ARTILLERY SHELL BREAKDOWN MACHINE

A Final Year Project Report

Presented to

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

Department of Mechanical Engineering

NUST

ISLAMABAD, PAKISTAN

In Partial Fulfillment
of the Requirements for the Degree of
Bachelor of Mechanical Engineering

by

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June 2020

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ABSTRACT

Artillery shell is mainly composed of two parts i.e. Shell and Cartridge Case. These parts are press fitted for use in artillery. In many applications, a shell needs to be dismantled so that the two parts can be separated. The applications can either be storage, demilitarization, improvement in technology or obtaining training rounds for soldiers. To achieve this goal, cartridge is usually held from its rim by a die and projectile is clamped from the front. Then the die is pulled back mechanically so that the two parts are separated

Locally available machines for dismantling shells are manual, slow and require human effort. The scope of this project is to increase the efficiency of this process by providing a detailed analysis and simulation of hydraulic and electric schematics of a new innovative design.

ACKNOWLEDGMENTS

Dr. Jawad Aslam, who is the project supervisor is to be thanked for his support and guidance during all phases of the project. Efforts of project participants in conducting comprehensive research into the matter and coming up with creative design ideas is to be acknowledged. We are also thankful to NUST administration for allowing us to use various resources. Workshop employees are to be credited for their help in the execution of this project.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOMENCLATURE

I	It is the interference between hub and shaft. Value of "I" is taken from ANSI Tables for LN 3 fit.
do	It is Cartridge's outer diameter
Eo	It is Cartridge's Young's Modulus (Brass 70/30).
Vo	It is Cartridge material's Poisson ratio (Brass 70/30).
Vi	It is Projectile material's Poisson ratio (Forged steel).
Ei	It is Projectile's Young's Modulus (Forged steel).
d	It is Projectile's outer diameter in mm.
P	It means the pressure of contact.
L	It is length of press fit in mm. It is a measure of how far the shaft has entered inside the hub for effective fit.
η	It is Friction coefficient between brass and forged steel.
Fp	It is the theoretical pulling force required to open the press fit.
FOS	It is Factor of Safety.
$Freq$	It is the actual force pulling required to open press fit with FOS included.
μ_f	It is the coefficient of static friction between artillery shell surface (Brass) and clamp (forged steel).
N	It is the normal reaction force.
$Fgrip$	It is the force required to keep the artillery shell clamped while dismantling it.
B	It is the diameter of bore of the hydraulic cylinder.
S	It is the stroke of hydraulic cylinder.
Dr	It is the diameter of piston rod.
Ap	It is the area of Piston.
Ar	It is the area of piston rod.
A_{upper}	It is the difference between piston area and piston rod area.
Pd	It is the pressure loss occurring due to length of pipes.
$Ftotal$	It is the total force that is required to be applied by the hydraulic cylinders' pistons.
$Pdesign$	It is the Pressure that is required to be delivered by pump.
Tf	It is the approximate time for forward stroke of hydraulic cylinder.
$Vcyl$	It is the volume of cylinder
$Vrate$	It is the flow rate of fluid inside cylinder and pipes.
η_{pump}	It is the efficiency of pump.
$Pump\_power$	It is the pumping power required to be delivered by the motor.
$Volume_{Cylinders}$	It is the total volume of fluid that is in cylinders.

CHAPTER 1: INTRODUCTION

Artillery Shell

An artillery shell is composed of multiple components. Generally, these components are,

1. Fuse
2. Projectile (containing payload)
3. Cartridge (containing propellant)
4. Primer

All the above-mentioned components together constitute an artillery shell. However, since there exists a large variety of artillery shells their design may vary from each other.

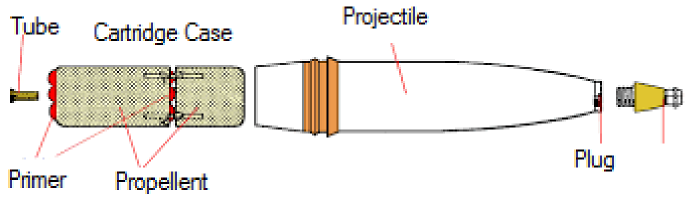


Figure 1.1: Components of Artillery Shell

Fuze

Fuze is the component of a machine that is used to trigger the main function of the machine. In artillery shells fuze acts as a trigger to initiate the explosion. In most artillery shells fuze is attached to the nose. Its shape is made such that it conforms to the shell's ogive.

Projectile

Projectile is the main component of artillery shell. It carries the payload which in turn is responsible for explosion. Artillery shell is often erroneously referred to as projectiles.

Cartridge

Cartridge contains the propellent which burns and provides forward thrust force to the projectile. Cartridge and Projectile are usually made of different materials for design and operational requirements.

Primer

Primer is inside the cartridge case and is responsible for the combustion of propellent inside the case. It is in the form of a rod inserted in from the bottom. Rapid combustion of propellent is ensured in this way.

Our Project

The scope of this project is to provide a detailed analysis and simulation of hydraulic and electric schematics of a machine to breakdown or dismantle the artillery shell and separate the projectile and cartridge case. The shells may be of various diameters ranging from 35mm to 106mm. This project is an improvement to the existing methods of opening artillery shells. It is more efficient, faster and safer than the conventional manual methods.

Motivation for this project

1. This project targets one very distinct industrial problem and provides a solution for it. It provides us an opportunity to apply our theoretical knowledge into practical situations.
2. The project is one of its kind as the locally available machines are inefficient and the design of this machine had to be made from scratch.
3. This project is closely related to our field of study i.e. Mechanical Engineering and incorporates basic concepts of the fundamental subjects of this field.

4. These machines are not locally manufactured and mostly have to be imported so cheap local manufacturing of this project is also a major motivation.

Objectives of This Project

1. Design and Analysis:

Designing a machine capable of dismantling shells of various diameters. The complete design and dimensions of clampers, main frame, moving assembly along with their adaptability is to incorporate different diameters.

Analysis of different parts of machine to make sure required task is completed with the highest possible efficiency and safety.

2. Control System:

Design and develop a control system for convenient use by workers. Ensure safety of workers and machinery parts. Achieve accurate working of actuators to ensure separation and avoiding slippage of parts.

3. Prototyping Testing:

Manufacture a working prototype of the proposed design and perform testing to find out technical and financial viability of the machine.

4. Optimization:

Optimizing the design of the machine to further enhance its capabilities and add more functions based on the requirements and results from testing.

CHAPTER 2: LITERATURE REVIEW

Artillery shell breakdown machine effectively dismantle the shell by separating the projectile and cartridge components. This is done by essentially pulling the cartridge away from the projectile. In simple words this machine acts as a puller.

Here the working is explained in detail

Working

1. Clamping by Rim

The cartridge case has a rim at the end which is slightly larger in diameter than the rest of the shell. This rim helps in clamping the cartridge case. Multiple shells have multiple diameter rims.

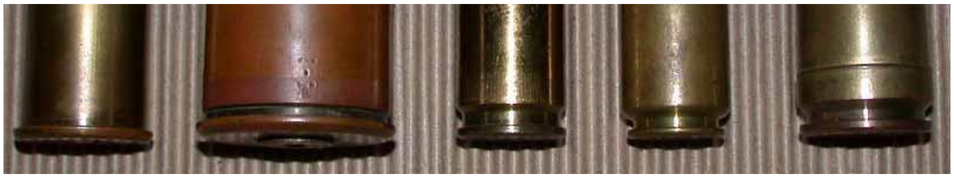


Figure 2.1: Common Rim Designs

Clamping other than this method creates problems as the cartridge can slip in between the clampers. Back clamper should incorporate this mechanism of fitting the rim and then pulling it.

2. Clamping the Projectile

The projectile at the front is clamped with the help of clampers. Projectile consists of several sections

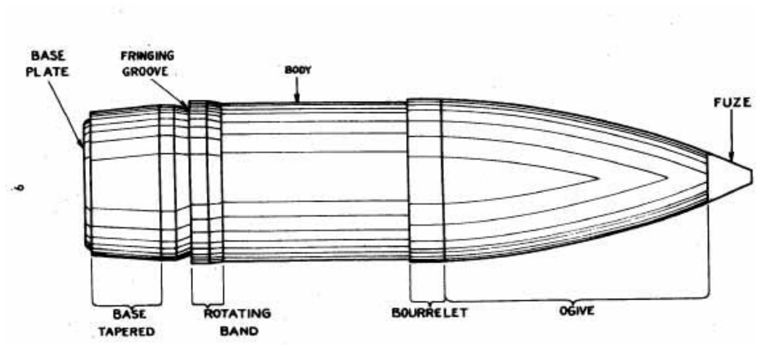


Figure 2.2: Components of projectile

The rotating bands stabilize the projectile while it's in flight, it also helps seal the combustion gases of the cartridge, so pressure builds up inside the gun which helps propel the projectile forward. The projectile must be clamped by its body not damaging the bands or any other parts, moreover clamping process should not damage or deform the projectile itself.

3. Pulling Action

Pulling action needs to be achieved in order to separate the projectile from the cartridge case after clamping of both parts. This can be achieved by use of any type of actuation.

Previous Works

Some of the machines that were studied and researched are as follows

1. Manual Clamping and Manual Pulling Action

This machine achieves the task by fully manual approach, clamping is done manually by pin jointed clamper in two parts. Worker has to put the shell in between the clamper and manually clamp the projectile

Figure 2.3: Manual Clamping and Manual Pulling Action

The pulling action of cartridge is also manual. Lead screw is connected with a hand operated flywheel and back clamper housing die is also connected which travels on the lead screw and pulls apart the cartridge.

This machine is cheap as no electrical parts are used, and all actions are completed manually.

Limitations:

a) This process requires a lot of human effort as the worker has to first place the shell in the clamper and then clamp it by hand and at the end pull it by the use of flywheel
b) This process is very time consuming
c) The machine is unsuitable for large diameter applications

2. Motorized Clamping and Hydraulically actuated Pulling Action

This process makes use of motors for the purpose of clamping the cartridge and projectile. Motors are manually operated and after clamping the parts, hydraulic actuator pulls apart the two parts.

The machine requires less human effort as the separation process is hydraulically actuated and can sustain large quantities of loads.

Figure 2.4: Motorized Clamping and Hydraulically actuated Pulling Action

Limitations:

1. Two motors and one hydraulic actuator are being used here making the process complex and inefficient
2. This machine will also cost more because of the extra electrical machinery.

3. Disassembly is extremely difficult as in case of changing diameters of shells, large time will be required.

Comparison and Conclusion

A comprehensive study and research of the currently available machines showed that following things need to be improved and enhanced in our project

1. Speed of the dismantling process
2. Cost of the equipment
3. Flexibility of machine to cope with changing diameters of shells
4. Minimal Human Intervention
5. Easy Operability
6. Safety of workers and machine parts
7. Weight of the machine

Actuators

Artillery shell breakdown machine effectively dismantle the shell by separating the projectile and cartridge components. This is done by essentially pulling the cartridge away from the projectile. In simple words this machine acts as a puller.

As far as this pulling force is concerned it can be supplied through different types of physical systems. These systems can be broadly divided into

1. Electro-Mechanically Actuated System
2. Hydraulically Actuated System
3. Pneumatically Actuated System

1. Electro-Mechanically Actuated System

In this category of systems, the pulling force can be supplied by using a lead screw-based actuator. This actuator moves across the lead screw delivering the essential pulling force as the electric motor rotates the lead screw.

2. Hydraulically Actuated System

In this category of systems, the pulling force is supplied by the hydraulic piston rod as it actuates inside the hydraulic cylinder. Such a system uses a pump coupled to a motor to provide the essential pressure and flow rate to the fluid along with valves such that it pushes the piston of the hydraulic cylinder in the required direction.

3. Pneumatically Actuated System

In pneumatically actuated systems, as the name suggests, the main pulling force is provided by pneumatic cylinder's piston. However, unlike hydraulic systems the pressure to deliver the pulling force is provided by compressor. This compressor is coupled with motor that supplies essential compression power.

Table 2.1: Actuator Comparison

Criteria	Electro-Mechanical Actuator	Hydraulic Actuator	Pneumatic Actuator
Availability	These actuators are not locally available in the size that is design requirement. Need to import it.	Available in the market by local vendors.	Easily available from local vendors.
Speed of Process	These systems are comparatively slower.	Faster than electromechanical but slower than pneumatics.	Faster than its hydraulic counterparts.
Ease of control with precision	Can be controlled to a high degree of precision relatively easily.	Can achieve sufficient precision as per our requirement with relative ease.	Can be controlled precisely by using complex design and expensive equipment.
Loading Capacity	Can support high load values using a custom design at the expense of complexity.	Can be easily customized to support large variety of loads.	Can support small loads very easily but is not reliable for higher loads.
Energy cost	Relative energy cost is quite high.	Relative energy cost is lower compared to electromechanical.	Relative energy cost is lowest among these three.

CHAPTER 3: METHODOLOGY

Various tasks are involved in the accurate working of this machine. It must operate precisely for the successful execution of the breakdown process. Few factors that need to be accounted for in the designing process are

1. Strength of the materials
2. Proper alignment of clampers
3. Appropriate selection of hydraulic actuators
4. Ease of operation
5. Easy removability of clampers and dies for operation on different diameter shells
6. Safety

The tasks were divided into three basic categories

Hydraulic System

a) Hydraulic Circuit

Once it was decided that we are going to use hydraulic system to provide the pulling force, the next step was to design the best possible hydraulic circuit. In our design we require force at two locations. One to clamp the projectile in place such that the cartridge can be effectively separated from the projectile.

The hydraulic circuit was designed keeping in mind following design requirements,

i. Two Locations where force is required
   - Clamping force
   - Pulling force

ii. First clamp then pull condition.

iii. Appropriate safety measures.

Following hydraulic circuit was designed to fulfil the above-mentioned design considerations.

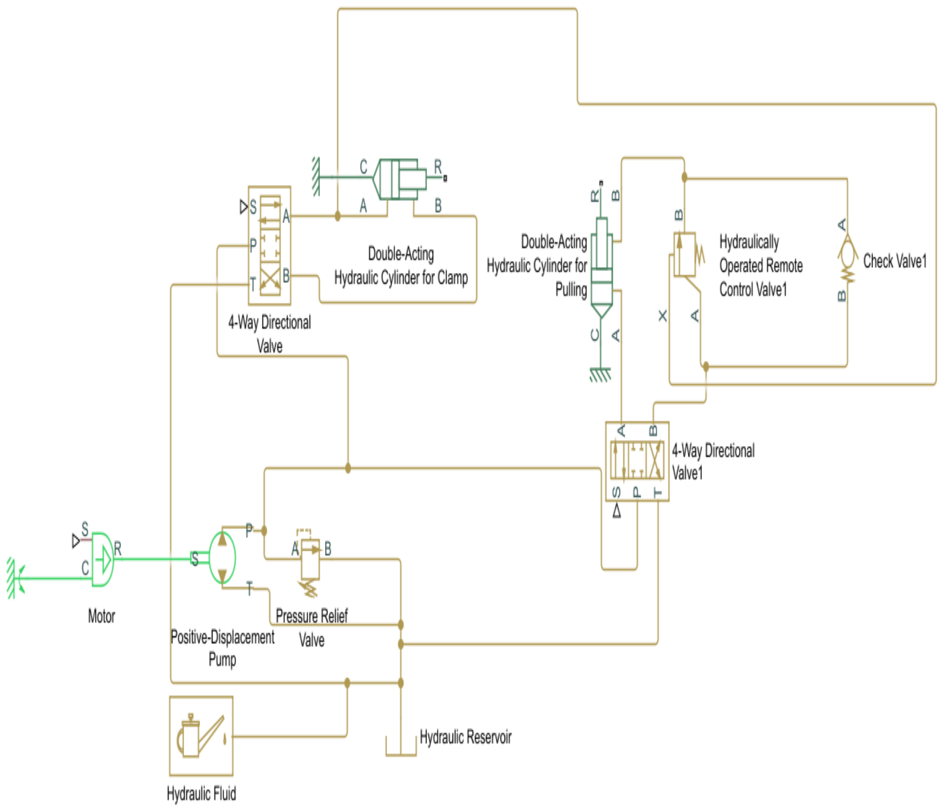


Figure 3.1: Hydraulic Circuit

Two hydraulic cylinders were used that act as actuators and provide required pushing (clamping) and pulling (dismantling) forces. These two cylinders are both linked with 4-way 3 position directional control valves. These valves determine the direction of motion of hydraulic cylinders.

It is clear from the diagram that during operation clamping cylinder moves in forward stroke while puller cylinder moves in reverse stroke direction.

It is important to note that a hydraulically operated remote valve is added to circuit before the puller cylinder. The way this valve works is that it takes pilot pressure input from the terminal A of the clamper cylinder. When pressure at A reaches the required clamping pressure value which is calculated in design calculations this remote input opens up this valve allowing the flow into puller cylinder. This way the valve ensures that the artillery shell is clamped properly before it is pulled and dismantled. It is necessary to add this valve in the design to ensure safety of the operator. It effectively eliminates the situation in which the artillery shell is not clamped properly, and it is pulled which can be hazardous for the operator as well as may destroy work piece. Another check valve is added in the reverse flow direction in parallel to this hydraulically operated remote valve that ensures quick discharge of flow when piston of puller cylinder moves in opposite direction.

Another important component is Pressure Relief valve which opens when pressure rises beyond safety limits and dumps the flow into the reservoir.

b) Primary Pull Force Calculation

In designing a hydraulic system, the primary design requirement was the pulling force. This pulling force was calculated using the press fit force formulas found in literature. To find this pulling force, the pressure of contact between hub (cartridge) and shaft (projectile) is calculated as follows,

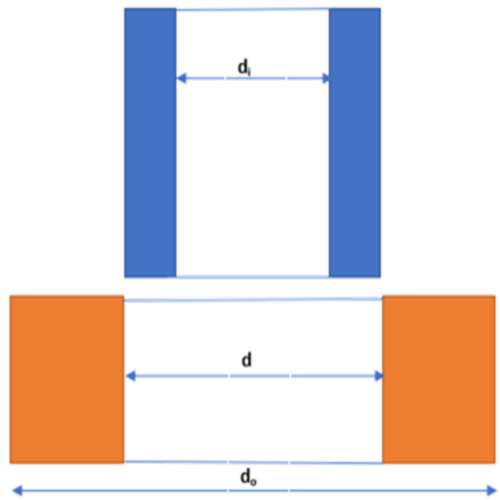
$Nominal\_dia := 105\ mm$ $Nominal\_dia = 4.134\ in$

$I := \frac{2}{1000}\ in$ $I = 0.051\ mm$ $Cartridge's\_inner\_dia := 105.703\ mm$

$do := 105\ mm$
$Sheet\_thickness := 1.14\ mm$
$d := do - 2 \cdot (Sheet\_thickness) + I$
$di := d - (2 \cdot Sheet\_thickness) = 100.491\ mm$
$d = 102.771\ mm$

$Eo := 110.317\ GPa$ $Ei := 210\ GPa$

$Vo := 0.331$ $Vi := 0.3$



Now putting all the relevant values into Eq 1, to find the pressure of contact at press fit location.

$$P := \frac{I}{\frac{d}{Eo} \cdot \left(\frac{do^2 + d^2}{do^2 - d^2} + Vo \right) + \frac{d}{Ei} \cdot \left(\frac{di^2 + d^2}{di^2 - d^2} - Vi \right)} \longrightarrow \textbf{Eq1}$$

$P = (2.334 \cdot 10^6)\ Pa$

Now using the pressure of contact we calculate force required to open press fit with the help of Eq2,

$$L := 20\ mm \qquad \eta := 0.51$$

$$Fp := P \cdot \eta \cdot d \cdot \pi \cdot L \longrightarrow \text{Eq2}$$

$$Fp = 7.687\ kN$$

$$Freq := Fp = 7.687\ kN \qquad Freq = \left(1.728 \cdot 10^{3}\right)\ lbf$$

c) Clamp force calculations

It is necessary to clamp the shell before pulling it to ensure safety of operator. The calculations of required clamp force are completely based on primary pulling force.

For finding the clamp force we use equation of static friction, Eq3. These calculations are shown below,

$$Fpull := Freq = 7.687\ kN \qquad \mu_f := 0.51$$

$$N := \frac{Fpull}{\mu_f} \longrightarrow \text{Eq3} \qquad N = 15.072\ kN$$

$$Fgrip := N = 15.072\ kN$$

$$Freq := Fgrip = 15.072\ kN$$

d) Cylinder and Pump Selection Process

Using the force requirement while keeping the economic aspects in view the most appropriate cylinder size was selected. Using this cylinder bore size and rod diameter, the pressure to be delivered at the piston by the pump was calculated. This whole cylinder selection was an iterative scheme. We made an initial Mathcad model of all the equations and entered multiple values of bore size iteratively to determine the best combination of cylinder and pump. This is because the greater the bore size, the lesser would be the pressure requirement. Thus, for a cheaper pump expensive cylinder will be used and vice versa. It is important to add here that another factor called stroke time determines the pump flow rate which is a key factor that adds to the cost of the pump. Thus, a compromise among flow rate, bore size and pressure required at piston was achieved to keep the overall system cost to a lowest possible value.

$$B := 2.5\ in$$

$$S := 11\ in$$

$$Dr := 1\ in$$

$$Ap := \pi \cdot \frac{B^2}{4} = 31.669\ cm^2$$

$$Ar := \pi \cdot \frac{Dr^2}{4} = 5.067\ cm^2$$

$$Aupper := Ap - Ar = 26.602\ cm^2$$

$$FOS := 1.5$$

$$Fgrip := Fgrip \cdot FOS = \left(5.083 \cdot 10^{3}\right)\ lbf$$

$$Fgrip = 22.608\ kN$$

$$Pgrip := \frac{Fgrip}{Ap} = \left(7.139 \cdot 10^{6}\right)\ Pa$$

$$Pgrip = 71.389\ bar \qquad Pgrip = \left(1.035 \cdot 10^{3}\right)\ psi$$

$$Fpull := Fpull \cdot FOS = \left(2.592 \cdot 10^{3}\right)\ lbf \qquad Fpull = 11.53\ kN$$

$$P_{pull} := \frac{Fpull}{Aupper} = 43.343\ bar$$

Since the value of P_{grip} is more than the value of P_{pull} thus gripping pressure becomes the dictating pressure for the choice of pump. Power required by the pump is calculated using flowrate and design pressure in Eq4.

$$Pdesign := Pgrip = 71.389\ bar \qquad Pgrip = \left(1.035 \cdot 10^{3}\right)\ psi$$

$$Tf := 12\ s$$

$$Vcyl := \pi \cdot B^{2} \cdot \frac{S}{4} = 884.838\ cm^{3}$$

$$Vrate := \frac{Vcyl}{Tf} = \left(7.374 \cdot 10^{-5}\right)\ \frac{m^{3}}{s}$$

$$Vrate = 1.169\ gpm \qquad Vrate = 4.424\ \frac{l}{min}$$

$$\eta pump := 85\% = 0.85$$

$$Pump\_power := Vrate \cdot \frac{Pdesign}{\eta pump} = 619.293\ W \longrightarrow \text{Eq4}$$

$$Pump\_power = 0.83\ hp$$

e) Cooling Requirement

One of the biggest drawbacks of hydraulic systems is their need to be kept within a certain temperature range for effective operation. This is because the inefficiency of pump results in heat generation within the hydraulic circuit. If this heat generated is not dissipated into the surroundings, then temperature of hydraulic oil can rise considerably causing damages to equipment.

So, to calculate the cooling needs for our system lets compare the heat generated with heat dissipation in our circuit. Working temperature of Hydraulic oil like other hydraulic systems in our case is about 70°C. Heat generated can be calculated as,

$$Q_{gen} := (1 - \eta pump) \cdot 0.83\ hp = 92.84\ W$$

Heat dissipation through our particular system will be through convection and radiation mainly. And most of the convection will occur from hydraulic cylinders. Thus, for convection heat dissipation through hydraulic cylinders at operating temperatures we need to find the value of convection coefficient h.

Considering the temperature of outer surface of cylinders as 60°C which is less than 70°C thus makes sense.

$$T_{amb} := 30\ °C$$

$$T_{max\_outer} := 60\ °C$$

$$T_{av} := \frac{T_{amb} + T_{max\_outer}}{2} = 318.15\ K$$

Now we find properties of air like conductivity, Prandtl number, kinematic viscosity, etc. at this temperature,

$$k := 0.02735\ \frac{W}{m \cdot K}$$

$$Pr := 0.7228$$

$$v := 1.798\ 10^{-5} \cdot \frac{m^2}{s}$$

$$\beta := \frac{1}{T_{av}} = 0.003\ \frac{1}{K}$$

Using these properties, we find Convective heat transfer coefficients for both cylinders differently. Because of their horizontal and vertical positions their values of coefficients are calculated slightly differently. Using the values above we first find Rayleigh number and then Nusselt number using Eq5 and Eq6. We use similar equations for vertical cylinder as well.

Note: D is bore diameter that is, 2.5in. For horizontal cylinder,

$$Ra_{D1} := \frac{g \cdot \beta \cdot \left(T_{max\_outer} - T_{amb}\right) \cdot D^3}{v^2} \cdot Pr = 5.294 \cdot 10^5 \longrightarrow \textbf{Eq5}$$

$$Nu_1 := \left(0.6 + \frac{0.387 \cdot Ra_{D1}^{\frac{1}{6}}}{\left(1 + \left(\frac{0.559}{Pr} \right)^{\frac{9}{16}} \right)^{\frac{8}{27}}} \right)^2 = 12.205 \rightarrow \textbf{Eq6} \quad h1 := \frac{k}{D} \cdot Nu_1 = 5.257\ \frac{W}{m^2 \cdot K}$$

For vertical cylinder,

$$L_v := 9\ in$$

$$Ra_{D2} := \frac{g \cdot \beta \cdot (T_{max\_outer} - T_{amb}) \cdot L_v^{\ 3}}{v^2} \cdot Pr = 2.47 \cdot 10^7$$

$$Nu_2 := \left(0.6 + \frac{0.387 \cdot Ra_{D2}^{\ \frac{1}{6}}}{\left(1 + \left(\frac{0.559}{Pr} \right)^{\frac{9}{16}} \right)^{\frac{8}{27}}} \right)^2 = 37.092 \qquad h2 := \frac{k}{L_v} \cdot Nu_2 = 4.438\ \frac{W}{m^2 \cdot K}$$

Now we find average coefficient for cylinders and then find convective heat dissipation using Newton's law of convection (Eq7).

$$h_{avg} := \frac{h1 + h2}{2} = 4.847\ \frac{W}{m^2 \cdot K}$$

$$L1 := 11\ in \qquad L2 := 9\ in$$

$$A_s := 2 \cdot \pi \cdot r \cdot (L1 + L2) = 0.101\ m^2$$

$$Q_{conv} := h_{avg} \cdot A_s \cdot (T_{max\_outer} - T_{amb}) = 14.737\ W \longrightarrow \textbf{Eq7}$$

Note: Q_{conv} is the steady state convection heat transfer rate through both cylinders.

Radiative heat transfer will mainly occur through pipes due to large area. Putting values like ambient temperature and pipe's surface temperature in Eq8 gives us radiative heat transfer. Calculations are shown below,

$$L_{pipe} := 29\ ft \qquad D_{pipe\_outer} := 0.023\ m$$

$$A_{pipe} := \pi \cdot D_{pipe\_outer} \cdot L_{pipe} = 0.639\ m^2$$

$$Q_{rad} := \varepsilon \cdot A_{pipe} \cdot \sigma \cdot \left(T_{max\_outer}^{\ 4} - T_{amb}^{\ 4} \right) = 119.224\ W \longrightarrow \textbf{Eq8}$$

Thus, total heat dissipation is given by,

$$Q_{total\_dissipation} := Q_{conv} + Q_{rad} = 133.961\ W$$

Since,

$$Q_{total\_dissipation} > Q_{gen}$$

Thus, extra cooling is not required for our system as heat generated can be dissipated on its own.

f) Reservoir Sizing

To size a hydraulic reservoir the most common practice in text is described as to make its volume equal to three to four times the volume flow rate in Gallons per minute of hydraulic fluid. Thus, using flow rate, we find reservoir volume in Eq9 as,

$$Reservoir_{Volume} := (3.5 \cdot Vrate) \cdot 1.1\ min = 17.033\ L \longrightarrow \textbf{Eq9}$$

$$Volume_{Cylinders} := 2 \cdot \left(\pi \cdot \frac{B^2}{4} \cdot S \right) = 1.77\ L \longrightarrow \textbf{Eq10}$$

Electric Circuits

The electric circuit design mainly revolves around electronic actuation of hydraulic valves in the circuit. The primary components in hydraulic systems that require electronic control are following

- 2 x 4way 3 position hydraulic valves

- 1 x induction motor for powering hydraulic pump.

Hydraulic valves are actuated using solenoids that are most commonly powered by 12V or 24V DC source. Each valve requires use of 2 solenoids for 3 position control (one for forward stroke and other for reverse stroke).

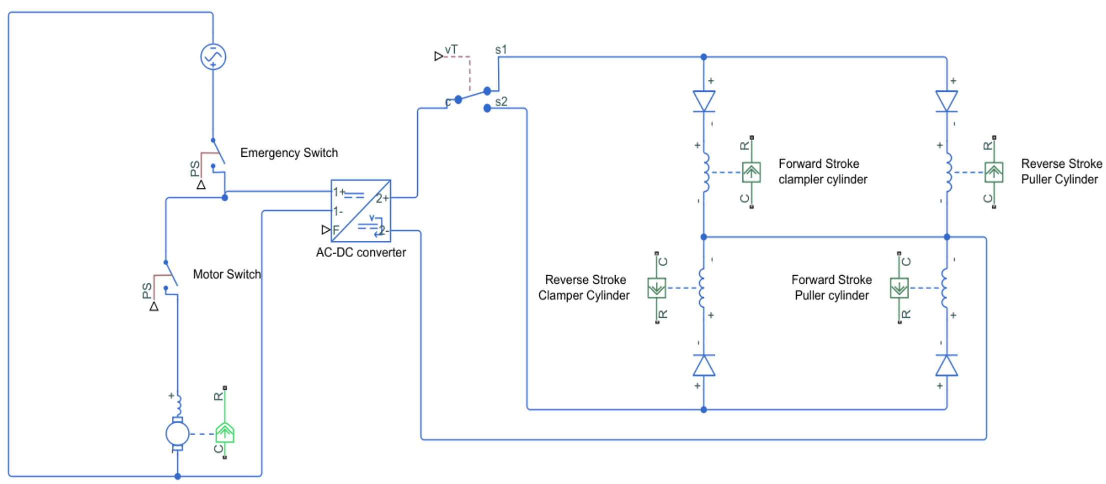


Figure 3.2: Electrical Circuit

For two valves, there are 4 solenoids that require actuation. Since solenoids can act as inductors as well, diodes are used to cater for back EMF as well.

Single emergency switch is added as a safety feature in case of some unwanted condition.

Mechanical Systems and Designing

a) Frame Design:

The frame of the machine is designed keeping in mind the loading conditions that it will sustain. Also, it is large enough to incorporate shells of various diameters. The frame supports the hydraulic cylinder in the back which moves the back-clamper assembly. The whole assembly for clamping projectile is moveable and different slots are made for operation on different length shells.

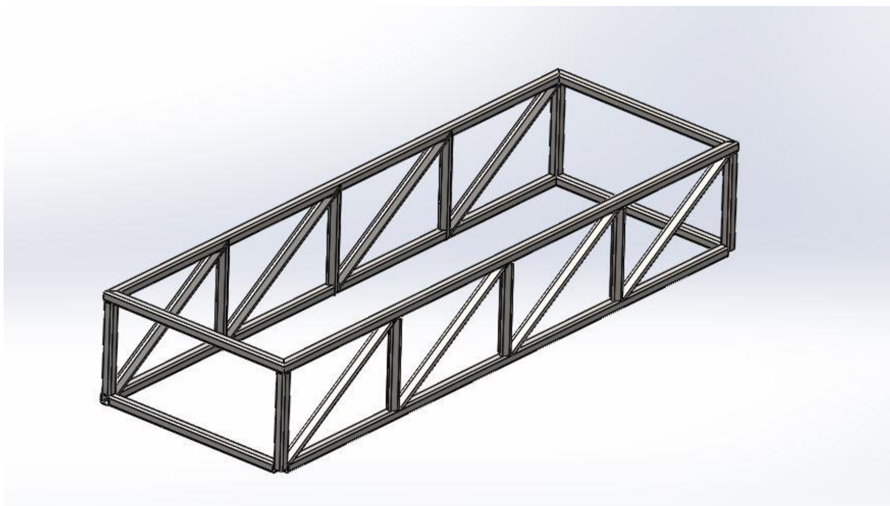


Figure 3.3: Frame

b) Cartridge Rim Clamper

The cartridge rim clamper is designed keeping in mind the fact that different diameter shells will be dismantled and thus a housing plate is bolted to the attachment on the piston and removeable clamper plate can be further bolted to this housing plate. Whenever shell is changed, plate can easily be removed and a different clamper plate for a different diameter shell and cartridge can be bolted to the housing plate. It also accounts for alignment of the shell. Cartridge cannot move horizontally once inside this clamper.

The housing plate also accommodates space for linear bearings through which guide rails are passing. This is done to make the motion of this whole assembly smooth

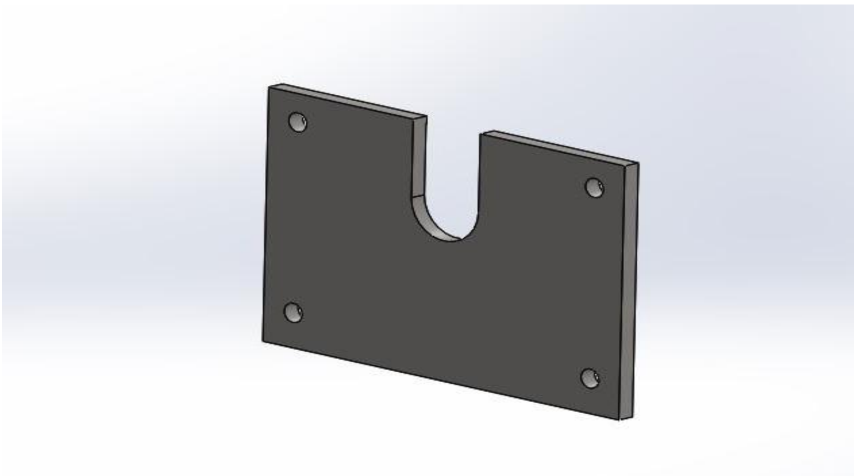


Figure 3.4: Cartridge Clamper

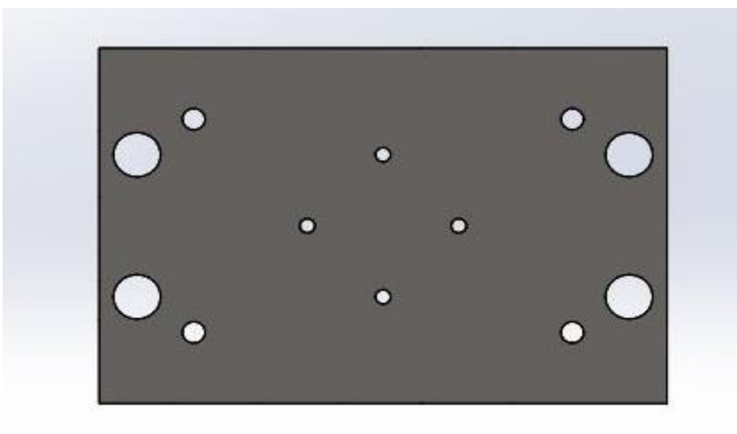


Figure 3.5: Housing Plate

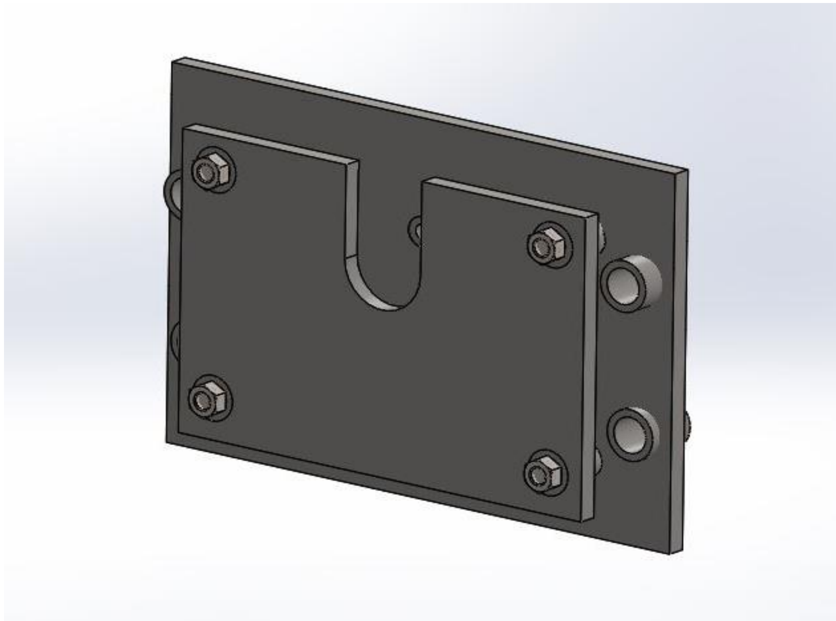


Figure 3.6: Assembly of Housing Plate and Cartridge Clamper

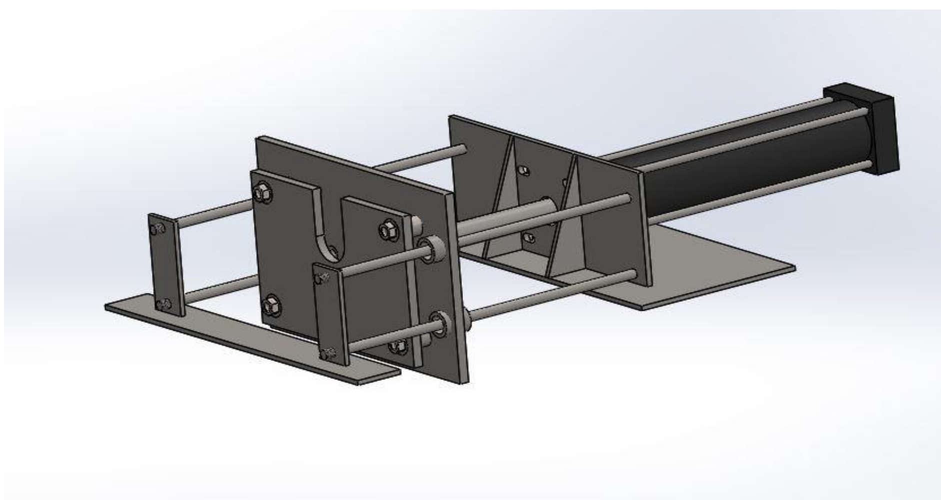


Figure 3.7: Complete Back Assembly (consisting of guide rails, actuator, base plates, cartridge clamper and housing plate)

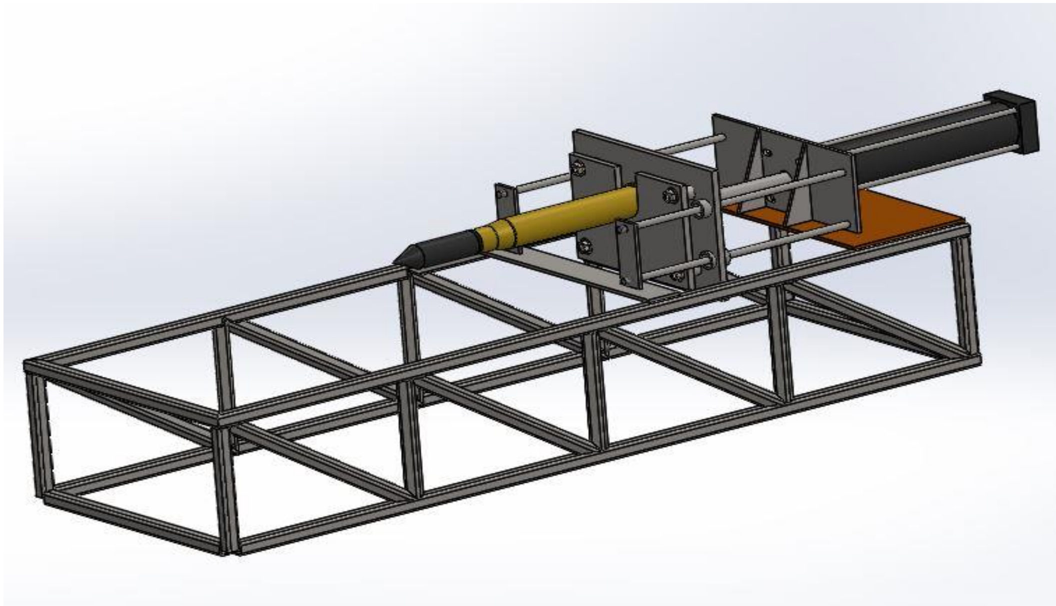


Figure 3.8: Back assembly clamping the cartridge of shell and placed on the frame

c) Projectile Clamper

The entire assembly for clamping of projectile is moveable and thus accounts for different length shells. This assembly can be bolted on the main frame and it supports detachable dies which rest in the slot made in clamper. The upper half of the clamper is attached to the hydraulic actuator which rests on a platform supported by four square pipes. When the shell is placed inside, the upper half moves down and clamps the projectile preventing it to slip while, the cartridge is pulled by the rim clamper.

The shape of the projectile clamper is made v shaped as can be seen in the Fig 3 10. The projectile is clamped forcefully by both clampers in the front assembly. An independent platform (Fig 3 11) is made to attach the lower clamper plate with it and provide a base for the hydraulic actuator to rest. It is supported by four metal square pipes.

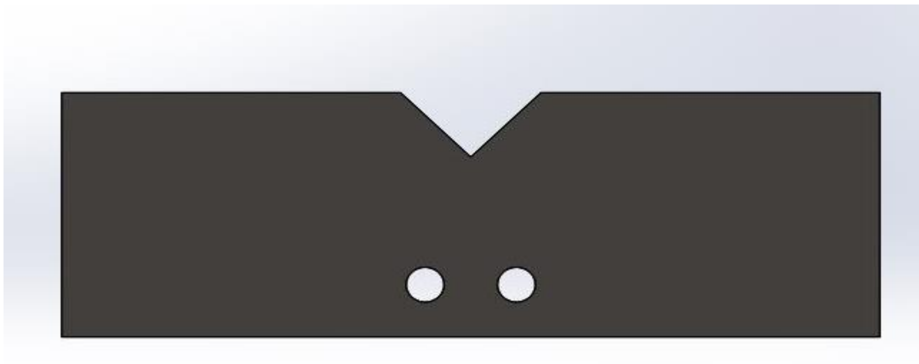


Figure 3.9: Projectile Clamper

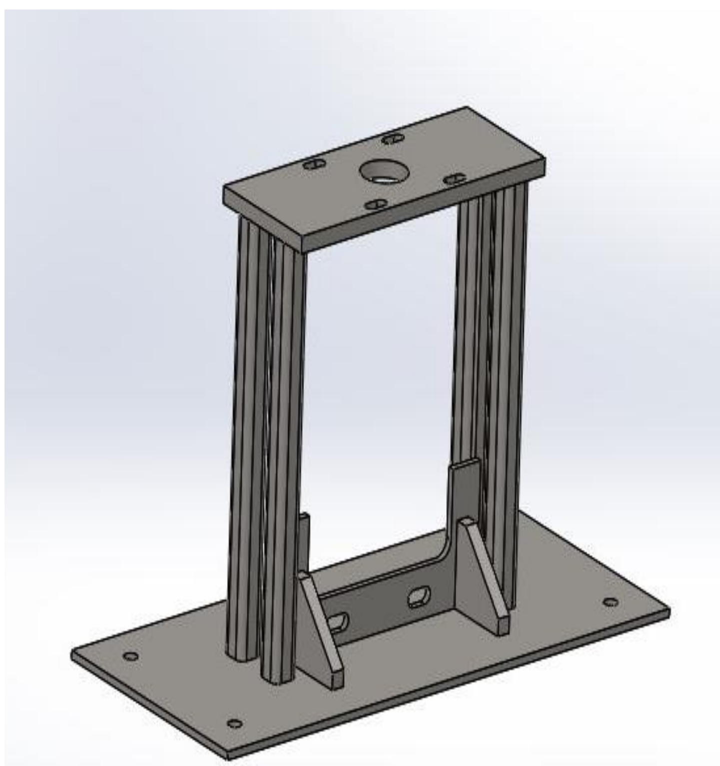


Figure 3.10: Front Assembly Platform

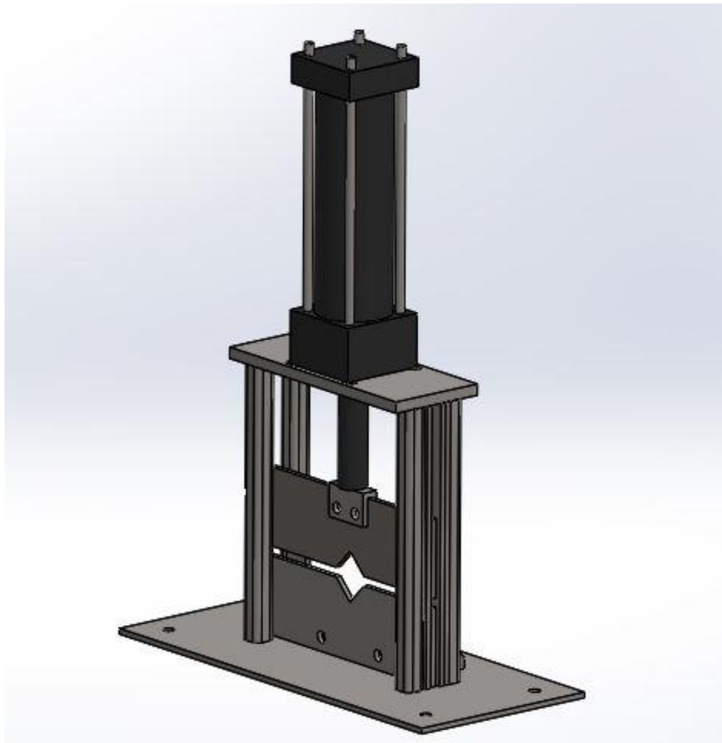


Figure 3.11: Front Assembly platform housing actuator

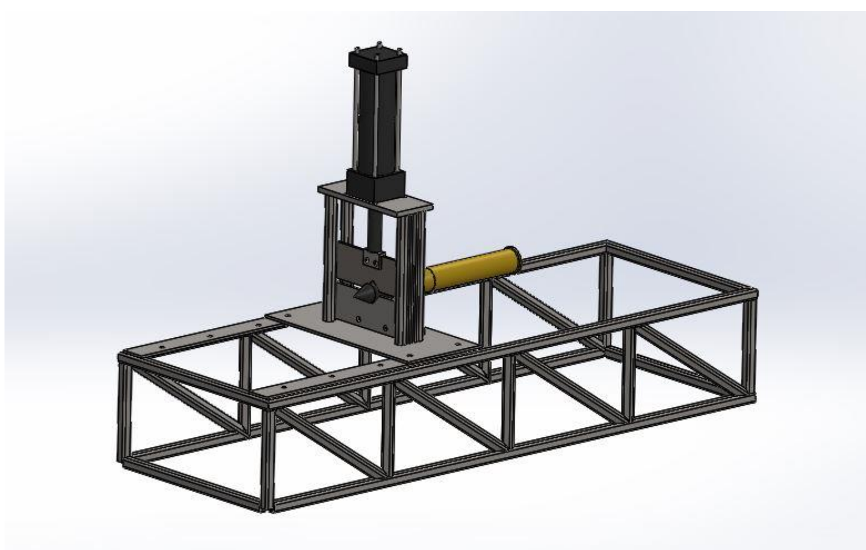


Figure 3.12: Front Assembly clamping projectile and attached with the frame

d) Guide Rails

Guide Rails are used for smooth and frictionless motion of the rim clamper. It prevents any damage to the piston rod as a result of any misalignment and shares the weight of it. Four guide rails are used at four ends of the plate. Linear bearings are used with the guide rails.

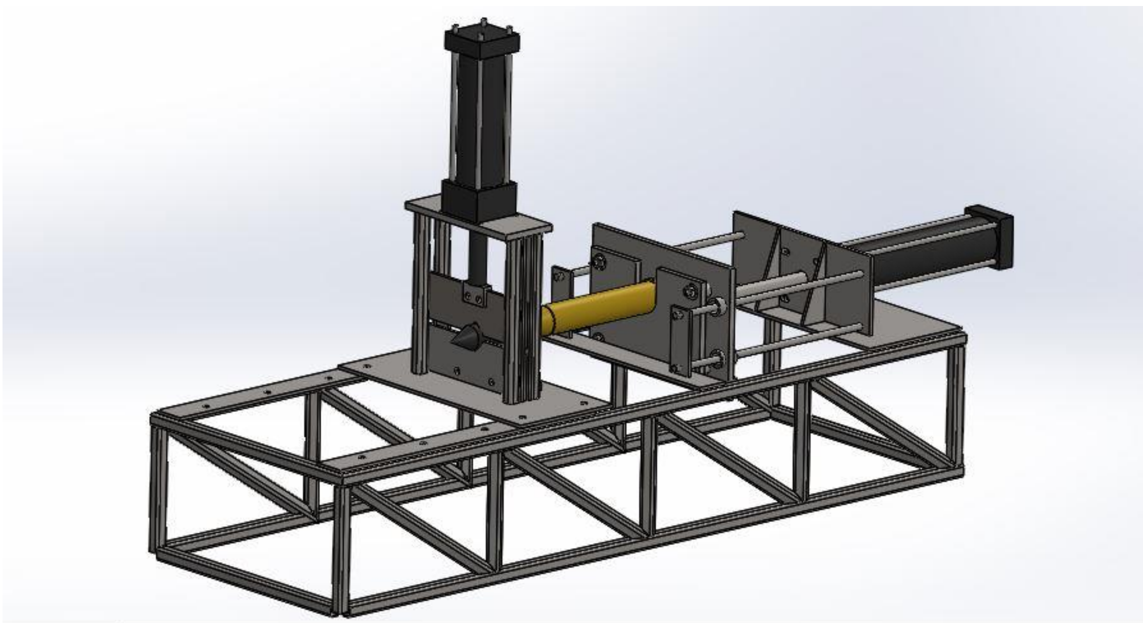


Figure 3.13: Complete Mechanical Assembly

Simulations and Testing

To perform simulations and analysis different software were used including SolidWorks and MATLAB. These simulations were done in two parts,

a) Hydraulic Simulation and Analysis

In these simulations the designed hydraulic circuit was put to test using MATLAB Simulink Module. Graphics are shown below,

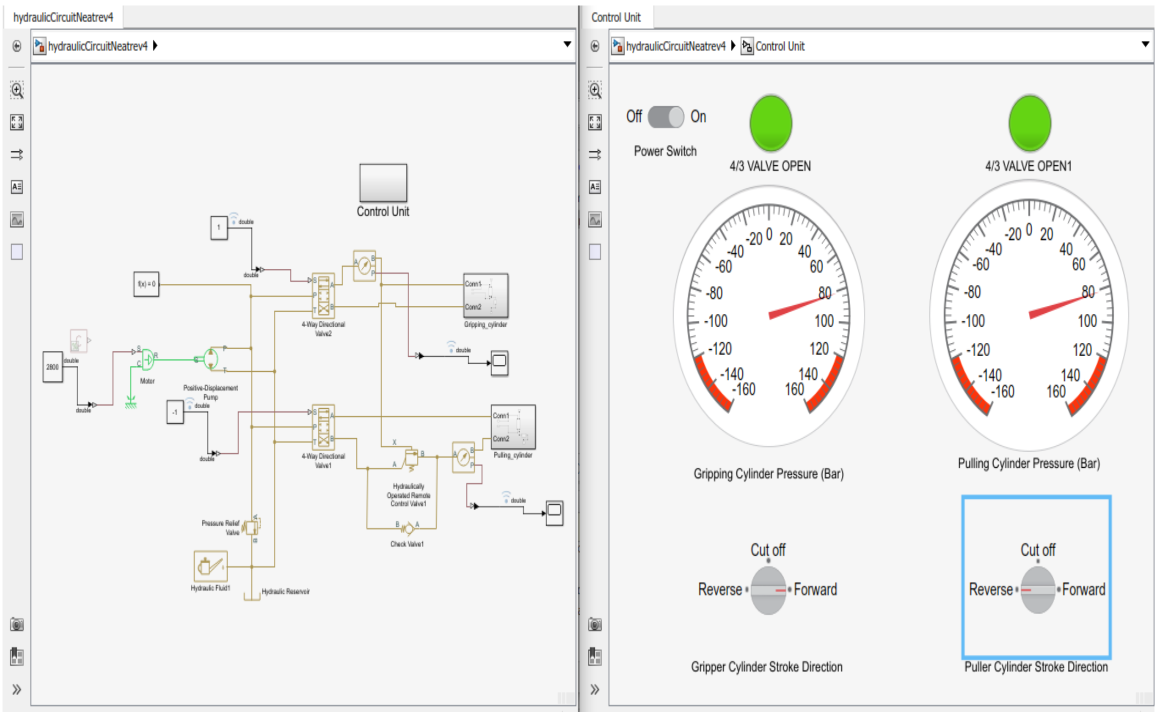


Figure 3.14: Hydraulic Simulation with Control Panel

It was found that the circuit was indeed capable of working according to required conditions. It was noted that the circuit met the required pressure and force conditions for both gripping and dismantling of artillery shell at the specified points along the circuit. Also, other hydraulic circuit components like pressure relief valves were also added in this simulation and the result showed that the safety measures were sufficient to cater the safety needs of hydraulic circuit.

Other than these gauges Simscape's data log shows that the pressure of 80 bar is reached almost instantaneously at point A of the gripping cylinder once the 4/3 valve is open in forward direction, that is Pump to A point. Point A is shown in figure below,

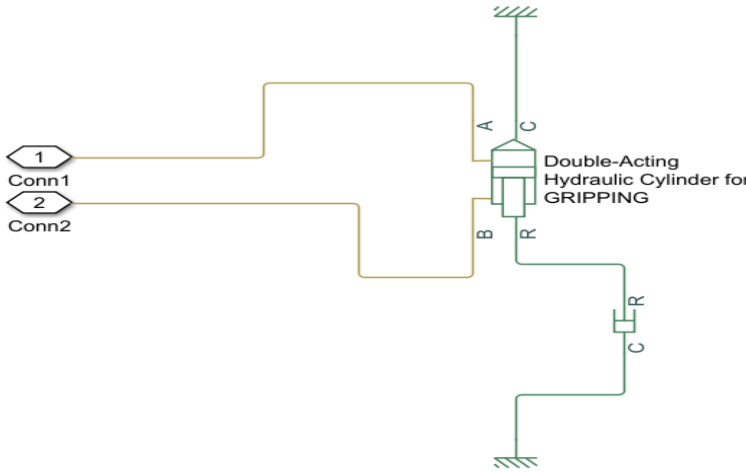


Figure 3.15: Gripping Cylinder with Labeled Points

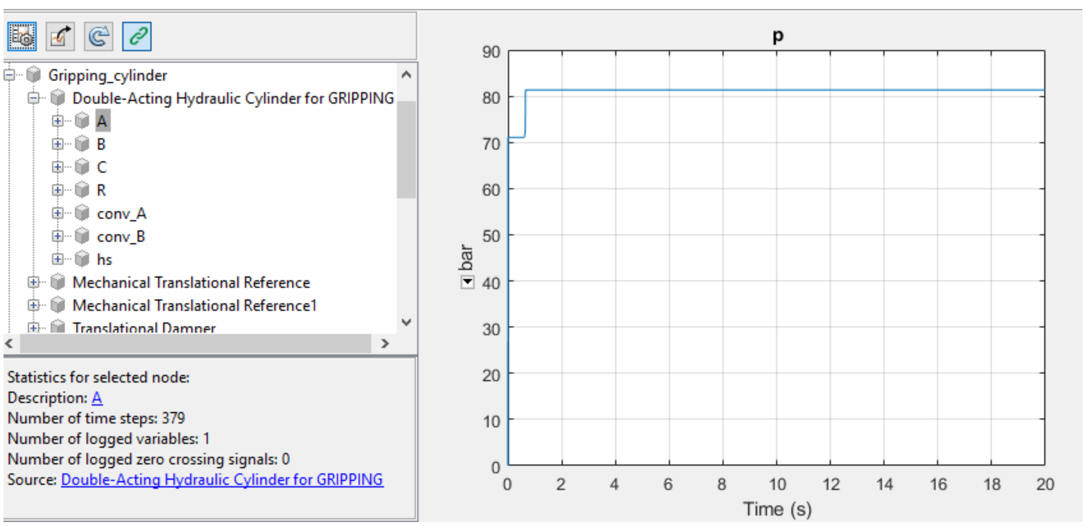


Figure 3.16(a): Pressure plot at point A of Gripping Cylinder during Forward Stroke

When the directional control valve inverts the stroke of gripping cylinder to reverse stroke, following pressure plot is achieved at point B. Note the time delay to reach 80 bar pressure, it shows the time it takes the piston to reach its boundary.

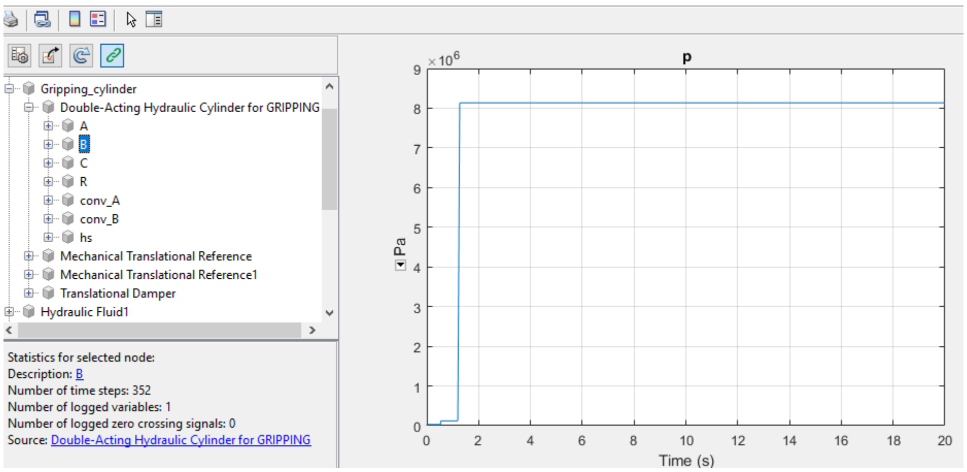


Figure 3.16(b): Pressure plot at point B of Gripping Cylinder during Reverse Stroke

Also, when the gripping cylinder is moved in reverse stroke to reset it for next shell, whole stroke is covered in about 2s, as visible from graph below,

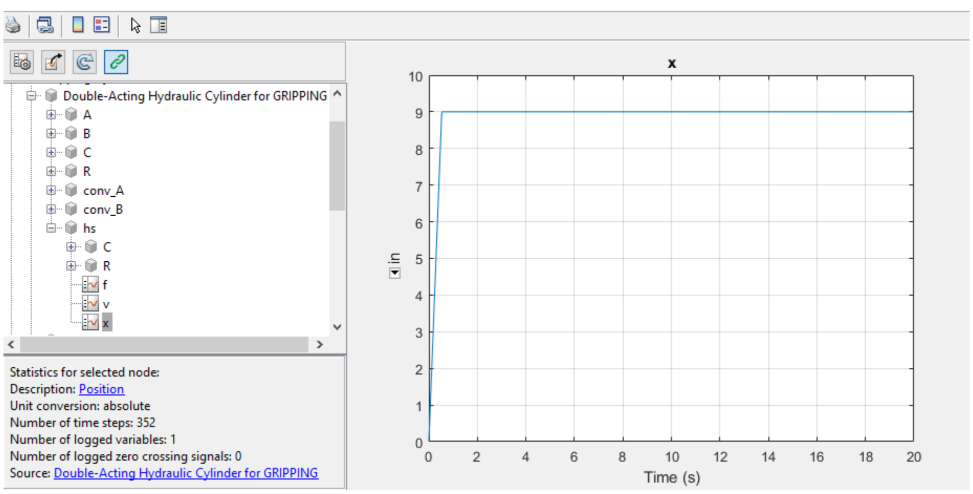


Figure 3.16(c): Motion of Piston of Gripping Cylinder During Reverse Stroke

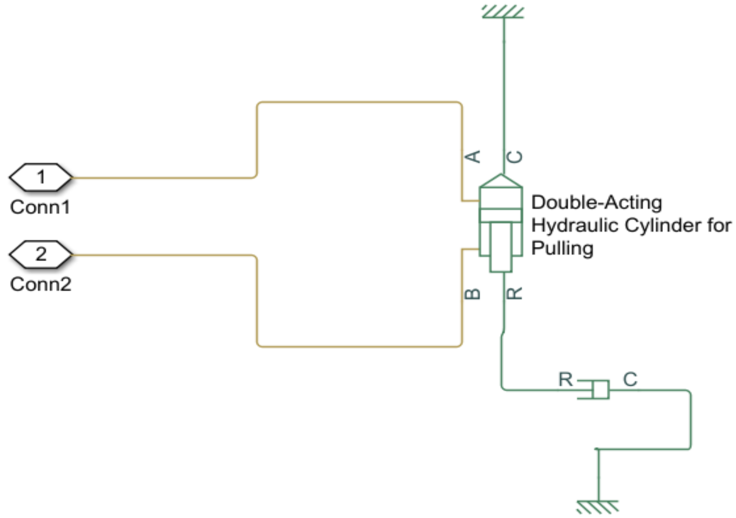


Figure 3.17: Pulling Cylinder with Labeled Points.

Similarly, for pulling cylinder the pressure reaches the required value during the reverse stroke, when the proper grip is established in the gripping cylinder. This can be shown by plot of pressure developed at point B of the pulling cylinder. Note the time delay compared to previous graph.

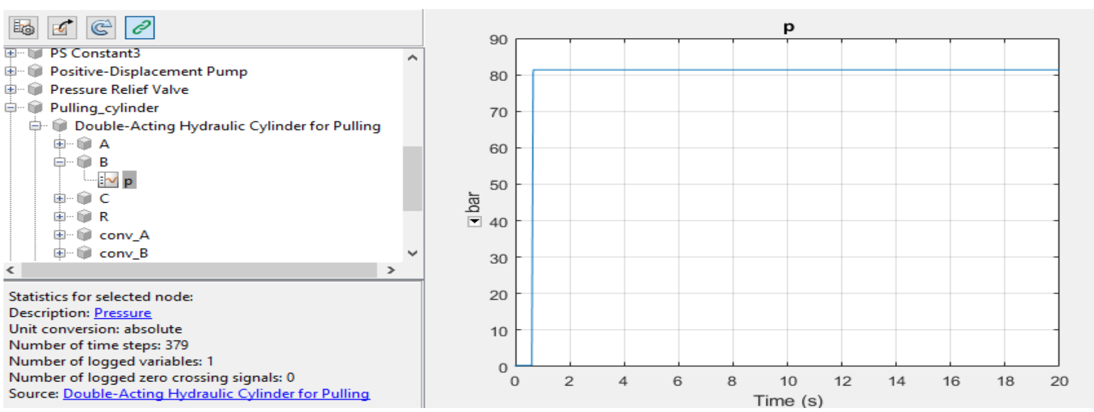


Figure 3.18(a): Pressure plot at point B of Pulling cylinder during Reverse stroke

When directional valve is used to change the stroke direction of pulling cylinder to forward stroke, this pressure curve is achieved at point A. Note the time delay to reach 80 bar pressure, it shows the time it takes the piston to reach its boundary.

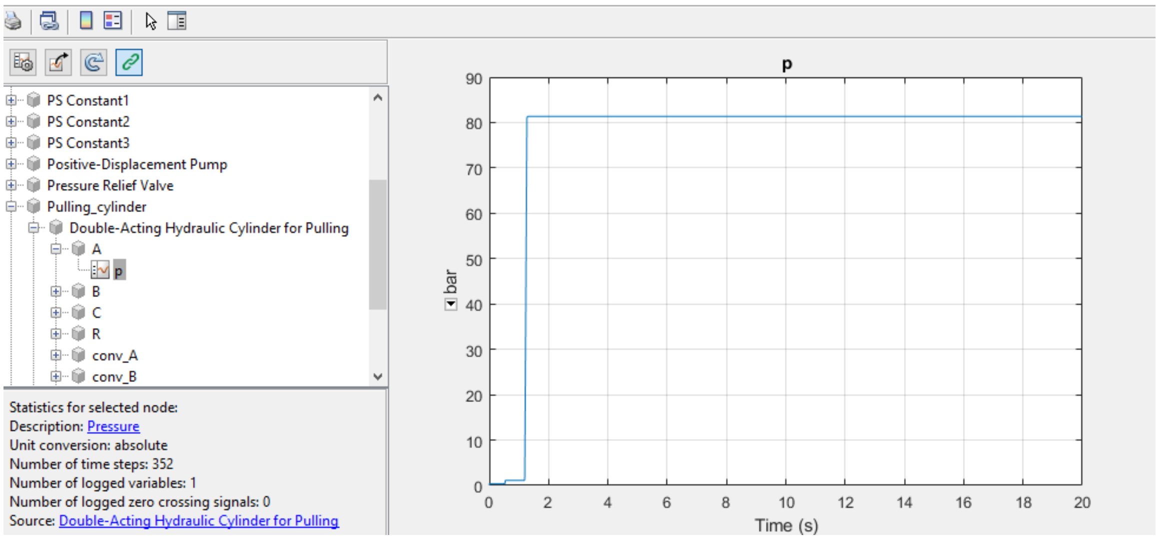


Figure 3.18(b): Pressure plot at point A of Pulling cylinder during Forward stroke

Similarly, to reset the pulling cylinder it needs to move in forward stroke, contrary to its pulling stroke (reverse stroke). It covers its stroke within 2s as well. Negative value of x shows motion in opposite direction to reverse stroke, that is, forward stroke.

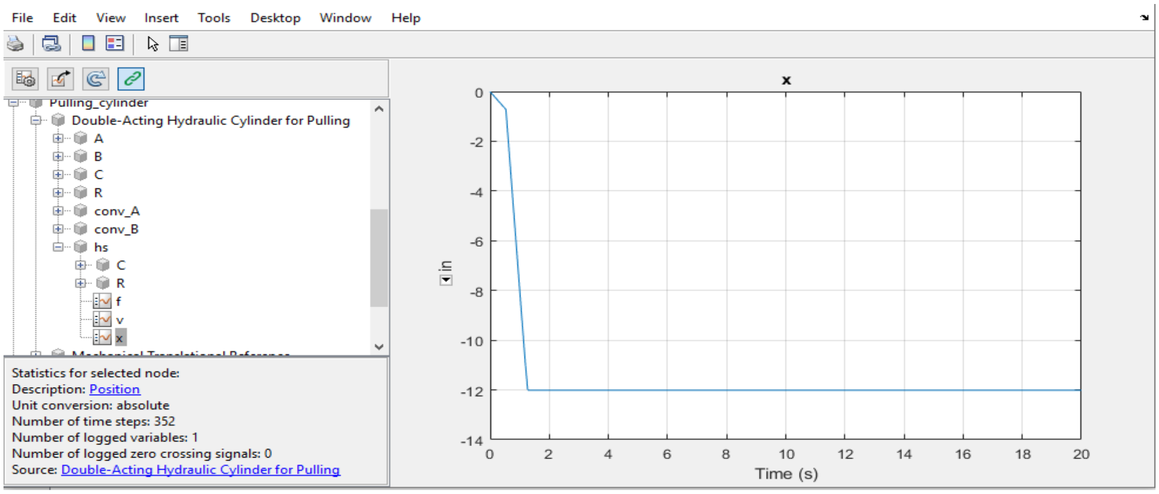


Figure 3.18(c): Motion of piston of Pulling cylinder during Forward Stroke

b) Mechanical Analysis

Detailed stress analysis is done to ensure the safety and operability of the machine. Forces commensurate with actual scenarios were applied in the software (SOLIDWORKS) and the results were considered. Design had to be changed at various points just to ensure a suitable factor of safety for the machine and smooth operation of the machine. Stress, Displacement and Factor of Safety plots of various parts are presented below

i. Actuator Attachment Plate:

The actuator is attached to a vertical plate in the back assembly through bolts and nuts. The plate is supported with ribs so that it can sustain the loads when actuator pulls the cartridge through the flange.

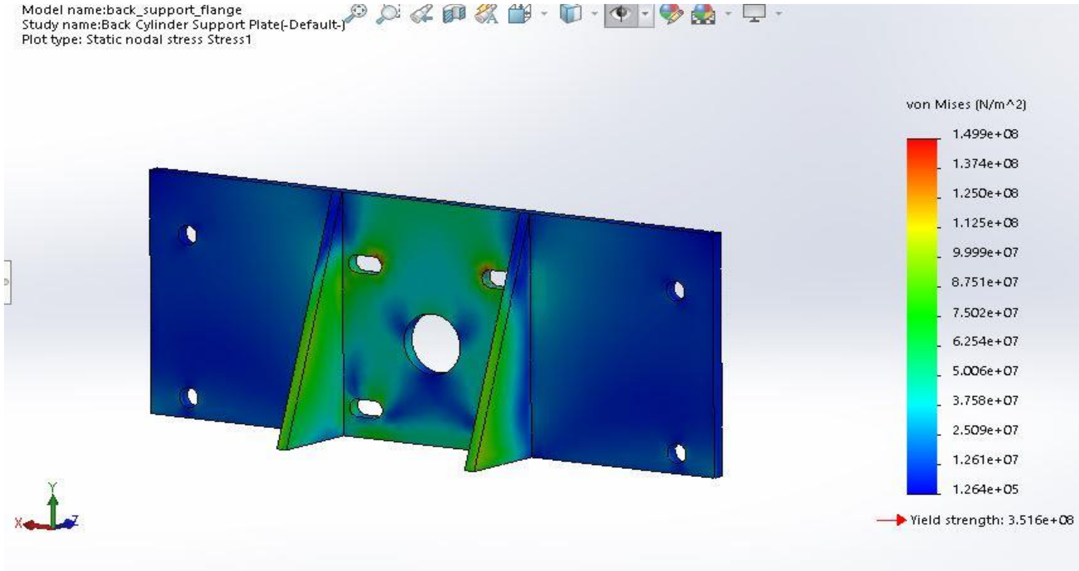


Figure 3.19: Stress Analysis of Actuator Plate

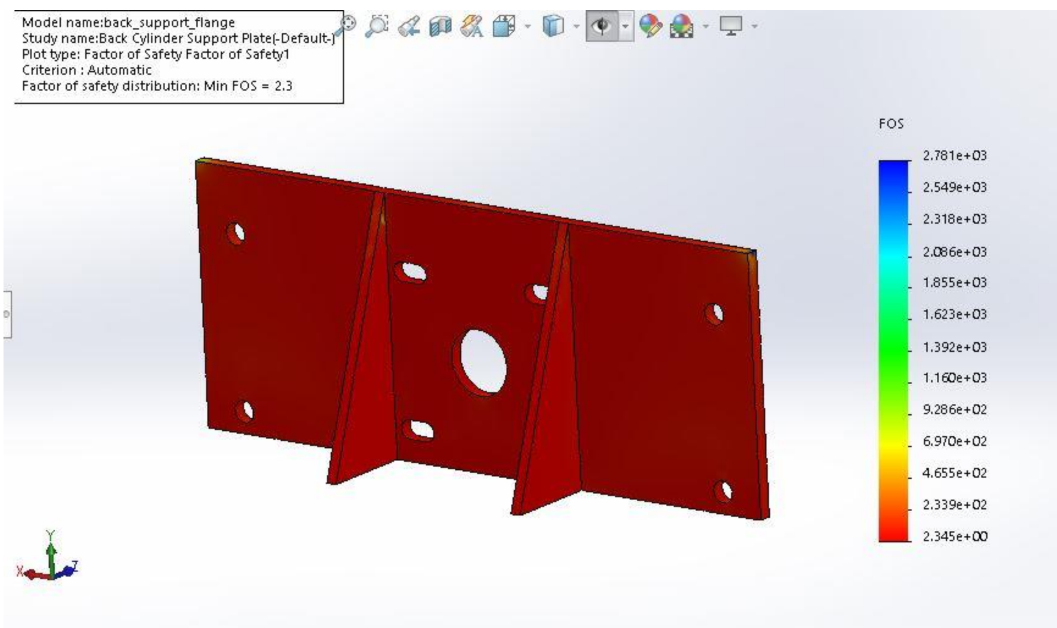


Figure 3.20: Factor of Safety Plot of the Actuator Plate

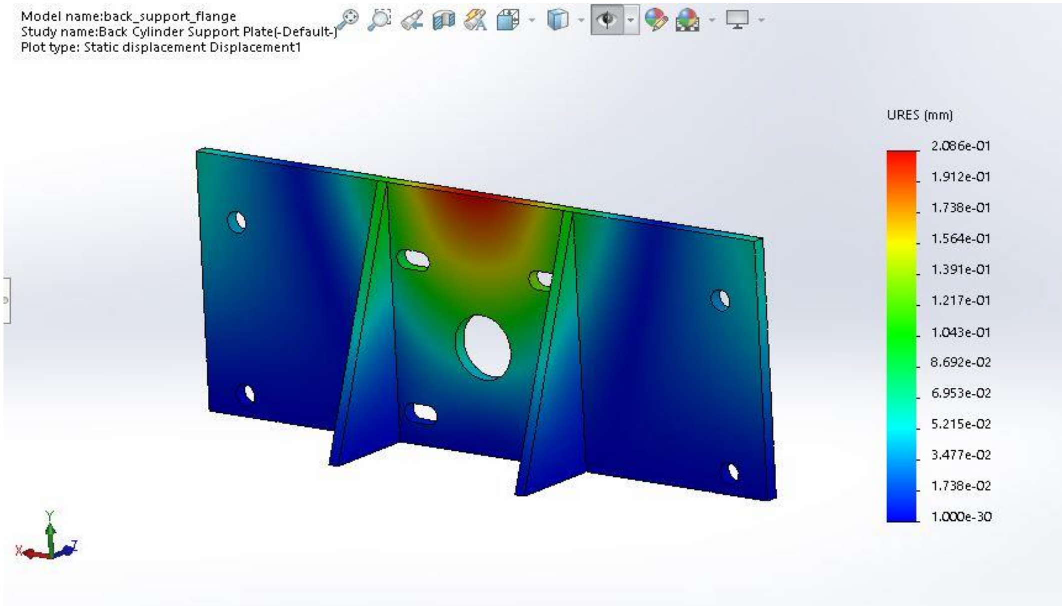


Figure 3.21: Displacement Analysis of Actuator Plate

ii. Housing Plate

The housing is attached to the piston attachment of the actuator and the cartridge holding plate through bolts. The structural strength of this plate is of high importance. It also holds the linear bearings which help in the straight linear motion of housing plate

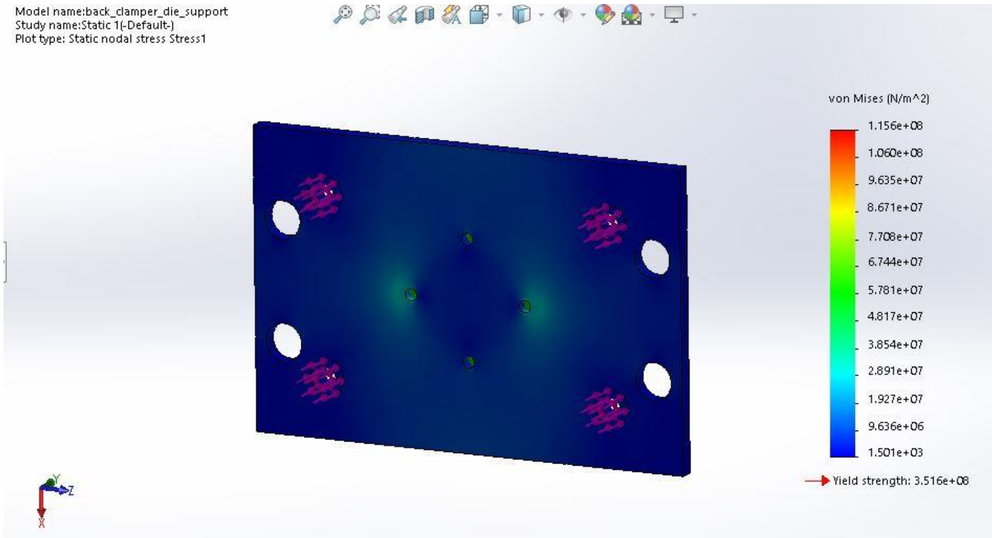


Figure 3.22: Stress Analysis of Housing Plate

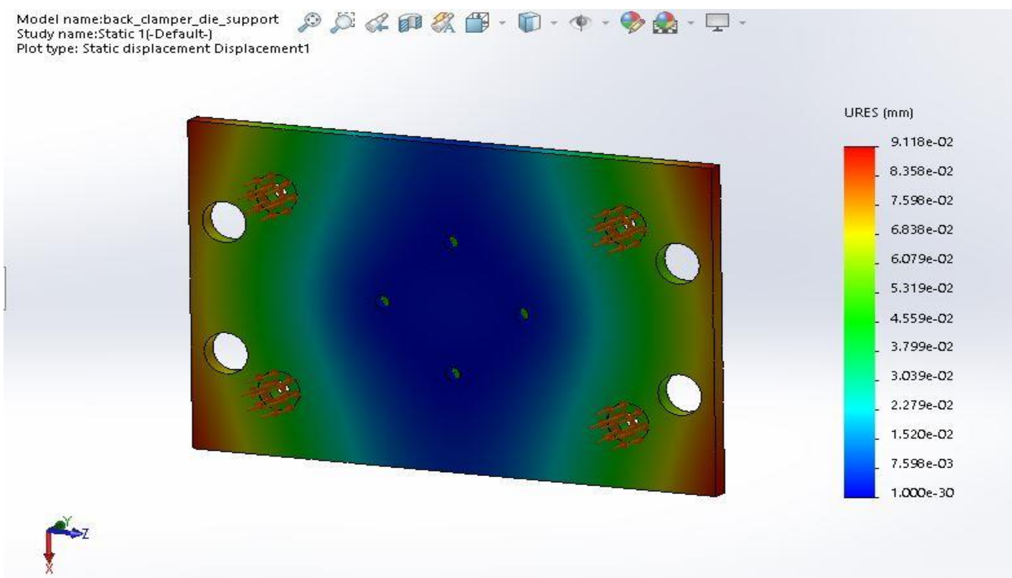


Figure 3.23: Displacement Analysis of Housing Plate

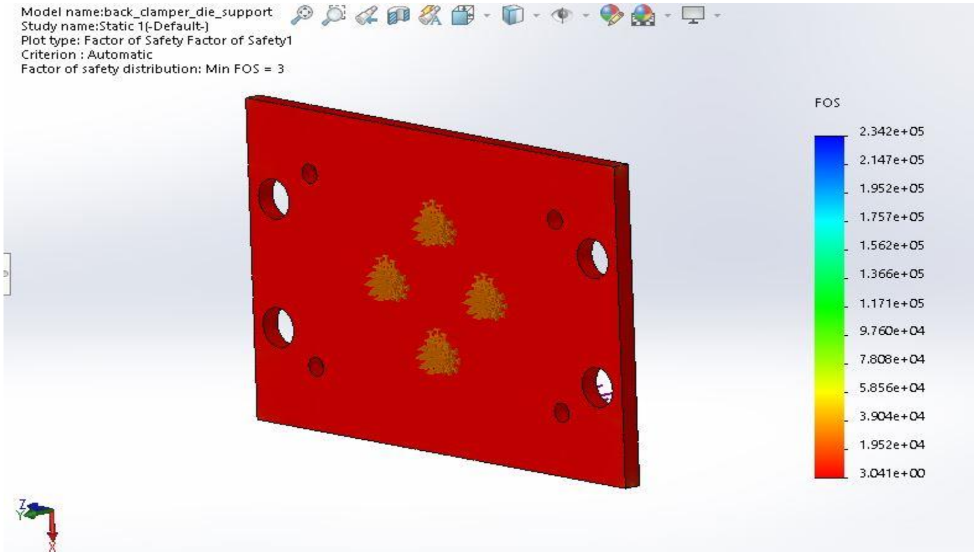


Figure 3.24: Factor of Safety of Housing Plate

iii. Cartridge Clamper

This plate clamps the cartridge through the rims and pulls it back. It is bolted to the housing plate. This plate is replaceable for different diameters of shells

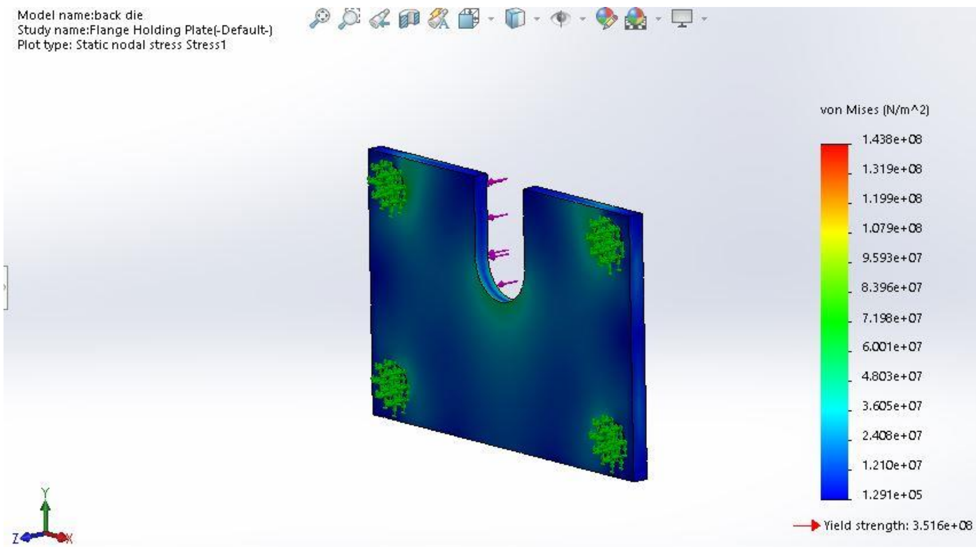


Figure 3.25: Stress Analysis of Cartridge Clamper

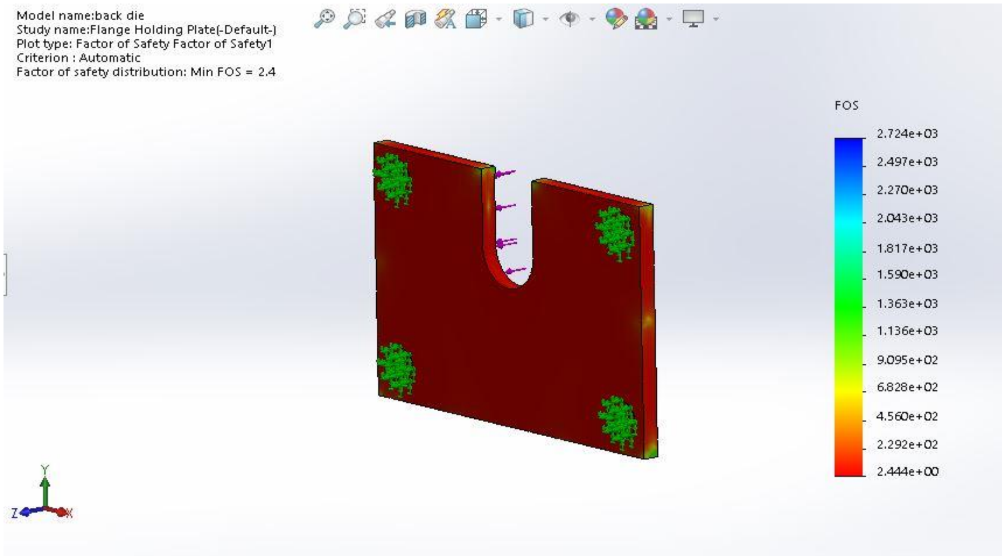


Figure 3.26: Factor of Safety Plot for Cartridge Clamper

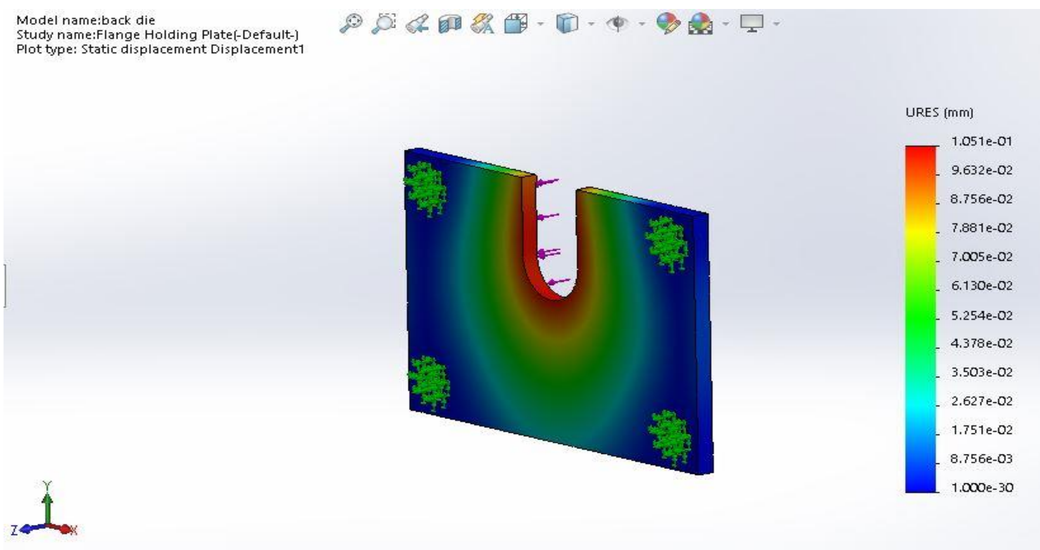


Figure 3.27: Displacement Analysis of Cartridge Clamper

iv. Front Assembly

The front assembly which is responsible for clamping the projectile is also properly designed and analysis done to ensure the structural integrity and safe operation. The results for stress analysis, deformation and factor of safety are as follows.

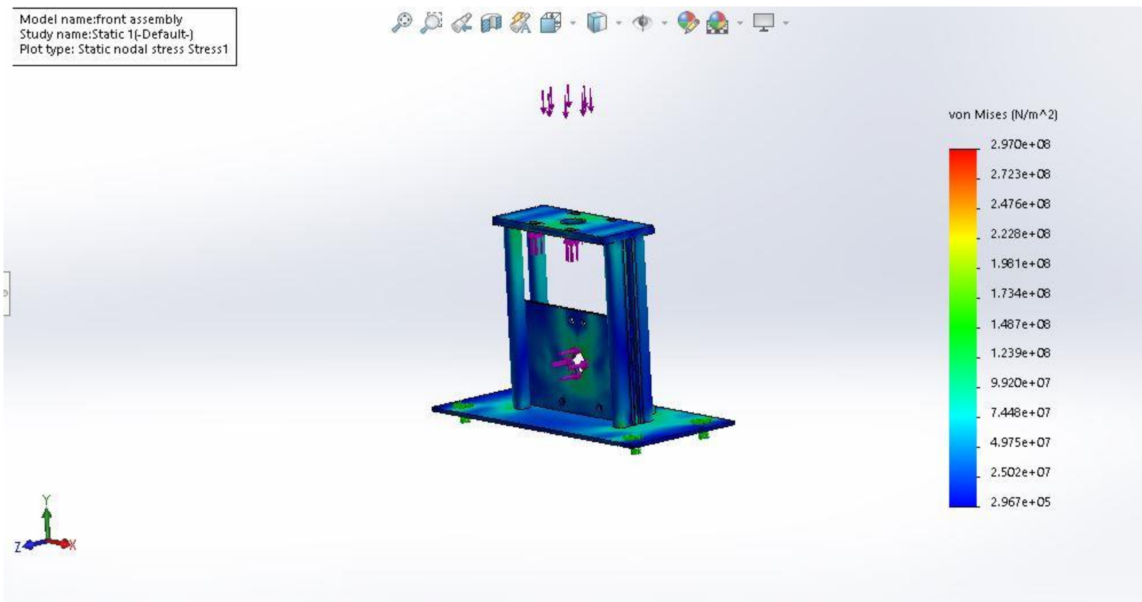


Figure 3.28: Stress Analysis of front assembly

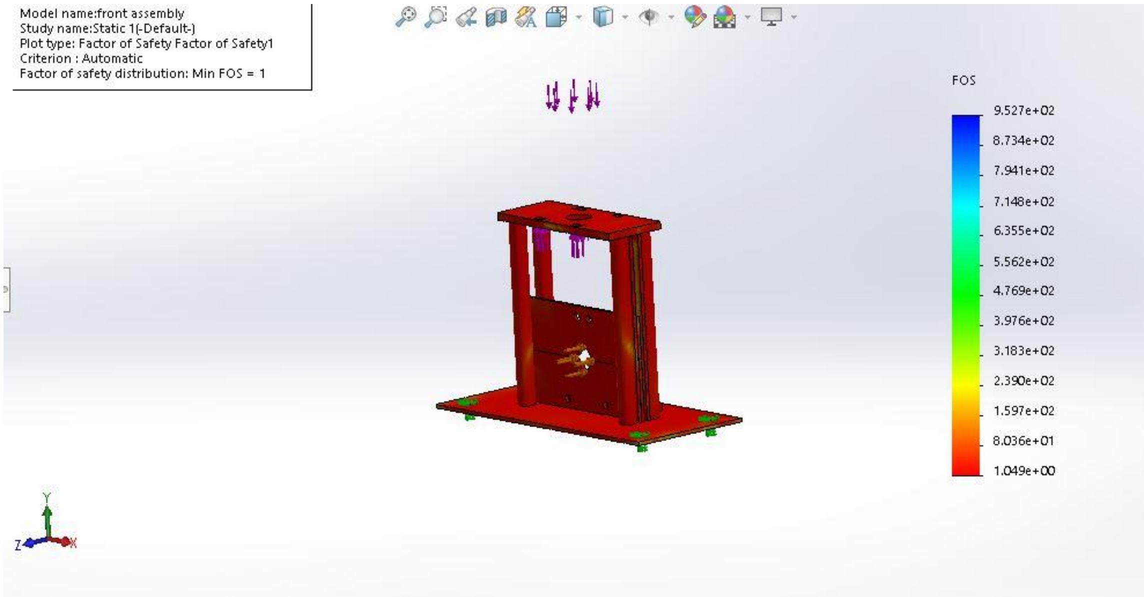


Figure 3.29: Factor of safety of front assembly

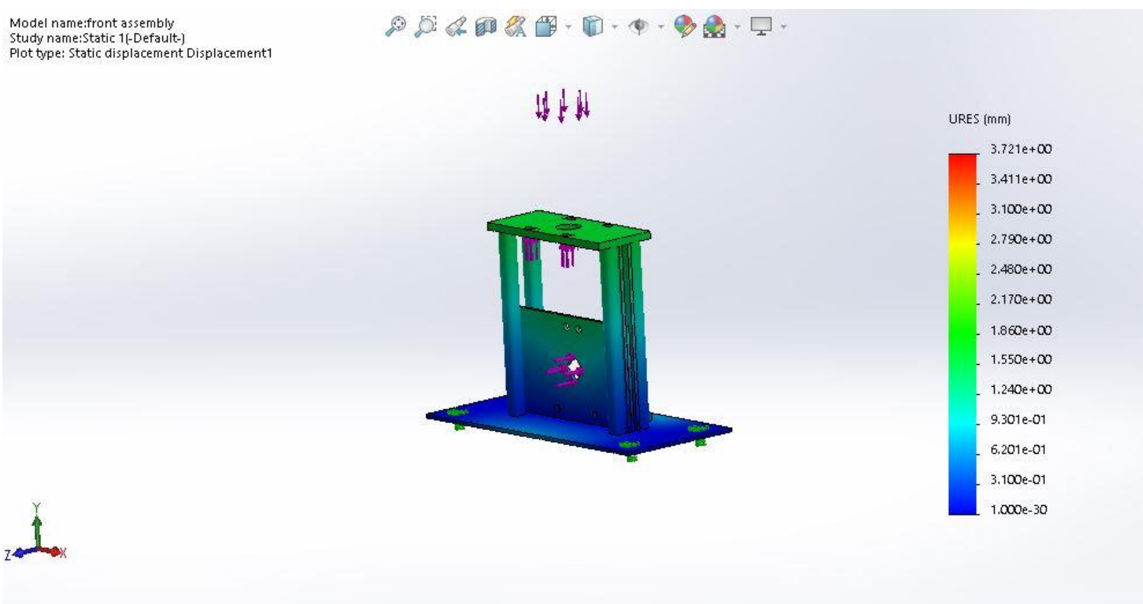


Figure 3.30: displacement Analysis of front assembly

CHAPTER 4: RESULTS AND DISCUSSIONS

The project is mainly focused on designing a complete system for military grade puller machine for various artillery shells currently used by Pakistan army. The primary insight behind this process is that currently employed techniques for this purpose involve manually operated machines which are both tedious and time consuming. This project primarily involved around improving these parameters.

The design process was initiated by calculating the force requirement for the process and then different mechanical systems were analyzed on the basis of these requirements while taking the time required was taken into consideration as well.

The preferred mechanism was selected on the basis of cost efficiency while fulfilling the time constraint for pulling an individual cartridge. Three main designs were considered for this process namely electromechanical systems involving lead screw, hydraulic systems and pneumatic systems. Hydraulic systems were selected on the basis of their cost efficiency and time efficiency.

The design for the mechanical structure revolved around providing the system with adequate support while minimizing chance of failure in the structure during the life cycle of the system. There are two main subsystems during mechanical design including a clamper and a puller. The clamper is vertically mounted system to provide enough gripping force to the shell and puller provides enough force so that fuse and cartridge are separated.

The design is further verified by performing FEA on the individual components and overall structure.

The gripper works by putting adequate normal force so that enough friction force is developed between shell and gripper. The rim is passed through a slot in the puller to grip it from other direction as well. The gripper and puller can be modified to incorporate different sizes of the artillery shell as primary components include easily removable dies. It provides robust design that and ease of modification for design.

Hydraulic system design involves design of hydraulic schematic, selection of pump for system and then subsequently bore and stroke for hydraulic actuator and finally the valves and pipes for the system. The details of this procedure are mentioned in the report. The hydraulic schematic is designed while taking into consideration the ease of use of the system. The valves that are used are 4/3 PT open valves.

There are three modes of operation for the hydraulic system forward, rest and reverse. At rest position, valves for both actuators are closed. The schematic is designed in such a way that during forward mode, the system starts the gripper and senses the pressure that is developed in the associated actuator. When this pressure is developed only then the puller actuator is started. The reverse operation simply returns both actuators to retracted position.

Electric system includes an AC-DC converter and solenoid actuated valves. Overall purpose of system is the switching of valves as per forward, rest or reverse position set on the three-position switch for control.

CONCLUSION AND RECOMMENDATIONS

Overall, this project provides the proof of concept as well as practical implementation of theoretical knowledge involved in mechanical design of the systems. This hydraulically actuated and operated with electrical control. Also, this apparatus can be modified with ease to cater for different shell sizes through changing die sizes.

In the initial prototyping phase, it is calculated that the hydraulic circuit has appropriate surface area to dissipate the heat of inefficiencies so that the oil temperature may not exceed more than 70 ^{0}C. While this temperature is appropriate to retain the desired properties of mineral oil for hydraulic operation, this temperature may get uncomfortable to work with for the worker and may cause burn and/or injuries, so it is recommended to incorporate a heat exchanger in the next iteration of the design.

Another recommendation is to include an automated feeding mechanism to completely eliminate human intervention. This will increase the overall speed of the process which was the primary goal of this process. Also, with this addition, the machinery can be sold at a higher price if the end user ever plans to commercialize the machinery.

The system is partially manufactured with the assistance of Manufacturing Resources Center (MRC) so it would be better if the system is manufactured completely so that it can be deployed for use of the end consumer.

REFERENCES

[1] Shigley, J. E. (2011). *Shigley's mechanical engineering design*. Tata McGraw-Hill Education.

[2] Jones, F. D., Amiss, J. M., & Ryffel, H. H. (2004). *Guide to the Use of Tables and Formulas in Machiner's Handbook*. Industrial Press.

[3] HIBBLER, R. MECHANICS of MATERIALS Fifth Edittion. *Chater*, *5*, 213-219.

[4] Prasuhn, A. L. (1987). Fundamentals of hydraulic engineering.

APPENDIX I: BILL OF MATERIALS

Vendor's Name	Part Number	Quantity (numbers)	Dimensions (LxWxH) *In cm unless specified	Weight (KG)	Specification (if any)	Price (PKR)
Shaheen Pipe Industry			600X2X2			1740
Kaleem Ishfaq Hydraulic, Misri Shah, Lahore		2			1)BORE=64mm Stroke=281.6mm 2) BORE=76.8mm Stroke=153.6mm	12000
Abdur-Rehman and Sons, City Saddar Road, Rawalpindi		Multiple	Thickness (0.3cm 0.5cm 1cm)	23		3500
Khurram Bearings, City Saddar Road, Rawalpindi		4	ID=1cm OD=1.8cm			800
M Sardar, City Saddar Road, Rawalpindi		4	1cm diameter			200
M Sardar, City Saddar Road, Rawalpindi		1				500
Hassan Khokhar Machinery Store, City Saddar Road, Rawalpindi		1			2 Horsepower, 2800 rpm	9000
Hassan Khokhar Machinery Store, City Saddar Road, Rawalpindi		1	72cm length			130
Abdur-Rehman and Sons, City Saddar Road, Rawalpindi		Multiple	1cm thickness	1.5	AISI 1045	300
Muhammad Akram Engineering Works, City Saddar Road, Rawalpindi		1				1050
Hassan Khokhar Machinery Store, City		1				2000

Saddar Road, Rawalpindi						
Abdur-Rehman and Sons, City Saddar Road, Rawalpindi		Multiple	0.8cm thickness	2		400
Nawaz Hardware, City Saddar Road, Rawalpindi		8				200
Abdur-Rehman and Sons, City Saddar Road, Rawalpindi		1	1.8mm diameter	0.5		50
Muhammad Akram Engineering Works, City Saddar Road, Rawalpindi						500
Nawaz Hardware, City Saddar Road, Rawalpindi		16				290
Pak-Japan Engineering and Pipe Services, Turnol		15 Pipes	Varying Lengths			16000
Hassan Khokhar Machinery Store, City Saddar Road, Rawalpindi	Bt-04	1				10000
Hassan Khokhar Machinery Store, City Saddar Road, Rawalpindi	Bt-04(external pilot)	1				10000
Hassan Khokhar Machinery Store, City Saddar Road, Rawalpindi	Rexroth 4WE 6 E62/EG24N9DK35L	2				16000
Coordinator Provided	Grade 8W40		12 Litres		Coordinator Provided	8000
Shaheen Pipe Industry				20ft		1500
Abdur-Rehman and Sons, City Saddar Road, Rawalpindi		3				4000
Coordinator Provided	GHP1A4S				Coordinator Provided	25000

Abdur-Rehman and Sons, City Saddar Road, Rawalpindi						8000
Ocean Electronics College road, Rawalpindi		multiple				500
Ocean Electronics College road, Rawalpindi						2500

Gross Total (Rs)	134160
Our Expense (Rs) (minus components provided to us by Our Coordinator)	101160

APPENDIX II: ENGINEERING DRAWINGS

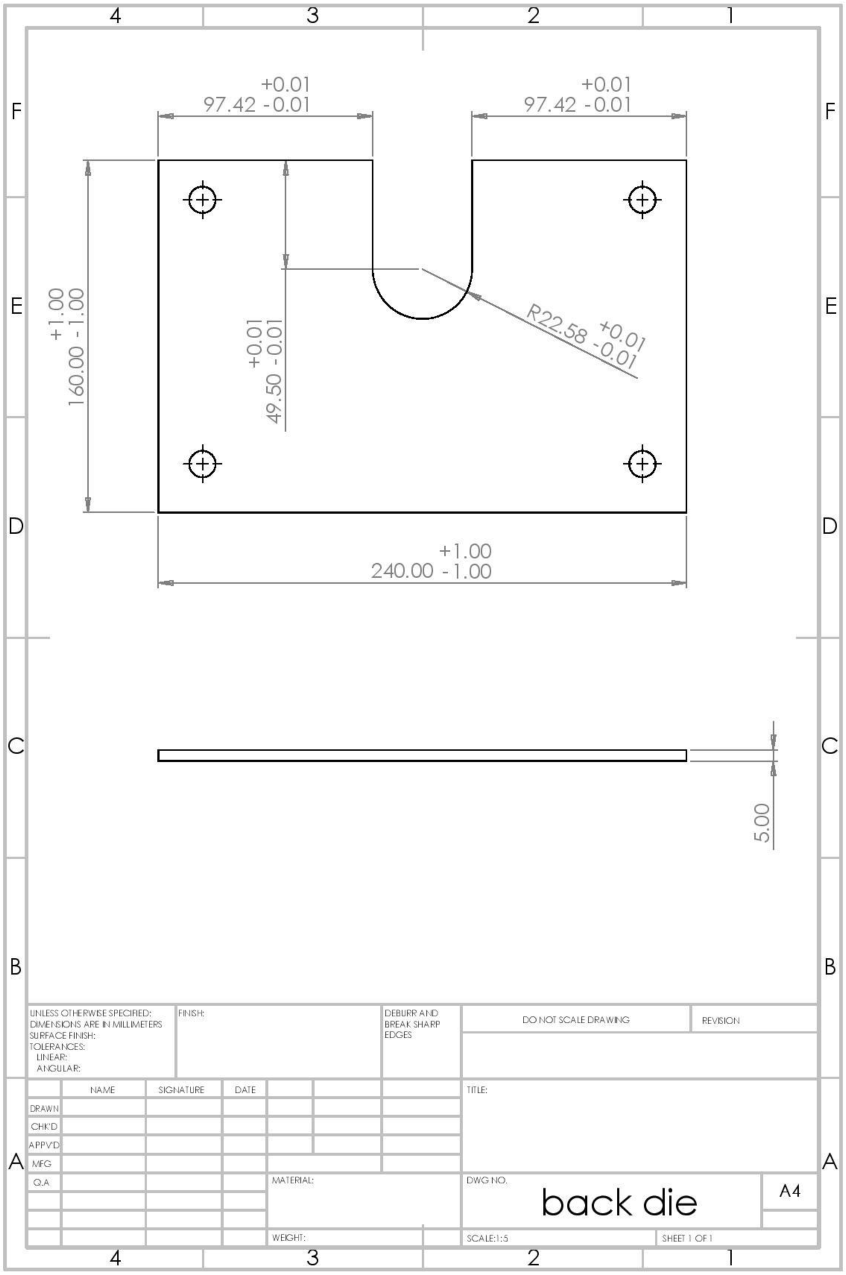


Figure I: Back clamper DIE (for clamping cartridge)

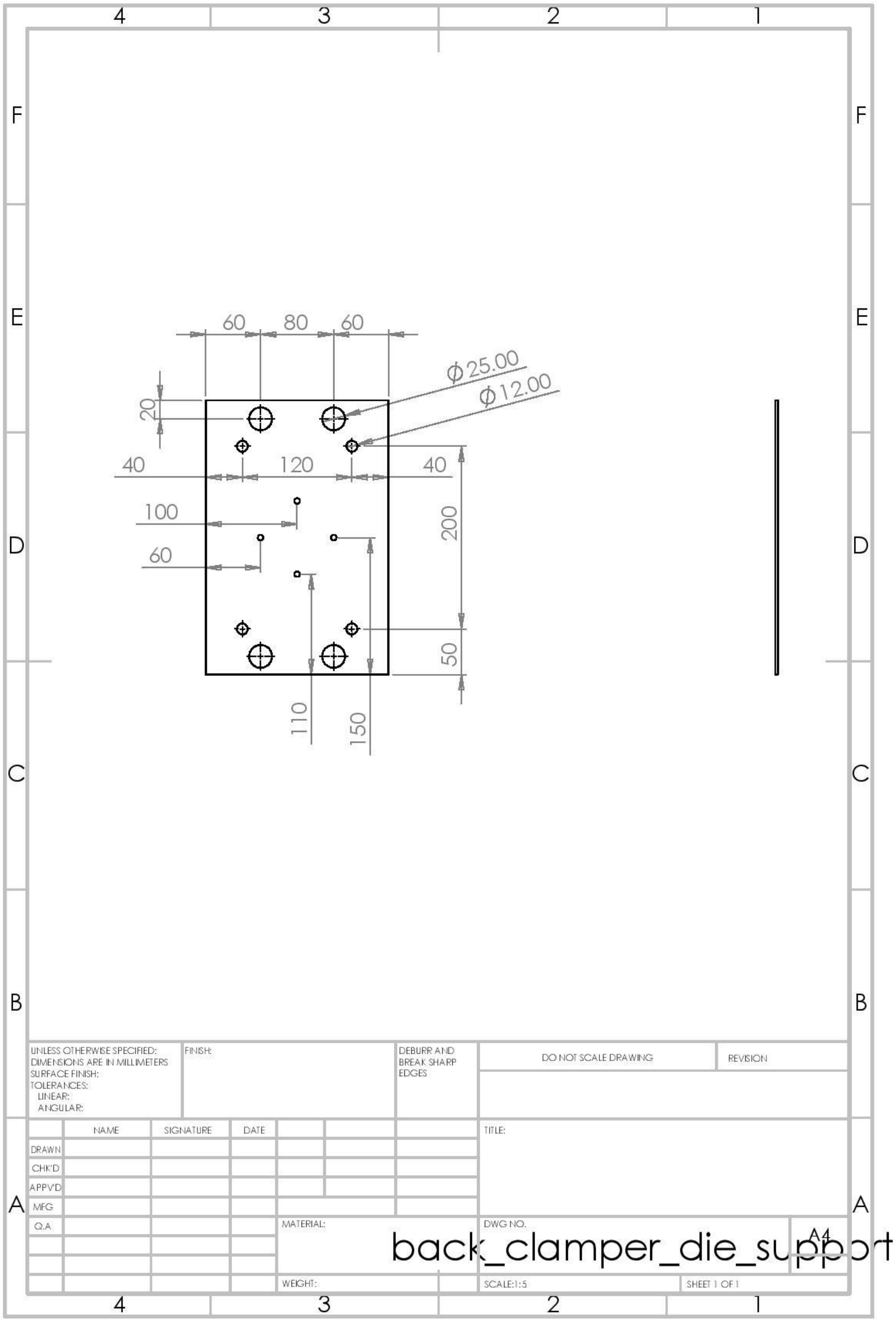


Figure II: Back clamper Die Attachment Plate

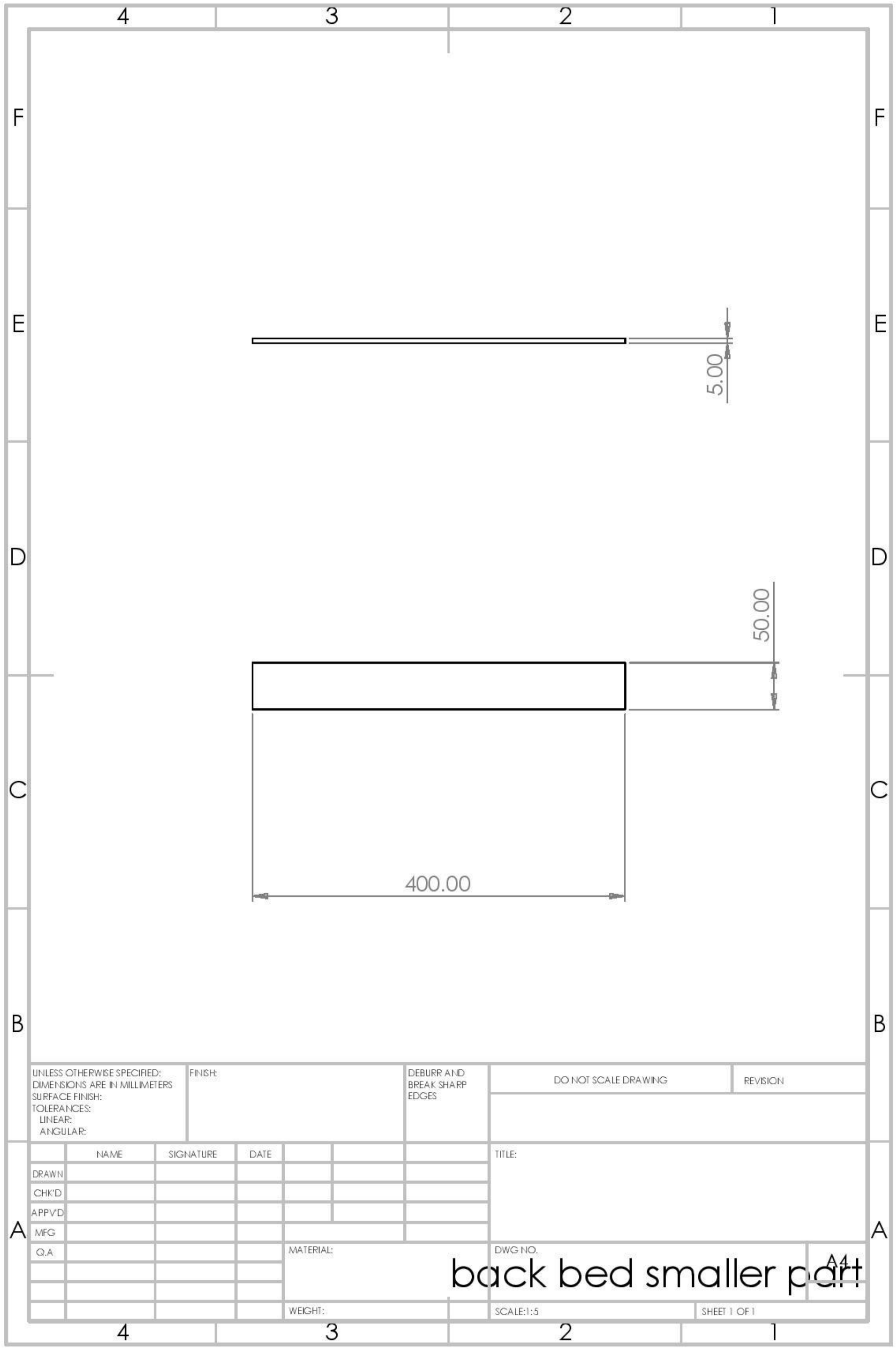


Figure III: Back Assembly Bed Plate

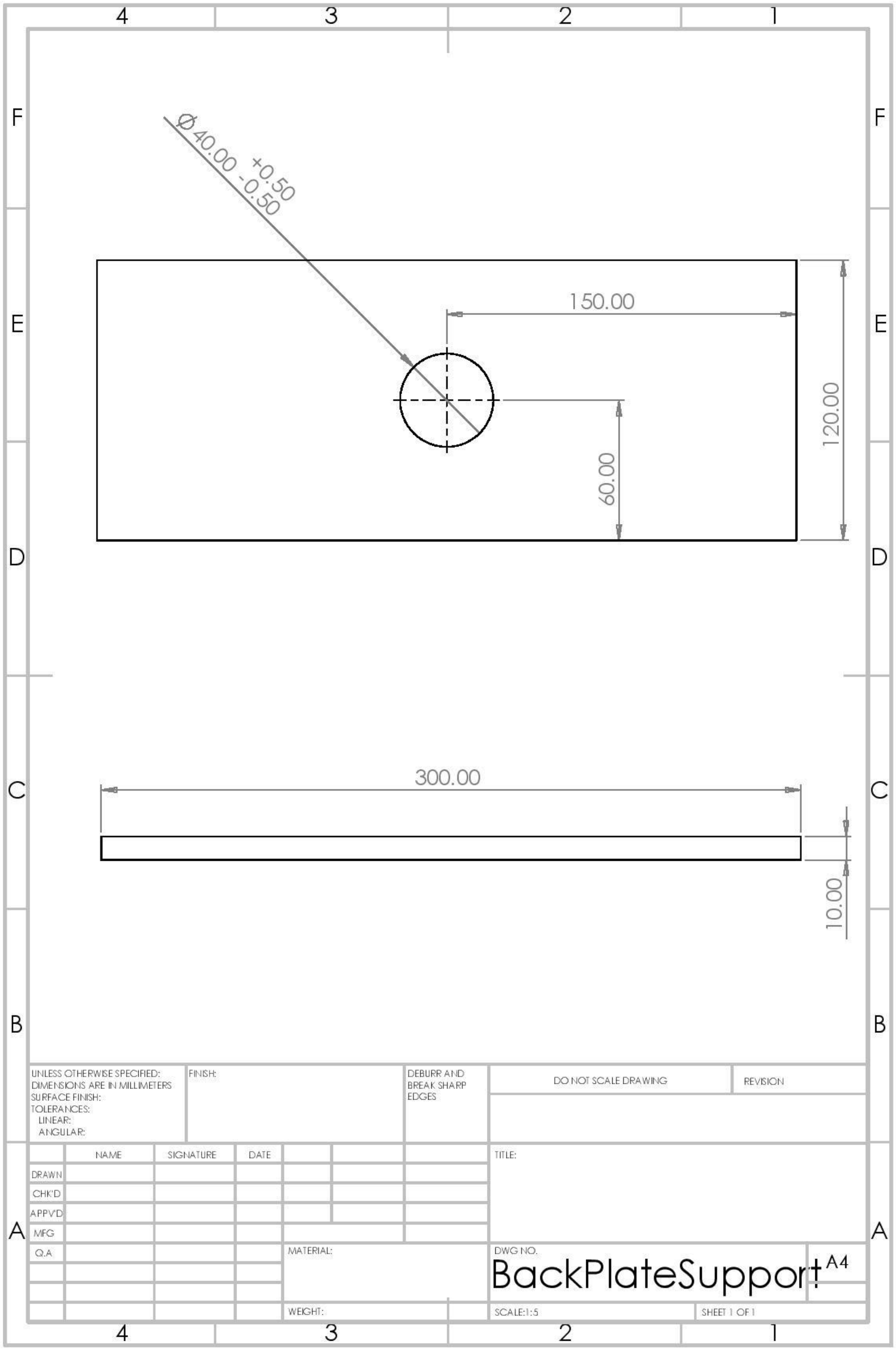


Figure IV: Back Assembly Support Plate for Actuator

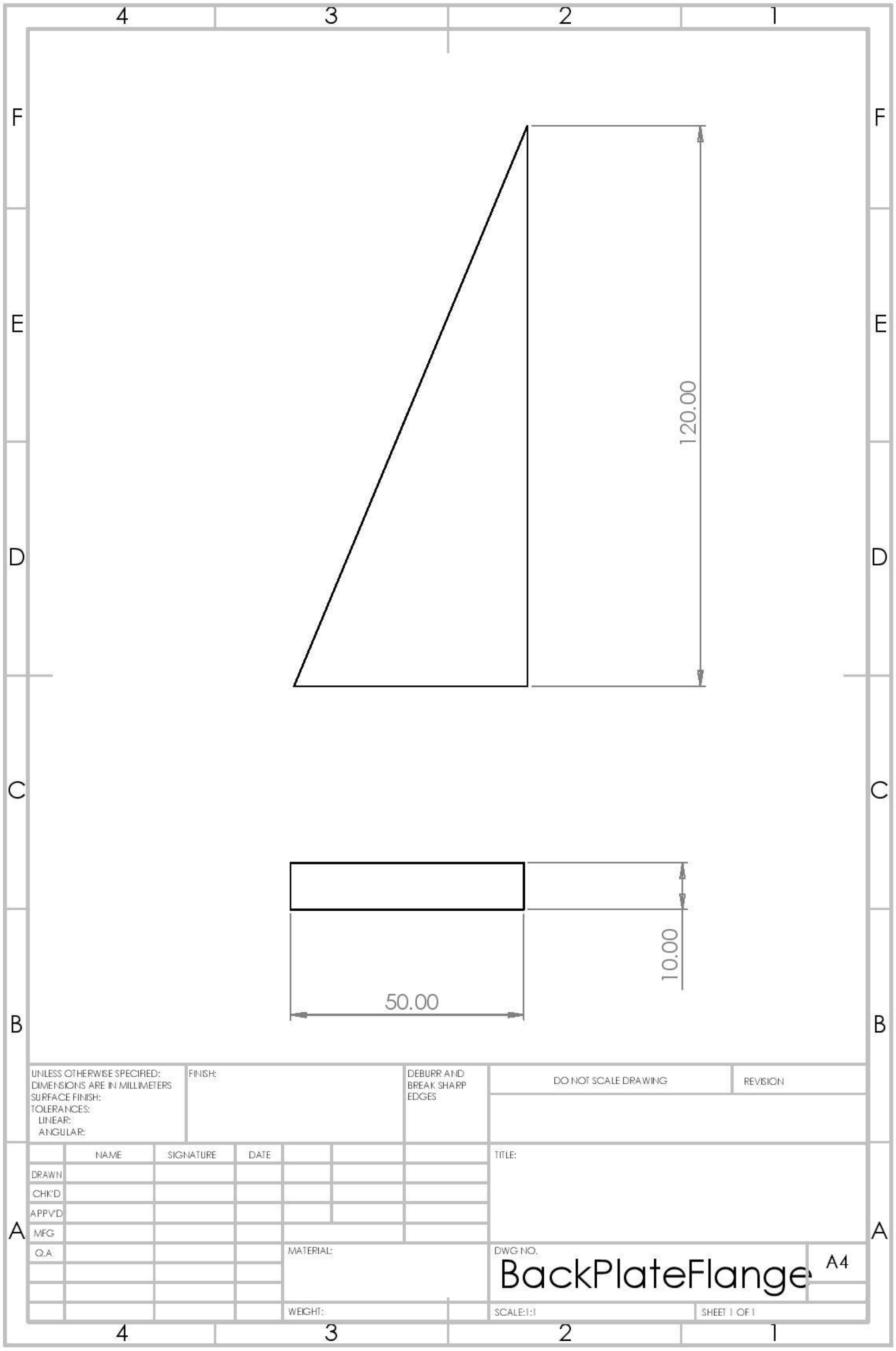


Figure V: Back Assembly Support Plate Flange

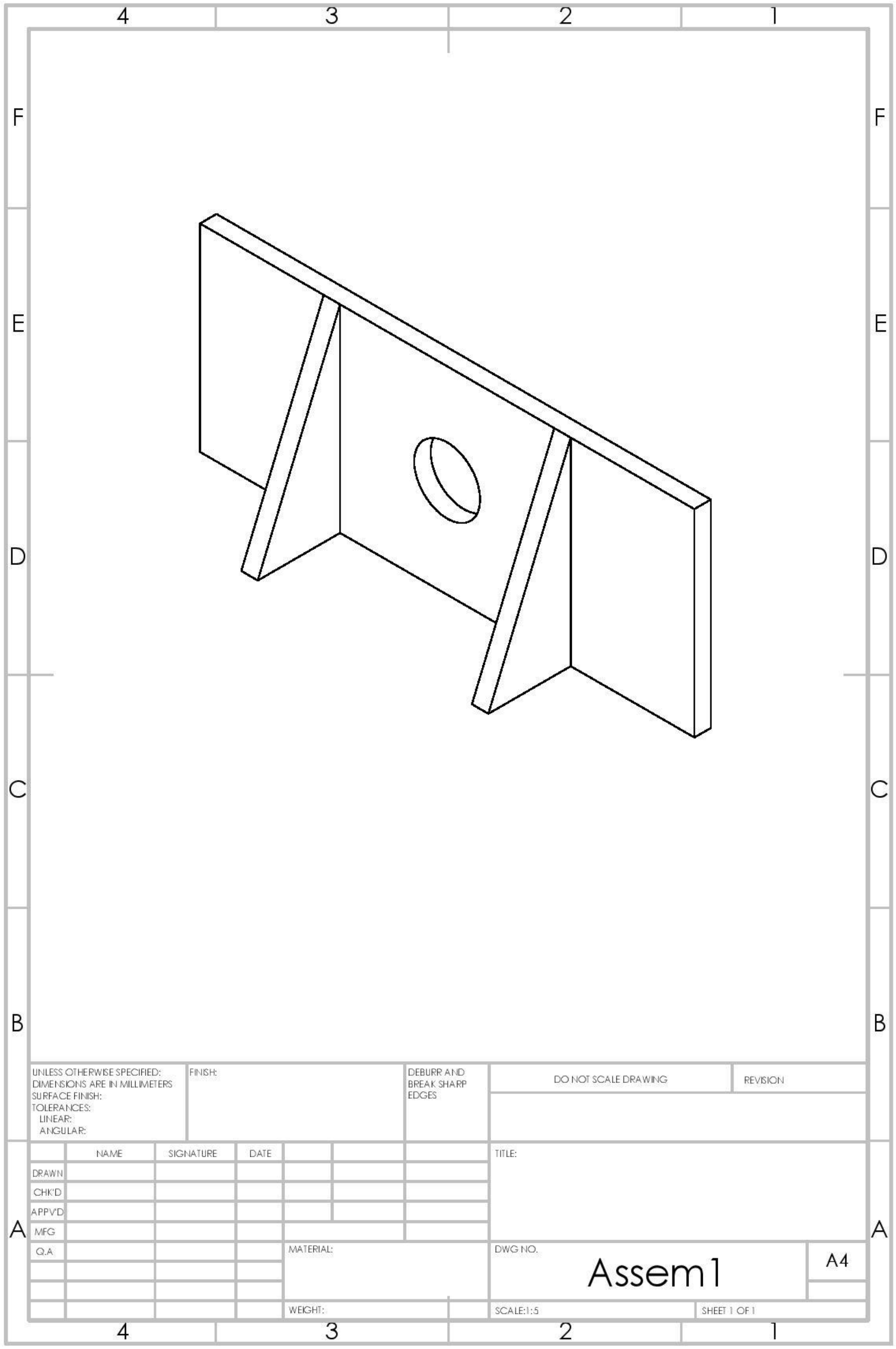


Figure VI: Back Support Plate Assembly for Actuator

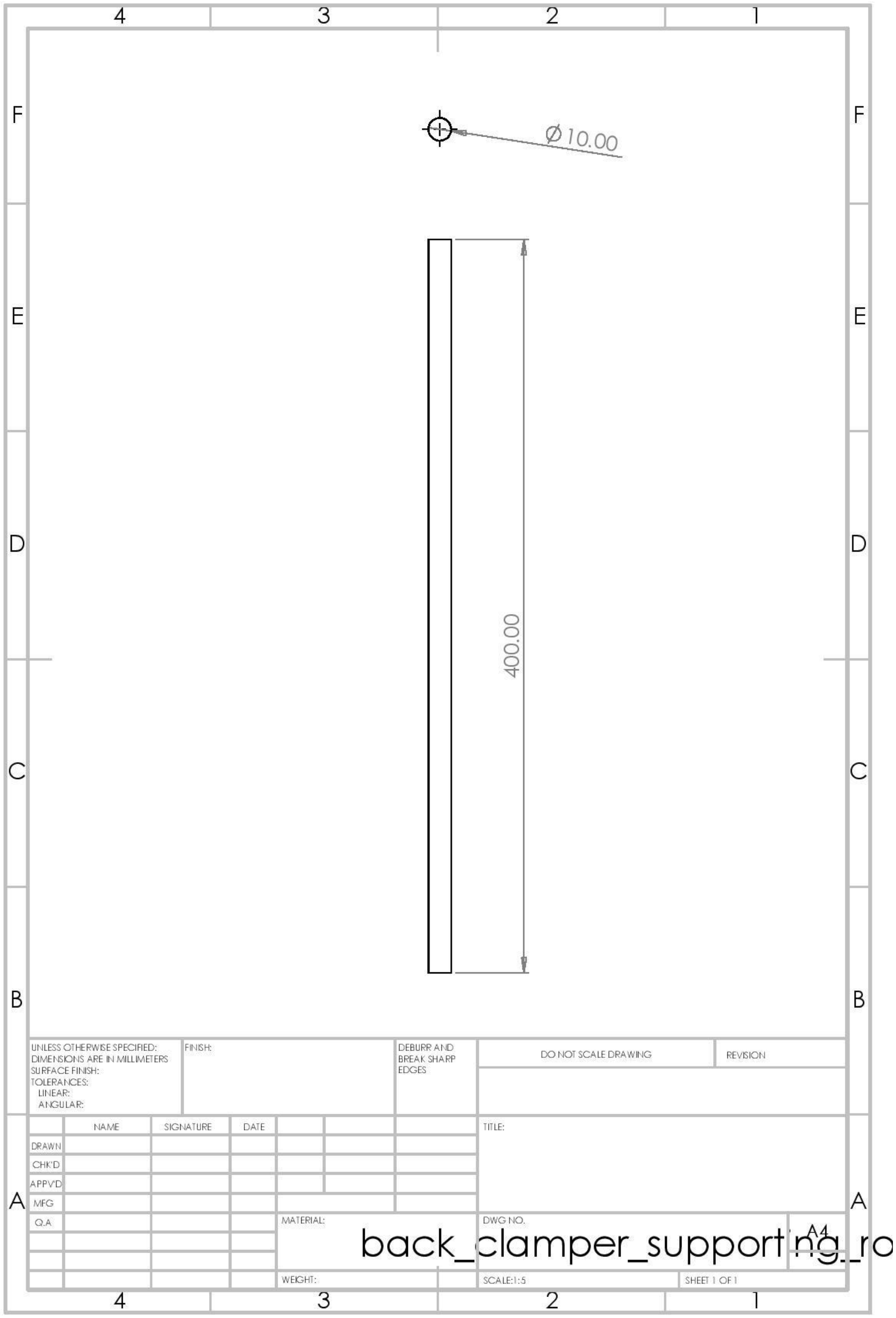


Figure VII: Back Assembly Guiding Rods

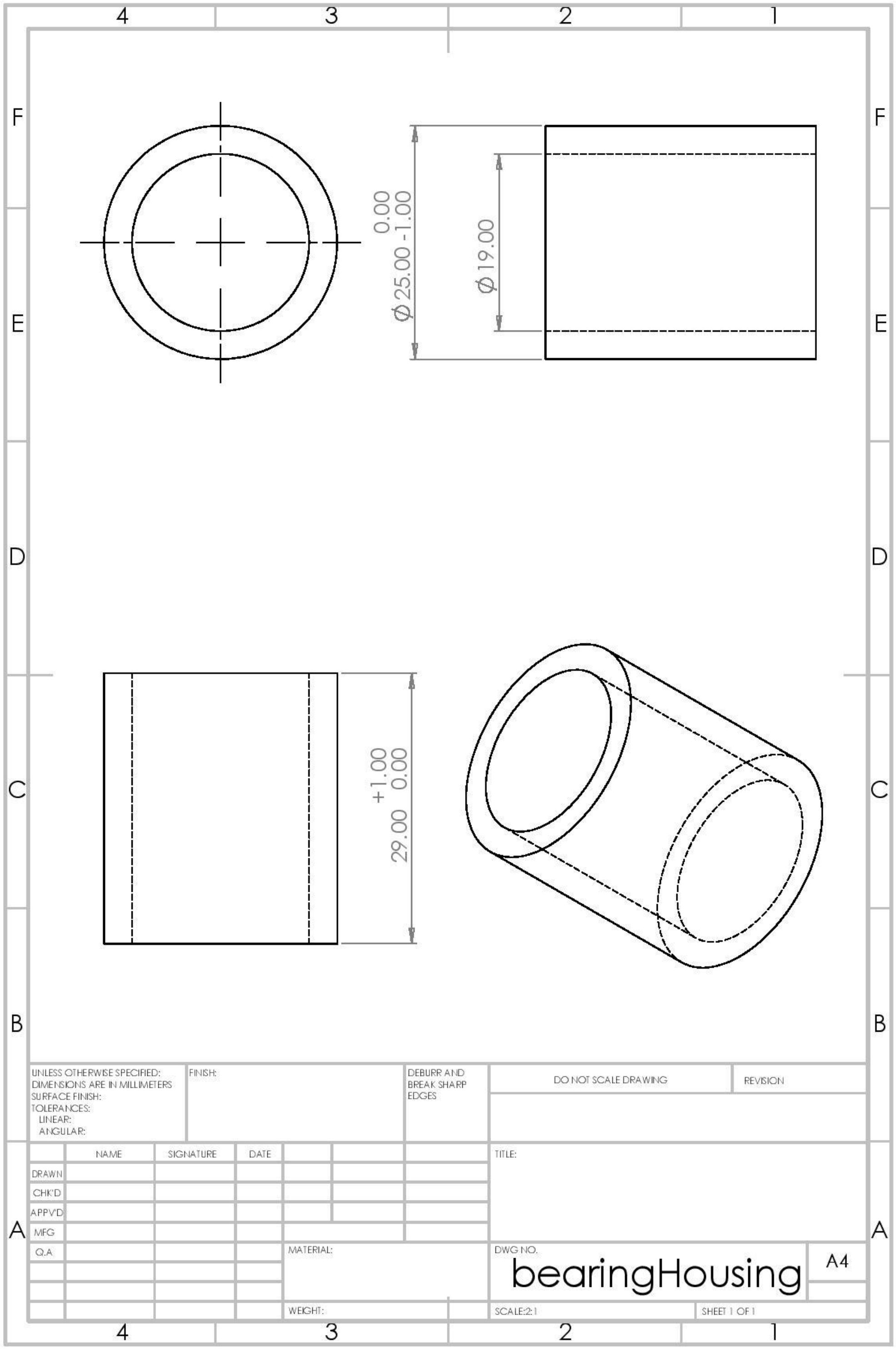


Figure VIII: Back Assembly Bearing Housing

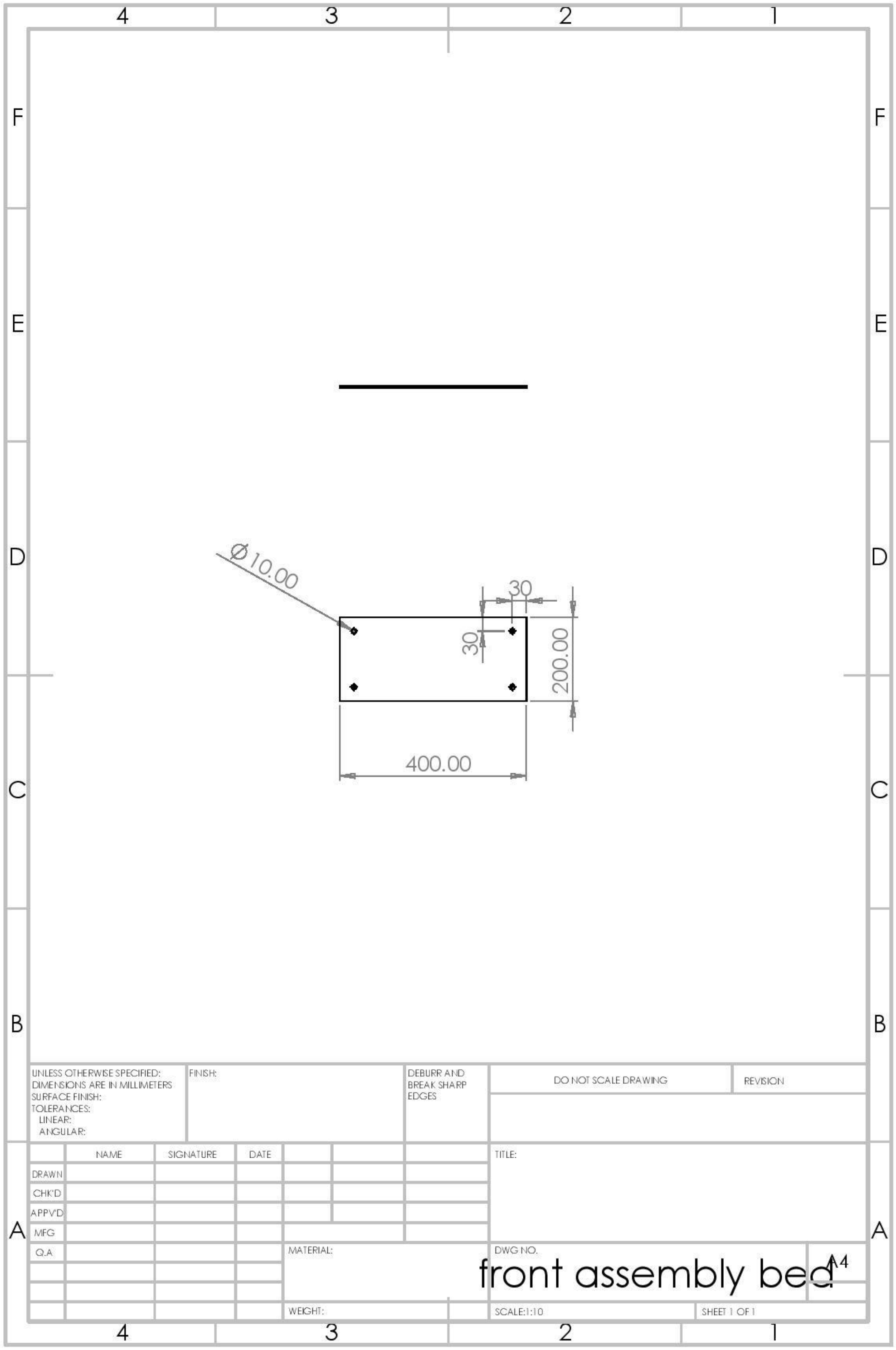


Figure IX: Front Assembly Bed Plate

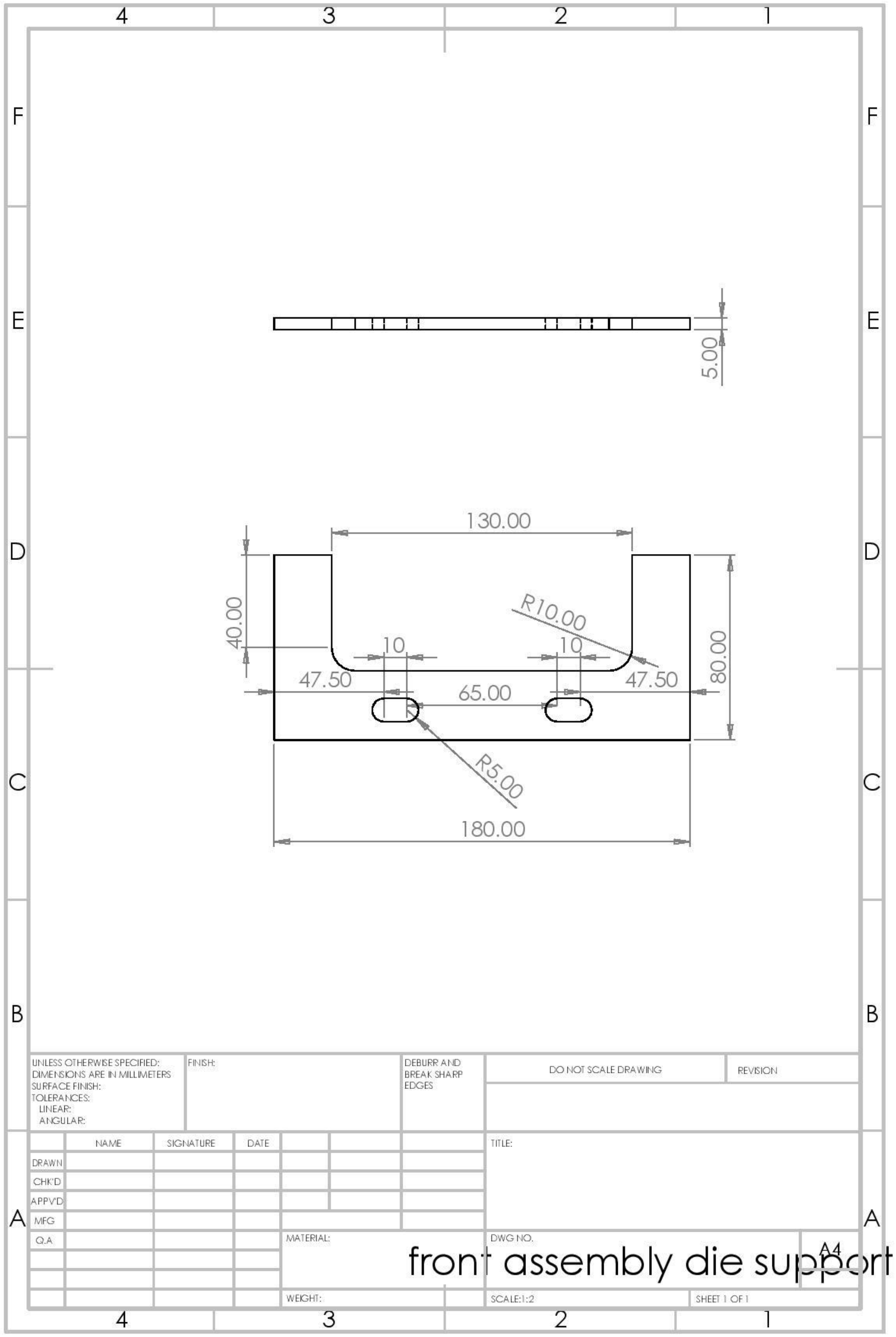


Figure X: Front Assembly Support Plate for Die

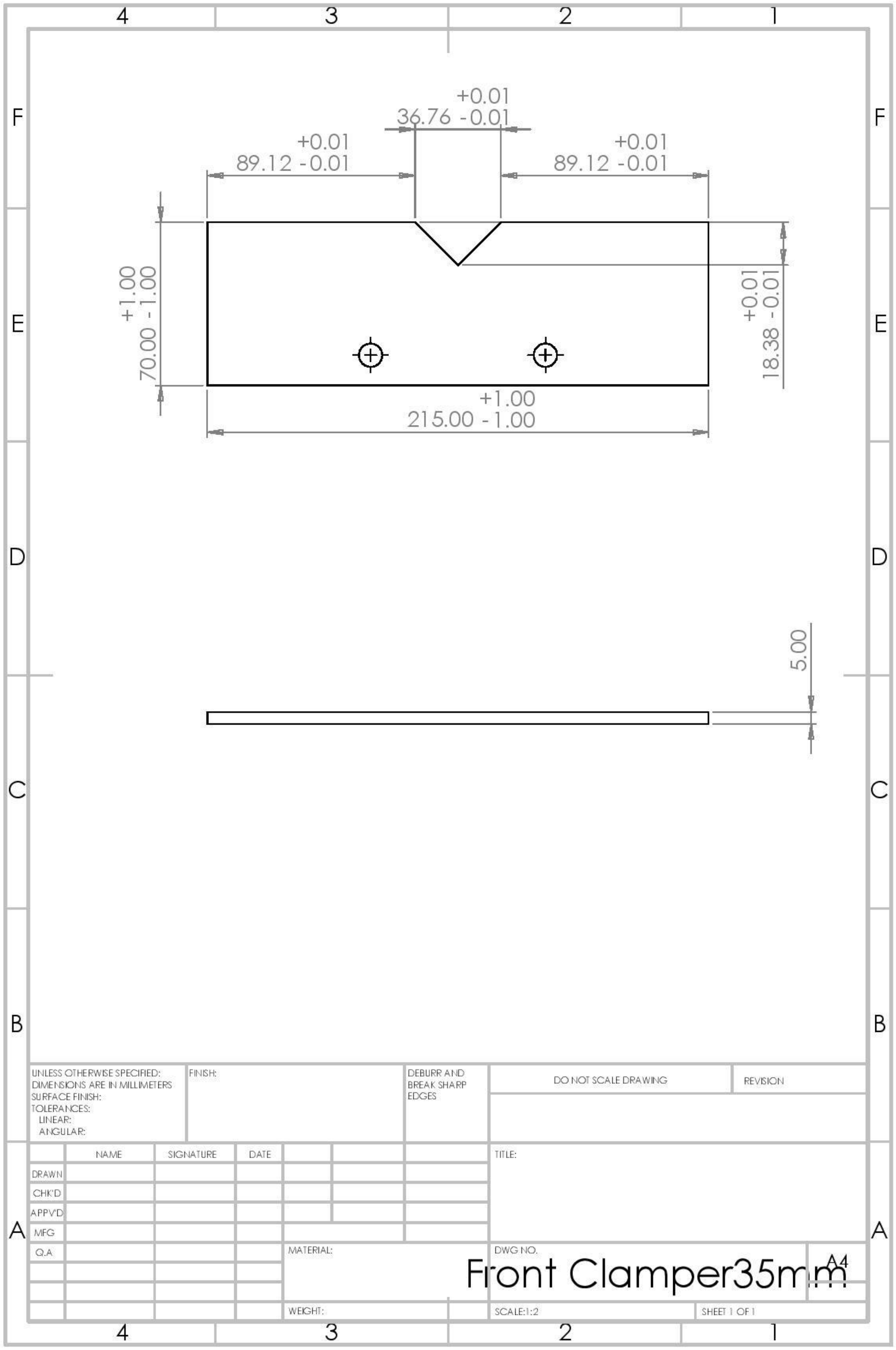


Figure XI: Front Assembly Clamper for 35mm Shell

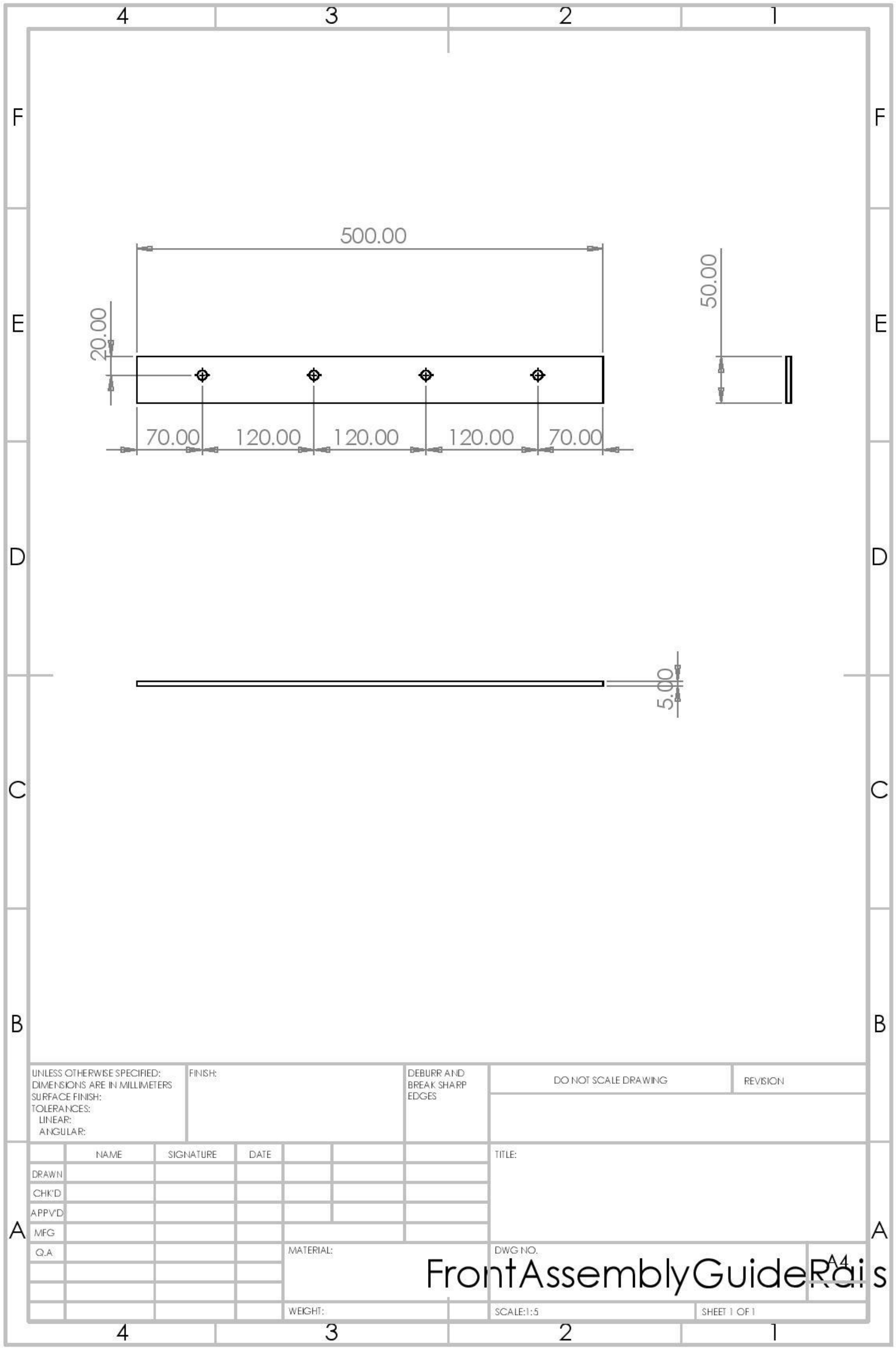


Figure XII: Front Assembly Guide Rails (For Moving Front Assembly Back and Forth)

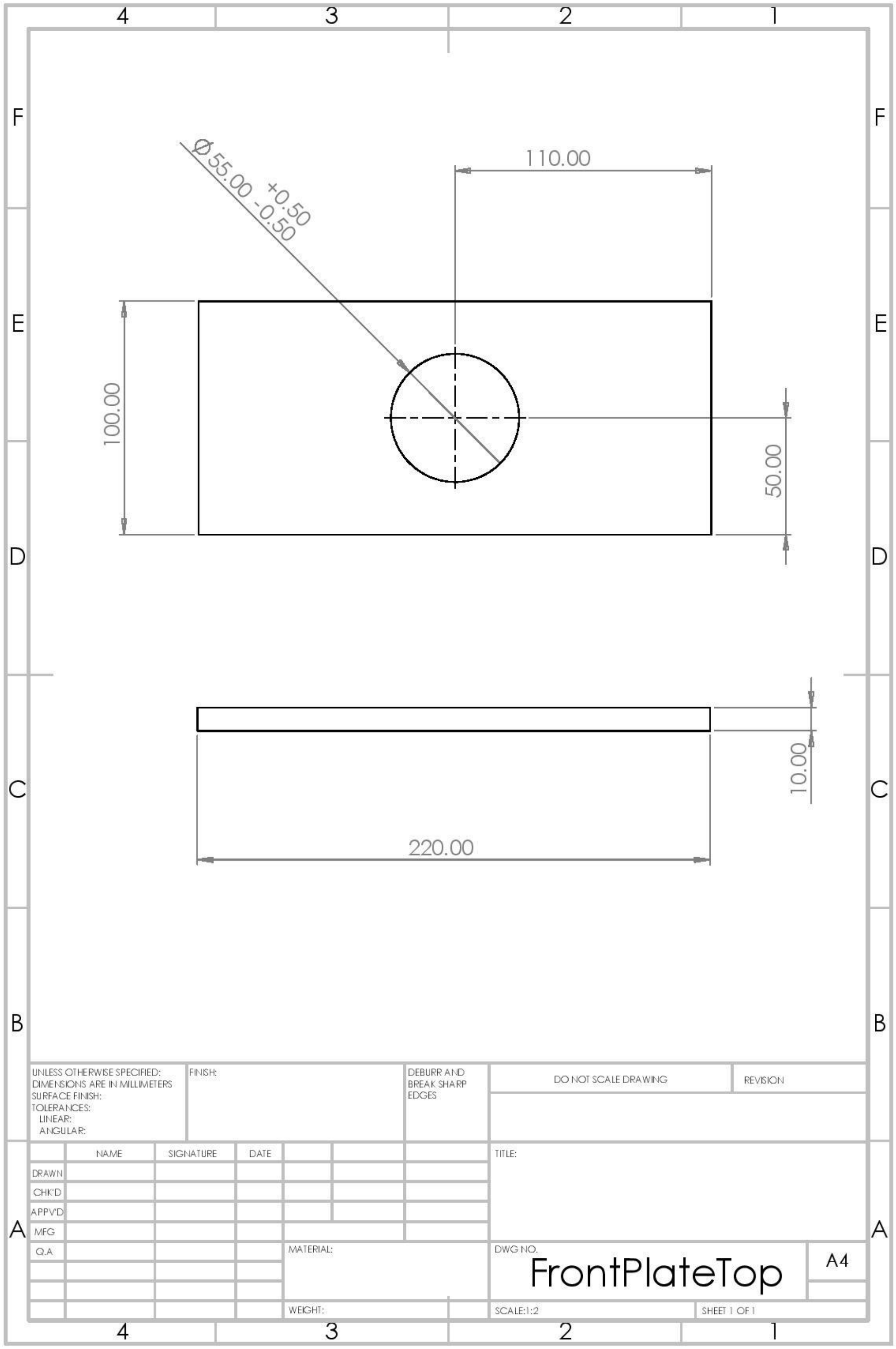


Figure XIII: Front Assembly Top Plate for Attaching Actuator

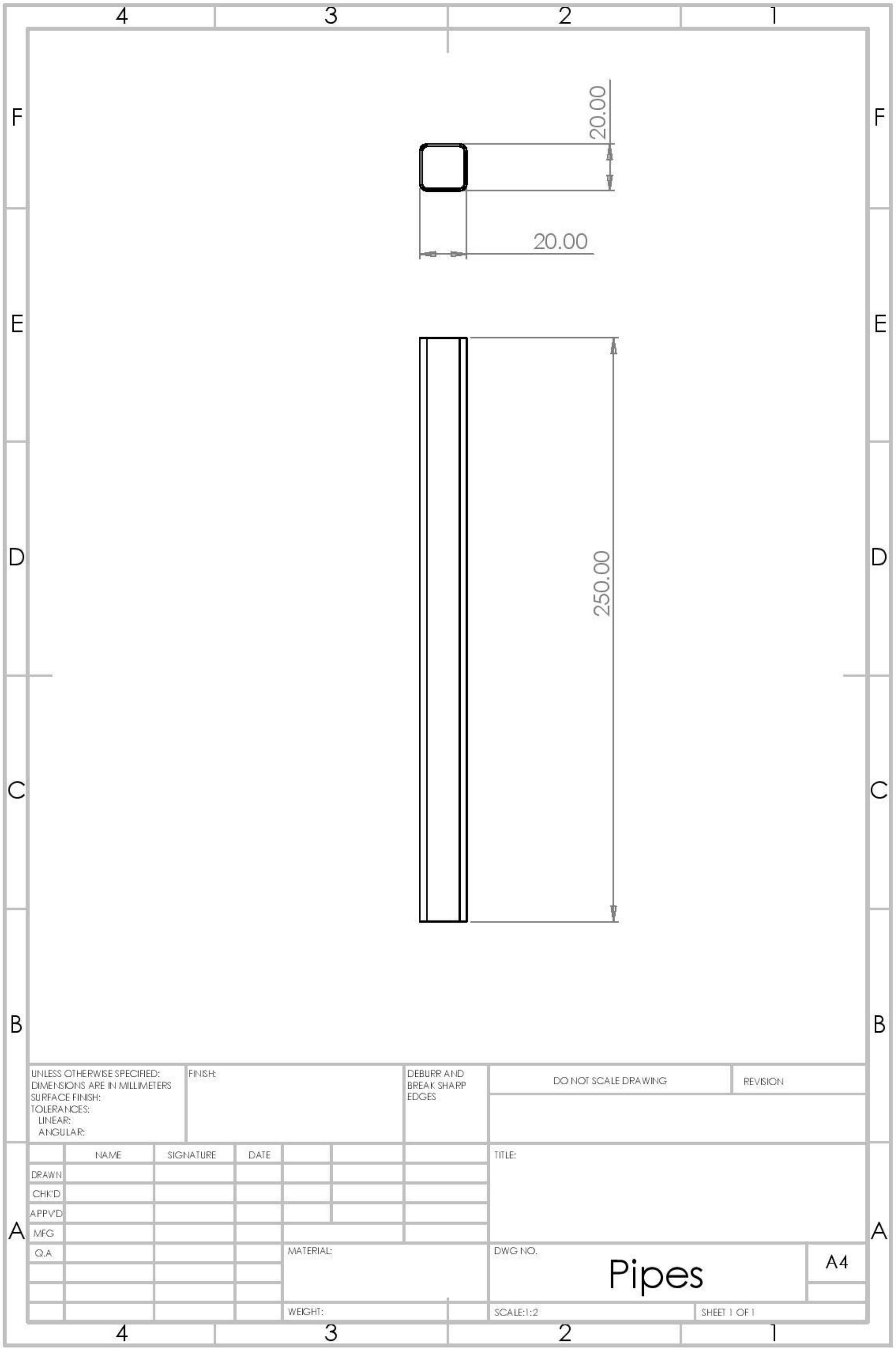


Figure XIV: Front Assembly Square Pipes for Supporting Top Plate

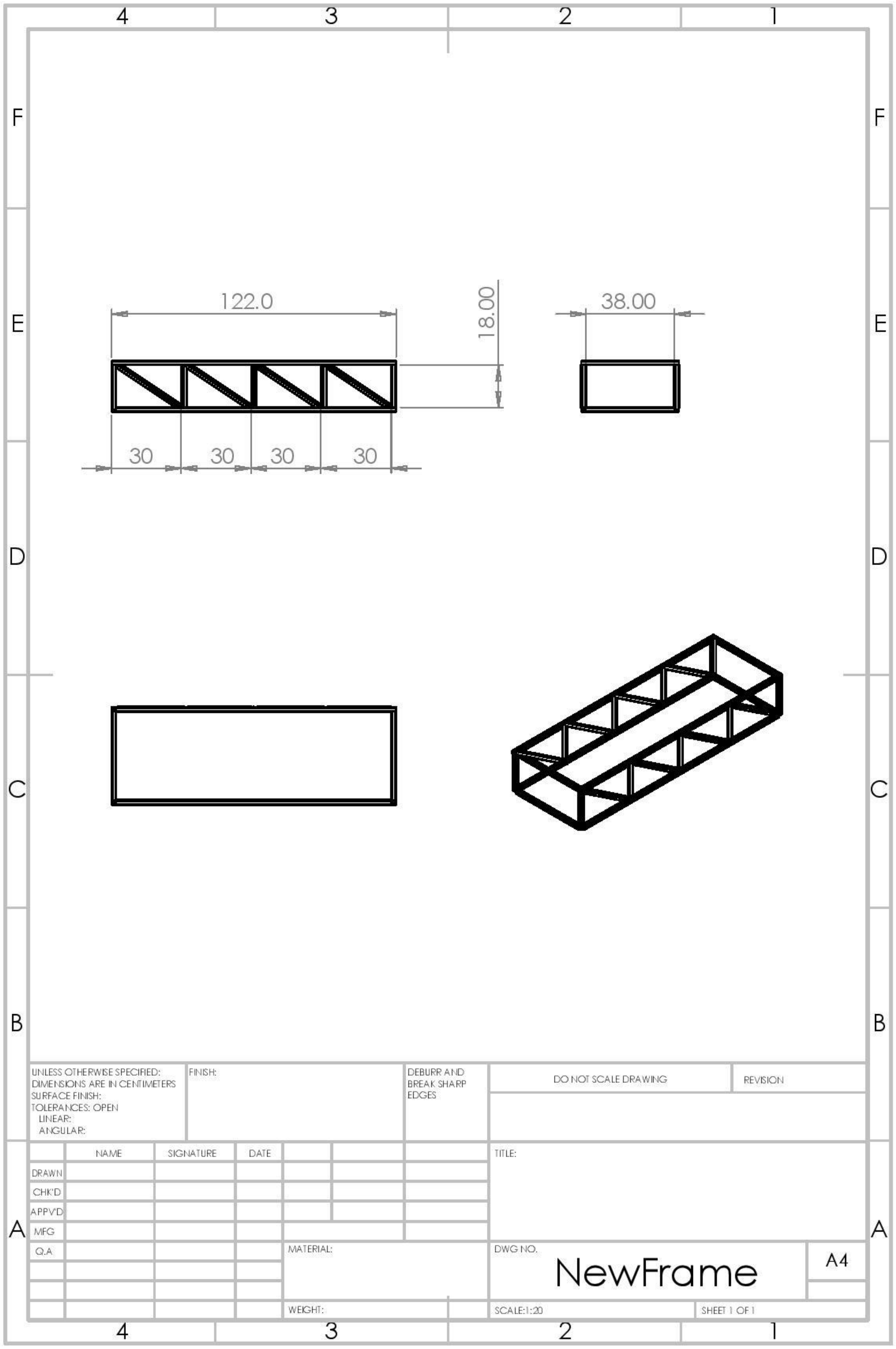


Figure XV: Base Frame