**The Automated Coil Winding Solution**

**Introduction**

I have been provided with an opportunity to improve a coil winding system for Buckley Systems. The company is an already well-established international manufacturer of high-quality electromagnets, selling mainly into the electronics manufacturing market with quality and reliability being the key selling point. The company’s engineering team has identified a gap in the facility for a machine that is able to assist the production of wire wound coils in the coil shop. The wire winder needs to be in the state of completion and ready to be used by the end of 2020. I will be provided with a budget with most of this budget being used on prototyping and testing the practicality of the wire winding system.

**Findings**  
Buckley Systems question the impossible and consistently innovate solutions for our customers that truly do represent the heart of what we are - Ingenious at Work. Creating unique manufacturing equipment can improve the process of innovation by making it more efficient, precise and minimize the risk of damage during the manufacturing process. Currently the wire winders used for the electromagnets require a long and complicated manual process.

**Problem Definition**

1. The wire is firstly purchased on a spool which is then assembled on a free spindle which means it can turn freely. The tension provided is proportional to the friction coefficient of the spool turning on the spindle, gravity, weight and the length of wire attached to the tensioner arm. The wire that is stored on the free spinning spool uses gravity as its main tension force source. As the copper wire starts getting used up the weight of the wheel starts to decrease. The tension force is directly proportional of the mass of the spool and as the mass of the spool decreases the tension also decreases and this situation is not ideal. It is quite common that when workers reach the end of the former, the wrapped wire may not be pushed hard against the side. In some cases, it may be too small or too big within the appropriate amount of turns. It is important to wind in even increments. A complicated step in the wire winding process is the transition from finishing one layer and winding the next. While observing the operators, workers often pack each layer in quite tightly before they start the next one especially on thicker wire which sometimes needs a deliberate kink put into it. The current system has uneven tension which makes it difficult for the operator and makes it a very time-consuming process.

Consistent tension needs to be applied to the wire during the winding process. The coil machine I noticed this problem on in the shop was a rectangular former. The consistency and quality of the tension applied depends on the shape of the wire. In a round coil, the tension remains constant during one full turn. However, in the rectangular coils, the wire tension is not consistent and experiences fluctuations. These fluctuations are due to quickly changing wire path length. The varying tension may affect the operation of shaft, and produce excessive forces, which may cause machine vibrations and non-uniform coil winding. When this happens, the rectification process is extremely time consuming, and it also may affect the productivity. Currently operators are using a soft head hammer to force the copper wire to contact and rectify the problem.

Using excessive force on an already uneven tensioned system to compact the wire means that the wire will be slightly deformed and will potentially damage the insulation layer, therefore stretched. The copper wire itself has its own width tolerance. The wire is measured initially without the coating and is not perfectly smooth. The wire has to some extent different measurement readings along the length of the wire (0.02mm-0.1mm difference). Slightly decreasing the width of the copper wire by stretching from excessive high tension and force means that more turns can be made in a given space and increase the resistance of the electromagnet. Damaging the wire can also affect the insulation contact area and create electric shorts in the final product.

1. The tension arm is fixed in one position which feeds through wire to the bobbin which is then compacted by impact by an operator. The machines are used via pedal. Much like a sewing machine, the operator can wrap the wire into a coil. On one machine, the tensioner arm is on a free moving slider. This means that the operator can adjust where the tensioner arm should be, but it is very unreliable.

To assist the operator, the moving tensioner arm is supposed to provide even increments along the width of the former, but it simply isn’t accurate enough. This can be a problem as it is difficult for the operator to use and the rectification process is time consuming. It is suggested that a different more accurate mechanism should be put into place to assist operator efficiency and production time.

**Solution Specifications**

Performance

* A unique variable tension meter.
* Evenly wind layers - programmable with variables.
* Integrate into a current machine.
* Compatible for winding different width wires.

Programmability

* User friendly interface
* Prompts for user input.  
  e.g. number of rotations, number of layers
* Optimal operations for one setting based on the other.

Electrical Characteristics

* Operate by being plugged into 240V AC power supply 50Hz.
* Compatible with current machine.

Maintenance

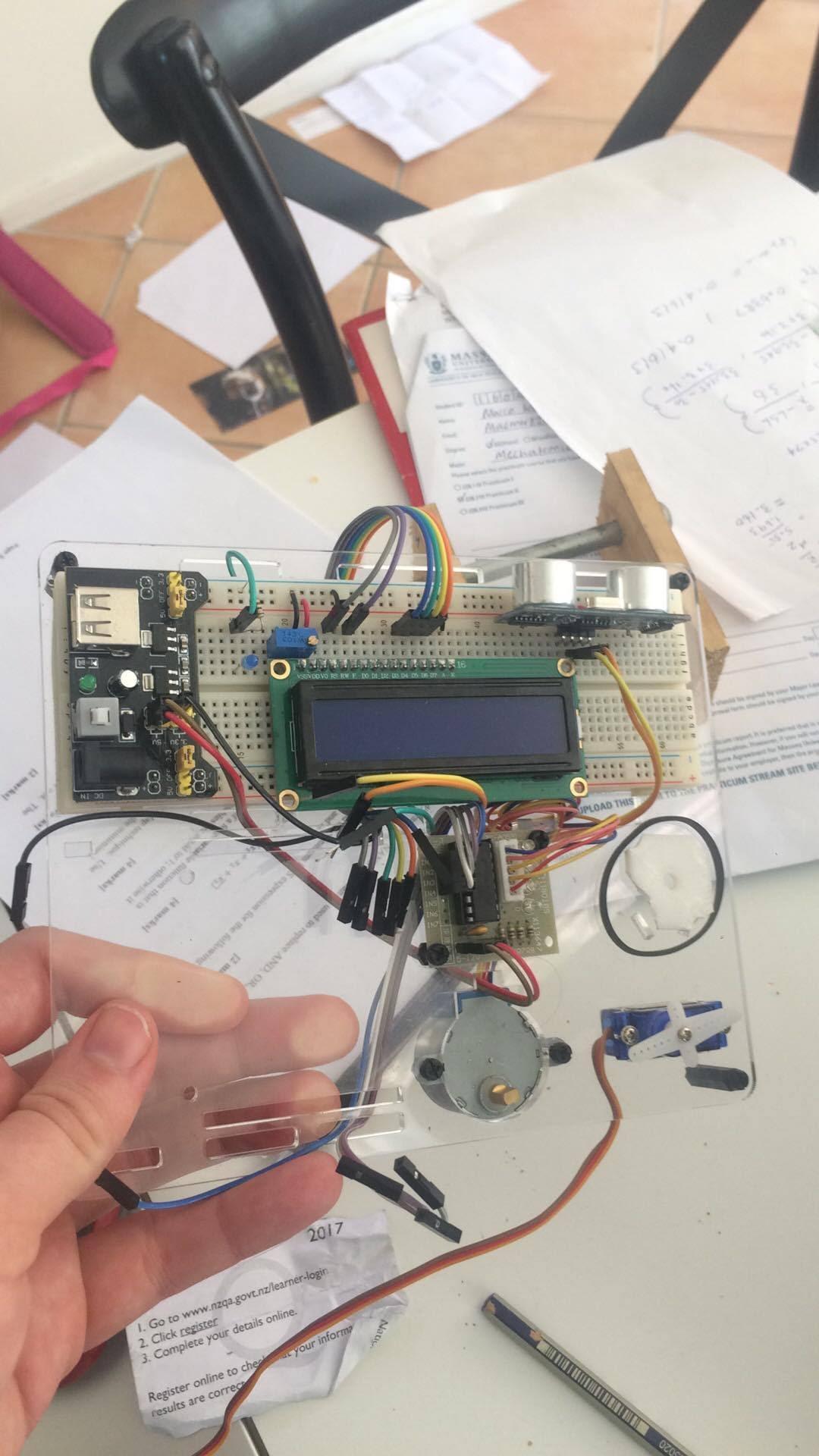
* Electronics checked by maintenance team every 2 years.
* Serviceable through removable base.

**Idea Generation and Concept Development Process**  
The current winding machines achieve the necessary job provided for the number of coils needed to be produced in the coil shop, but they are simply outdated. The coil shop has good machines from the 1970’s that work perfectly fine but could work better with the aid of some modern technology. Some coils are best wound by hand because of the complicated steps needed to be done. In the AIBT rectangular source coil formers and other rectangular formers alike, a faster production rate could be achieved by simply modifying one machine. Currently the tensioning systems are fixed and must be manually moved. By adding an option to have the tensioner pulley arm move would assist operators in the production of some coils.

A system where the tensioner could move along in a set amount of increments programmable by the operator would assist accuracy and production. Moving the tensioner arm by means as simple as a lead and ball screw can make it easier for the operator to wrap the wire around the former.

The lead screw will have a motor attached and this will drive the tensioner arm for the length of the former in steps set by the worker. The necessary framework will support the apparatus and will be structurally sound to take the strain of the tension forces.

*Lead and ball screw with frame.*

The system will need to have an independent operations system. There will be a display inputting for a list of integer variables. This will include the width of the wire, the perimeter of the former, number of layers, changes per layer and the number of turns. It will indicate the amount of rotations done, have a pause button and a reset button. A display system is necessary to move the arm accurately and effectively.

To move the tensioner arm accurately there must be an even amount of tension throughout the entire system. A variable tension meter that can adjust tension would help. This means it will take the strain and adjust it independently. This could be used on multiple coil winding machines throughout the coil shop.

*Simple display, stepper motor set up used during my university studies.*

**Calculations**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Parameter** | **Formula** | **value** |
|  | **Power rating** | (known) | 50VA |
|  | **Voltage** | (known) | 230 volts |
|  | **Current** | VA/Vp | 50/230= 0.23 A |
|  | **Conductor size** | A1 = current/ current density | A1 = 0.23/2.3 = 0.1mm^2 |
|  | **Wire gauge (wire width)** | (standard table) | 28 AWG |
|  | **Former perimeter** | Pir^2 or LxWxH | 17.78cm |
| **Design parameters** | **Number of turns** | Turns per volts x volts | N1= 2.6 x 230 = 600 turns |
|  | **Changes per layer** | Number of turns/total wire length | 600/106 =5.6 |
|  | **Total wire length** | Number of turns x perimeter of former | L1 = 600 x 17.78cm = 106m |
|  | **Volume of copper wire** | Area x length | 0.1x10^-6 x 106 = 1.06 x 10^-6 m^3 |
|  | **weight** | Weight = density x volume density of copper = 8960 kg/ m3 | W1= 8960 x 1.06 x10^-6 = 0.095 Kg = 100grm |

**Code  
Variable Tensioner System (VTS)**

To make my design work, the hardware must be programmed to move specific to the task at hand. Since the wire is generally thick and heavy the motor is strong enough to pull the spool around easily, but it does not consider the change in weight as the wire on the spool decreases. The solution here is to create a variable tensioning system. This can be done by motorizing the winding of the coil and the unwinding of the spool. The motors speeds must be dynamically adjusted. Tension can be set with the current tensioner system (adding weight). The speed of the spool is governed by a variable resistor which senses when more wire is needed from the spool.

C code--> Arduino--> stepper driver--> stepper motors--> spool --> coil

|<--variable resistor- Amount of wire needed

|<-- variable resistor global speed of the motors

|<--variable resistor-maximum spooling speed

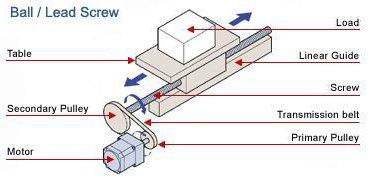
|<-- IR/optical sensor length of wire on coil feedback

|<--> computer compatible runs code and prints info about the coil

Another two variable resistors could control the global speed of the whole winding process and the max speed of the spool coil. Lastly, a roller and an IR detector detect the amount of wire that has come off the spool, allowing the winder to stop at a set resistance, and print out in real-time the resistance of the coil as its being wound. Simply enter in the wire gauge you're using and the desired resistance of your coil, then run the script. The script will cause the winder machine to automatically make the coil. Once complete, the script will print out all the information that it knows about the coil, including how many turns have been completed. An LCD display would display the results and real time variables.

**Moving Tensioner Arm(MTA)**

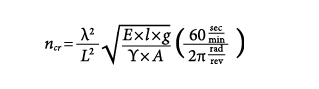
To move the tensioner arm accurately we must use a precise motor. A stepper motor is similar to a servo motor – we can position it to a particular angle, but there is no restriction on the angle. The motor can rotate continuously either clockwise or counter clockwise. With a stepper motor we can determine how many cycles there are in one complete revolution. Sending pulses into the stepper motor in a cycle of 1-2-3-4 will move the teeth one place clockwise. If there are 100 teeth, 100 cycles will move 360°, so each cycle rotates 3.6°. Therefore, the stepper motor will move the ball and thread screw in precise increments. To adjust this, gears can be used to alter the speed or help move the weight of the whole tensioner arm system.



*online calculator diagram.*

*http://www.orientalmotor.com/motor-sizing/ballLeadScrew-sizing.html*

The size, pitch and angle of the ball/ lead screw will need to be known to calculate the critical speed of the nut. The critical speed is the speed at which a screw resonates, varies with unsupported length, diameter, end fixity, and rotational speed. This is important to know as the nut is where the load of the tensioner arm will be carried. The tensioner arm must not resonate as it will create inaccurate increments.



Where L = distance between supports (mm); E = modulus of longitudinal elasticity (2.05 × 106 N/mm2; I = minimum second area moment of inertia of screw shaft cross section (mm4), where I = (πdr4)/64; dr = screw shaft root diameter (mm); g = acceleration of gravity (9.81 × 103 mm/sec2); γ = specific weight (7.71 × 10-5 N/mm3); and A = minimum cross-sectional area of the screw shaft (mm2), A = π dr2/4.

**Sketches**A close up of text on a whiteboard

Description generated with high confidence

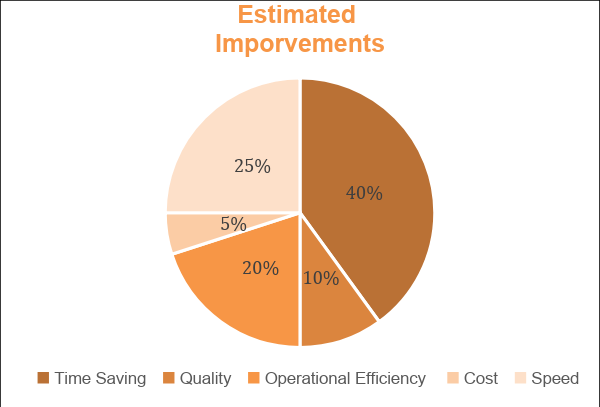
A close up of text on a whiteboard

Description generated with high confidenceA close up of text on a whiteboard

Description generated with high confidence

**Conclusion**

While working as a Quality Technician at Buckley Systems, I have Identified some areas that could be improved with the current coil winding manufacturing process. Firstly, the spool is stored on a free-turn assembly which means that there is uneven tension through the entire system. This makes the manufacturing process more difficult for the operator and makes it harder to create even winds. The second is that there is no way to move the tensioner arm accurately in desired increments. Currently workers are using force to rectify this problem which risks damaging the copper wire.

My proposal is to modify a spare machine supplied by Glen Schultz, manager in the coil shop. I will create a Variable Tensioning System (VTS) and a Moving Tensioner Arm(MTA) as discussed above. There will be software for the operator to enter integer variables or to use present scripts for specific coil winds. Integrating these concepts onto the machine and making them work together in sync will be my end goal. The designs and concepts are early ideas and are readily open to be changed and improved as needed. The situation is dynamic, and the ideas are not finalized at this stage.   


My improvements will improve many aspects of the end results. The operation process will be improved by 40% but this will have to be perfected with set-up and adjustments. The cost is very cheap compared to a brand-new automated machine estimated to be 5% of what a brand-new machine would cost. The speed of operation will increase from current production by 25% at optimum. Finally, Buckley Systems final products will be estimated to improve in quality by 10%.

The benefit of the proposed modifications will make it easier for the operators, improve productivity and improve the quality of the finished coils.

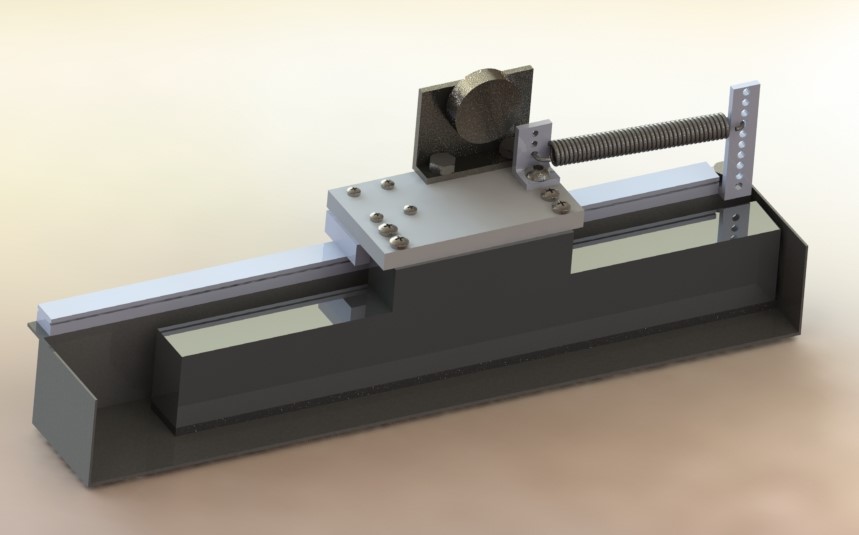
Decorative sidebar

*Figure 2.Tensioning System Final Render 1*

*Figure 1. Linear Guide Final Render 1*

**Buckley Systems Coil Winding Project  
*The Autonomous Coil Winding Solution*  
*Design & Engineered by Marco Wells***

**A close up of a device
**

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**Executive Summary**

The Buckley Systems Coil Winding project is an autonomous coil winding solution for winding formers with no breaks and a relatively small dimensions. The application can do a variety of coil formers ranging from 0.28mm to 2.5mm wire with current prototyping material. The solution contains two parts, the Tensioning System and the Linear Guide. Together they can work together to create a stable system with accurate results or individually for unique applications.

**Contents**

**Design Concept**

The design consists of two separate mechanisms. The first part is the Tensioning system. The tensioning system is going to be used as a way of creating variable tension on the copper wire. The second part is the Linear guide which will direct the wire to the former autonomously.

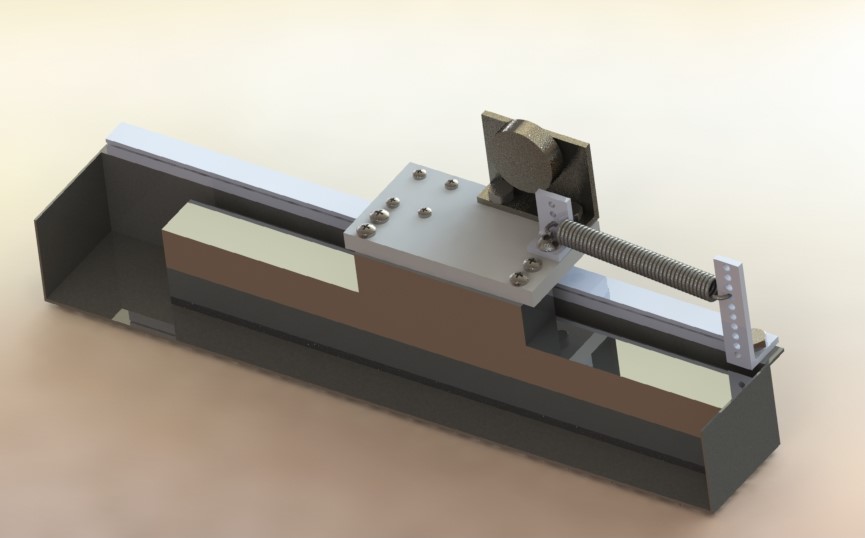
**Tensioning system**  
The mechanism of tension control is to feed a wire via a pulley that is pulled by a coil spring (tension pulley) and apply a constant tension by applying feedback so that the extension of the coil spring is always constant.

The tension pulley is attached with a linear rail that precisely detects the position between the zero tension and the maximum tension, and a position control motor that feeds back the extension of the coil to the drive voltage of the supply motor. When the wire is wound the tension, pulley is pulled and the tension increases. When the wire is being released the tension, pulley is released and the tension decreases.

At the same time the position sensor of the tension pulley detects the at the tension currently rises above the target tension, determines the drive voltage of the supply motor based on the difference value, rotates the motor in the direction to supply the magnet wire, lowers the tension.

If the supply motor drops the wire too far or the winding up motor reverses the current tension drops below the target tension , the supply motor is rotated in the take-up direction with the same control and the tension is raised.

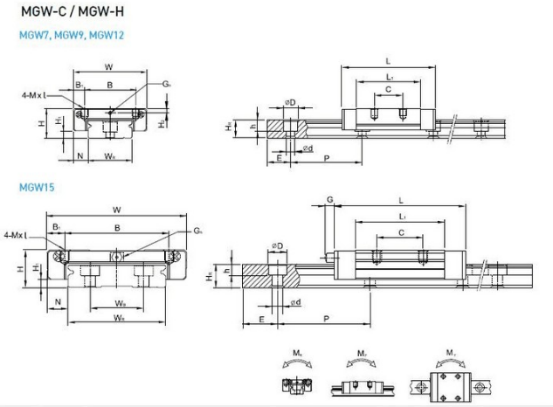
Large stress is applied to the tension pulley, precision is required for the tension pulley, so a linear slider is used and are mounted on a chassis connected to a linear slider. It is necessary to operate smoothly against a change in tension, so less friction is needed.

**

*Figure. Tensioner system assembly*

Linear Encoder

The linear encoder Rail is a slider that returns a value to the nearest 5um. The scale has an effective slide distance of 300mm. The Encoder has a DB9 Output port.

DB9 output:

1. -

2. 0V Black

3.-

4.-

5.-

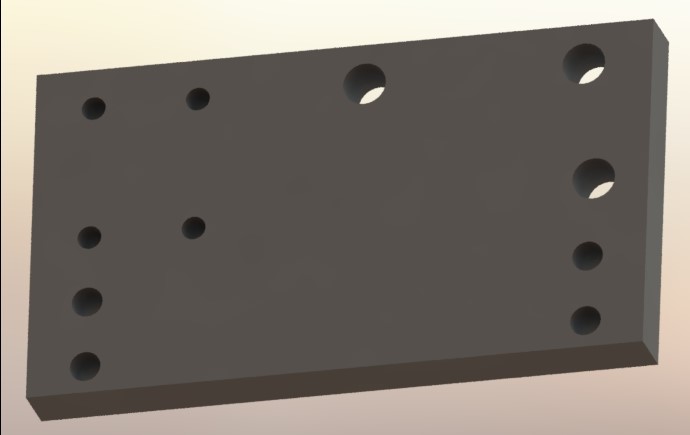
6. A Green

7. 5V Red

8. B White

9. Orange

The output is fed to the Arduino where a value, depending how far the slider has travelled is returned for the duration. The Linear Encoder is connected to a linear guide which is free to move along the rail. The L-Bracket is then mounted on the linear guide which is attached to the linear encoder. The brace which mounts these parts is then attached to a spring located on the base. The copper wire is wrapped on a pulley located on the L-Bracket. When the wire is pulled the carriage which it is mounted to, slides in a direction. The motor control system has a simple PID code which directs the motor to rotate in the opposite direction the carriage slides. This effect creates stable tension on the wire and the wire spool always stays spooled.



*Figure. Tensioner Link*

**Linear Rail**

The linear rail is controlled by a stepper motor that travels a ball and lead screw up and down the total length of the thread. The linear rail is used to feed copper wire onto the former. Accuracy , speed, stability and durability and installation is very important to use the rails efficientsy and use. There is an extra unit to enhance support which protects the motor from damage. The motor has a maximum speed of 1200 rpm. The ball screw position has accuracy of up to (+-) 0.02mm. An oxide aluminium coating is used to avoid rust and there are easily accessible m4 screw fitments to mount the frame to.

*Ball Screw Parameters*

|  |  |  |  |
| --- | --- | --- | --- |
| Model No. | Dia.(mm) | Lead(mm) | Accuracy |
| G1605(100~500mm stroke) | 16 | 05 | C7 |

*Motor Parameters*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model  No. | Step Angle | Motor Flange | Holding Torque | Current | Resistance | Inductance | Rotor Inertia | Lead Wire |
| FM57  56SFD | 1.8° | 57 mm | 0.93 Nm | 2.0 A | 3.0(+-) 20% | 3.19mH | 200 gcm^2 | 4 No. |

Load Capacity

|  |  |  |  |
| --- | --- | --- | --- |
| Load | | 0~10kg | 10~20kg |
| Max Speed | Horizontal | 140mm/s | 80mm/s |
| Vertical | 100mm/s |  |

*Pulses*

Pulse for one full rotation of stepper motor 360°/1.8° = 200 pulses. If 200 pulses move the lead screw 5mm how many pulses are needed to move it 0.28mm?  
200/5 = 40 Pulses

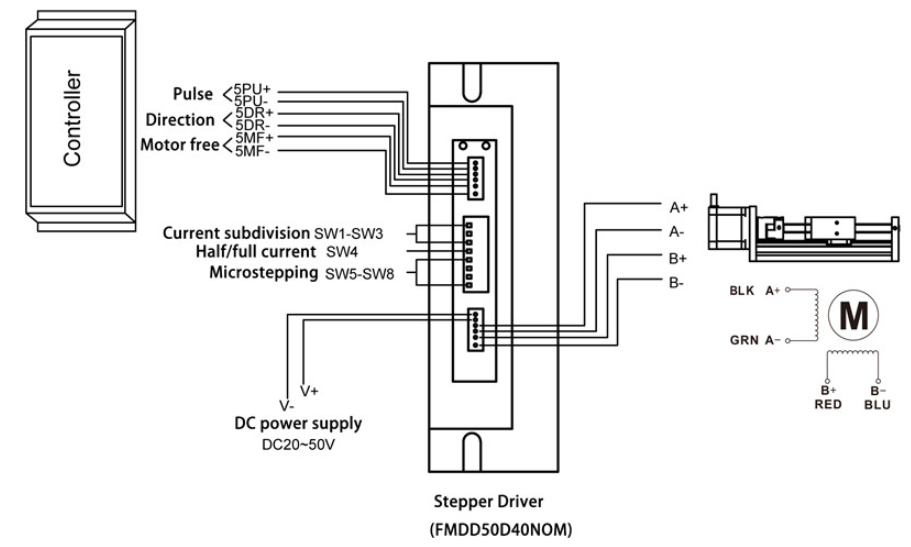
40 x 0.28 = 11.2 Pulses

From this we can see that there is a relationship between Copper thread width corresponding to pulses to achieve the same distance. These pulses can be used to achieve high accuracy for the different types of copper wire found in Buckley Systems.

*Pulse Calculations*

|  |  |
| --- | --- |
| Diameter of copper wire (mm) | Pulses (x) |
| 0.28 | 11.2 |
| 0.315 | 12.6 |
| 0.71 | 28.4 |
| 0.80 | 32 |
| 1.00 | 40 |
| 1.32 | 52.8 |
| 1.50 | 60 |
| 1.60 | 64 |
| 2.00 | 80 |
| 2.30 | 92 |
| 2.50 | 100 |
| 3.55 | 142 |
| 500( length of rail) | 20,000 |
| 250 (half of rail) | 10,000 |

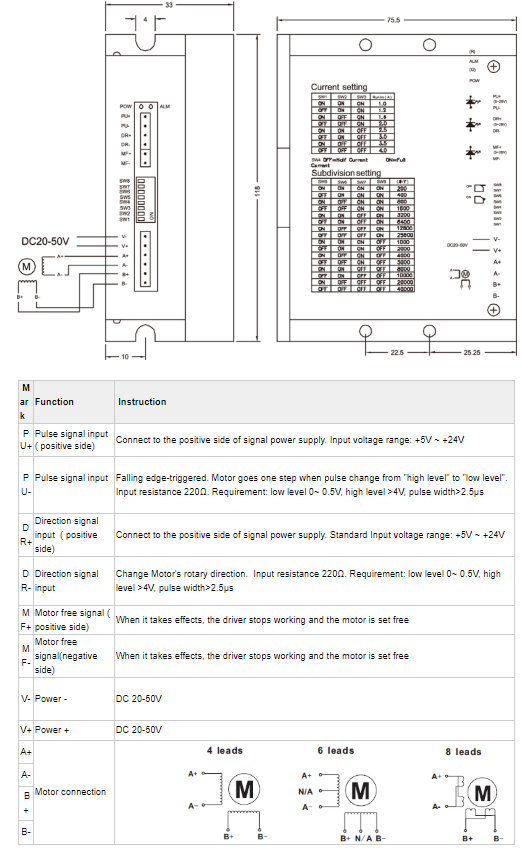
*Linear Rail wire Diagram*



*DC Power Supply*

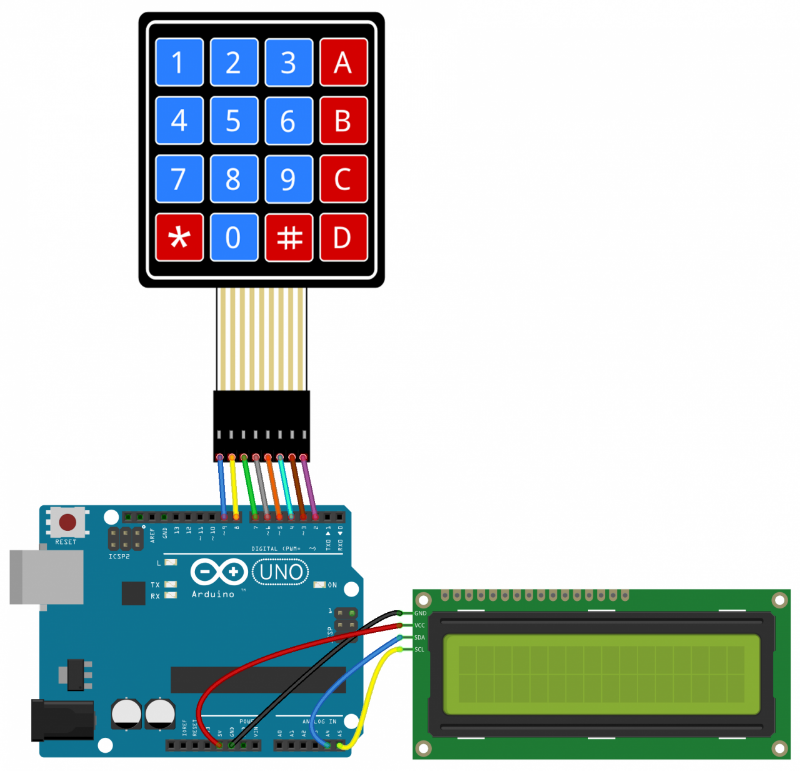


*Nema23 Stepper motor driver for FLS40 FUYU linear motion guide*



*Communication*

The Linear rail communicates through a pulse, direction and an enable signal to the Arduino. The user then uses a number Pad to enter in the desired function.



A menu screen cycles on the LCD screen. When a number button is pressed following the “#” key, a pulse is sent and to the stepper motor where it then

Marco Wells Buckley Systems

Coil Winder Prototype

------- MENU -------

0. Proximity Sensor Test

1. Wire Gauge

2. Former Size

3. Wire test

***Code***

Still To be Done

*Linear Guide Mechanism*

**![A close up of a final linear rail design
Description generated with very high confidence](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4Rx2RXhpZgAATU0AKgAAAAgABgALAAIAAAAmAAAIYgESAAMAAAABAAEAAAExAAIAAAAmAAAIiAEyAAIAAAAUAAAIrodpAAQAAAABAAAIwuocAAcAAAgMAAAAVgAAEUYc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAFdpbmRvd3MgUGhvdG8gRWRpdG9yIDEwLjAuMTAwMTEuMTYzODQAV2luZG93cyBQaG90byBFZGl0b3IgMTAuMC4xMDAxMS4xNjM4NAAyMDE4OjA3OjEzIDA4OjAxOjEyAAAGkAMAAgAAABQAABEckAQAAgAAABQAABEwkpEAAgAAAAMwOQAAkpIAAgAAAAMwOQAAoAEAAwAAAAEAAQAA6hwABwAACAwAAAkQAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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The linear mechanism designs purpose is to feed a copper wire onto the former while keeping consistent tension and increments on system. The Linear guide mechanism comes with an adjustable pulley that has an effective range of 28mm. This range enables different wire sizes to be adjusted to different tensions to achieve the best wind for the specific former.

The adjustable system has a maximum and a minimum point that can be calculated with known parameters. The first thing we must know is the required amount of force to break copper wire.

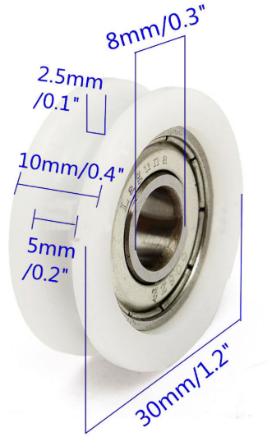
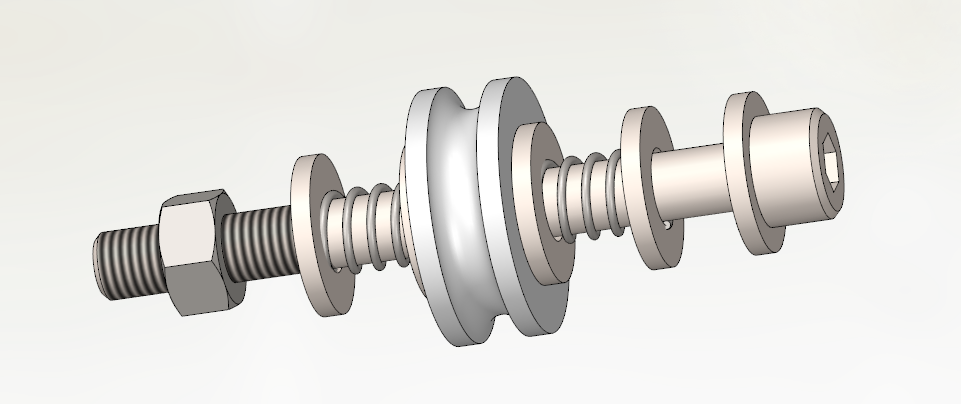
From research the force required of the breaking point is proportional to πr ²  
F  ∝ πr ²

F1/F2 = (R1/R2) ²  
F = 0.282 x π

F = 0.24N  
Stress (σ) = maximum Force (N) / minimum Cross-sectional area (m2)

A= πr ²

*Pulley Mechanism*

**

W bolt = M8 x 1.25 x 80 Hex SHCS = 0.0318 kg

W Pulley = 0.09/6 = 0.015 kg

W Springs = 0.01 kg

W Washers = 0.002 kg  
WT = 0.0318+0.015 +0.01+ 0.002 = 0.0588 kg

*Maximum Tension  
 T Max*

FX= T2CosB -T1CosA = 0  
FY = T1SinA + T2SinB – W = 0

T2CosB = T1CosA

T2 = T1(CosA/ CosB)

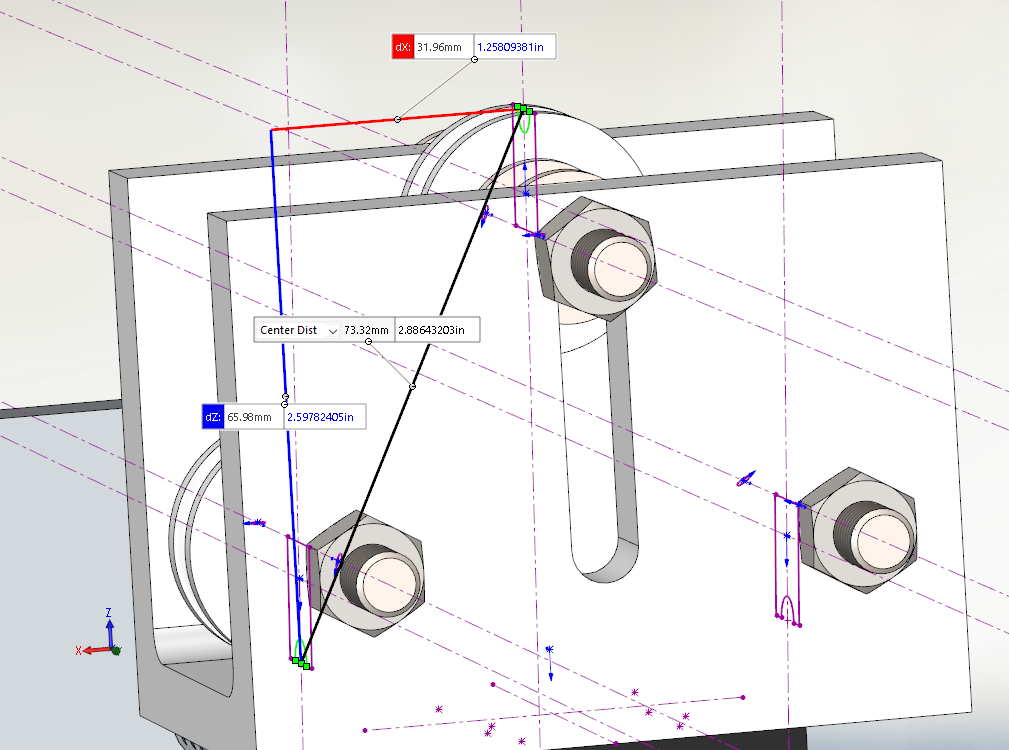
T1SinA + T1CosA/CosB)SinB = W

T1(SinA +(CosASInB / CosB)) = W

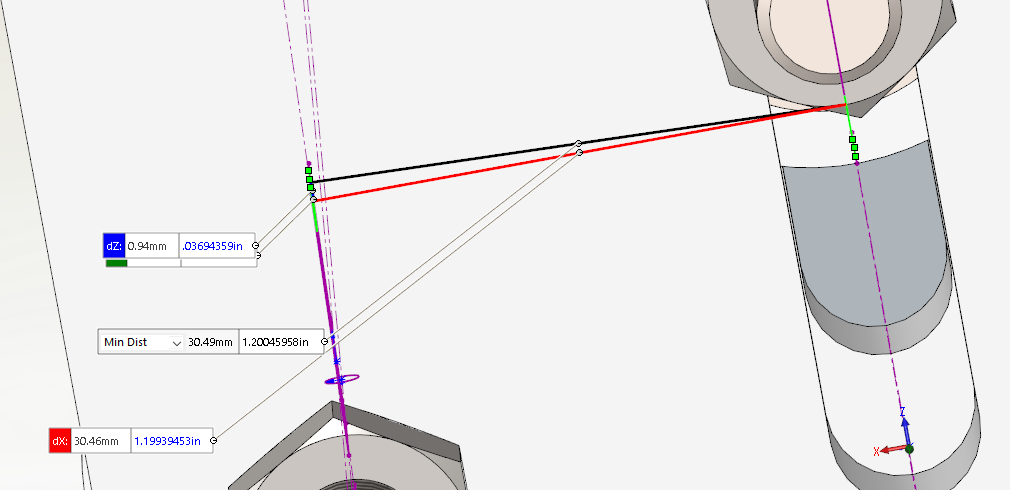
T1 = W/ (SinA +CosASinB/CosB) = W/( (SinA CosB/CosB) + (CosA SinB/CosB))

T1 = W/ (SinA CosB+CosA SinB/CosB) = W CosB/ SinA CosB+CosA SinB  
T1 = W CosB/Sin(A+B)

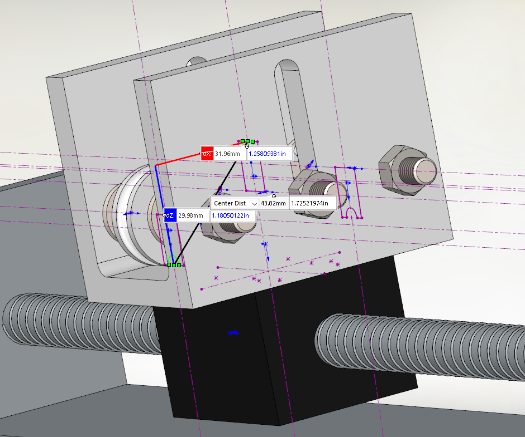
T2 = W CosA/Sin(A+B)



*T0*

**

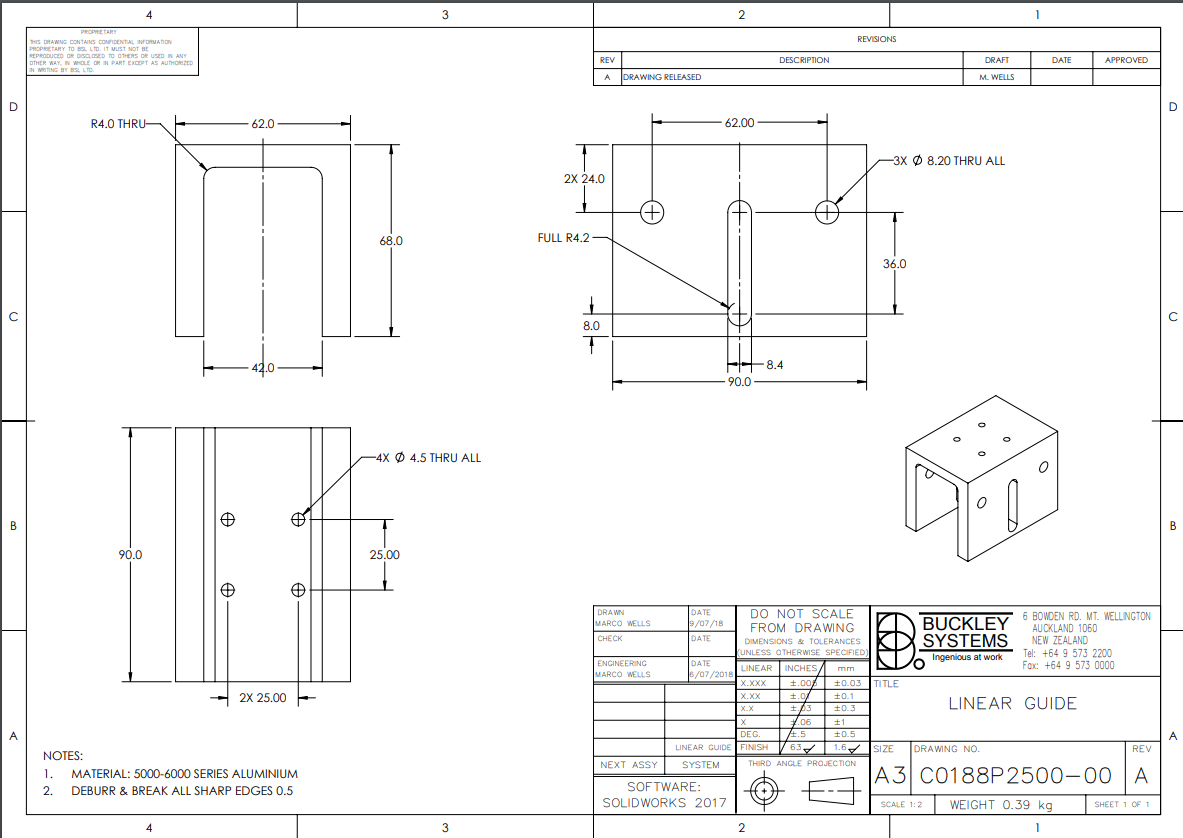
*T Minimum*

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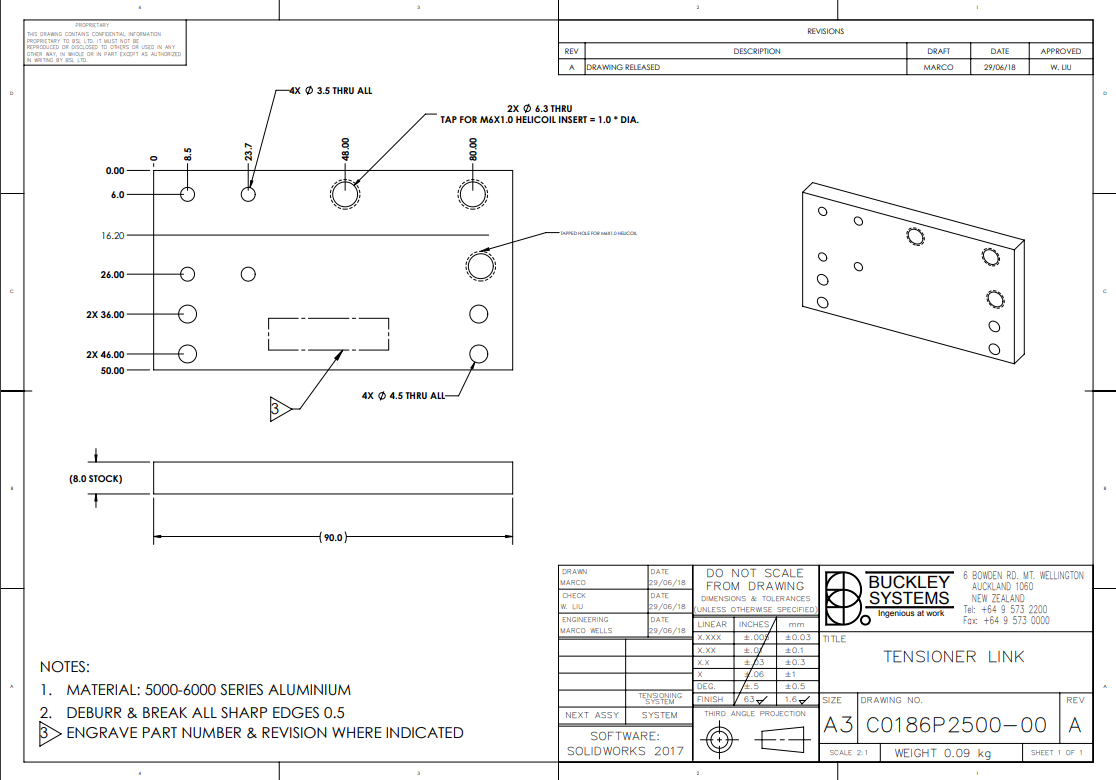
T1 = W CosB/Sin(A+B)

T2 = W CosA/Sin(A+B)

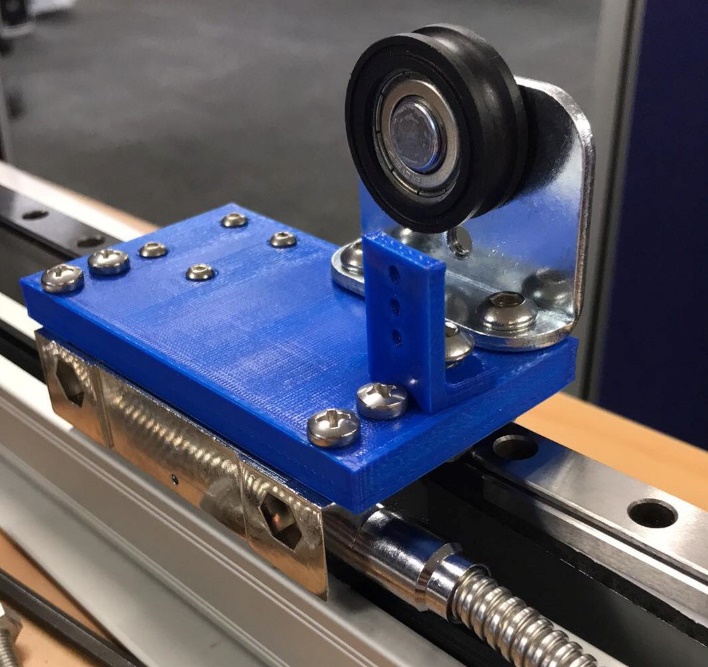
*Linear Guide Drawing*

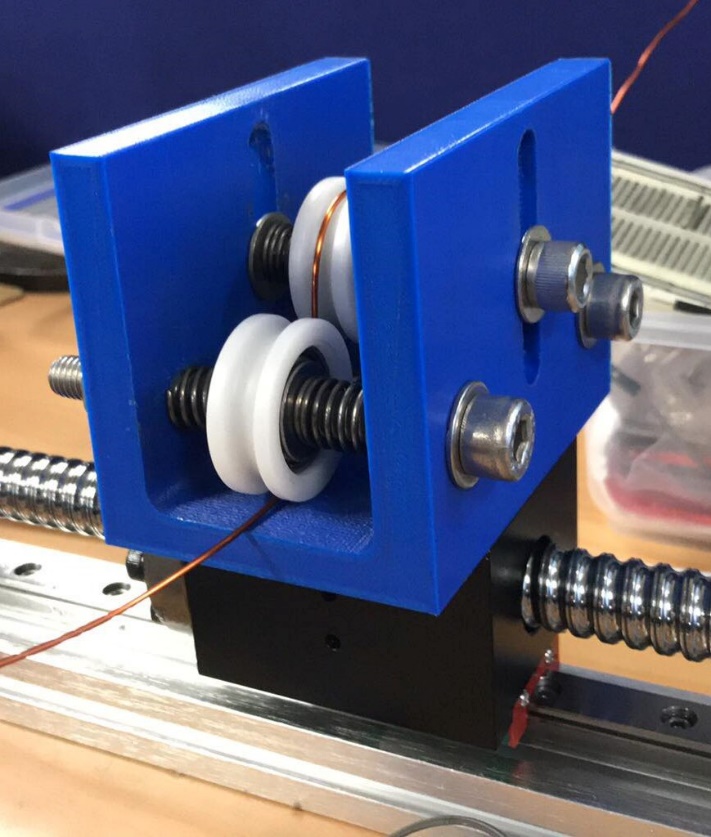


*Tensioner Link*

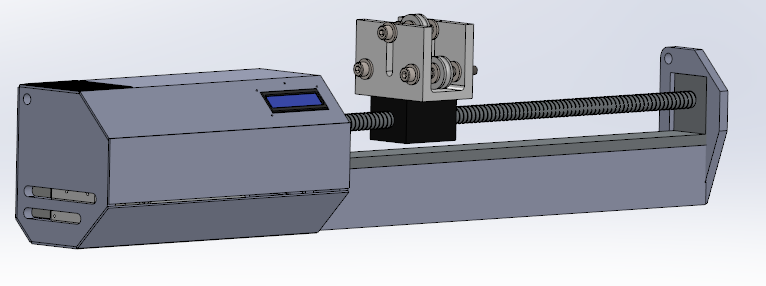
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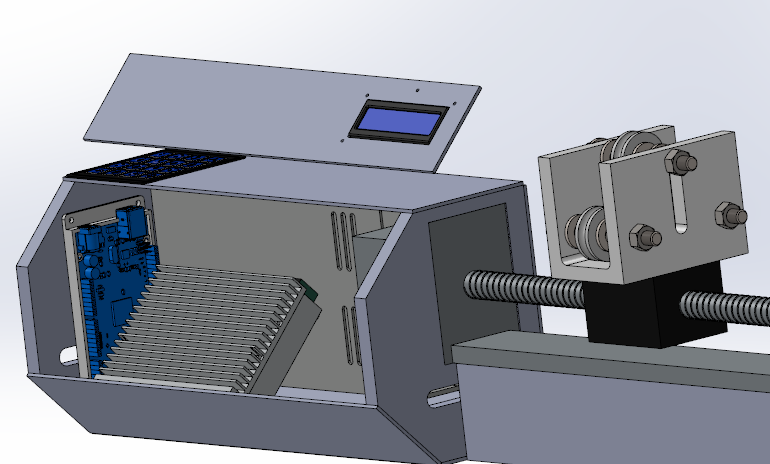
*Prototype pictures*

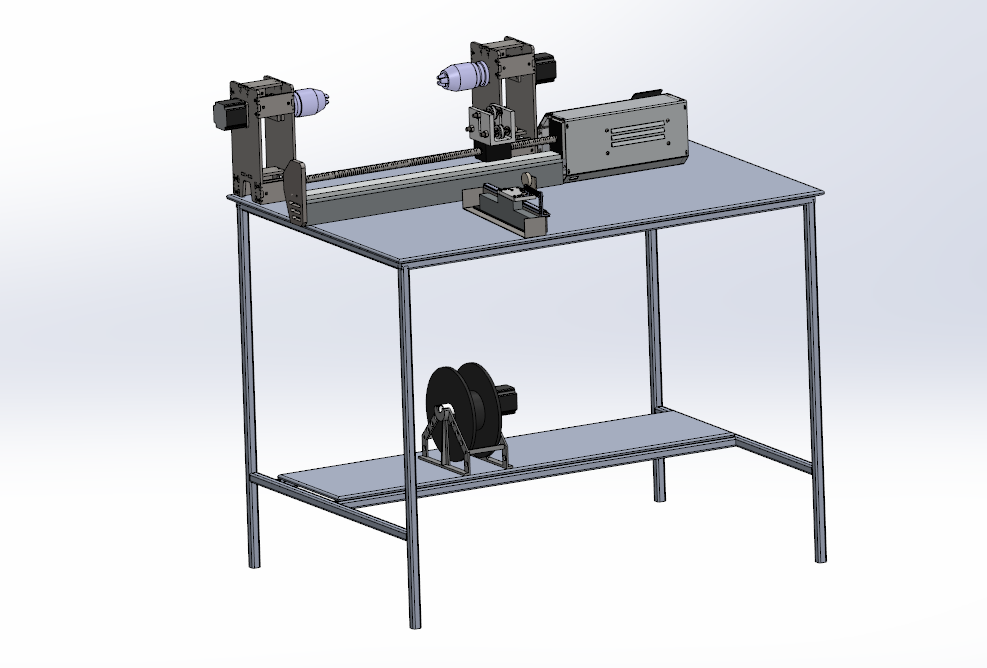
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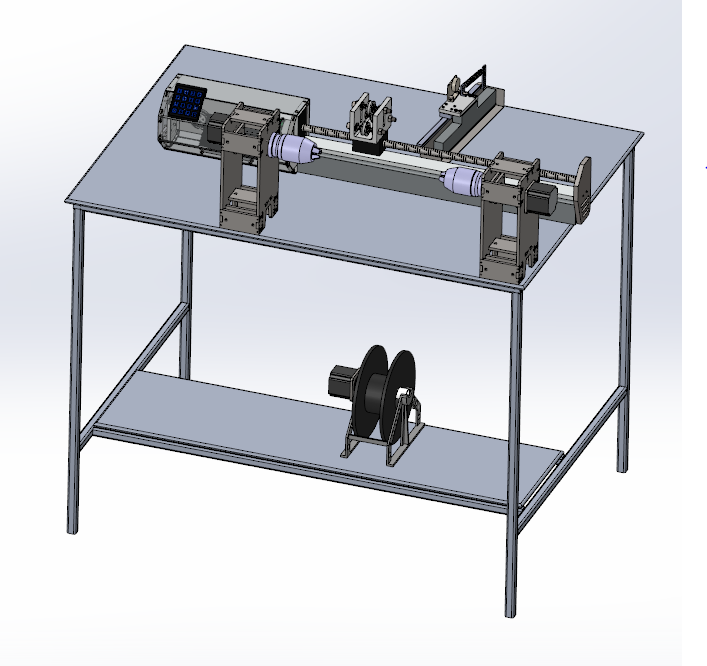
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*Coil winder machine frame design*





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