the conveyor belt for a specified time until the electrode is under the outlet of the funnel. Once this time has passed and the electrode is under the funnel the program will turn on the actuators and open the outlet of the funnel allowing for the SLMP to flow. At this point the program will enter a loop where it control the conveyor belt to move it forward the length of the electrode and then move it back the same length 5 times. Once this process has been done 5 times the outlet of the funnel will then be and the actuators will be turned off. The MCU will continue to send the electrode down the conveyor belt for a specified time and then will stop and enter a "standby" mode. In this "standby" mode the MCU will then wait for another command such as the user asking to coat another electrode by pressing the proceed button or will wait until the on/off switch is flipped, turning off the machine. Another feature that our program will include is the ability to be turned off at any point of the process. By constantly checking the on/off switch and analysing feedback from sensors will allow for the program to be powered down at any time if an error happens to occur.

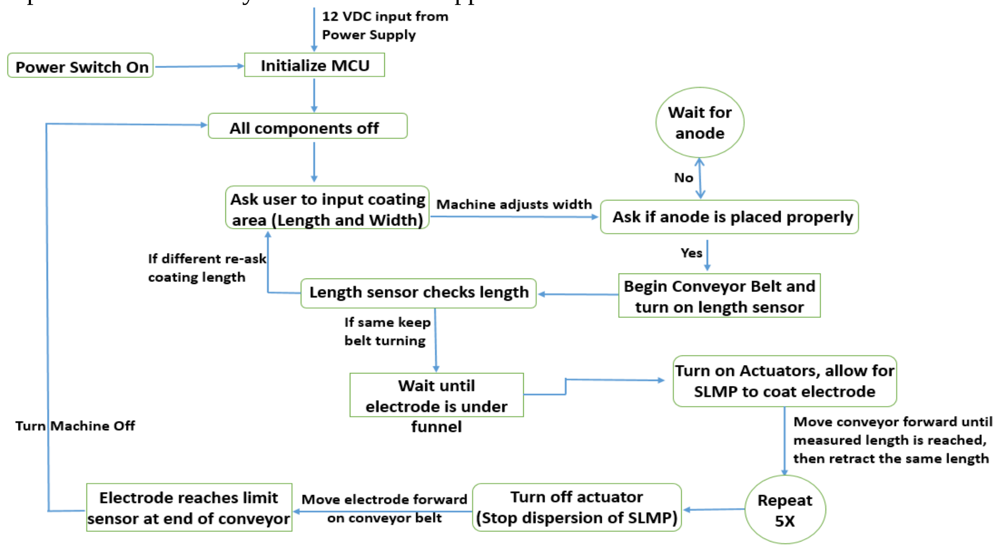


Figure 19: Flow chart of logic behind MCU Controller.

IV. Risk and reliability Assessment

Stabilized lithium metal powder is inherently reactive and could combust under many circumstances. Exposure to water will cause a violent reaction and must be avoided. Consequently, all handling of SLMP must be conducted inside of a dry room with specialized low moisture levels. Time within the dry room must be limited to avoid dehydration. In the case of combustion, the resulting flame must be extinguished using specific means; the fire can be extinguished using a copper powder, graphite, or preferably a Lith-X fire hydrant.

SLMP is extremely light and easily scattered. Consequently, while handling SLMP, all members in the dry room must be equipped with safety goggles and face masks. SLMP is harmful if inhaled or ingested. Additionally, side panels made of plexiglass will be installed to the frame to avoid scattering SLMP into the surrounding area.

In order to avoid the case of static build up and the consequential combustion, all electrical components will be grounded. In the event of a machine malfunction there will be a manual kill switch to cease all operation. Additionally feedback sensors will shut off the machine if an error is detected.

V. Final Design

Based on the criterion discussed above in section III.C.1 and III.C.2, the best overall design choice was design #5. This design was concluded to be the safest, easiest to repair, and easiest to use. It encompassed components that would fulfil all of the necessary objectives: dispersion, coating, and pressing. Design #5 consists of a stainless steel frame that is enclosed by a plexiglass casing to ensure that the SLMP will not harm the user. Within the center of this frame, a funnel will be hanging down from a shaft. The funnel will be loaded with a sufficient amount SLMP for one anode. With actuators along the outlet of the funnel, the SLMP will be vibrated toward the exit of the funnel and through a series of meshes placed directly below the outlet. There will a series of 3 different meshes to control the flow rate and dispersion area of the SLMP onto the anode. Actuators of varying frequencies will also be placed on these meshes to further control the flow rate. Once the SLMP has dropped on the anode below, the conveyor belt on which the anode is situated on will roll the coated anode onto a flap that will feed into an electric roller press. The press will then exert a force of 500 lb/cm^2 on the anode, activating the carbon lithiate coat on the SLMP finalizing the coating process. The manner in which the design has been configured also allows for modifications if it is deemed necessary after initial testing.

VI. Detailed design and design for Manufacturing

Most of the components for the SLMP coating machine are off-the-shelf parts that will be ordered through an online distributor. This will save time and energy in the design process. The hopper will be bought itself, but an adjustable plate will be custom built to adjust and close the opening of the hopper. The plate will be made from aluminium sheet, but a power screw will extend and retract the plate itself. The frame of the coating machine will be made from aluminium square tubing. This aluminium square tubing will be cut and welded to the open rectangular box shape desired. A flap also made from aluminium sheet will be made for the purpose of feeding the anodes into the press machine. All the cutting and welding of the aluminium sheets and tubing will be handled by the machine shop at FAMU-FSU College of Engineering. Holes will be drilled in the frame to be able to attach major components of the coating machine such as: the hopper, springs of the meshes, plexiglass, hinges, and adjustable plate.

VII. PROCUREMENT

A. Purchase orders and machining

Six components of the coating machine have been ordered as of the first week of December 2014. The square aluminium tubing of the custom frame has been ordered. A kilogram of microcarbon beads, which have similar surface properties of the stabilized lithium metal powder, have been ordered. Dorner has been contacted and an estimate of the conveyor belt is on its way. Micromeshes have been ordered. The microcontroller that will communicate with the electrical components of the coating machine is in possession of the group. Dr. Zheng has provided the group with a press machine with sufficient accuracy and power to coat the anodes with SLMP. All parts and details of the already ordered components are seen below in Table 4.

Table 4: Compilation of components ordered thus far

Component	Item	Distributor	Unit Cost	Quantity	Total Cost
Frame	Aluminium 6061-T6 Extruded Square Tube 2.5" x 0.25"	Online Metals	$178.13	1	$178.13
Powder	Microcarbon Beads	Gelon	$35	1	$35
Conveyor Belt	1X Series Line	Dorner	TBD	1	TBD
Meshes	Micro-mesh	Component Supply	$20	3	$60
Microcontroller Board	Arduino Uno R3 - MCU	Arduino	$29.95	1	$29.95
Press Machine	MR-100A	Sponsor	Donated	1	$0.00
Cost to date:					$303.08
Total Budget					$2000
Budget Remaining					$1696.92

A detailed list of the components needed to build the prototype of the lithium coating machine will be made during the Christmas break. All the components will be ordered as soon as possible to be able to start building the prototype during the first week of January 2015. As many off-the-shelf components will be ordered to not waste time and energy to design the necessary components, as per the design of manufacturing guidelines [5]. Shipping time will be crucial to the build and desired progress of the coating machine. Closer, yet more expensive, distributors may be needed to be used if time is of the essence.

The machine shops at the FAMU-FSU College of Engineering will be used to cut and weld the aluminium square tubing. To be determined holes will be drilled in the frame to be able to attach the main components such as the funnel and plexiglass walls. The flap to feed the anodes into the press machine will be built in the machine shops as well. Aluminium sheets will be used to make the flap that will be attached to the end of the conveyer belt. Machining time will be allocated by the use of appointments with the machinists at the machine shops. Further adjustments to the frame will be handled in the machine shops if needed. Testing of the built prototype will occur in the dry room of the AME building.

VIII. COMMUNICATIONS

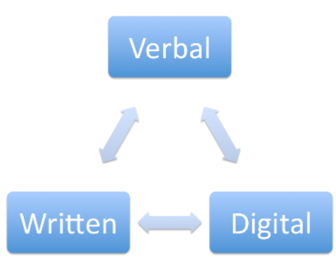


Figure 20. Foundation for an effective communications system within a team

By setting up a clear communication system within our team protocol, we have effectively set working inner dynamics and processes for our project. We have and are continuing to develop interpersonal skills in coping with project problem solving. Verbal communication is of key importance to create a clear path of the end goal of the team project, as seen in Figure.20. This sets the stage for an effective team with the following skills: group effort of all members, clear goals, focus on learning, mutual trust and support, open communication and a democratic process. Verbal communication defines the tasks/objectives to be achieved in a work plan. Every has a role to play for each individual part of project deliverables, as tasks are identified and assigned to group members. The next line of effective communication: written documentation on paper, Word docs, PowerPoint, Excel, etc. This portion takes effect in developing technical knowledge that can include: doing calculations, drawing graphs/tables, preparing designs, and analysing data. This helps with preparation and organization of idea and goals. Plans are drawn out to progress with the project deliverables, by creating timelines and schedules, and communicated to each individual member. The nest step to close the triangle of effective communication within a team dynamic is to set up digital communication systems. For example, but not limited to: email, text messaging, and online programs. Email is used to effectively communicate with group members and sponsors, advisers and mentors. Wiggio.com is an online toolkit that facilitates working in groups. This website allows for keeping a shared calendar, sending mass group emails, and uploading/ relevant documents files. The group can set up meeting polls to plan events, meeting, and deliverable due dates. Google Docs is a web-based word processor allows team members to simultaneously work and access documents anywhere and at any time.

IX. Environmental and Safety Issues and Ethics

A. Environmental Effects of Lithium

Lithium is an alkali metal that easily reacts with water and does not occur freely in nature. "Lithium is moderately abundant element and it is present in the earth crust in 65 pmm (parts per million)" [13]. Lithium metal has the potential to react with various components in airs, nitrogen, oxygen and water vapor. Lithium can react violently in an exothermal reaction with water to form lithium hydroxide. According to lenntech.com, Lithium in water falls under water hazard class 1. Meaning that lithium in water is not a very big threat to flora and fauna, nor on the mainland but the hydroxide ion may affect the pH of water. Lithium is said to be easily absorbed by plants, some reaching 30 pmm in some plants, acting like a growth stimulant [13]. The range at which normal absorption occurs of lithiated plants is between 0.2 and 30 pmm. A hazardous characteristic of lithium in the environment is demonstrated in its corrosive properties. Corrosive fumes of lithium oxide can be released upon reaction [10].

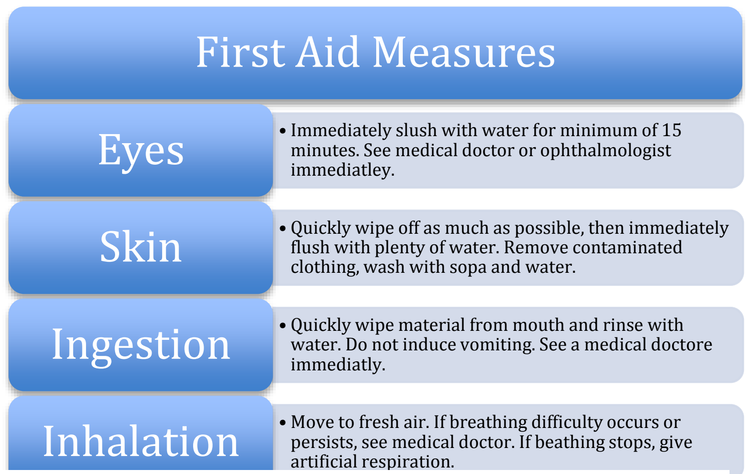


Figure 21. First aid measures to enact in case of bodily exposure.[4]

B. General Safety Issues

Toxicological reports state that lithium is not carcinogenic and not mutagenic/Genotoxic. According to the Globally Harmonized System of Classification and Labelling of Chemicals, Lithium is classified Category 1B skin corrosive and class 4.3 dangerous when wet classification [4]. Meaning, lithium is extremely reactive with body moisture, corrosive to skin, nose, stomach, eyes, highly flammable, and corrosive.

Therefore proper handling of SLMP is necessary to maintain safety. SLMP should only be handled by trained professionals. This means wearing the appropriate personal protective equipment (PPE) like, safety glasses for solid lithium, full flame-resistance face shield and clothing, rubber gloves. Laboratory facilities should be equipped with quick-drench eyewash stations and safety showers. In case of bodily contact with lithium the following guidelines should be followed from figure 20. Proper storage of lithium materials should be followed for safety hazard regulations. SLMP must be stored in a cool, dry location, before opening the shipping container. Once the container is open, it is most suitable to store the material under argon gas, in a dry room or under mineral oil [4]. A water fire-suppression system should not under any circumstances be used in the storage area of lithium. Containers with lithium material should be kept away from water, humid air, acids, heat, sparks, flames and oxidizing materials. Waste containing lithium metal, is required to be properly disposed of. This should be done by contacting a reputable licensed hazardous waste disposal facility. Extinguishers for lithium only should be used, for example, graphite, copper powder, and Lith-X (Ansul) [4].

C. Ethics

Ethics are the standards of conduct set up to describe the appropriate or expected behaviour in a field of study. In research, there are several established organizations with sets of ethical rules and regulations for professionals, for example, the IEEE code of ethics or the National Society of Professional Engineers (NSPE) code of ethics. It is stated, in the NSPE code of ethics "engineers are expected to exhibit the highest standards of honesty and integrity" [3]. A person who enters a profession acquires ethical obligations because society trusts them to provide valuable goods and services with specific conduct to certain standards. For example, it would be unethical to improperly dispose of SLMP into the environment. When conducting research, one is responsible on how that research and its entirety might affects society and/or the environment.

The project team has weekly meetings to discuss future plans and the course of actions that will be taken to further the progress of the project. During these meetings, any team member has the opportunity to voice their opinions or concerns regarding the course of the project and any ethical matters that maybe attached to them. To be a good engineer throughout the course of this project we will adhere to the morals and duties expected of an engineer according to the NSPE code of ethics as well as the team's own ethical standards.

X. Future plans for prototype and others

This project's goal is to have a working prototype machine that can effectively coat a pre-existing anode. Once the mechanism has been successfully manufactured and assembled, intense rounds of experimentation will begin. As mentioned above in section III, to properly identify the correct combination of meshes our team will be testing various open area percentages and varying mesh counts. We will also make our final selection on the shape of the funnel through experimentation. Once all of the components have been selected for the optimum results, we will begin to focus on scaling up our design. Our prototype is the first constructed mechanism for SLMP surface applications.

XI. Project managament

The design process and construction of the prototype machine will require a vast amount of research, manufacturing, construction, testing, and analysis. This overall process with take a significant amount of time and as such will need to broken down into tasks and mile stones. Our schedule breakdown can be found below in section X.A along with figures and tables with further explanation.

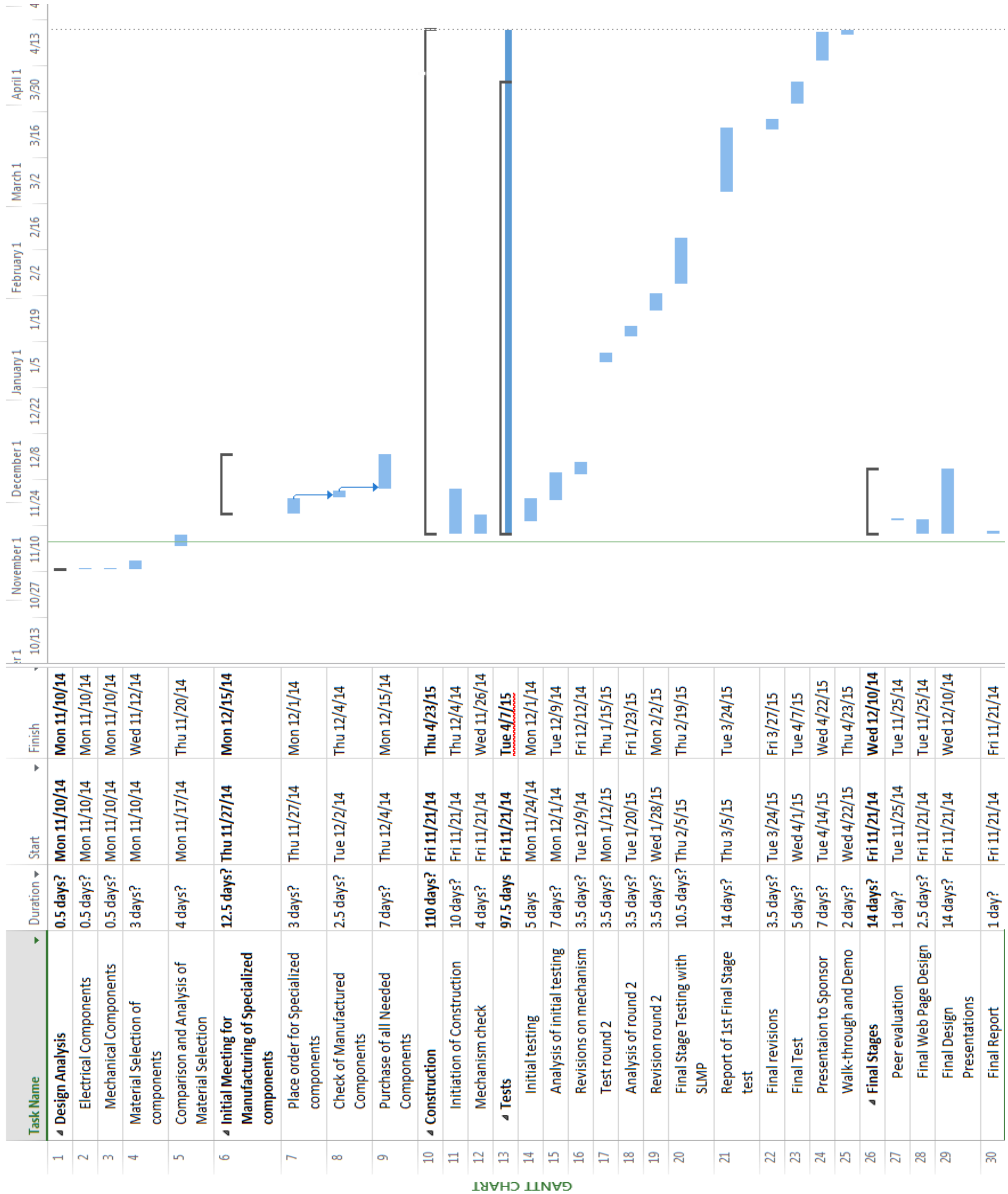
Another portion of our project that will need to planned out and scheduled will be programming of certain components and user interfaces. Our prototype machine will have a programmable logic controller that will be utilized to allow a user to input the desired values.

A. Schedule

To properly develop a prototype machine that will uniformly coat an electrode with stabilized lithium metal powder a strict schedule must be adhered to. Below in figure 22 is a breakdown of all of the tasks and milestones required to fulfil our goal. Many of the tasks will be dependent on precedent work, while others will grow upon one another from this point forward. Typically major tasks will be given a 7-day period for completion. For Milestones the time period can range from a 14-day to 30-day period. The time limit assigned is based on the amount of research, analysis, and labor that we as a team have deemed necessary for each task.

1) Gantt chart

A detailed Gannt chart can be found on the next page in figure 22.



	Task Name	Duration	Start	Finish
1	**Design Analysis**	**0.5 days?**	**Mon 11/10/14**	**Mon 11/10/14**
2	Electrical Components	0.5 days?	Mon 11/10/14	Mon 11/10/14
3	Mechanical Components	0.5 days?	Mon 11/10/14	Mon 11/10/14
4	Material Selection of components	3 days?	Mon 11/10/14	Wed 11/12/14
5	Comparison and Analysis of Material Selection	4 days?	Mon 11/17/14	Thu 11/20/14
6	**Initial Meeting for Manufacturing of Specialized components**	**12.5 days?**	**Thu 11/27/14**	**Mon 12/15/14**
7	Place order for Specialized components	3 days?	Thu 11/27/14	Mon 12/1/14
8	Check of Manufactured Components	2.5 days?	Tue 12/2/14	Thu 12/4/14
9	Purchase of all Needed Components	7 days?	Thu 12/4/14	Mon 12/15/14
10	**Construction**	**110 days?**	**Fri 11/21/14**	**Thu 4/23/15**
11	Initiation of Construction	10 days?	Fri 11/21/14	Thu 12/4/14
12	Mechanism check	4 days?	Fri 11/21/14	Wed 11/26/14
13	**Tests**	**97.5 days**	**Fri 11/21/14**	**Tue 4/7/15**
14	Initial testing	5 days	Mon 11/24/14	Mon 12/1/14
15	Analysis of initial testing	7 days?	Mon 12/1/14	Tue 12/9/14
16	Revisions on mechanism	3.5 days?	Tue 12/9/14	Fri 12/12/14
17	Test round 2	3.5 days?	Mon 1/12/15	Thu 1/15/15
18	Analysis of round 2	3.5 days?	Tue 1/20/15	Fri 1/23/15
19	Revision round 2	3.5 days?	Wed 1/28/15	Mon 2/2/15
20	Final Stage Testing with SLMP	10.5 days?	Thu 2/5/15	Thu 2/19/15
21	Report of 1st Final Stage test	14 days?	Thu 3/5/15	Tue 3/24/15
22	Final revisions	3.5 days?	Tue 3/24/15	Fri 3/27/15
23	Final Test	5 days?	Wed 4/1/15	Tue 4/7/15
24	Presentaion to Sponsor	7 days?	Tue 4/14/15	Wed 4/22/15
25	Walk-through and Demo	2 days?	Wed 4/22/15	Thu 4/23/15
26	**Final Stages**	**14 days?**	**Fri 11/21/14**	**Wed 12/10/14**
27	Peer evaluation	1 day?	Tue 11/25/14	Tue 11/25/14
28	Final Web Page Design	2.5 days?	Fri 11/21/14	Tue 11/25/14
29	Final Design Presentations	14 days?	Fri 11/21/14	Wed 12/10/14
30	Final Report	1 day?	Fri 11/21/14	Fri 11/21/14

Figure 22. Gantt chart showing the milestone tasks that will be completed throughout the process of the project

B. Resources

Resource Allocation has been divided amongst the team equally. Each member will be required to put in a minimum of 1,000 hours of work into this project. These hours are divided throughout the year as to minimize the burden on the team. Each team member will have time to rest in between assigned tasks to be fair and to ensure efficiency and productivity. The detailed division of labor can be found below in Table 5.

Table 5: Shows the Resource Allocation of all tasks/milestones of the project. It shows which members are responsible for what tasks as well as the amount of time allotted for each task.

		Team Members					
Task/ Milestone	Hours/Days to Need Complete	Marcos Leon	John Magner	Vannesa Palomo	Maria Sanchez	John Shaw	Benjamin Tinsley
Design Compliation	16 Days	X	X	X	X	X	X
Review of Design with Advisor and sponsor	1 day			X		X	
Project Plans and Product Specs	9 days	X	X	X	X	X	X
Midterm Presentation	8 days	X			X	X	
Web Page Design	27 days						X
Midterm Report	13 days	X	X	X	X	X	X
Midterm Presentation 2	13 days		X	X			X
Design Analysis- Electrical Components	3 days		X		X		
Design Analysis- Mechanical Components	3 days					X	X
Material Selection of components	3 days	X		X			
Comparison and Analysis of Material Selection	4 days		X		X		
Place order for Specialized components	3 days	X				X	
Check of Manufactured Components	2.875 days			X	X		
Purchase of all Needed Components	8.5 days	X					
Initiation of Construction	10 days	X	X	X	X	X	X
Mechanism check	4 days		X			X	
Initial testing	5 days			X	X		
Analysis of initial testing	7 days		X				X
Revisions on mechanism	3.875 days	X				X	
Test round 2	3.875 days				X		X
Analysis of round 2	3.875 days		X	X			
Revision round 2	3.875 days	X				X	
Final Stage Testing with SLMP	10.875 days			X	X		
Report of 1st Final Stage test	14 days	X	X	X	X	X	X
Final revisions	4 days	X	X				
Final Test	5 days			X			X
Presentation to Sponsor	7 days	X	X	X	X	X	X
Walk-through and Demo	2 days	X	X	X	X	X	X
Peer evaluation	1 day	X	X	X	X	X	X
Final Web Page Design	14 days						X
Final Design Presentations	14 days	X	X	X	X	X	X
Final Report	14 days	X	X	X	X	X	X
Number of tasks to Complete		17	17	18	17	17	17
Total Amount Time Spent on Task/Milestone		1,096Hours	1,077Hours	1,139Hours	1,107.4 Hours	1,020.4 Hours	1,215 Hours

C. Budget

The allotted budget for this project, as given to our team by General Capacitors LLC Inc., is $2,000 USD. A detailed breakdown of components, prices, and quantities, can be found below in table 6. As of current, we have allocated roughly 59% of our budget as corresponding to our final design choice, design #5.

Table 6: Budget breakdown with component name, quantity, price per unit, and total price.

Components	Quantity	Price per unit	Total Price
Arduino Uno R3- MCU	1	$29.95	$29.95
Conveyor Motor	2	$13.98	$27.96
Limit Switch	2	$65.00	$130.00
Adjusting Motors	2	$10.00	$20.00
Switch	1	$1.00	$1.00
1000 W Power Supply	1	$200.00	$200.00
Conveyor Belt	1	$15.00	$15.00
Wiring/ Connectors	1	$35.00	$35.00
14 GA. Stainless Steel Sheet (4 x 8 ft.)	1	$200.00	$200.00
Table for Conveyor Belt	1	$100.00	$100.00
Trough Funnel	1	$40.00	$40.00
Meshes	3	$20.00	$60.00
Actuator	2	$15.00	$30.00
Hinges	4	$4.00	$16.00
Plexiglass	2	$25.00	$50.00
Vibration Damper	4	$9.00	$36.00
Character Display	1	$5.00	$5.00
Keypad	1	$6.00	$6.00
Input Button	2	$2.00	$4.00
Powder beads	1	$25.00	$25.00
Cost		$1,030.91	
Total Cost		$1,185.55	
Total Budget Given		$2,000.00	
Percentage of Budget Spent		59%	

XII. Conclusion

After design concept analysis, a final design selection was chosen to meet the specified requirements for the SLMP anode coating machine. The proposed method shows a promising design that meets the requirements for application of SLMP to anodes used in lithium ion batteries. The semi-automatic coating SLMP onto a flat battery electrode. By applying a variation of frequency oscillations on the separate meshes, the SLMP powder can be evenly distributed. By addressing both the mechanical and the electrical components (rollers, motor, microcontrollers, etc.) of the design, the design is further validated. The lithiated electrode will be easily activated by using the “press” unit to break the SLMP particle shells. As no drying time will be required and the SLMP material will remain unprocessed (no slurry) the design process will be time efficient, to the required ~10 min coating time. The suggested design provides a new method that compensates for the shortcomings of previous standards used in industry. Design #5 meets the safety, affordability, ease use, ease of repair, and dispersion parameters. Future work will include, final design realization, implementation and testing of the unit. Testing phase would start with the individual components to acquire preliminary data on flow rates of the material through the funnel and meshes, appropriate motor speeds, frequencies, power distribution, program implementation, etc.

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