NUST COLLEGE OF ELECTRICAL & MECHANICAL ENGINEERING

Design and Fabrication of Computer Controlled Riveting Machine

A PROJECT REPORT

DE-40 (ME)

SUBMITTED BY

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Acknowledgment

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Abstract

In industry, mechanical fasteners are widely used for joining materials [1]. There are two types of fastening processes, non-permanent and permanent fastening. The non-permanent fasteners can be joined and removed without causing any damage to the components. Bolting is one of the most common non-permanent fastening processes [2]. When there is vibration in bolted components, the strength is reduced, and the connections weaken. In permanent fasteners, once the joint is made, the parts cannot be removed without destructing the joint. Besides welding, riveting is a major permanent mechanical fastening process [3]. A rivet is a mechanical fastener and has different types, designed according to its application e.g., solid rivets, blind rivets, tubular rivets, metal-piercing rivets, and split rivets.

Blind rivets are used in trailers, aircraft, structural beams, and many general applications such as attaching wall and ceiling decorations, fastening knobs and handles, securing door and window hinges, holding nameplates and signs, etc. Blind rivets can be completely installed from one side of the joint. Blind rivets have significant advantages over other types: their installation tool is portable, installation is faster, and a given-length rivet can be used for a range of material thicknesses [4]. Three types of rivet guns are used for blind riveting, manual, pneumatic, and electric rivet guns. The electric blind rivet gun is a next-generation riveter that is cost-effective and is handled more easily than a pneumatic rivet gun [2].

This project aims to provide a prototype of a low-cost electric blind riveter. The prototype will be designed that can fix a 4.0 x 12.7mm pull-mandrel blind rivet. The extraction release motion of the blind rivet mandrel in the rivet gun will be computer-controlled via sensors to prevent excessive displacement which can cause damage to other components of the riveter. The housing will be designed and analyzed using SolidWorks and ANSYS to sustain the torque produced via the electric motor.

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Chapter 1

Introduction

A fastener is a tool that holds objects mechanically. Fastening is the process of installing fasteners. Most of the fasteners make non-permanent joints. It means that you can make a joint and take it apart and separate the objects without causing any damage to the objects. A permanent joint is a joint that cannot be taken apart without causing damage to the joined objects. Rivets are fasteners that make a permanent joint. Rivets have low installation costs, and materials are permanently clamped that can sustain high vibration and environmental conditions.

1.1 Riveting Process

Riveting is a process of joining objects using a metal piece called rivets. A rivet is put in the predrilled hole between the workpieces. One or both ends of the rivet is formed over a connection, which makes a joint. Different types of rivets are designed according to their applications, e.g., solid rivets, blind rivets, tubular rivets, metal-piercing rivets, and split rivets. Self-piercing rivets do not require a predrilled hole between the workpieces. Each of these types is installed using a unique set of tools.

1.2 Blind Rivets and Hand Riveter

Blind rivets can be installed completely from one side of a joint. Blind rivets provide a uniform clamping force over the joint. There are three types of blind rivets; Pull mandrel, Threaded stem, and Drive pin, categorized according to the methods used to install them. A Pull mandrel blind rivet is a hollow tube (shell/shank) with a headed stem (mandrel) inside it. A mandrel has a head and a pre-notched breaking point. When a pulling force is applied to the mandrel, the head deforms the tube thus making a joint. After the joint is made, the pulling force breaks the mandrel at the pre-notched breaking point. A hand riveter, pneumatic riveter, and an electric riveter are used for installing a Pull mandrel rivet.

The hand riveter is the oldest tool for installing a pull mandrel rivet. The pulling force is provided by squeezing the lever handle of the hand riveter. The process of hand riveting is slow and large diameter rivets cannot be installed easily. Long handle hand riveters are used to install large and strong rivets. Using hand riveters in production lines, where large quantities of rivets are installed, is not feasible. Pneumatic riveters are used in production lines and when the rivet material is relatively stronger, i.e., stainless steel and copper-nickel rivets. Pneumatic riveter uses air pressure to provide pulling force to the mandrel.

1.3 Pneumatic and Electric Riveters

Pneumatic riveters use a compressor unit to create the air pressure needed for creating a pulling force. That makes them costly and difficult to use in hard-to-reach applications. Electric hand riveter is a next-generation riveter that uses electric motors to create a pulling force. An electric hand riveter is easily handled and can set a relatively stronger rivet like a pneumatic riveter. The cost of an electric riveter is higher than a hand riveter and the installation time of a rivet is relatively slower than a pneumatic hand riveter. Some manufacturers provide a heavy-duty electric riveter that can set a rivet at almost the same time as a pneumatic hand riveter, but the cost of such riveters is much higher than other electric riveters.

1.4 Motivation

Blind riveting is a common riveting process. Blind rivets can be installed from one side of the joint. Blind rivets have significant advantages over other types: their installation tool is portable, installation is faster, and a given-length rivet can be used for a range of material thicknesses [4]. Blind rivets are used in trailers, aircraft, structural beams, and many general applications such as attaching wall and ceiling decorations, fastening knobs and handles, securing door and window hinges, holding nameplates and signs, etc. The Boeing 747 is a large, long-range wide-body airliner manufactured by Boeing Commercial Airplanes in the United States. A modern Boeing 747 has almost 1 million installed blind rivets [9].

1.5 Aim

This project aims to design a prototype of an electric riveter with a simple design. The design will be cost-effective and would install a blind rivet quickly.

1.6 Plan for report

Chapter 1 provides a simple introduction to the riveting process and types of riveters. It also explains the motivation for the project and its aim. Chapter 2 provides a detailed literature review and objective of the project. In chapter 3, design mythology tasks, elaboration of designed mechanism, details of the parts, and their fabrication processes are explained. Details of ANSYS static analysis and fatigue analysis are provided in chapter 4. Chapter 5 is the design of our control system for the rivet gun. Chapter 6 provides the future recommendations and chapter 7 is the conclusion of our project report.

Chapter 2

Literature review

2.1 Types of Rivets

There are different types of rivets designed according to their applications. These types include solid rivets, blind rivets, tubular rivets, metal-piercing rivets, and split rivets. Following is a brief explanation of the main types of rivets i.e., solid rivets, blind rivets, and tubular rivets.

2.1.1 Solid Rivets

A solid rivet is the most reliable type of rivet and is used where structural integrity is vital. A solid rivet is the oldest type of rivet. Solid rivets in some archaeological findings date back to the bronze age. Solid rivet is a metal shaft with a round head available in a variety of materials (Figure 1). It is inserted in a drilled hole and the flat side of the rivet is deformed with a hammer of a solid riveting tool.

Figure 1 Round Head Steel Solid Rivets

2.1.2 Blind Rivets

These rivets can be completely installed by accessing only one side of the joint. Blind rivets have a cylindrical shell and a headed stem called mandrel, both having the same materials or a combination of two different materials (Figure 2). There are three types of blind rivets; Pull mandrel, Threaded stem, and Drive pin, categorized according to the methods used to install them. Blind rivets are used in trailers, aircraft, structural beams, and many general applications such as attaching wall and ceiling decorations, fastening knobs and handles, securing door and window hinges, holding nameplates and signs, etc.

Figure 2 Aluminum Pull-Mandrel Blind Rivet

2.1.3 Tubular Rivets

Like a solid rivet, a tubular rivet is a metal shaft with a solid head, but the shaft is hollow on the inside to reduce the force required for installation (Figure 3). Tubular rivets are available in different materials and types i.e., compression tubular rivets. full tubular rivets, and semi-tubular rivets. Some applications of tubular rivets include light fixtures, HVAC ducts, electronics, ladders, etc.

Figure 3 Steel Tubular Rivets

2.2 Pull Mandrel Blind rivet design

This type of blind rivet consists of two parts, (i) Shell (Shank), and (ii) Headed stem (Mandrel). The rivet is installed by pulling the mandrel, which causes the shell to deform and clamp the material. The mandrel has a pre-notched breaking point. After the workpieces are clamped, enough pulling force breaks the mandrel at the breaking point. A small portion of the stem remains trapped in the bottom of the shell to ensure the clamping force is retained in the joint (Figure 4).

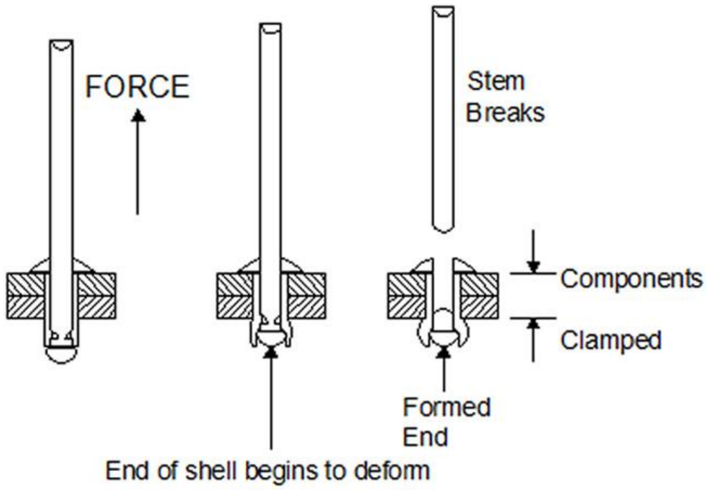

Figure 4 Design and operation of Pull Mandrel Blind Rivet

2.2.1 Breaking load

Breaking load is the load required for shell deformation and after clamping, break the mandrel at the breaking point. The breaking load is defined to avoid developing too much force, which can damage the workpiece being clamped. The mandrel must not break with a load that is less than the clamping force. If something like this happens, the joint's structure could be compromised.

2.2.2 Grip Range

Grip range is the thickness of the part of the workpieces being clamped. Blind rivets are designed for various ranges of thickness. The shell is deformed until the grip range is reached. If the grip range is too short than the shank length, excessive breaking load is required to set a rivet. If the grip range is nearly equal to the shank length, insufficient material may be left on the blindside to secure the joint.

2.2.3 Shell and stem material

Pull mandrel blind rivets are available in different shell and stem material combinations, each suited according to their application. Strength, corrosion resistance, and the material to be secured are the main factors in material selection. The shell material should match the material under the head; for example, if aluminum is fastened to steel, steel rivets should be used. Common shell materials are aluminum, steel, stainless steel, and copper. Stem material selection is not as crucial because most of it is wasted after breaking. The stem must have the equivalent strength of shell material [2]. Ni-Cu blind rivet has the most tensile strength among rivets of other materials. The tensile strength is around 3000 kN (Figure 5).

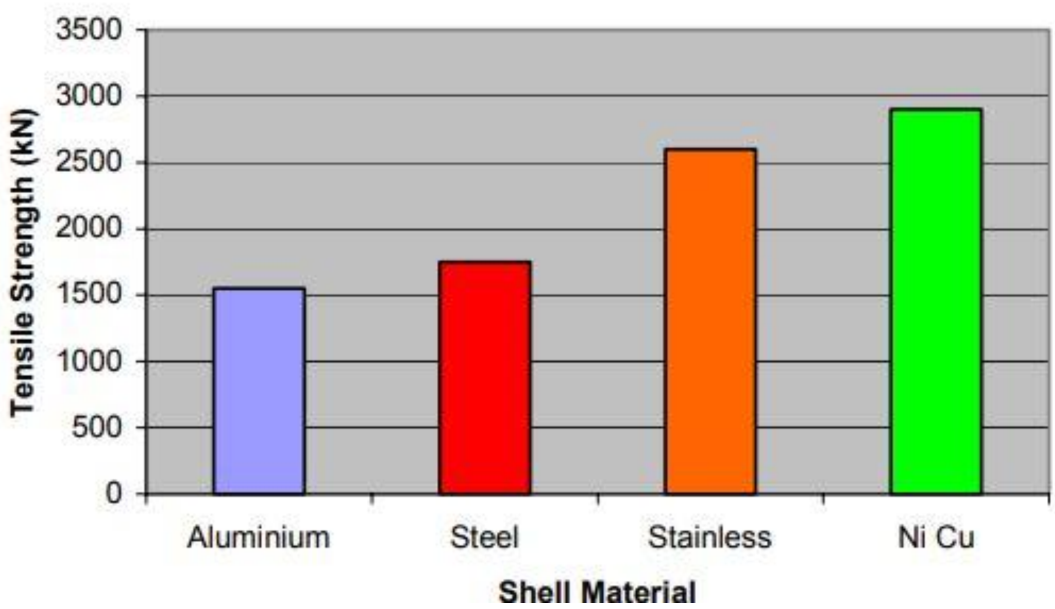

Figure 5 Relative strengths of Blind Rivet materials (Source: Ajax Fasteners, Riveting Handbook)

2.3 Hand Riveter Design

Hand riveters are the oldest invention for the installation of Pull Mandrel blind rivets. Most of the patents of hand riveters differ in liver sizes and design but the gripping and pulling of mandrel mechanisms are almost the same in every patent (Figure 6). In the Chinese patent (CN201728323U) for *Rivet gripping mechanism of hand riveter*, the basic gripping mechanism is patent which is used by most of the hand riveter's patents [5]. A similar gripping mechanism is also a patent in US patent US4353239.

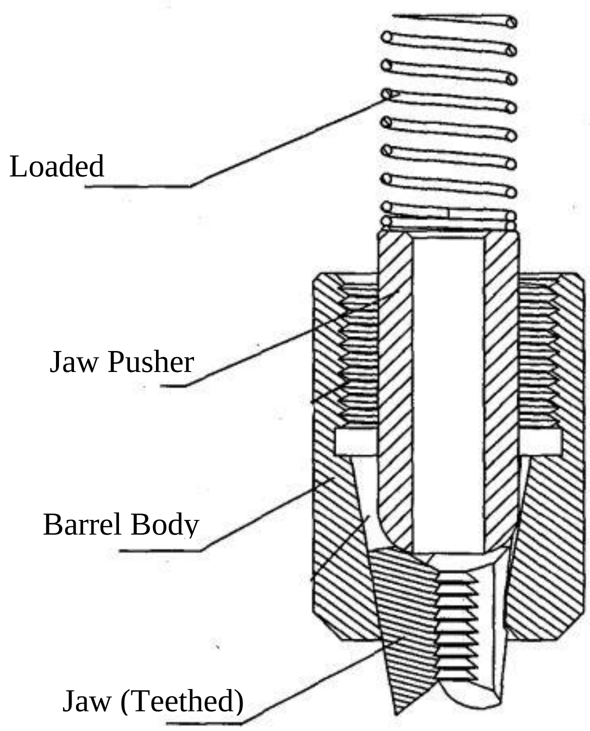

Figure 6 Rivet gripping mechanism of hand riveter (Chinese patent CN201728323U)

2.2.1 Working Mechanism

The jaws are used to grip the mandrel. These jaws are pushed together by the jaw pusher which is attached to a loaded spring. The spring in the barrel is always loaded which keeps the jaws pushed together. The jaws are opened when the barrel reaches the bottom of the housing, and the jaws are pushed to open by the chamfer in the “head”. The lifting of barrel provides the pulling force.

When the Jaws are open, the Blind rivet’s mandrel is inserted inside the head (Figure 7). When the lever handle is squeezed by hand, the barrel moves upward (Figure 8). As the barrel is lifted, the jaws are closed, gripping the mandrel. When the barrel is pulled upward, the shell is deformed. Using Hand Riveter, two or more squeezes are required to break the mandrel while clamping the workpieces together [6].

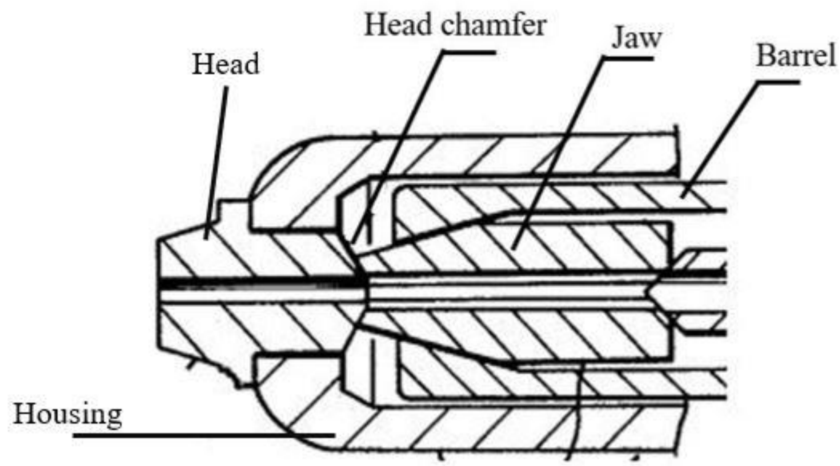

Figure 7 Opening of Jaw (US Patent US4353239)

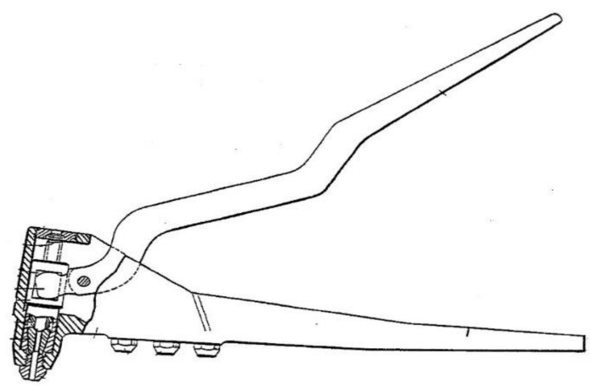

Figure 8 Hand Riveter

2.4 Electric riveter

In an electric riveter, the pulling force is provided by an electric motor. All the patents have different designs and control elements. Common components include electric motor, transmission, barrel, loading spring, and jaws.

Control systems are used to control the forward and backward motion of the barrel. Controlling forward and backward motion is important to prevent damage to other components due to excessive displacement. In patent US,8,109,123 B2 (Figure 1Figure 10), position sensors are used to define the forward and backward limits of the total displacement. When the button is pressed, the barrel moves backward and as it touches position sensor P2 (Figure 10), the direction is reversed. The barrel moves forward until it touches position sensor P1 (Figure 10) [7].

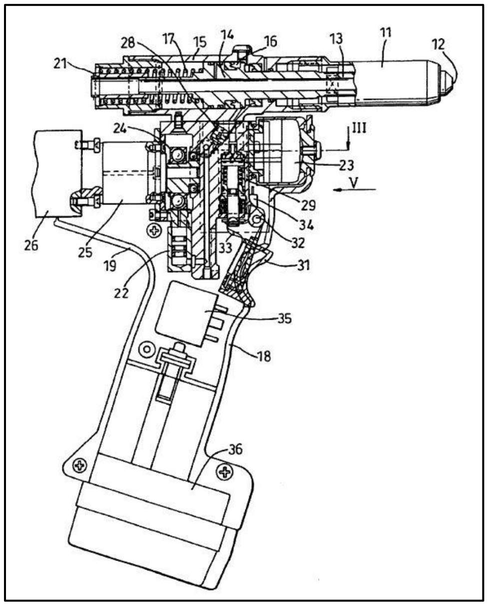

Figure 9 Patent US 6,886,226 B1

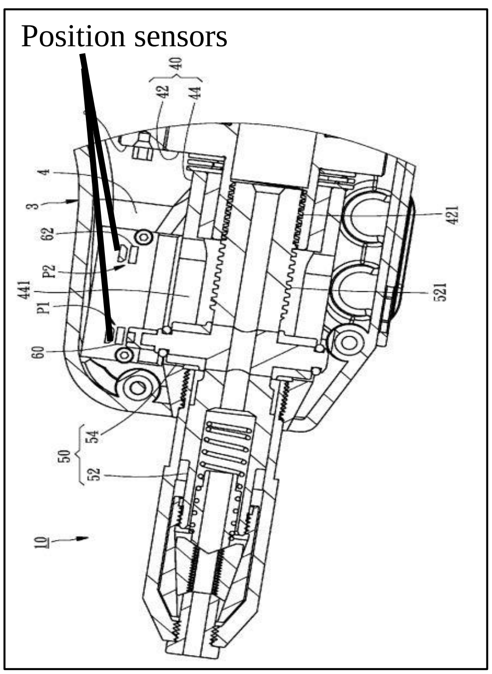

Figure 10 Patent US 8,109,123 B2

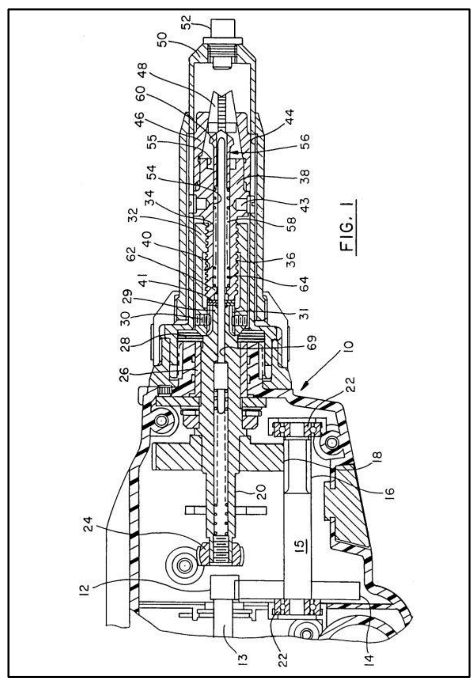

Figure 11 European Patent 0 594 333 A1

A very different and unique control system is designed in European Patent 0 594 333 A1 (Figure 11). A voltage sensor is connected to the motor which senses the motor load. When the barrel starts pulling the mandrel the motor load rises. As the mandrel is broken, the motor load decreases, and the control system reverses the direction of the motor. The barrel moves forward until it touches the bottom of the housing which again increases the motor load, and the control system stops the motor (Figure 12) [8].

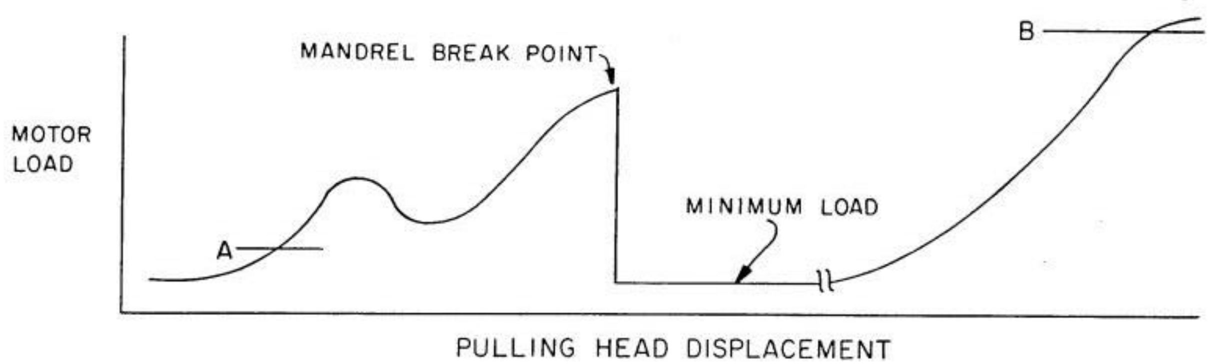

Figure 12 Voltage sensor reading graph (EU 0 594 333 A1) | Motor starts at point A and stops at Point B

2.5 Objective

The design of an electric rivet gun can be quite complex. That complexity increases the cost of individual rivet guns. The objective of this project is to provide a prototype of a low-cost electric blind rivet gun that can set rivets and then release the broken mandrel in a suitable amount of time. The barrel of the rivet gun should sustain the breaking load. The rivet gun should ensure a clean rivet installation process.

Chapter 3

Design Methodology

For prototyping, we will be focusing on setting an aluminum rivet GAMD58A [9]. GAMD58A has a diameter of 4 mm, a tensile strength of 1023.1 N, a shear strength of 845.1 N, and a mandrel max breaking load of 2668.1 N [10]. We intend to adopt the following design methodology for our project.

1. Designing the mechanism for installing a rivet
2. Design and selection of parts and material selection
3. ANSYS analysis
4. Arduino based control system
5. Fabrication of the parts of the riveting gun
6. Testing by installing GAMD58A rivet and rivets of different diameters

3.1 Designing of mechanism

The basic mechanisms involved in a riveting gun are grabbing of blind rivet's mandrel and pulling that mandrel to install the rivet.

3.1.1 Grabbing the mandrel

In our design, we have used the same mechanism of grabbing the mandrel as most of the patented riveting guns. The mandrel is grabbed using jaws which are preloaded with a spring. The jaws and spring setup are inside a barrel (Figure 6). When the barrel is at the bottom of the housing the jaws are pushed open by a chamfer in the head (Figure 7). At that position, the rivet is inserted through the head of a riveting gun. When the barrel is pulled up from the chamfer, the jaws close, and the mandrel is grabbed.

3.1.2 Pulling of the mandrel

As the barrel moves upward the mandrel is grabbed and pulled. A motor is used to pull the barrel using gears and a power screw.

3.2 Design of parts and material selection

Following are the parts involved in our design (Figure 13).

1. Barrel
2. Jaws
3. Spring and Jaw-pusher
4. Barrel Housing
5. Main Housing
6. Bearing Housing
7. Head
8. Power screw and Nut assembly
9. Geared Motor and Motor shaft with spur Gear
10. Limit switch stand

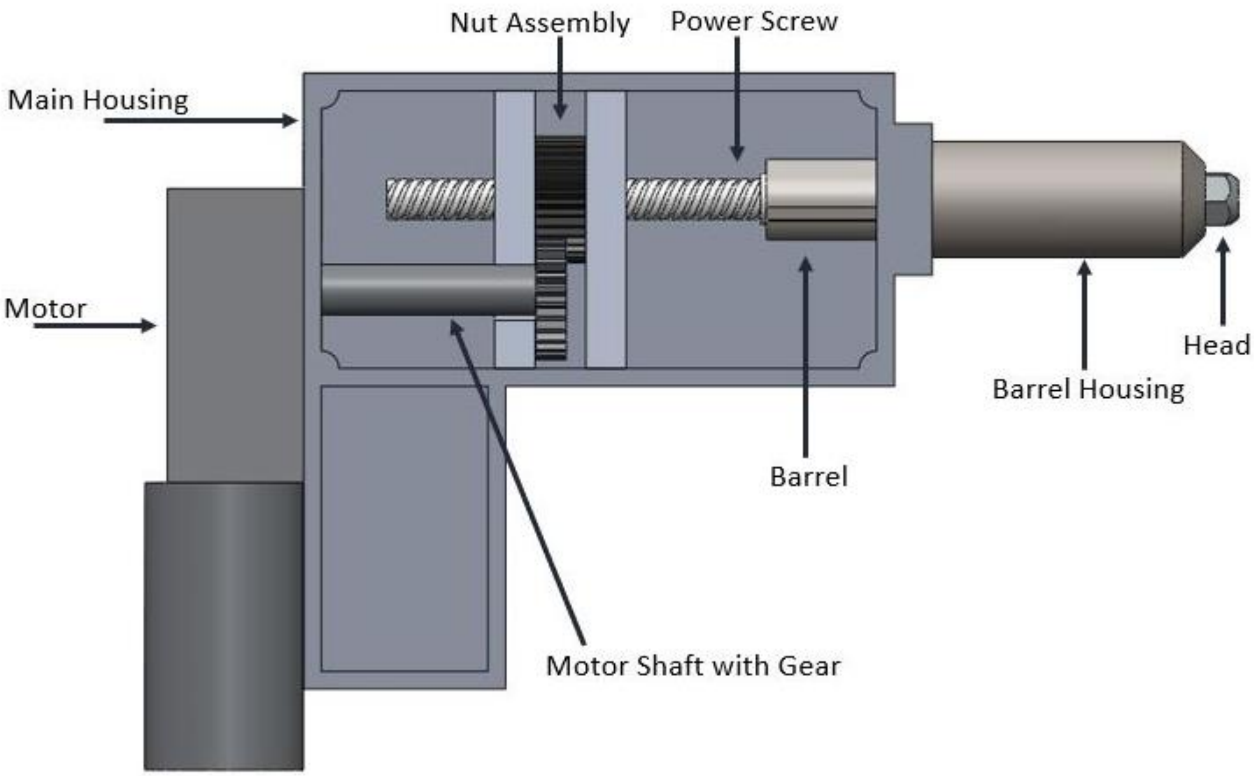

Figure 13 Riveter Assembly

3.2.1 Barrel

The barrel is a hollow cylinder with an internal taper at the bottom (Figure 14, Figure 15). Internal taper in use as a jaw bed. Jaws and spring setup are inside the barrel. The barrel holds the maximum load in the process. Therefore, we used Carbon-Steel AISI 1065 as a material for the barrel. CAD model and respective dimensions are shown below. The dimensions of the barrel are set according to jaws and spring setup, i.e. we are using a 9 mm spring, so the internal diameter of the barrel is set to 10.1 mm to give clearance for jaws and spring setup, and the head chamfer diameter is 6.40 mm, so the minimum diameter of the taper is set to 6.45 mm. There are symmetric keyways on the outside diameter of the barrel to restrict the rotation of the barrel and only allow linear displacement along the axis of the barrel.

3.2.2 Jaws

The jaws we are using are borrowed from a hand riveter assembly bought from hardware market. The hand riveter used a set of 3 jaws (Figure 16). Jaws are pushed closed together by a jaw pusher and a preloaded spring.

Figure 14 CAD Model of Barrel

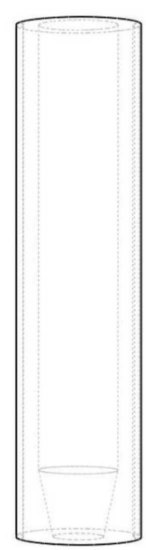

Figure 15 CAD Model of Barrel (with hidden lines)

Figure 16 Set of Jaw

3.2.3 Spring and Jaw-pusher

The spring and jaw-pusher are also borrowed from hand riveter assembly bought from hardware market. The jaw-pusher is a steel body used to push the jaw close. It is attached to a spring (Figure 17). The spring is loaded by pushing it inside the barrel and then fixing it.

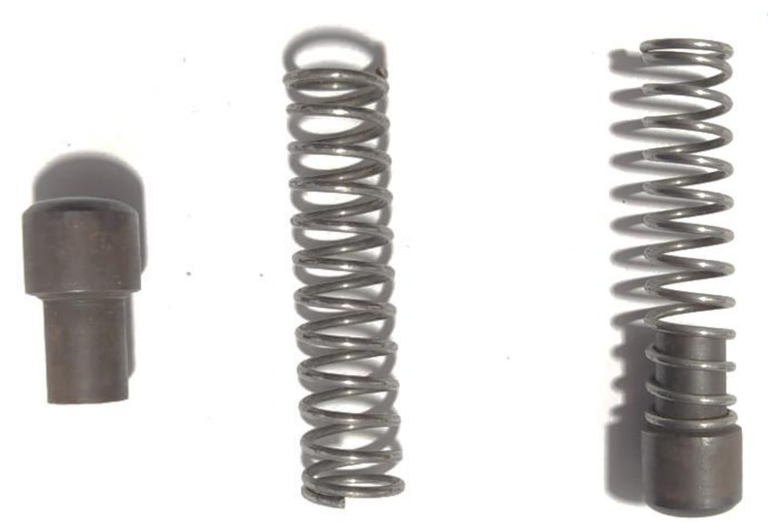

Figure 17 Jaw-pusher (left), Spring (right)

3.2.4 Barrel Housing

In our design, the housing consists of 3 parts; housing covering the barrel, bearing housing (bearing attached to nut assembly), and the main housing. Mild Steel is selected for housing covering the barrel, and aluminum for bearing housing and the main housing. The housing covering the barrel is designed to restrict the rotation of the barrel and only allow it to displace in a linear direction along the axis of the barrel. Key-seat is designed at top of the inside diameter of the housing (Figure 20, Figure 21). There is a threaded hole at the bottom of the barrel housing to fit the headpiece of a riveting gun (Figure 20).

3.2.5 Main Housing

The main housing is designed in a way to accommodate the mechanism on the inside and DC motor on the outside of the housing. The main housing also has a lid on one side (Figure 18). Material used for the main housing is aluminum. Aluminum is selected because it is easy to cast, and the machining can be performed on it easily. Dimensions are given in Appendix A (Figure 48).

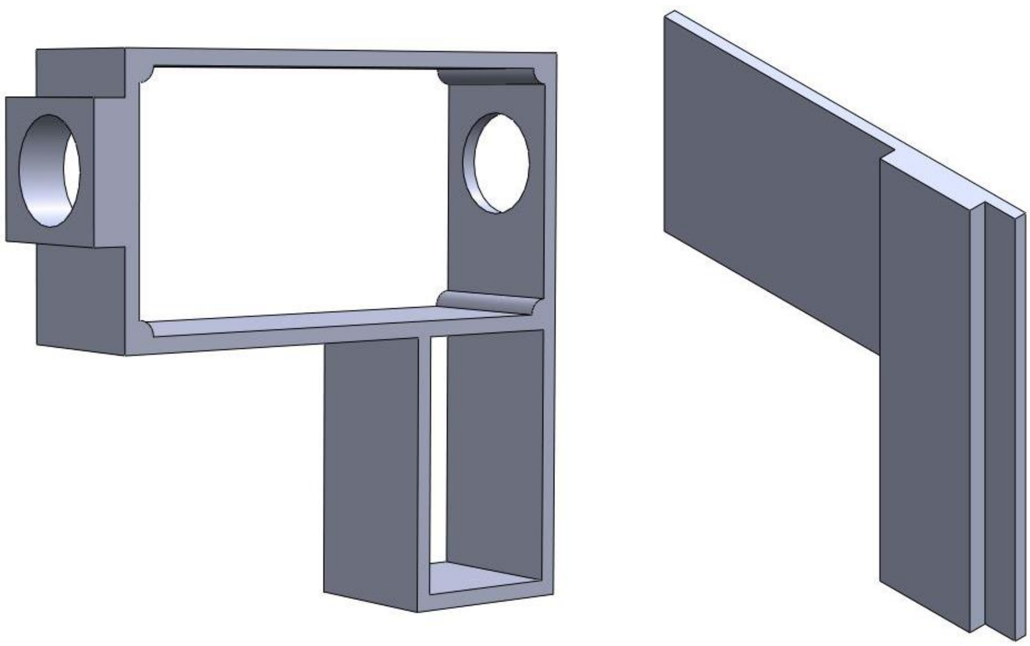

Figure 18 CAD Model of Main Housing (left) and Main Housing Lid (right)

3.2.6 Bearing housing

The bearing housing consists of two parts. Both parts fix the nut assembly on both sides. Both pieces have bearing seats to fix bearings. One part has a slot to allow motor shaft gear to mesh with the gear on nut assembly (Figure 19). The material for bearing housing is also aluminum because it is easy to cast and perform machining on it. Dimensions are given in Appendix A (Figure 51, Figure 52).

3.2.7 Head

The head is also borrowed from a hand riveter assembly bought from hardware market. The head has a chamfer to push the jaws open when the barrel is at the bottom of the housing covering the barrel (Figure 22).

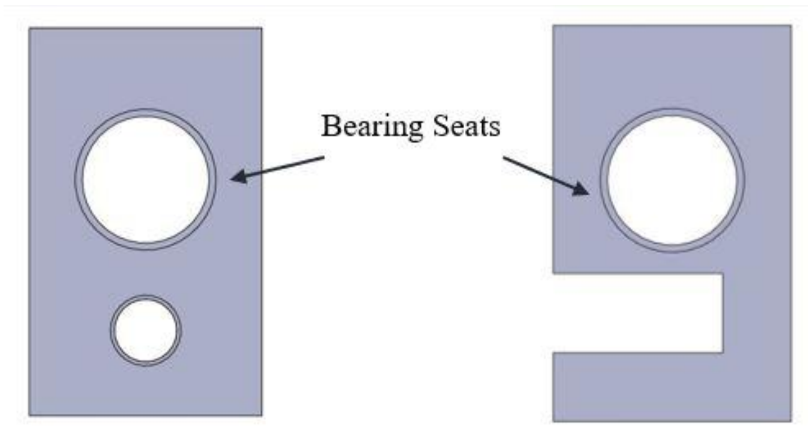

Figure 19 Bearing Housing Parts

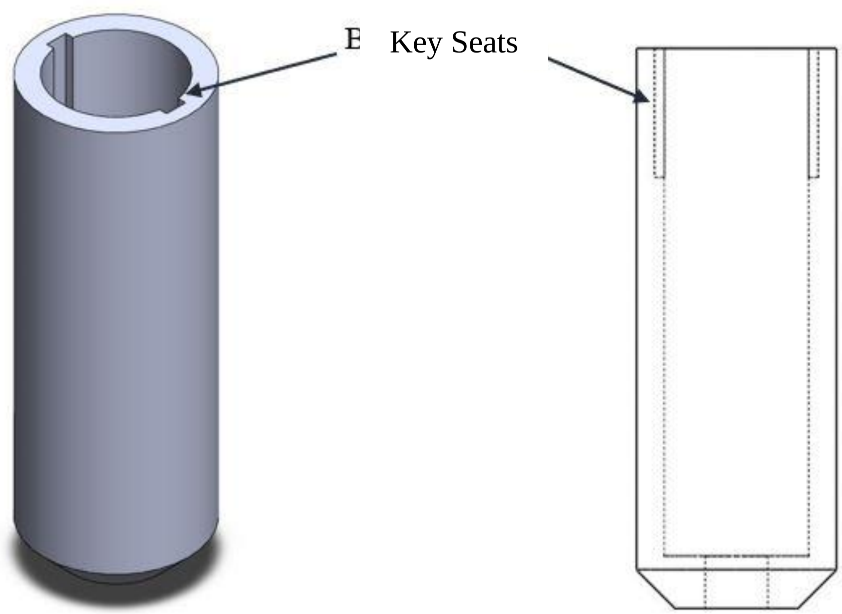

Figure 20 CAD Model of Barrel Housing

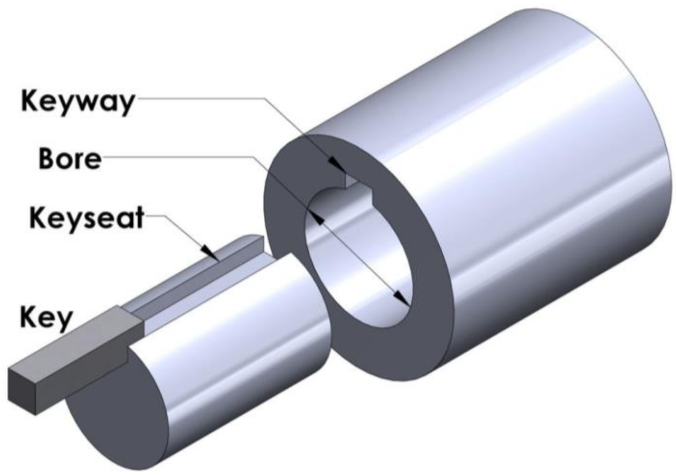

Figure 21 Key, Keyway, and Keyseat

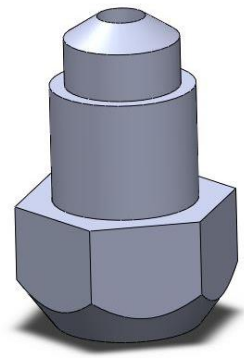

Figure 22 Head of the riveting gun

3.2.8 Power-screw and Nut assembly

A power screw and a nut assembly are used to pull the barrel with the help of a motor. The T8 power-screw is selected for pulling of the mandrel (Figure 23). T8 Power-Screw is selected because it is easily available in the hardware market and is usually found in desk size 3D printers. This lead screw has a pitch of 2mm. It has a single start thread, so the lead is also 2mm. The torque required to pull the barrel is calculated and its value is 2.4615N.m. Calculation for the torque required to pull the barrel is given below [11] [12].

Figure 23 T8 Power screw

Calculations for Torque needed to pull the barrel

Required load on power screw for breaking rivet's mandrel = W = 2700N

Nut material: Brass

Screw material: Steel

Friction between nut and power screw = f = 0.16m [13]

Diameter of the screw = d = 8mm = 0.008m

Pitch of the screw = p = 0.002m

Thread angle = $2\alpha = 30° = 15°$

Lead = 0.002m

Lead angle = tan^{-1} $\left(\frac{lead}{\pi d}\right) = 4.54° = \lambda$

$d_m = d - {}^{p}/_{2}$ = 0.007

$\alpha_n = \tan^{-1}[\tan(\alpha) \times \cos(\lambda)] = 14.955°$ (Figure 24)

Torque required to break the mandrel = $\tau = w\frac{dm}{2} \times f\frac{\pi dm + Lcos\alpha n}{\pi dm \cos \alpha n - fL}$ = 2.4615N.m

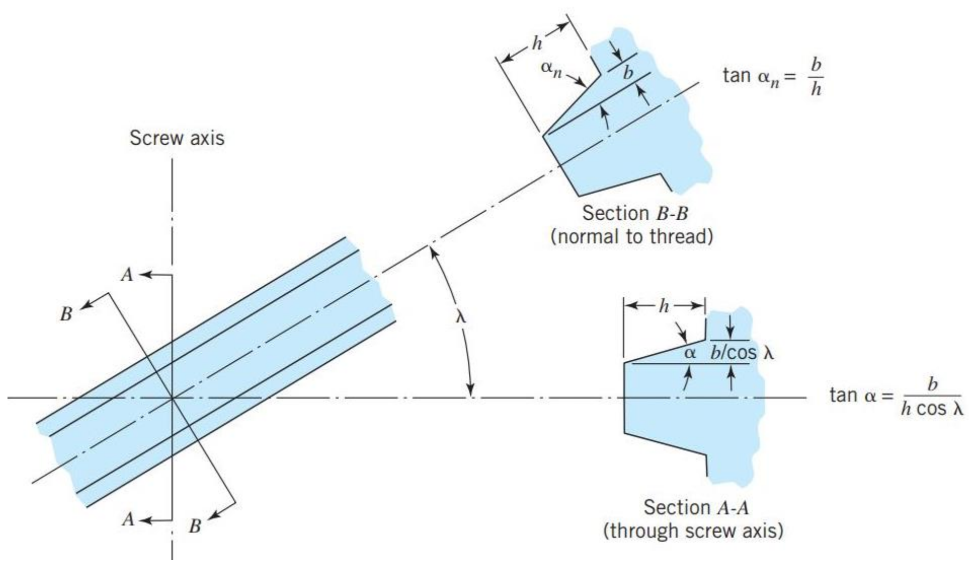

Figure 24 Comparison of thread angles measured in axial and normal planes [11]

Nut assembly has a gear, two bearings on both sides, and a nut for the power screw (Figure 25). All these components are tight-fitted together. The gear is to mesh with the gear on motor shaft making a gear ratio of 5:4.

Figure 25 Nut Assembly

3.2.9 Limit switch stand

The limit switch stand was designed to fit the limit switches under the barrel (Figure 41). The height of limit switch stand was adjusted such that when the barrel slides over the switch, the switch button is pressed. The stand was 3D printed and fitted in the assembly. The cad model is given in the Figure 26.

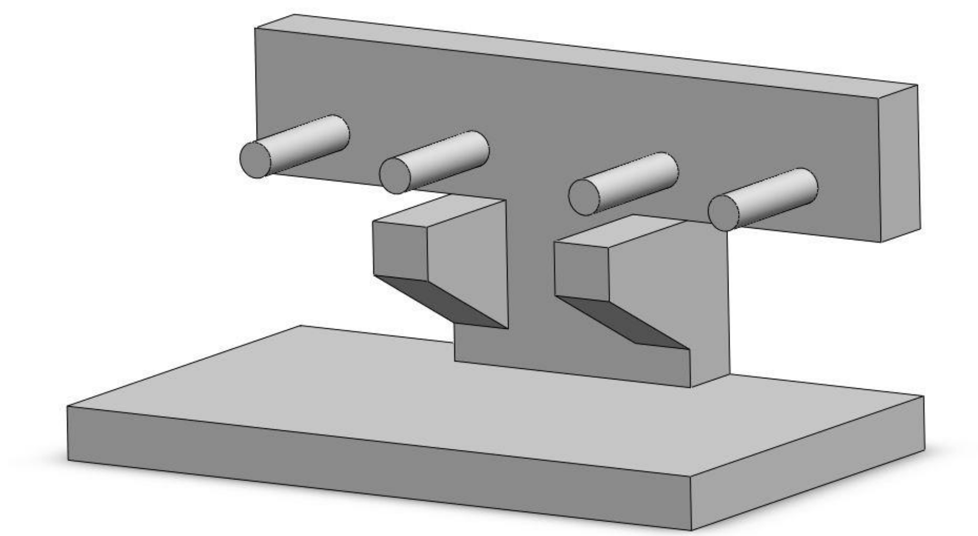

Figure 26 Limit switch stand

3.3 Fabrication of parts

Following are the parts fabricated.

1. Barrel
2. Barrel Housing
3. Bearing Housing
4. Main Housing
5. Modification to T8 Power Screw
6. Nut assembly

3.3.1 Barrel

The barrel is a hollow cylinder with an internal taper at the bottom (Figure 14). Internal taper in use as a jaw bed. Jaws and spring setup are inside the barrel. We used Carbon-Steel AISI 1065 as a material for the barrel body. The body was fabricated according to the dimensions given in Appendix A (Figure 47). Following are the steps used for the fabrication of the barrel.

1. A workpiece of diameter 20 mm was fitted into the lathe machine
2. The outer surface was machined to make the outer diameter equal to 16 mm.
3. The workpiece was drilled with a tool piece of 9 mm to the depth of 57 mm.
4. The internal diameter was increased to 10.1 mm via boring.
5. The hollow cylinder was cut from the workpiece at a length of 56.55 mm.
6. The tapered part was created via a taper tool having an angle of 102.2 degrees and then tight fitted to the hollow cylinder of 56.55 mm length via tight threading.
7. The workpiece was then fitted into a milling machine.
8. The keyways of 1 mm depth were machined on opposite sides of the outer diameter using a cutting tool (Figure 14, Figure 27).
9. Internal threading was done to accommodate the welded thread on the T8 power-screw.

3.3.2 Barrel Housing

Mild steel is used in the fabrication of housing covering the barrel. It is designed to restrict the rotation of the barrel and only allow it to displace in a linear direction along the axis of the barrel. key-seat is designed at top of the inside diameter of the housing (Figure 20). There is a threaded hole at the bottom of the housing covering the barrel to fit a headpiece of the riveting gun (Figure 20). It is fabricated according to the dimensions given in Appendix A (Figure 48). Following are the steps that we took for the fabrication of the housing covering the barrel.

1. A workpiece of 25 mm diameter was fitted into a lathe machine.
2. The outer diameter was machined to 23 mm.
3. The workpiece was drilled with a 15 mm drilling tool to the depth of 59 mm.
4. To make the internal diameter uniform, the internal diameter was bored with the boring tool to 17 mm.
5. The workpiece was cut at 65.1 mm.
6. A threaded hole was machined to fix the headpiece of the riveting gun (Figure 28).
7. A key seat was machined in the internal diameter of the housing
8. Keys of 2.5 mm thickness were soldered to the housing (Figure 29).

Figure 27 Fabricated Barrel

Figure 28 Fabricated barrel Housing

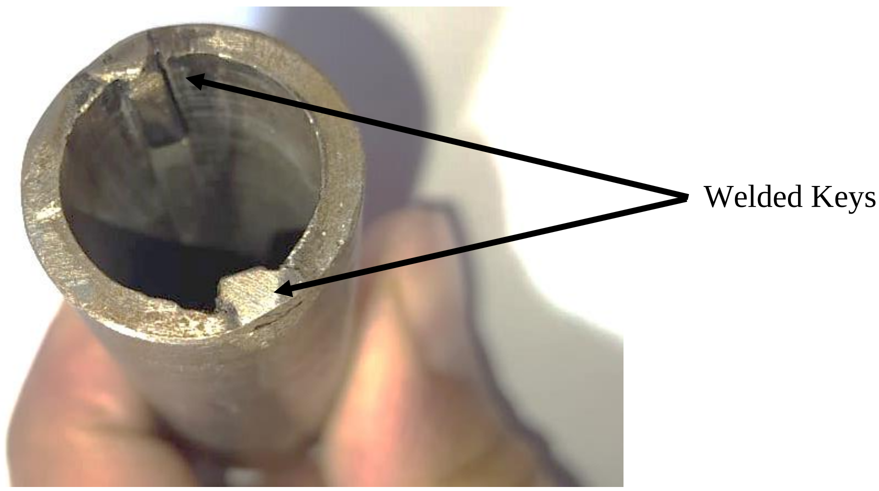

Figure 29 Keys on the internal diameter of the housing

3.3.3 Main Housing and Main housing Cover

The main housing is the outer case in which the whole mechanism is fitted. The motor is fitted on the outside of the main housing. The motor shaft goes inside the main housing and the gear on shaft meshes with the gear on nut assembly. The main housing and the main housing cover were first designed in SolidWorks (Figure 18). The design was then 3D printed. ABS material was used to 3D print the main housing and main housing cover. This 3D print was then used to make a sand-casting mold. Aluminum was used to cast the main housing and main housing cover (Figure 30).

3.3.4 Bearing Housing

Bearing housing is designed to hold the bearing in the nut assembly on both sides. It also holds the bearing at the end of motor shaft. Two slabs of aluminum were casted and then machined to fit the bearings (Figure 31). These slabs were then screwed to the main housing. M3 screws were used to fit slabs in the main housing. The nut assembly was aligned to the barrel so there are no excessive friction forces on the in main assembly.

3.3.5 Modification to the T8 Power-Screw

A hollow cylinder was machined with external threading on it. This piece was welded to the end of a T8 power screw (Figure 32). This modification is used to fix the power screw to the barrel.

3.3.6 Nut Assembly

A set of spur gears having a gearing ratio of 5:4 and a diameter of 19 mm were selected from a metal gear shop. One of those gears was drilled and then fix fitted on the nut of the power screw. A bearing was also close-fitted on the nut of the power screw (Figure 33).

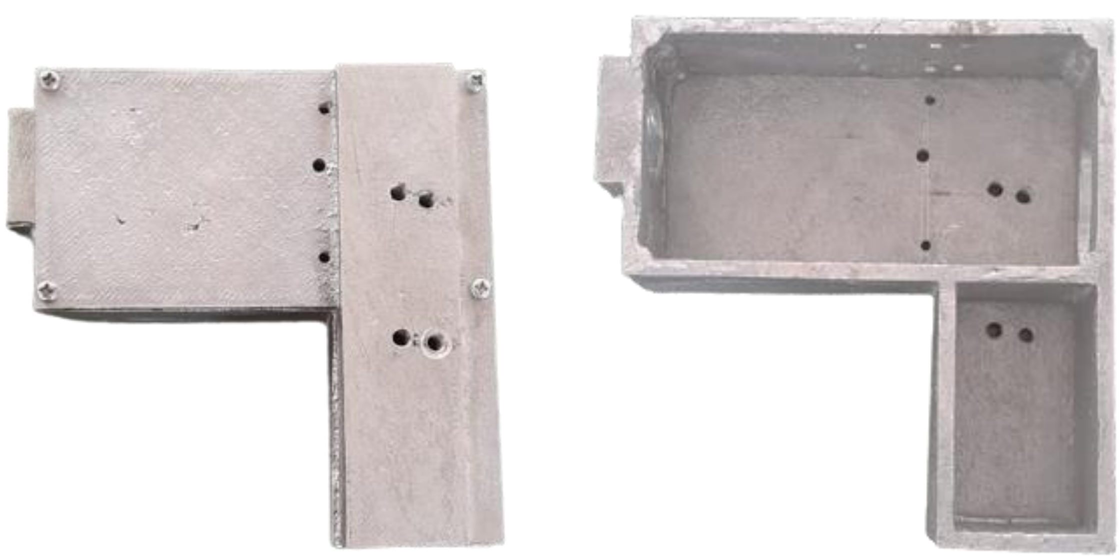

Figure 30 Main housing Cover (left) Main Housing (right)

Figure 31 Both Parts of Bearing Housing

Figure 32 Additional Thread on the Power Screw

Figure 33 Nut Assembly

3.4 Assembly of the riveter

The parts were fixed to the main body via M3 screws. Motor is fixed to the main body via M5 screws. Additional support was installed to the bearing housing to limit the movement of bearing housing (Figure 34).

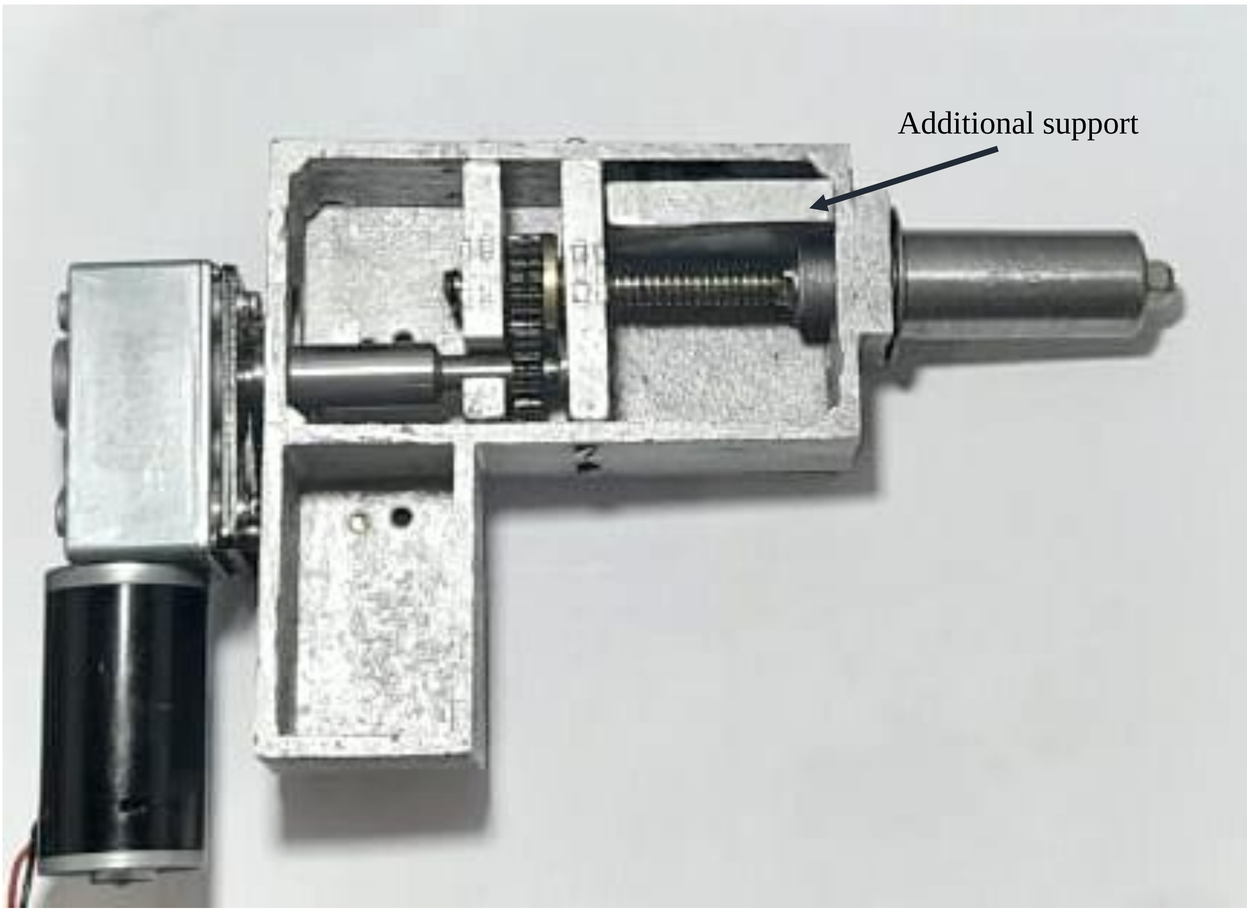

Figure 34 Riveter Assembly

Chapter 4

ANSYS Analysis

ANSYS analysis is performed on the barrel of the riveting gun as it carries almost all the load of installing a rivet. The maximum mandrel breaking load of rivet GAMD59A is 2668.1 N. This load is transferred to the jaw bed inside the barrel which causes tension in the barrel body. Following is the procedure was taken to get a factor of safety of the barrel body in static loading conditions.

4.1 Getting Engineering Data

We used Carbon-Steel AISI 1065 as a material for the barrel. Following are the material properties for AISI 1065 [14].

Table 1 Mechanical Properties of AISI 1065

Properties	Metric Values
Tensile strength, ultimate	635 MPa
Tensile strength, yield	490 Mpa
Modulus of elasticity	200 Gpa
Bulk modulus	140 Gpa
Shear modulus	80 Gpa
Poissons ratio	0.3
Density	7.85g/cm^3

4.2 Meshing Model

The .STEP file of the barrel CAD model was generated in SolidWorks and then imported to ANSYS. A Mesh model was generated using the following settings (Figure 35).

4.3 Applying Loads

Fixed support was added to the top surface of the barrel (Figure 36). A Force of 2700 N was applied on the surface of the taper.

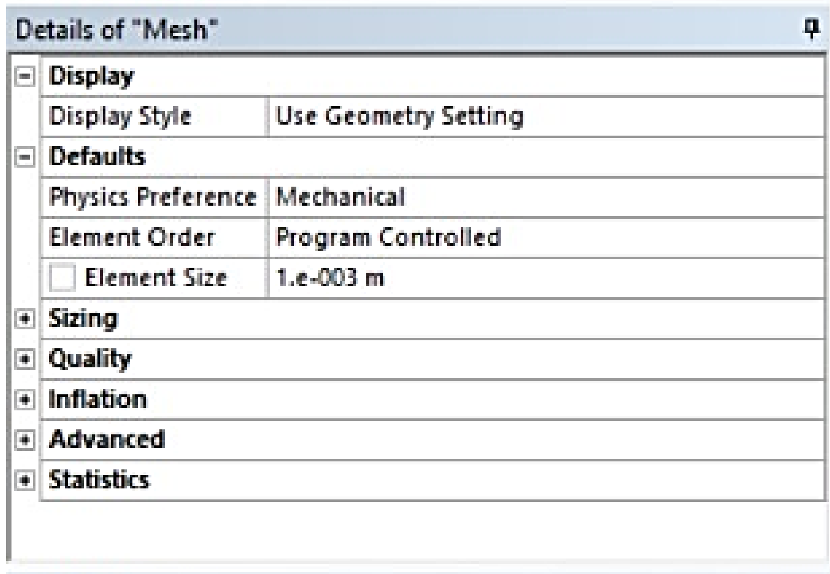

Figure 35 Mesh Settings

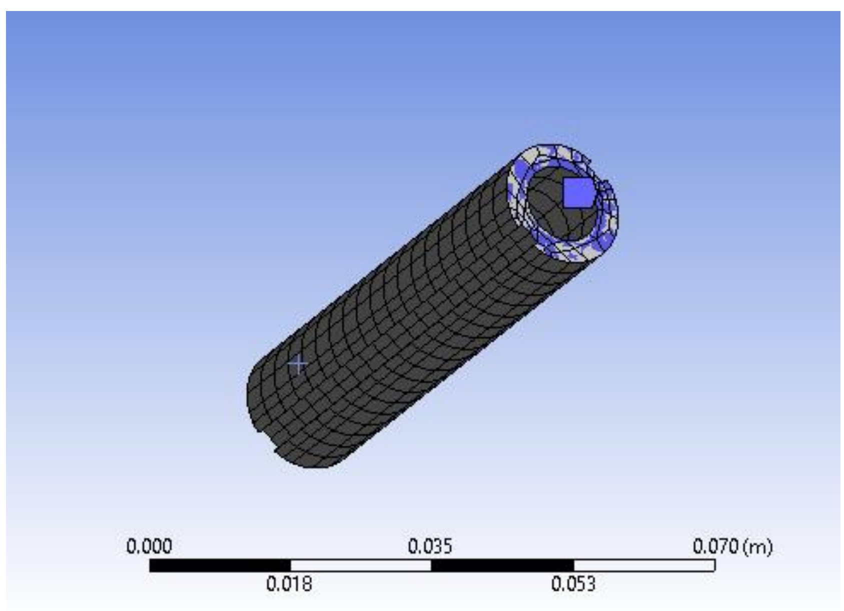

Figure 36 Fixed Support

4.4 Static Factor of Safety

After solving the model, the Static Factor of safety (SOF) is calculated using stress tool in ANSYS. The minimum factor of safety throughout the body is measured 7.5129 (Figure 38).

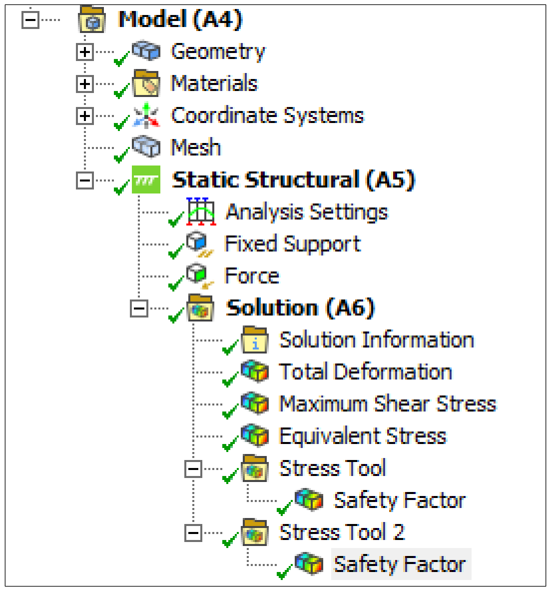

Figure 37 ANSYS Model

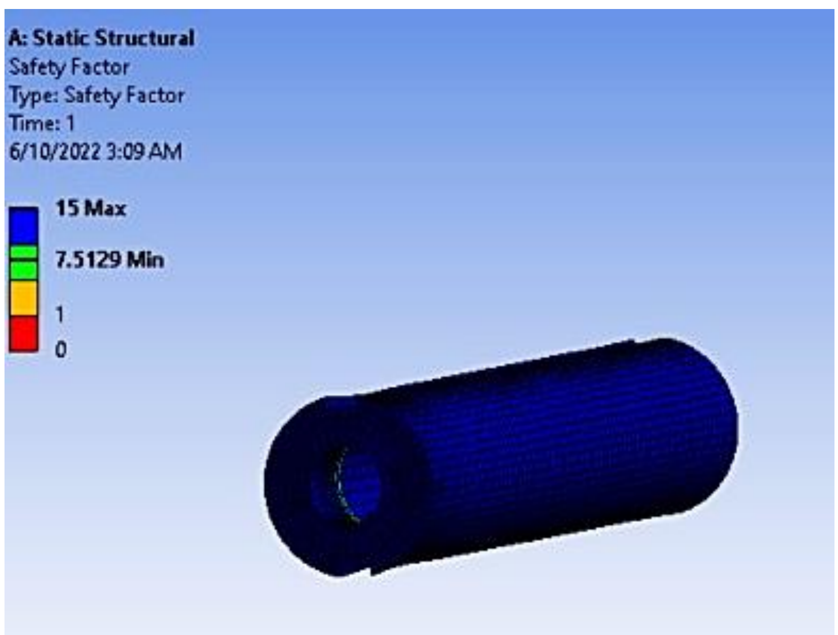

Figure 38 Static SOF

Chapter 5

Control System

The forward and backward displacement of the barrel in the riveting gun is controlled via an Arduino control system. We have devised a semi-automatic control system to control the displacement of the barrel. LC30G191C DC motor is used to displace the barrel and the forward and backward motion is controlled via motor controller BTS7960. The displacement is limited via two micro limit switches. A 12 V power supply is used to power the motor and a 5 V power supply is used to power the Arduino. Following are the components used in our Arduino control system.

1. Arduino UNO
2. 24 V DC Motor
3. Micro Limit Switch
4. BTS7960 Motor Controller
5. Push-Button
6. 12 V Power Supply

5.1 Arduino UNO

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button (Figure 39). The program is coded into it via windows software Arduino IDE. The device is very useful in prototyping control systems. It uses a 5 V power supply and a data transfer cable to upload the code.

5.2 12 V DC Motor

We used a 12 V geared motor manufactured in China (Figure 40). The motor shaft has a spur gear welded to it to mesh with the spur gear on the nut assembly. Following are the specifications of the motor (Table 2). The working load torque of the motor is 3.92 N.m at 30 rpm. The gear on motor shaft when meshes with the gear on nut assembly, makes a gear ratio of 5:4. The output torque becomes 4.9 N.m at 24 rpm

Table 2 Specification of the Motor

Gear ratio	1:200
Working Voltage	12V
No Load RPM	40rpm
No Load Current	≤ 350mA
Working Load RPM	30rpm
Working Load Current	≤1.6A
Working Load Torque	3.92N.m
Stall Load Torque	6.86N.m
Stall Load Current	6.5A

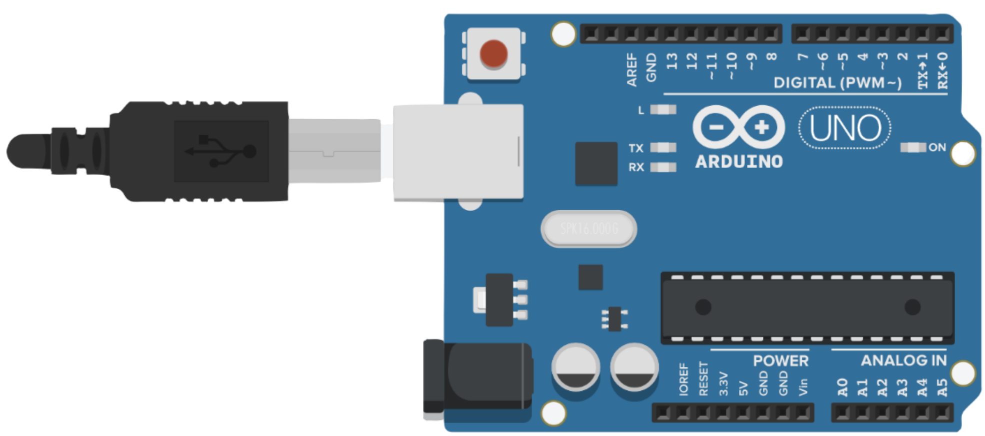

Figure 39 Arduino UNO Schematic

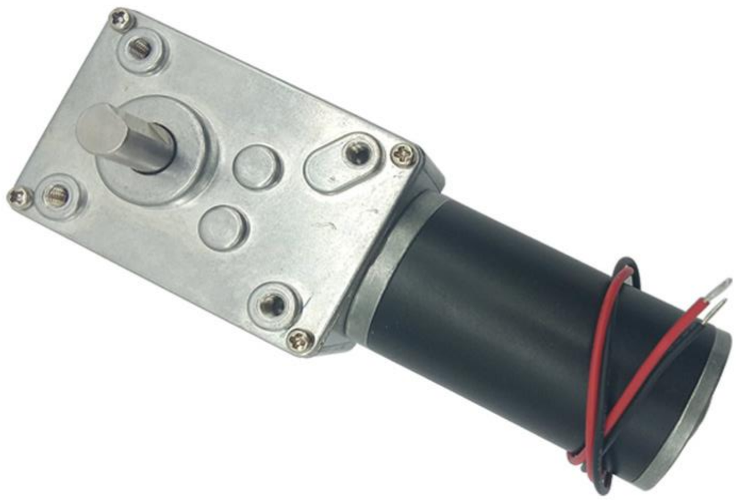

Figure 40 Geared DC Motor

5.3 Micro Limit-Switches

We have used 2 micro limit-switches to limit the displacement of the barrel (Figure 41). The micro limit-switches we selected are easily available in the market. We have kept them in a “normally open” configuration.

Figure 41 Micro Limit-Switch

5.4 BTS7960 Motor Controller

The drive uses an H-bridge driver module composed of Infineon power drive chip BTS796, with overheating and over-current protection (Figure 42). We selected this Controller because it can drive a 24 V motor and has a high maximum current limit, up to 43 amperes (A). This controller has following applications.

- Current diagnostic
- Slope adjustment

- Dead Time generation
- Over-temperature, over-voltage, under-voltage, over-current protection
- Short circuit protection

5.5 Push-Button

We have used two push-buttons, one for the forwarding motion of the barrel and one for the backward motion of the barrel. The push-buttons we selected have rectangular caps for ease of pushing them (Figure 43) and are easily available in the market.

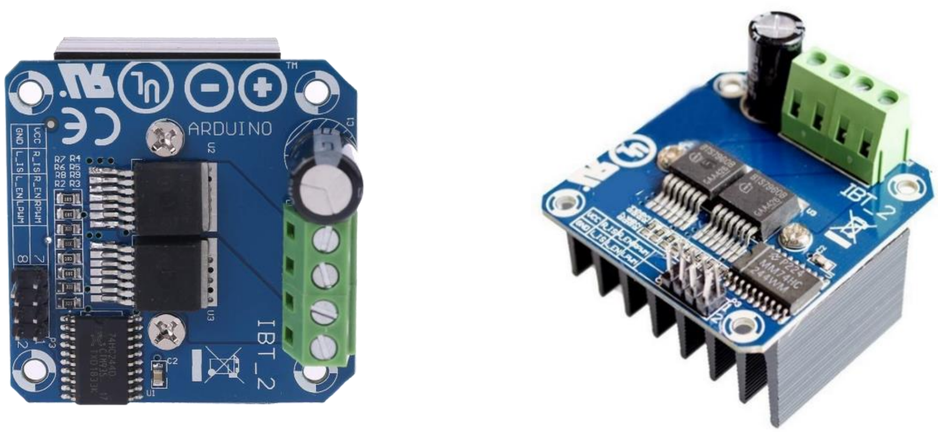

Figure 42 BTS7960 Motor Controller

Figure 43 Push-button with cap

5.6 Schematic of the Control System

Following is the schematic of our control system designed using windows software “fritzing”.

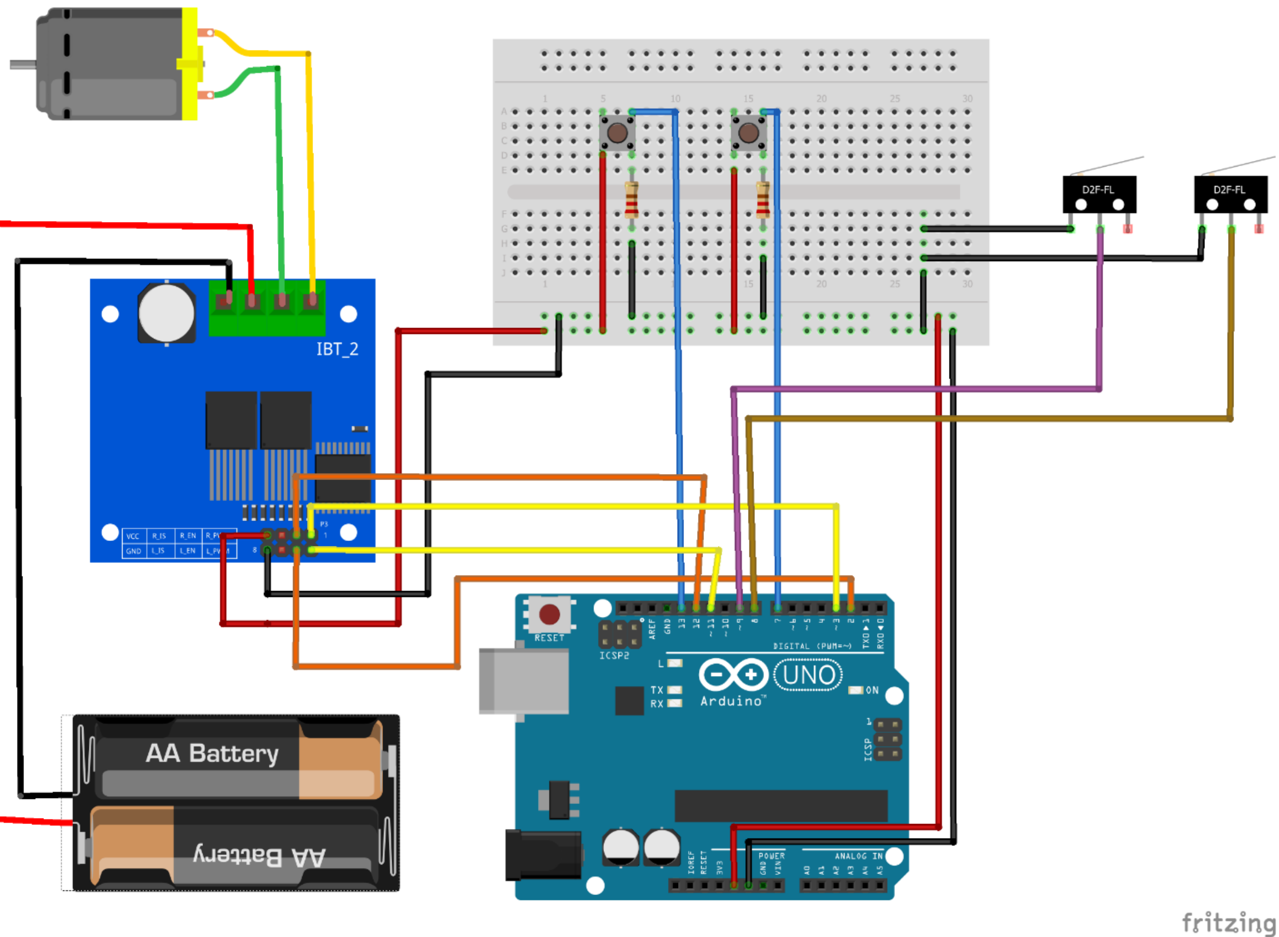

Figure 44 Riveting gun Control System Schematic

5.7 Arduino IDE Coding

The code is coded in Arduino IDE and uploaded to Arduino UNO in the control system. The code is provided in Appendix B.

Chapter 6

Testing and Results

The riveter was tested by installing GAMD58A rivet (4mm Aluminum-aluminum rivet). 12 V power supply was used to give power to the riveter. Maximum current input was around 4.2 Ampere. The riveter was able to install GAMD58A rivet in 7 seconds. Figure 45 shows image of the tested rivet.

Figure 45 Tested rivet

Figure 46 Installed rivet

Chapter 7

Conclusion & Future Recommendations

In this thesis, we reviewed the design of a Pull Mandrel blind rivet and related tools for setting a blind rivet such as hand riveter and electric riveter. A mechanism of installing rivet is devised and a whole new design is adopted. Dimensions and materials of different parts are elaborated in this project thesis. A control system to control the displacement of the barrel is designed and tested. Some parts are machined in a workshop, some are bought ready-made from the market (power-screw, spur gear, and bearing) and some of the parts are borrowed from hand rivet gun (jaws, spring, and jaw-pusher). The conventional fabrication processes were used to fabricate each part i.e., manual machining processes. The riveter was able installed the GAMD58A rivet in 7 seconds.

Following are the future recommendations for our project.

- The design we adopted did not involve space and material management. The prototype can be optimized to make its size small.
- The parts we machined manually that’s why the alignment is not precise. More advanced methods can be adopted to fabricate the parts to make the alignment more precise.
- The power screw we selected was selected because it was available in the market. Power screw can be designed and manufactured to get a better mechanical advantage.
- The main housing of the riveter was fabricated from cast aluminum which is not ideal. The main housing can be fabricated from plastic via injection molding.
- A better motor can be selected that can install larger diameter rivets.

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Appendix A

Dimensions of the Barrel

Unit system: MMGS

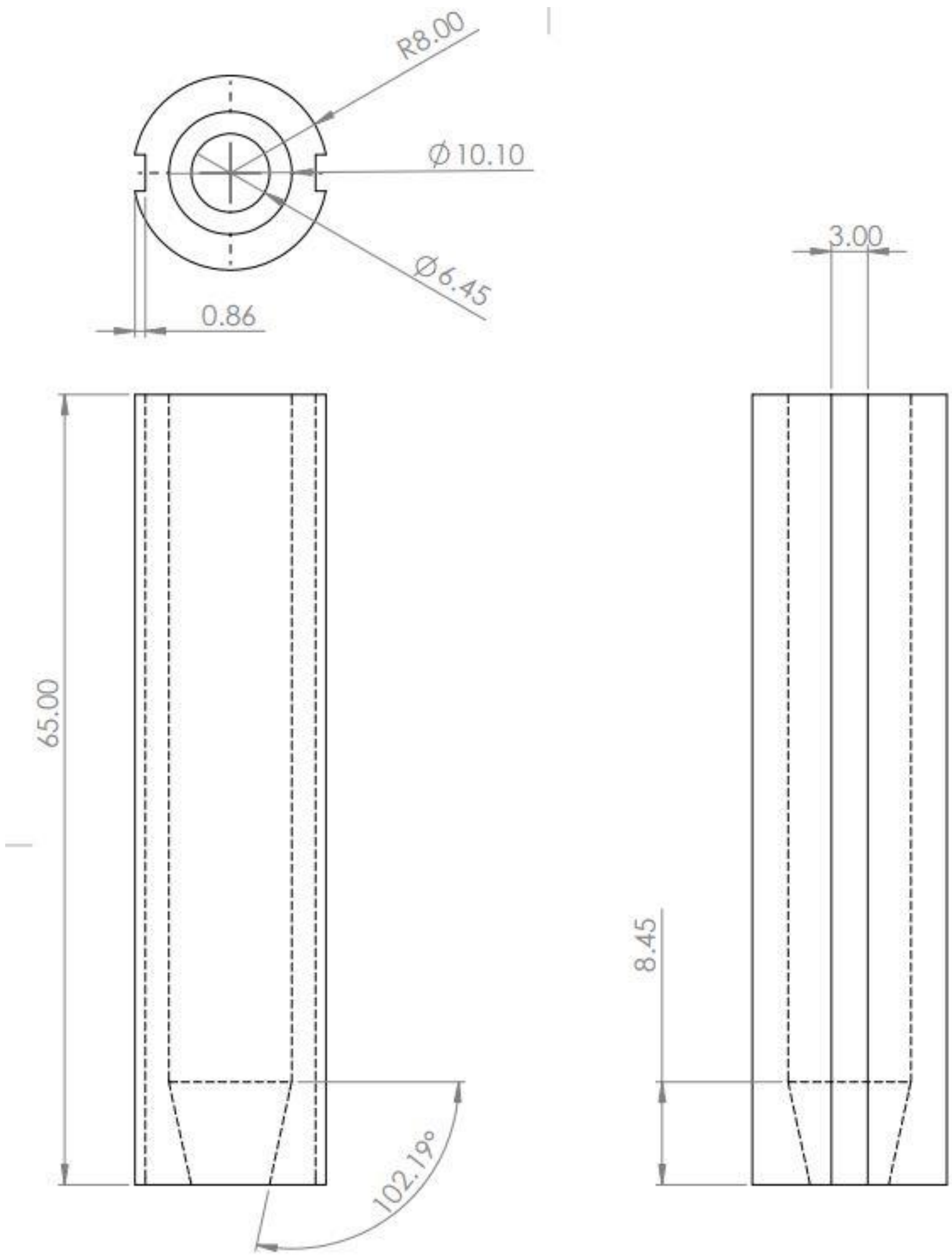

Figure 47 Dimensions of Barrel

Dimensions of the Barrel Housing

Unit system: MMGS

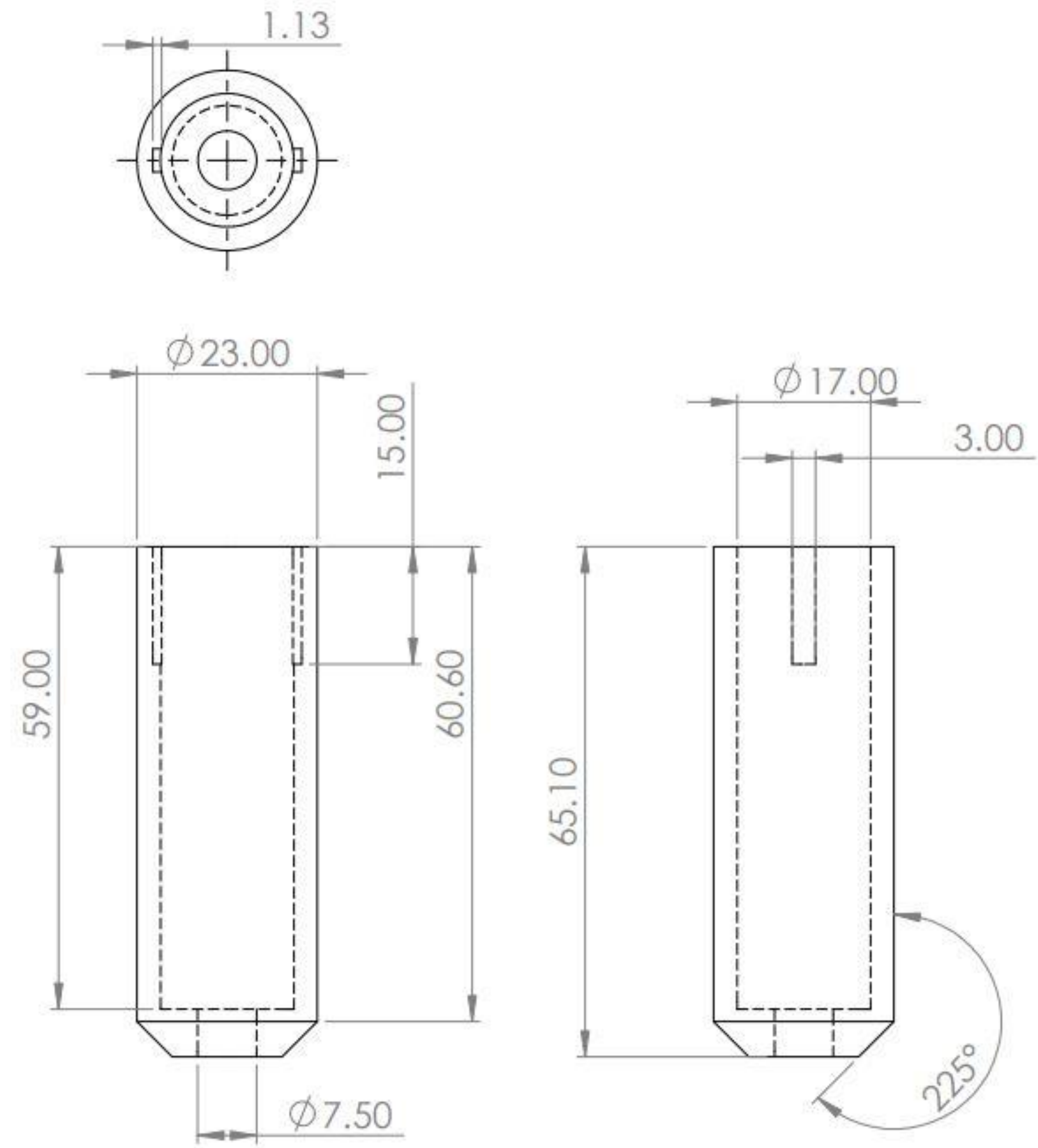

Figure 48 Dimensions of Barrel Housing

Dimensions of the Main Housing
Unit system: MMGS

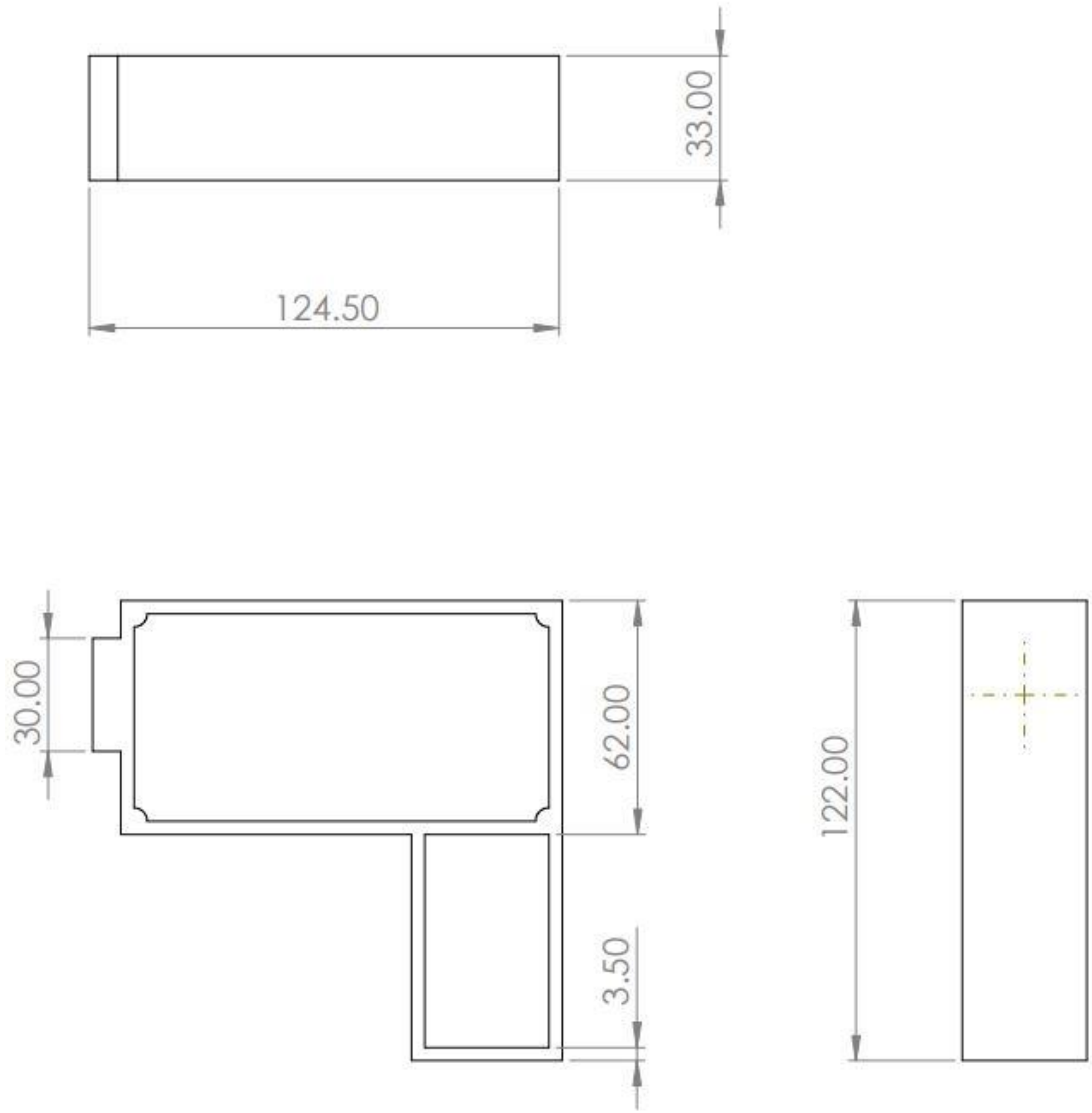

Figure 49 Dimensions of Main Housing

Dimensions of the Main Housing Cover
Unit system: MMGS

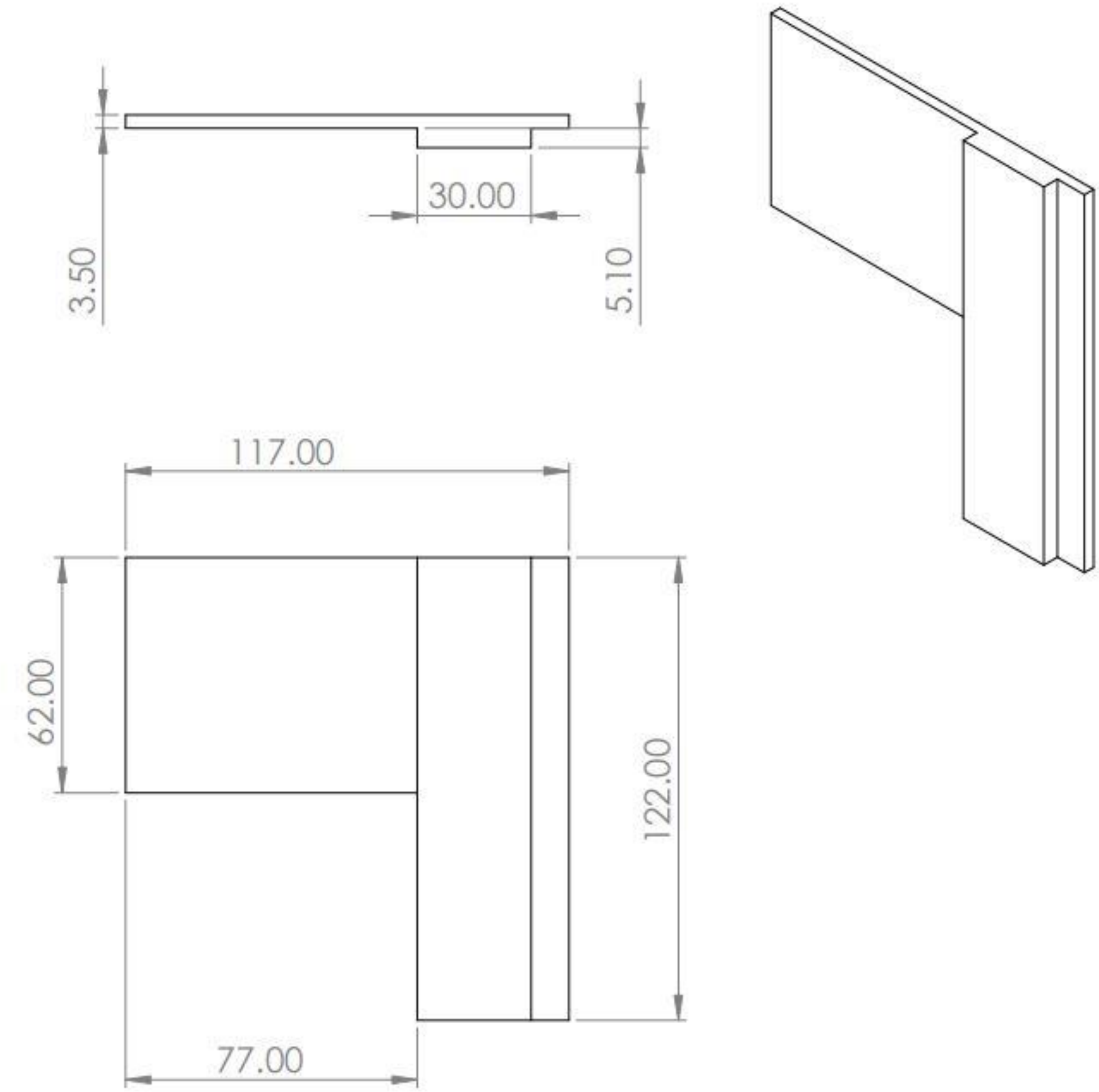

Figure 50 Dimensions of Main Housing Cover

Dimensions of the Bearing Housing 1
Unit system: MMGS

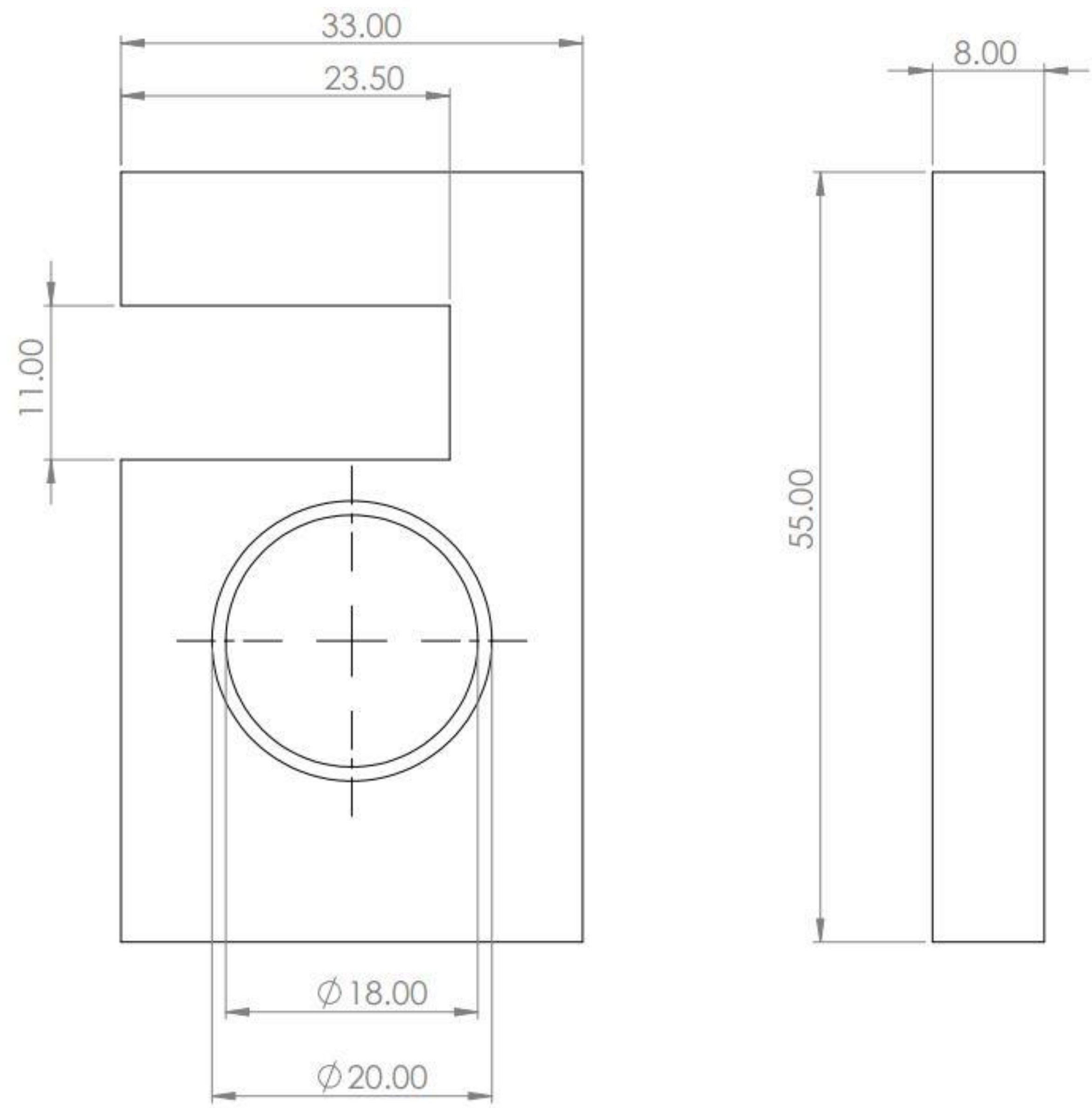

Figure 51 Dimensions of Bearing Housing 1

Dimensions of the Bearing Housing 2
Unit system: MMGS

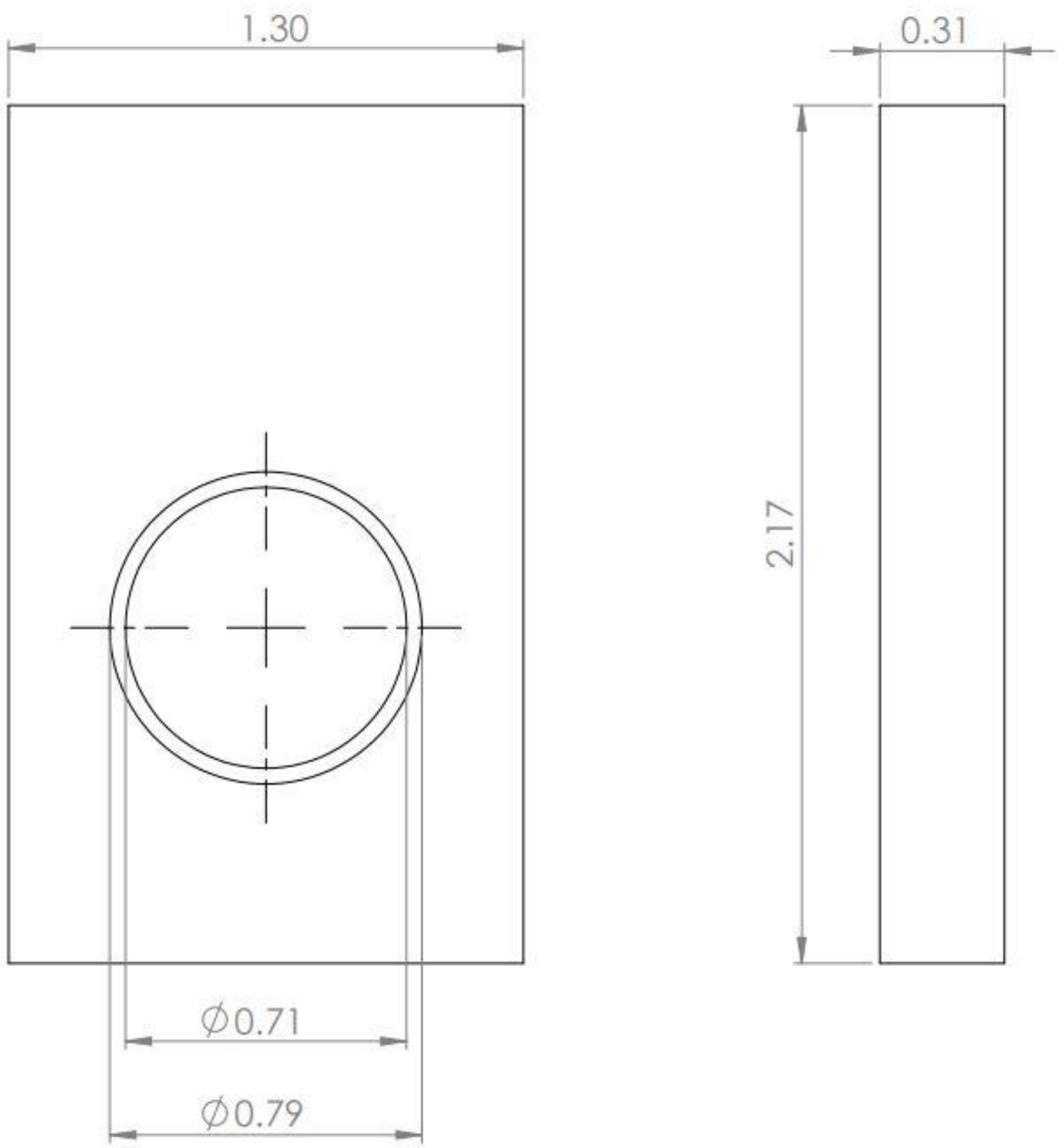

Figure 52 Dimensions of Bearing Housing 2

Appendix B

Arduino IDE Coding

Defining Pins

```
int RPWM=11; //PWM signal to Motor
int LPWM=3;  //PWM signal to Motor
int L_EN=2;
int R_EN=12;
int S1=7;    // Push-Button 1
int S2=13;   // Push-Button 2
int L1=9;    //Limit-Switch 1
int L2=8;    //Limit-Switch 2
```

Void Setup

```
void setup() {
  // put your setup code here, to run once:
  pinMode(RPWM,OUTPUT);
  pinMode(LPWM,OUTPUT);
  pinMode(R_EN,OUTPUT);
  pinMode(L_EN,OUTPUT);
  pinMode(S1,INPUT);
  pinMode(L1,INPUT);
  pinMode(L2,INPUT);
  pinMode(S2,INPUT);

  digitalWrite(R_EN,HIGH);
  digitalWrite(L_EN,HIGH);

}
```

Void Left

This function is defined for the backward motion of the barrel.

```
void left()
{
  if (digitalRead(S1)==HIGH && digitalRead(L1)==LOW  )  // the barrel will go backward
      {
        analogWrite(LPWM,255);
        analogWrite(RPWM,0);
      }

      else       // the barrel will stop due to limit switch
      {
        analogWrite(LPWM,0);
        analogWrite(RPWM,0);
      }
}
```

Void Right

This function is defined for the forwarding motion of the barrel.

```
void right()
{
  if (digitalRead(S2)==HIGH && digitalRead(L2)==HIGH ) // the barrel will go backward
      {
        analogWrite(LPWM,0);
        analogWrite(RPWM,255);
      }
       else       // the barrel will stop due to limit switch
      {
        analogWrite(LPWM,0);
        analogWrite(RPWM,0);
      }
}
```

Void Loop

This is the main loop of the code.

```
void loop()
{
  if (digitalRead(S1)==HIGH && digitalRead(S2)==LOW)
          {
            left();
          }
  else if (digitalRead(S1)==LOW && digitalRead(S2)==HIGH)
          {
            right();
          }
  else
          {
           analogWrite(LPWM,0);
           analogWrite(RPWM,0);
          }
}
```