TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of Power Engineering and Mechatronics

HEAVY COMPONENTS LIFTING

RASKETE KOMPONENTIDE TÕSTMINE

MASTER THESIS

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177186MAHM

Tallinn 2020

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THESIS TASK

Student: Nitin Gupta,177186MAHM

Study programme, MAHM02/13 -Mechatronic

main speciality:

Supervisor(s): Leo Teder, Teaching Assistant

Consultants: Vjatseslav Koop Manager of Manufacturing Tech. Development,Ericsson Eesti AS

Thesis topic:

(in English)*Heavy Component Lifting*

(in Estonian) Raske komponendi tõstmine

Thesis main objectives:

1. To develop Common Solution to lift and move heavy Units.
2. Developing Tool to Assist workers to lift extremely heavy product.

Thesis tasks and time schedule:

No	Task description	Deadline
1.	Understanding of the Technical Requirement	01.09.2019
2.	Comparison of new Idea	05.10.2019
3.	Developing of Mechanical Design	20.12.2019

Language: English **Deadline for submission of thesis:** 03.05.2020

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List of abbreviations and symbols

ESD	Electrostatic discharge
CE	European Community
FIB	Forwarding information base
HMI	Human machine interface
PIM	Passive Intermodulation
3-D	3-Dimensional
NEMA	National Electrical Manufacturers Association
UL	Underwriters Laboratories
°	Degree
SPDT	Single Pole-Double throw

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1 Introduction

1.1 Overview

This thesis is focused on developing the solution to Lift the Heavy Radio Units in Collaboration with Manufacturing site and Tallinn University of Technology. The initiative to this thesis Idea began with the introduction of the Latest 5G Radio Units at the Manufacturing site which are weighing above 70 kg. Also, the Length of the Unit is above 1 meter. There will be more heavy units coming in the future e.g. of the radio unit is shown in Figure 1 below.

Figure 1 Example of Heavy Radio Units of Manufacturing site [1]

The problems that arose with the production of heavy units are the lifting, rotation and Transportation of the Product. As the Production area is Limited and must be used efficiently. So, the solution to tackle these problems must be developed in a lean and mobile way. Before the beginning of the thesis, some different solutions have been already been used in production. But the problem with those solutions are mentioned below: -

1. Zero mobility
2. Heavy
3. Expensive

4. Needed different machine for different process

The new design development must be done keeping the above drawbacks into consideration. The initial approach to solve this problem was to make the team of the students which will provide different Idea to tackle the problems. All these Ideas will be compared to each other and to the current production solutions. After the comparison of all the ideas and solutions, one solution will be finalized, and the realization of this idea will start by developing the realistic 3-D model of the idea which will require the development of the child Parts and assemblies. During the development, the selection of standard parts has to be done. These standard parts must be selected on the base of market research which will include a comparison of the different standard parts from a different company. In the realization phase, all the Technical parameters of each part must be calculated to check the reliability of the product.

This solution is going to be the first prototype. The basis on the results of this prototype the future placement of the solution in real production will be decided.

1.2 Motivation

The reason to choose this topic was the board approach to the tasks. As, from the problem discussion it was clear that this thesis requires a lot of research and the development in the field mechanical design, electronics and control. Because this is going to be the new solution build from scratch which allows us to practice all the aspects of our Master's in Mechatronics. Mechatronics is a simple way is defined as the combination of mechanical, electrical and software. In thesis, the author is going to develop a solution based on this combination as previously mentioned. Besides, this the thesis topic is time and budget bounded. This project is also going to make us work into the field of logistic because some parts must be ordered which require a price and lead time research. For this, the author must contact different companies to extract information and analysis of the information has to be done to select the best.

1.3 Scope

As the author had already discussed the this is a prototype which it itself clarifies that to reach the final fully developed product a lot of research and improvement has to be made. In this project, a detailed study of the production process must be done. This project also requires the work in the three big fields of engineering which are: -

1. Mechanical Design Engineering
2. Electrical/Electronic Engineering
3. Software Engineering

There will different tools which author are going to use in this thesis. For e.g. CAD software for 3D model and analysis. As this is a team project good understanding and management is required. In management the following details must be clarified for the smooth cooperation: -

1. Task distribution
2. Follow-ups on the status of the task
3. Defined roles in Project
4. Understanding of problems

1.4 Background Research

As the main approach of this thesis topic is to Develop solution in a certain timeframe which requires us to understand the current production process in-depth and to develop a new solution for it. For which similar kind of literature study must be done. To understand the previously developed similar solution. This research should also include the Technical data analysis of the machine which is in the current production process of heavy radio units. This analysis will give us the in-depth details about limitation in the current production process, which the author has to overcome in our new solution.

1.5 Problem

As mentioned earlier. Manufacturing site is coming up with new and highly advanced antenna integrated radio products. Some of those new products are quite heavy up to 90 kg. This product weighs 90 kg and it's quite heavy for a human to lift and move around which is required for the production, testing and sometimes troubleshooting. Currently, Manufacturing site is using a fixed crane which does provide all the solution but in a confined area and because of which the layout of production is optimized to keep everything within the reach of the crane and the similar crane is installed in a warehouse. In the cases where the product needs to be picked and placed in other production hall or the area out the reach of the crane working area. It would be impossible to do such tasks because the fixed crane and in future more products are coming with similar characteristics. So, it's not an optimal or mobile solution which can be used in different production hall or situations.

1.6 Requirements

For any solution that was proposed, it was important for that proposal to check whether it can perform the said function and to meet the following requirements. [2]

- The proposed solution should be ESD safe.
- The proposed solution should comply with CE standards.
- The proposed solution should be easy and safe to use.
- The proposed solution shouldn't require maintenance more than once.
- The proposed solution should be future proof meaning it should not only provide a solution to one product but will be able to work with future products right away or with small modifications.
- The proposed solution should not take too much time to start-up.

These requirements are were explained initially in the proposal of the project.

2 Process Analysis

2.1 Introduction

This chapter contains a detailed description of the process required for the manufacturing of the Antenna Integrated Radio. The process analysis was done to provide the best solution possible because the process includes some complicated/unique manoeuvres which are required during the manufacturing of the product which also includes the testing of the Radio. Also, this process analysis will help us to gather information about technologies used in the current solution and what can be done better. To produce an efficient solution.

2.2 Existing Solution

One of the technologies used in the existing solution is the LionGrip Hydraulic lift. LionGrip, you can lift huge loads in the mix with a long reach. The heap can be grasped outside the focal point of gravity. LionGrip is furnished with a power touchy handle and lifts easily at the littlest hand development. In the standard forms, LionGrip handles loads up to 200 kg, has a working sweep of up to 4 meters and more than 400° working region. But this is a heavy and rigid mechanism, which has to be fixed in one place. To lift the Radio manufacturing site is currently using the standard Liongrip Lift platform with a specific gripper which is not a standard part. Below is the picture of the lift without the gripper. [3]

Figure 2 LionGrip Lift [3]

2.2.1 Pulley gripper

So to lift and rotate the radio manufacturing site is using the two pulleys type gripper. In which the radio is hanged on the pulleys using nylon straps. The pulleys provide easy rotation of the unit on the gripper. Below is the picture of the gripper.

Figure 3 LionGrip Gripper with Nylon strap

2.3 Layout

The manufacturing sites have to defined limited space for the production of each individual product. Even though the factory has a lot of ground space but there are a lot of products which is used produced in the factory because of which space has to to be used efficiently. To make the most out of the available space. For our focused 5G Radio the layout is set up around the LionGrip.The reason behind this layout of the no mobility of LionGrip lift. The layout can be changed is future depending upon the production requirement. Below is a 2D representation of the layout.

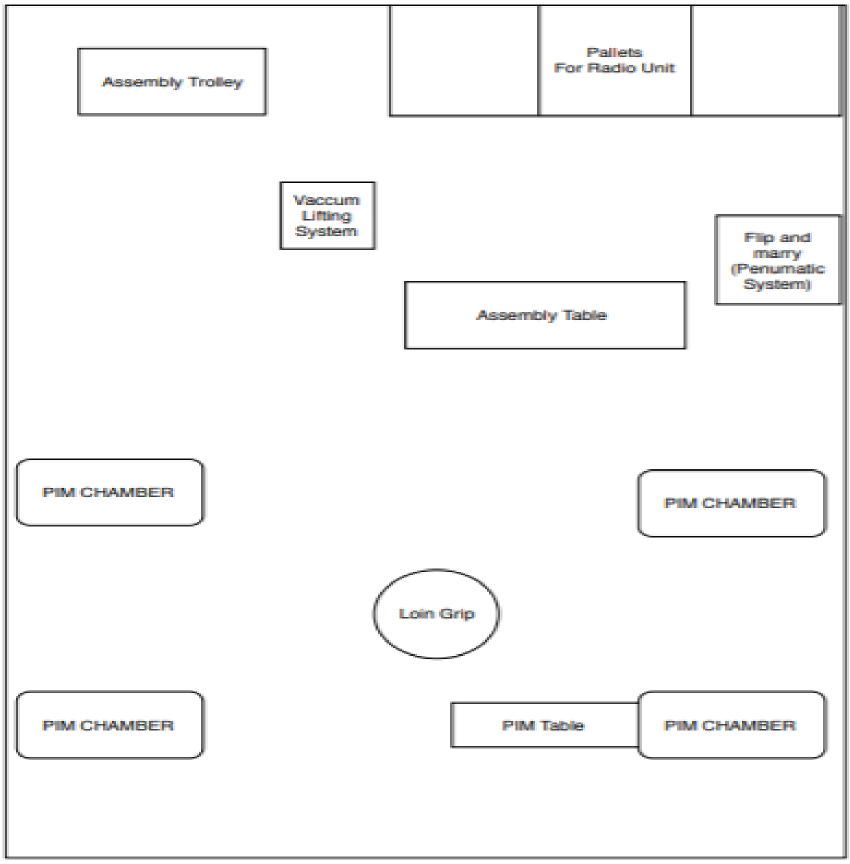

Figure 4 Assembly Layout

2.4 Assembly Process

The assembly process is based upon the design of the Radio. This radio contains two smaller size radio, one FIB(Forward Information Base) and one very large Antenna Head. The initial step of assembly begins with picking up the "Antenna" from the pallets and then placing it on the Semi-Automated Assembly System. The Radio and antenna connection is made on the Semi-Automated system in Controlled and precise way. After the assembly Complete Unit(Contains Radio, FIB and Antenna) is taken to the PIM(Passive Intermodulation)Chambers to test the Radio Unit for verification and validation. For testing in PIM Chamber unit has to be picked up from the Semi-Automated System and rotated 180^0 degrees to put on the PIM table. Later this table is slide into the PIM chamber to begin the test. In the last step, after the Unit passes the test in the PIM chamber, the unit is lifted out from the PIM table and rotated again to put it into the package placed on the pallets. The Further detailed description and visual representation of assembly is explained below.

2.4.1 Flip and Marry

The small radio units and FIB have to be picked up from the pallets and rotated 180^0 degrees. Before placing it on the Semi-Automated System for assembly. To do this current solution is Flip and marry machine base on Pneumatic mechanism. The Flip and marry gripper is designed specifically according to the radio design specification to lack and rotate the Radios and FIB. Below is the Picture of the flip and marry system.

Figure 5 Small Radio Unit Gripper

2.4.2 Semi-Automated System

The Connection between radios and Antenna is done through RF Coaxial connector. As these connectors are small and delicate the placement of the radio units has to to be done in the controlled and precise way. For this current solution is semi Automated assembly system. The Process Involved in the Semi-Automated Assembly system:-

- The placement of the approx 1 meter Long Antenna head Upside on the base of the system.
- Placement of individual Radios and FIB on the System.
- The alignment and placing of the Radios and FIB on the Antenna base.

2.4.3 PIM Table

The UNIT after getting assembled on the Semi-automated System is lifted with LionGrip Lift and taken to PIM chamber test. The unit is lifted and rotated 180^0 degrees before placing it on the PIM table. The PIM chamber is test reflected signal signals because of which table can't be made of metal. This table is made of wood. The Table is slide inside and out at initialising and at the end of the test. Below is the picture of the PIM table.

Figure 6 PIM Table

After Passing the test, Unit is lifted from the PIM table with hydraulic lift with nylon straps and rotated 180^0 degrees and place in the package with styrofoam coating to protect the unit from any possible damages during transportation and storing.

3 Task Formation

3.1 Introduction

After a clear understanding of the process, author-defined certain tasks in the initial stage. To distribute the work responsibilities. These responsibilities were divided into Tasks which are defined below: [2]

- Dimensions measurement
- Mechanical child parts and whole assembly 3-D Models individual
- Improvements in Designs

3.2 Dimensions measurement

For the prototype to work in a similar way as a current solution author must keep the dimension of the manoeuvres the same as the current solution. To achieve that precise recording of the dimension was needed. These dimensioning includes the following parts:

1. Distances of each process from the ground: The ground is as the reference value of zero which is common for all the dimension.
2. Individual production machine dimensions: To merge the design with current machines (Assembly machine, Test chamber, Palette and Trolleys) our design must reach and fit in all the required positions and sizes.
3. In-depth product dimension analysis for new Idea generation: The product each point dimension must be clear to create a solution which will accumulate the design perfectly according to the size of the Product.

3.3 Mechanical child parts and whole assembly 3-D Models individual

In the 2nd part of the task formation CAD models of the idea must be made to understand and explain the concepts of the solutions. With these 3D models, the initial analysis of the ideas would be easier and visually understandable. The Basic 3D models of the Initial Ideas was done individually then the analysis and the improvement was done by the team.

3.4 Improvements in Designs

During Idea generation, all the designs were appearing flawless, but the author started facing a lot of problems when the author started analyzing all the Designs in depth. As the author found out all the design Required the improvement based on the following points:

- Based on the Complexity of the mechanism and manufacturing
- Availability of the Standard parts
- Safety of the mechanism

3.4.1 Based on Complexity of the mechanism and manufacturing

The design must be amended according to a practical limitation of the manufacturing. Also, the mechanism must simple in function to reduce the chances of failures. Because something which might be easy to conceptualize in the 3D model, but realization might not be possible or difficult.

3.4.2 Availability of the Standard parts

To prepare the solution in the least possible time frame design must include as many standard (market) parts available as possible. It will give benefit in reducing the timeframe of the prototype building. Also, most of the standard parts come with CE and UL safety certification which will increase the overall confidence of the design reliability.

3.4.3 Safety of the mechanism

As this is industry-oriented Solution, so it must be made according to the safety norms CE and UL. The solution is going to be operated by a human. So, it should consist of all the required safety Locks in case of mechanical failure.

4. Idea Generation

4.1 Introduction

After understanding of the problems and the process, several different ideas were presented and compared based upon there merits and demerits. Different ideas were developed by all team members. The importance of this part was to come with an innovative and efficient solution which will not be limited by a single person thinking ability. This comparison helped to select the best design and efficient design. By comparing it on below-mentioned attributes: -

1. Flexibility
2. Space
3. Time
4. Cost
5. Design
6. Lead Time
7. Safety
8. Ergonomics
9. Mobility
10. One Man Operation
11. Future Proof
12. Product Independent
13. Customizable

4.2 Design 1 (Trolley Lift)

Initial Idea was focused on providing the solution to all the processes with the author required in the production. The Lifting solution in this idea was to provide by using the same gripper with nylon slings which are used in the current solution. This gave us the advantage to use this design in production without any mechanical modification of the process and parts. The Idea generation of the Rotation mechanism was similar to the current small radio units rotation solution which is 180 degrees rotating (Clockwise and anticlockwise) gripper which goes inside the grooves of the unit. This Idea was enclosed in the frame of 2x2 m to provide isolation from any human accident (due to the interface). The Idea was providing us with all the solution shown in Figure 7. But there were below-mentioned problems that the author faced are:

1. Size: As the whole radio unit was getting rotated 180° degrees. The plate which was needed to handle the Rotation of the Unit was exceeding the Length of 1.5 m because of which the size of the whole design was getting large.
2. Manufacturing: In this design, the manufacturing was complicated, and the reason was limited use of standard (market available) parts. The creation of new complicated mechanism in certain time limit was a huge negative point in this design.
3. Locking danger: In this design, the whole radio unit was getting rotated on the Grooves which was supposed to be locked by the locking prongs. As these prongs are not attached to the unit by pressing force which reduces the safety in the whole design.

Figure 7 Design 1 (Trolley Lift)

4.3 Design 2 (Prong lift)

This solution [4] was developed by another team member and explained in detail in another volume. The visual representation of the design is shown in the figure below:

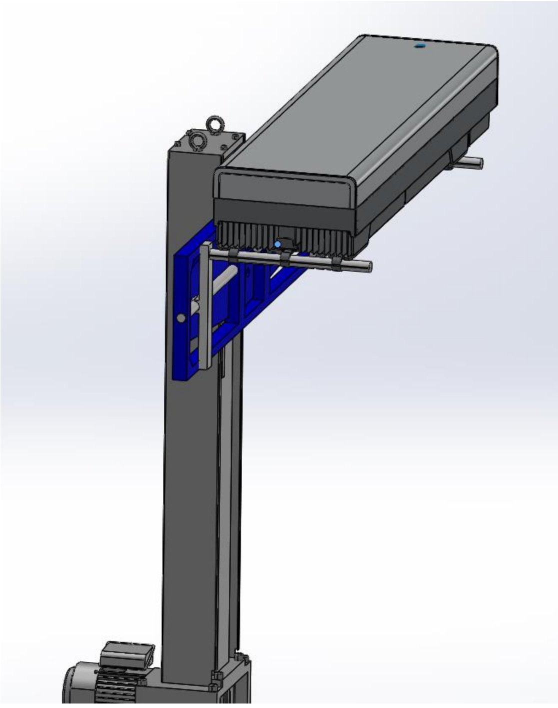

Figure 8 Design 2 (Prong Lift) w/ Antenna Integrated Radio [4]

4.4 Design 3 (3rd Fulcrum Lift)

This Design was proposed after the analysis of the first two designs and comparing overall efficiency with the current solution. In this design, the author had omitted the solution to lift small radio units which give us more room of improvement in the lifting and rotation of the whole radio unit. In this solution, the lifting solution is again the same as the current solution with nylon slings gripper which will be attached to movable cranes which will lift the whole Radio unit by cylindrical actuators. These actuators will provide us with an increase and decrease in height and length. To rotate the whole unit, the author introduced the idea of the rotating box which will cover unit partially from one end and provide the rotation force instead of manual human rotational force which is used in the current solution.

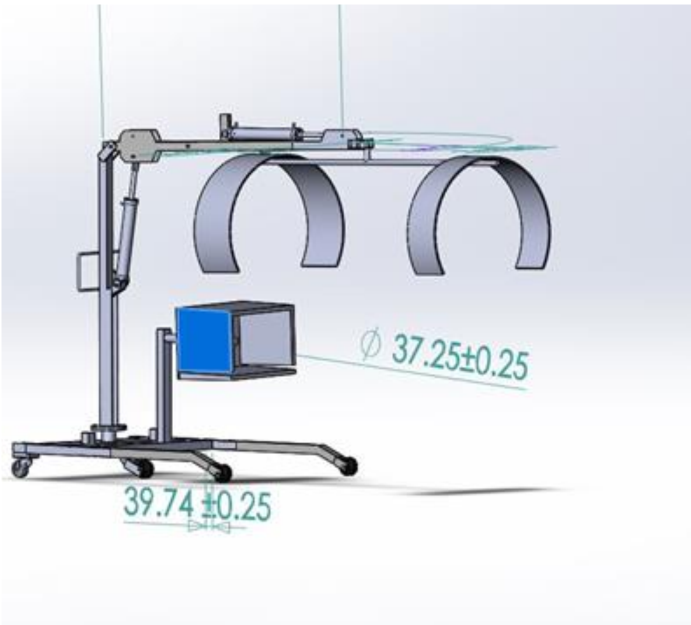

Figure 9 Design 3 (3rd Fulcrum Lift)

4.5 Design 4 (Ball Screw)

This solution was [4]developed by another team member and explained in detail in another volume. The visual representation of the design is shown in the figure below:

Figure 10 Design 4 (Ball Screw) [4]

4.6 Comparison Matrix

Comparison matrix is prepared to compare and analysis in easily understandable. The points on which the designs are compared is based on Production, Design, Feasibility and Practicality.

All the design are given +1 point for merit,-1 for demerit and neutral is zero. Merit is denoted by green colour, demerit by red colour and neutral by yellow colour.

4.7 Conclusion

Table 1 shows the comparison between the different design based on the below-mentioned attributes.

Attributes	Design 1	Design 2	Design 3	Design 4	Existing Sol.
Flexibility	Assembly Table Adjustment	Equipment Adjustment Required	No Change Req.	No Change Req.	No Change Req.
Space	2 X 2 X 2 m	2 X 2 X 2 m	2 X 2 X 2 m	2 X 2 X 2m	Fixed
Time	Approx. +4 mins	Approx. +4 mins	+0	+0	+0
Cost	Most of the parts need manufacturing	Parts not available	In Budget	In Budget	N/A
Design	Complete solution but slower	Complete solution but slower	Can perform all task of with more safety than the existing solution	Complete solution	Complete solution
Lead Time	N/A	N/A	7 Weeks	9 Weeks	N/A

Safety	Improper use may result in injury or product damage	Improper use may result in injury or product damage	Safe	Safe	The long boom can be dangerous
Ergonomics	Bulky, not easy to steer	Bulky, not easy to steer	Lean, Easier to steer.	Light, But big	Fixed,
Mobility	Yes	Yes	Yes	Yes	No
One Man Op.	No	Yes, but not recommended	Yes	Yes, but not recommended	Yes, but not recommended
Future Proof	No	Yes	Yes	Yes	N/A
Product Independent	No	Yes	Yes	Yes	Yes
Customizable	Difficult	Yes	Yes	Yes	Yes
Points	2	5	11	10	6.5

Not Applicable (0)	Demerit (Point: 0)	Neutral (Point: 0.5)	Merit (Point: 1)

Table 1 Design Comparison

From the comparison shown above, Design 3 is the best way of moving forward. This table is based on the knowledge the author had about the designs. It also shows how our designs improved with each new proposal. There is still development needed which author will do in the next steps and will discuss in detail later in this thesis.

5 Mechanical Design

Mechanical design Development was done on the design selected after the comparison of all the first Ideas for the project. The designs were presented as a very raw concept. Further development was needed to prove the design feasibility and make it producible. As this design is going to be the semi-automatic system. The work is divided into two parts:

- Mechanical
- Electronics and control

In this volume, only mechanical design development is discussed.

5.1 Calculations and Analysis of Child Parts and Assembly

To proof the concept of various calculations and analysis done for verification and components selections. As design need constant improvement. In this thesis, the author will describe the development which has been done in this project. The solution that the author came up with is a lifting crane which is the combination of all ideas in a more lean and efficient way. In figure 17 & 18 below is the complete picture of the solution lifting the desired radio unit.

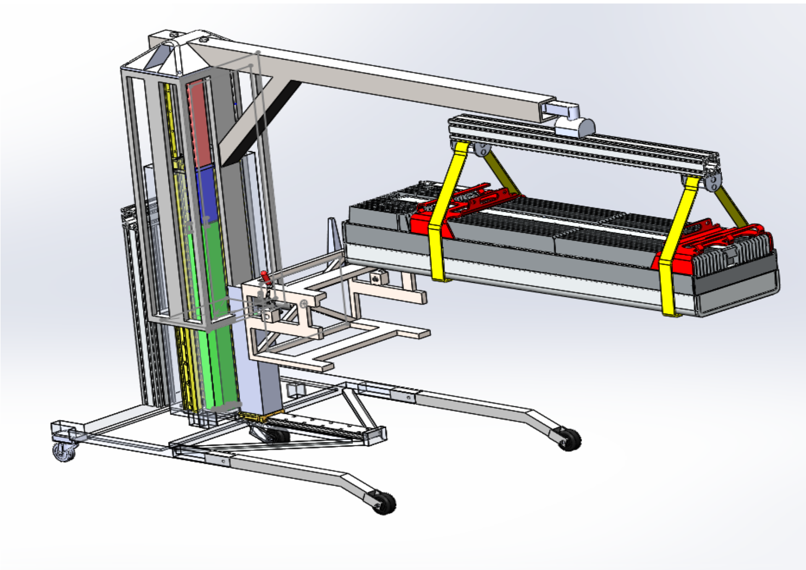

Figure 11 Visual Representation of the Unit in Nylon Gripper

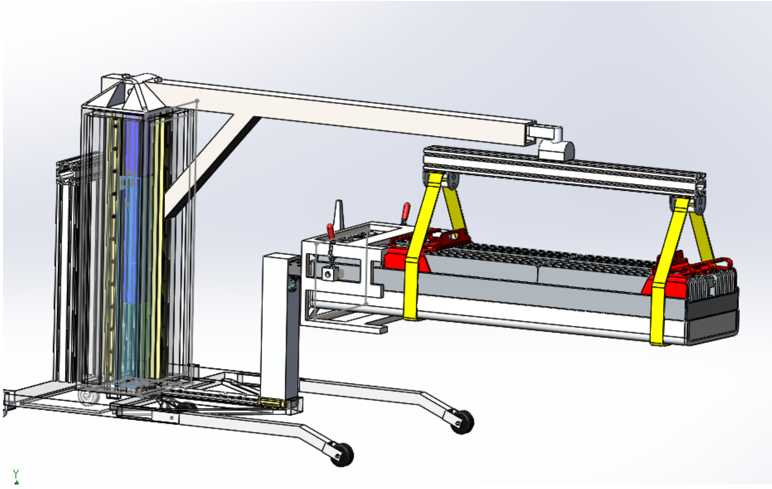

Figure 12 Visual Representation of the Unit on Nylon Gripper in Rotating Frame

As seen from the above Figure 11 &12 this solution contains a lot of different child parts attached in a final assembly. In this chapter, the author will describe how the author selected the component (Material and design and how the author had improved it over time. As the design initially was just a concept describing the functionality which got improved over the period.

5.1.1 Realisation of the design

From concept stage to realization the design has been changed drastically. The reason behind the change is the practical feasibility of the concept. As designed concept priority was to provide the solution to the problems in production. When the concept was ready the next step was to introduce as many standard parts as possible to reduce the manufacturing complexity and the time. The selection of standard part was based on the analysis described in the initial part of the chapter.
Even though the author found out a lot of standard parts which are suitable for are design but still, there were some parts which must be manufactured. Before the manufacturing of these parts, all the FEA (Finite element analysis) [5] must be made in order to secure the safety and reliability of the design.
To understand the failure point of the design all the bending moments and loads has to be analysed. This moment will give us an understanding of the most stressed point in the design. All the moments and loads are shown in the line in the figure below.

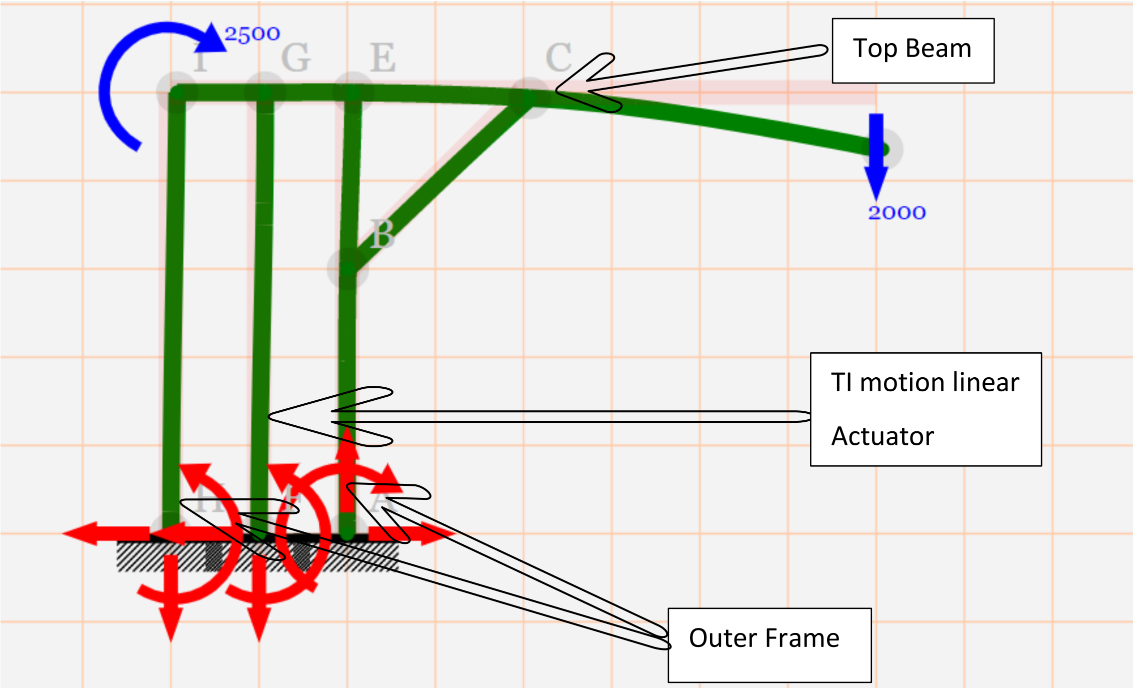

Figure 13 Moments directions and Loads

After representation of the moment's directions and loads. It is also important to find out the stress points which will help us to design the critical points/parts in the which are facing high stress. Below figure is standing for the stress distribution throughout thedesign.

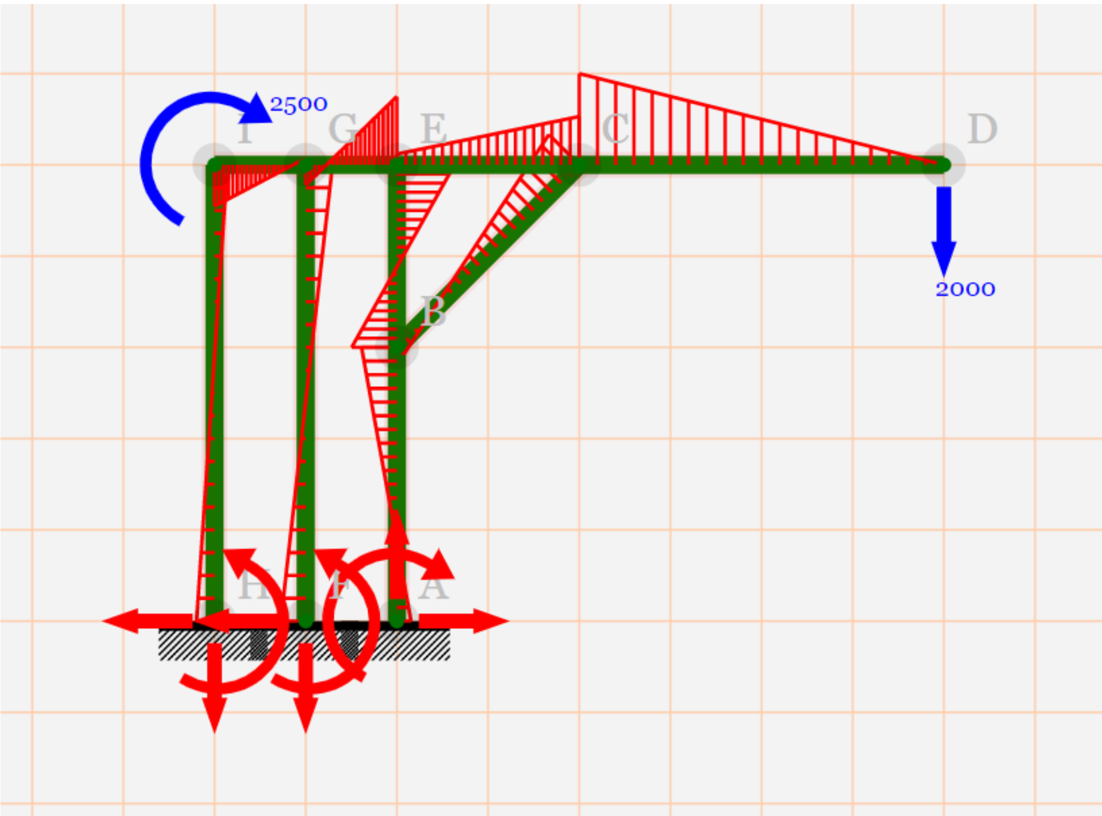

Figure 14 Stress distribution

5.1.2 Description of Individual parts and assembly

Below author is going to discuss each individual child part and assembly which contains 8 main parts.

5.1.2.1 Beam

As described above the Nylon gripper [referred to 5.2.5] to is used in the design which is attached on the hollow steel beam with below dimension.

Length: - 1800 mm, Height: - 80 mm, Width: - 80 mm, Thickness: - 10 mm

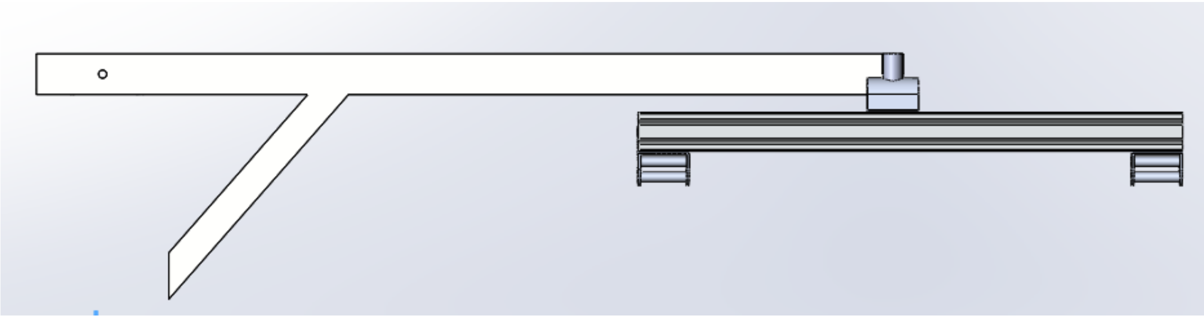

Figure 15 Image of Beam attached to the gripper

The material used is steel [6] . The reason for using steel is the easy availability and desired result which the author got after the FEA [7]analysis. As shown in figure 20 below:

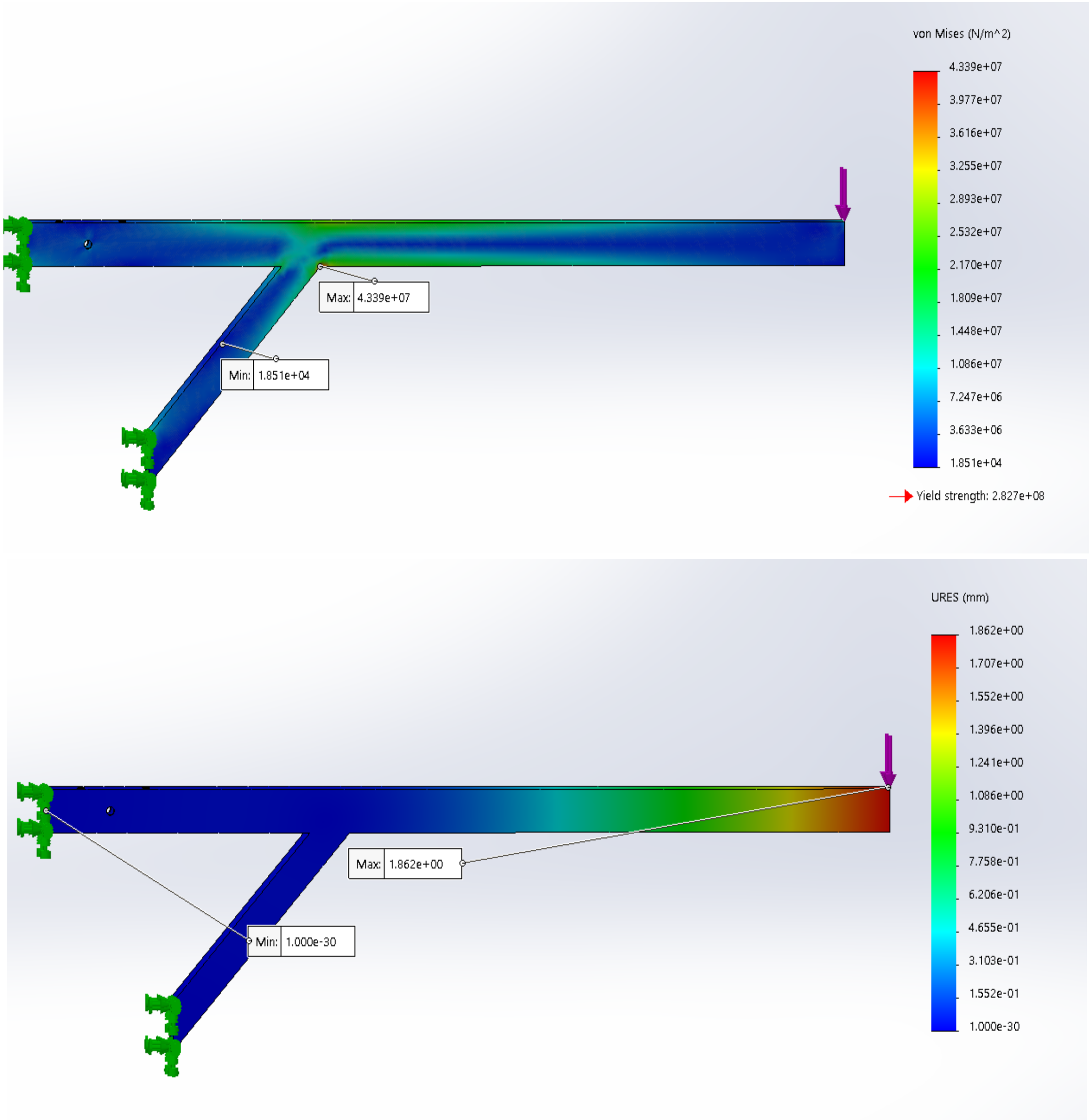

Figure 16 Solidworks Simulation results of Beam [7]

As the load is calculated by the sum of weights of all the parts and the units. Weight of unit is the 90 kg and weight of nylon sling is 10 kg including nylon straps and screw. So are total force will be:

Total Force = Weight of Gripper +Weight of Radio Unit = (100+900) N = 1000 Newton

But for analysis, the author had used 1500 N force to increase the safety factor. But even after 1500 N it can be seen from the Figure, the results of this analysis are positive [8]. The shape of the Figure is stable and no major bending is detected that can affect the overall performance or shape. The most critical part in the displacement analysis is shown in red and the highest value is 1.862 mm. This value defines the actual displacement of this area from its original shape into 1.862 mm. This value is too small to affect the device and it can be that Beam is durable enough to withstand the load. [9]

The lower part of Figure shows the stress analysis that determines the maximum pressure the part can withstand and the pressure it is experiencing along the whole area.

In this case, the maximum pressure it can withstand, AKA yield strength is 2.827e8 N/m2.

The most critical area of the beam has a brighter red colour and by the red area according to the results is experiencing a pressure of 4.339e7 N/m2. This value is smaller than the maximum value, and it means that the structure is strong enough to handle the force or 1500 N or 150 kg.

5.1.2.2 Upper Frame (Cover)

In our design author are a Linear column (referred to 5.2.1) showed in figure 21 below. Maximum Bending moment it can withstand is 1000 Nm at the stroke of 200-300 mm and the maximum required Stroke is 1200 mm. The bending moment withstands capacity reduced to 200 Nm which is way less than our required bending moment calculated below:

Maximum Bending Moment = Force on the end of the beam x length of the beam from Upper frame

$$= 1500 \text{ N x } 1.5 \text{ m}$$

$$= 2250 \text{ Nm}$$

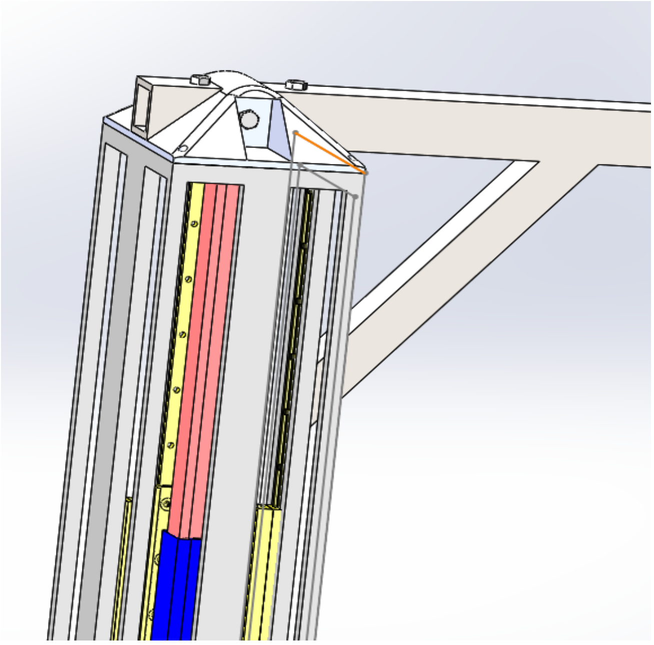

Figure 17 Image of Beam attachment to Cover

To improve the Bending moment capacity additional cover to Linear column was designed to introduce the additional moment of resistance for the linear column. To check this, the author made a simulation in the Solidworks. The author gave a remote load on the Cover and to the area where the strut is attached to the cover to check the Yield strength and maximum displacement [10]. The remote load was applied on the coordinates where are radio unit is going to hand which is 1500 mm in Z axis and Y [9]axis 400 and force of 1500 N or 150 kg are applied towards the ground as shown in figure 22 below:

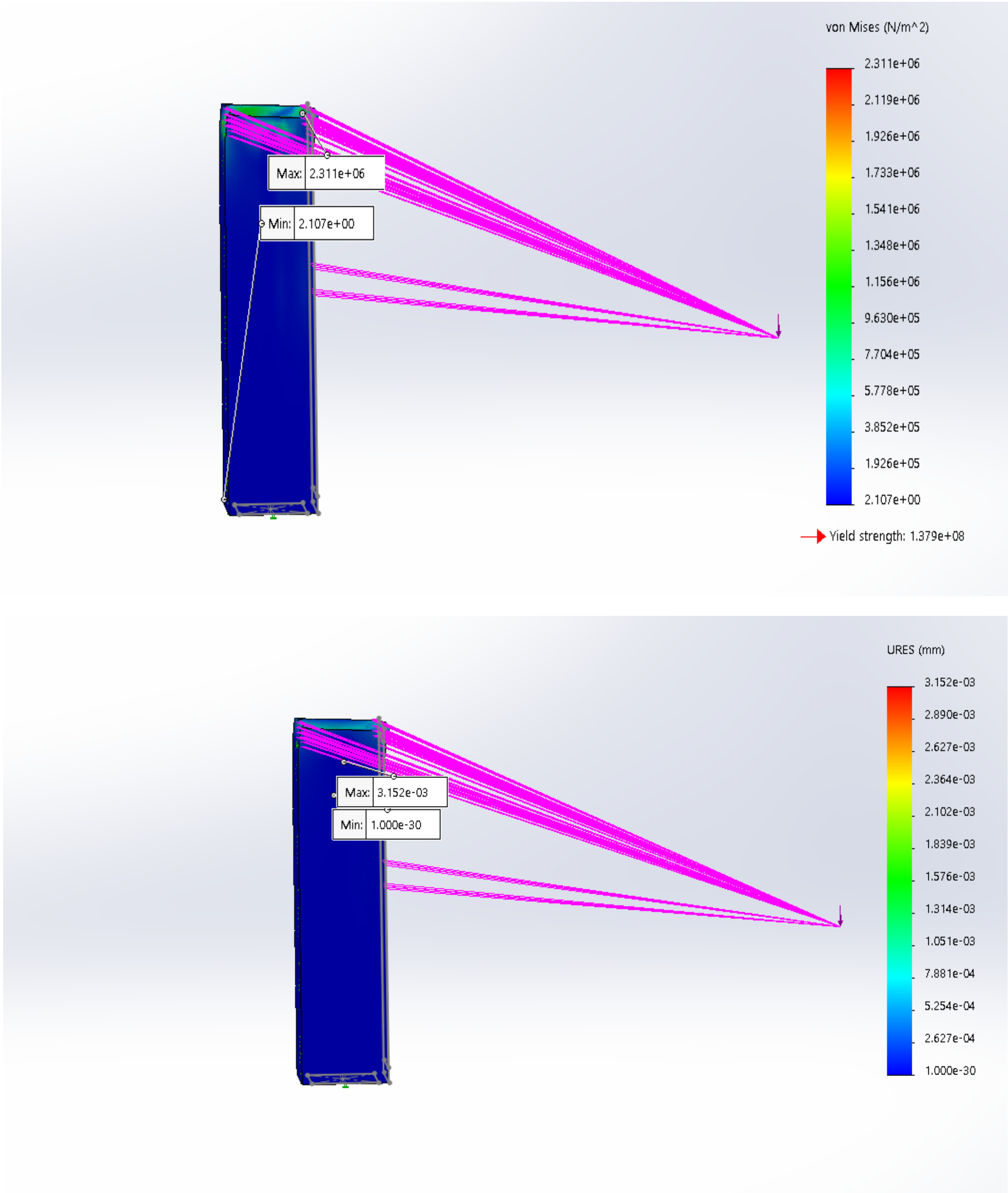

Figure 18 Solidworks simulation results

As from figure 23 and values, the author can analysis that the design is without any hotspot. The figure shows the design stable and no major bending are detected that can affect the overall performance or shape. The most critical part in the displacement analysis is shown in red and the highest value is $3.152e^{-3}$ mm. This value defines the actual displacement of this area from its original shape into 0.003152 mm. This value is too small to affect the device. This is almost negligible, and the author can state that Cover is durable enough to withstand the load. Besides this, in the Upper picture, the maximum stress that the author had encountered is $2.311e6$ N/m$^{2.}$

Maximum yield strength which the design can bear before going to the plastic region [11] which might cause the breaking or fracture is 1.3719e8 N/m^2 which is less then are maximum stress and give huge factor of safety of 60.
This was the most critical part of the mechanical design and it has been improved after FEA before it was bar design which reducing the weight but yield strength was reduced and was lower than the maximum strength. The material of steel was selected instead of aluminium because of high Young' modulus which provides us with more resistance to moment (M_r). The high moment of resistance was required to the opposite bending moment which was caused due to a radio unit hanging on the beam.

5.1.2.3 Telescopic Guide rails.

The cover which is used in the design is four-sided and to provide desired smooth and linear upward moment by the push of linear column author used four telescopic guide rail of 930 mm length with the stroke of the of 960 mm which required the lift the radio unit to a maximum length of 1700 mm. These guide rails are attached to the upper cover and bottom frame which was introduced to reduce the bending moment on the linear column as shown in figure 23 below:

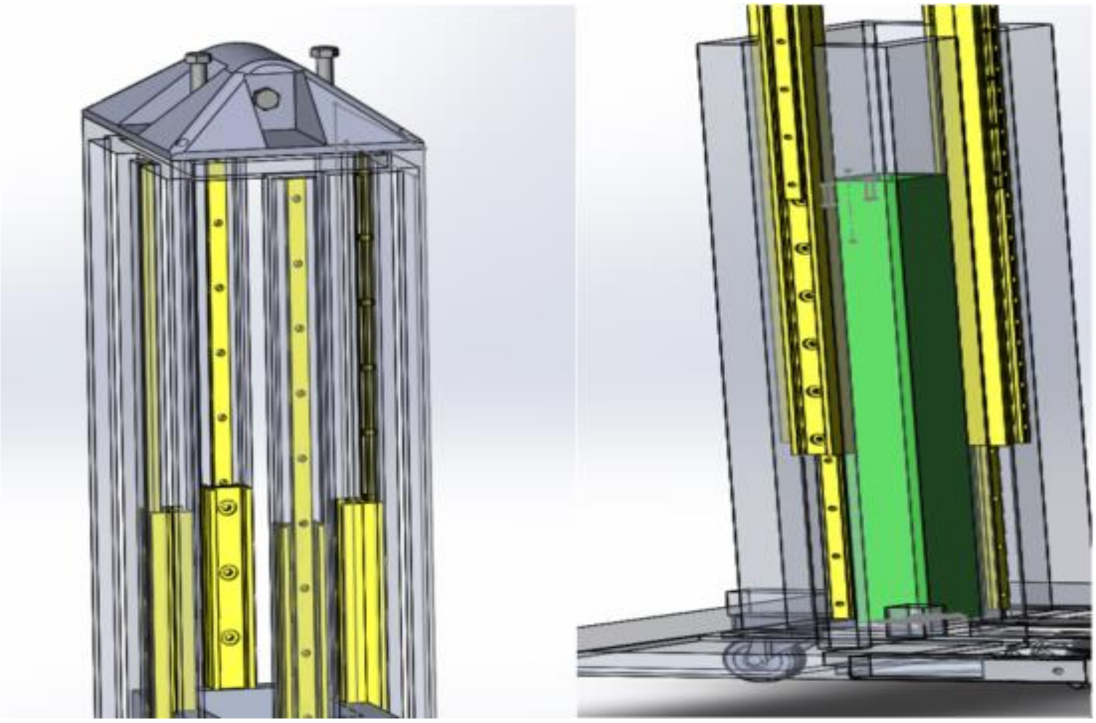

Figure 19 Implementation of the Telescopic Guide rails on the Cover and the base

As this is the standard part from company "IBC" (referred to 5.2.4). These guiding rails calculation is provided in the datasheet [12]. From the datasheet, the author knows that if you install two rails parallel to each other the permissible load capacity would double. So, for a single rail the permissible radial load is 2581 N and for two at parallel then it'll be 5162 N. Similarly, the allowed axial load is 905 and for two the combined load would be 1010 N. So, after confirmation from the company author found out that the permissible load = permissible moment. Hence, the permissible radial moment is 5162 N and permissible axial loads are 905 N. [12]

5.1.2.4 Base Design

The base is the part of the design which must support all the load. Keeping this thing in mind, the base is designed with steel. The heavyweight of the base will provide us with more stability and it must strong enough to support all the forces. In figure 24 below:

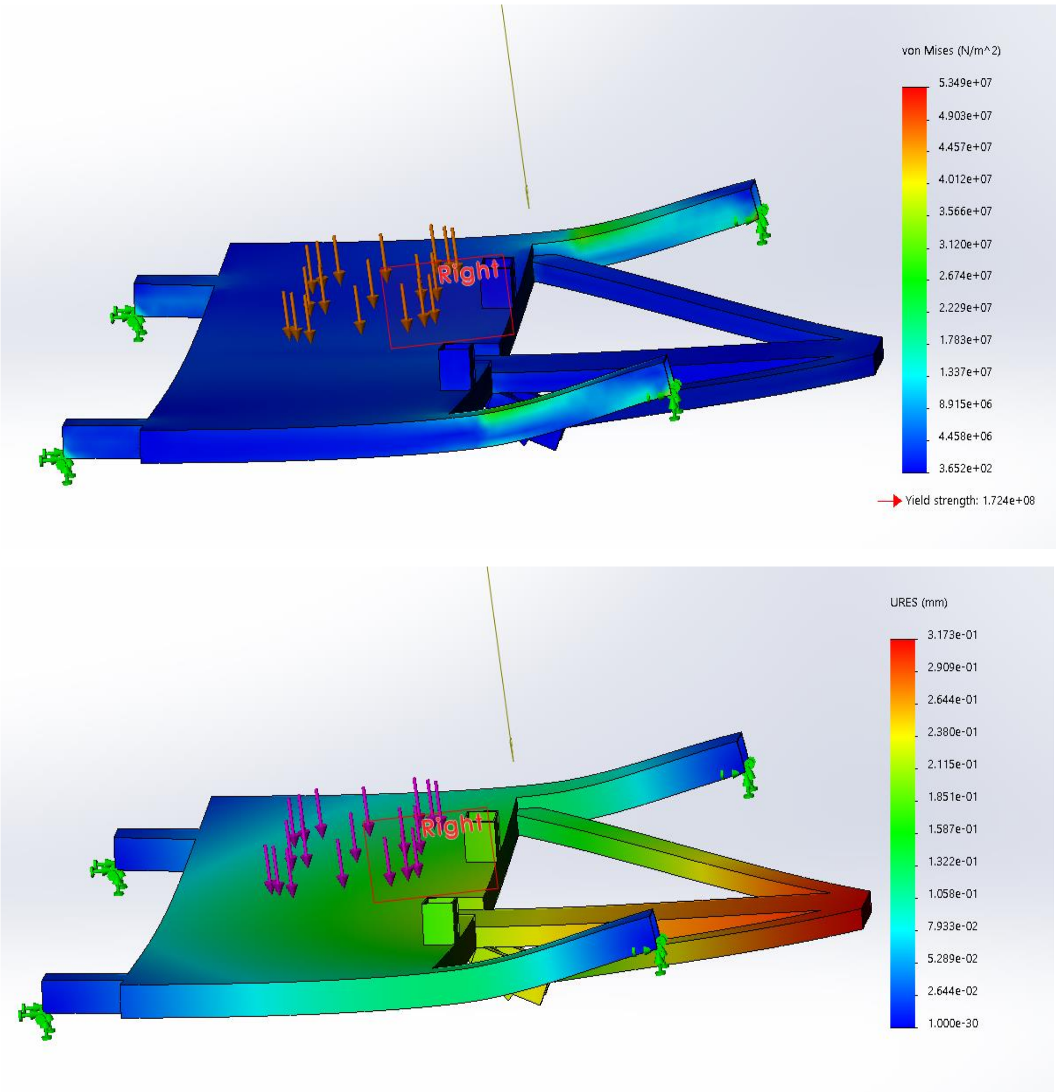

Figure 20 Solidworks Simulation results of Base

The weight of 250 kg or 2500 N on the base to make the analysis. The 250 kg of weight is the addition of the all the parts above from the analysis author had got the maximus stress of 5.349e7 N/m^2 which is lower than are yield strength of the 1.724e8 N/m^2. Also, in the image below the maximum Displacement is of 3.173e^{-01} mm. Which supply us the value of maximum displacement of 0.317 mm. This value is too small to make and any harmful effect on the design [13]. Thus, by this analysis, the author found out that the design is stable and durable. But as this is whole steel plate and weight around 80 kg. To reduce the weight some change will be made. Currently, the solution which the author will implement is chassis frame similar automobiles in the base.

5.1.2.5 Sliding Mechanism for Frame

Our design includes the rotational frame which will provide the required 180o rotation to the unit. But this frame must glide over the unit for which the Linear slider is used to provide smooth and desired front and back moment as shown in figure 25. But this mechanism which will be attached to the base which has to bear all the stress created by the mechanism including the motor and the frame weight. [14]

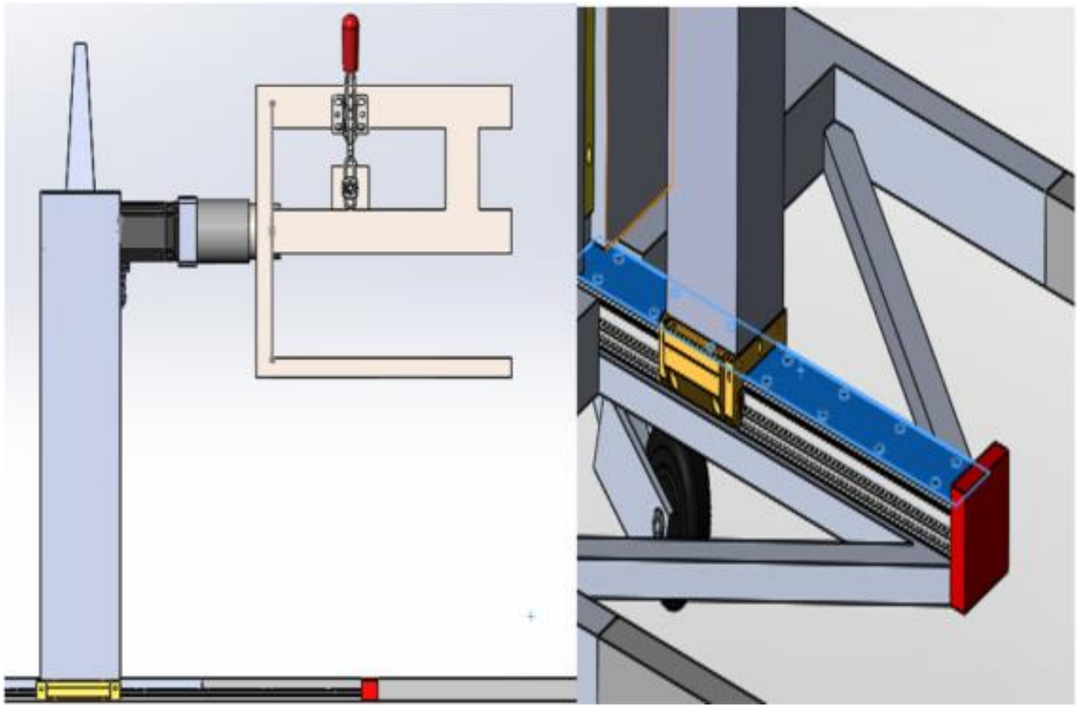

Figure 21 Implementation of the Frame and Sliding rail in Design

The Total Weight of mechanism is 45 kg. Author applied this force on the front part of the base it will attach and results are below:

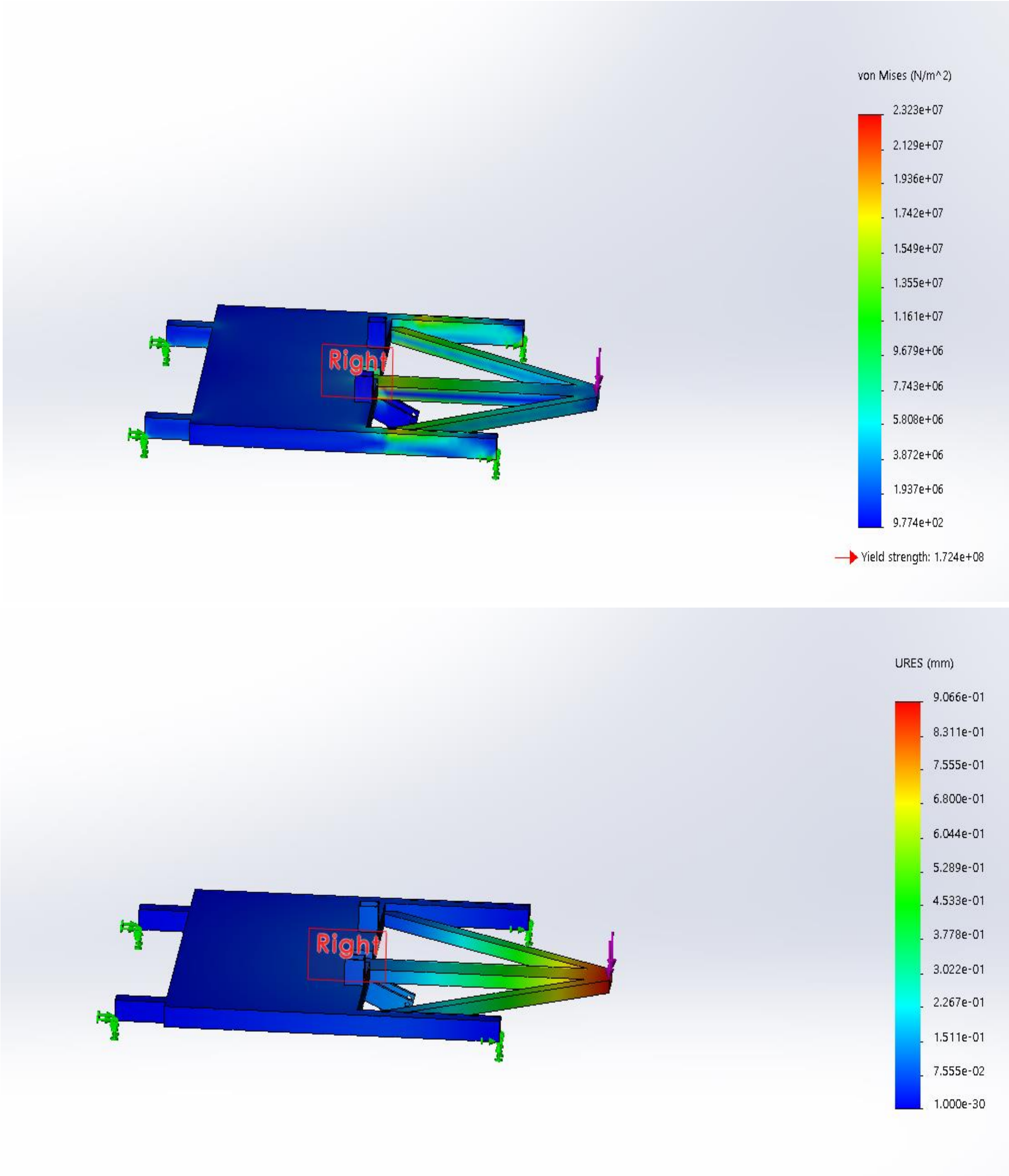

Figure 22 Solidworks Simulation results of Base for the Sliding mechanism

After the simulation results that author got are:

Maximum stress = $2.323e^{7}$ N/m^2

Yield strength =$1.724e^{8}$ N/m^2

Maximum Displacement = $9.066e^{-1}$ mm

These values are desired because our maximum stress is less than yield strength. Also, the maximum displacement is 0.9066 mm which is really small to make any harmful change in the system [13].

5.1.2.6 Rotating Frame

One of the main requirements of the design is the rotate the unit to 180°. For which author came with the Idea of the box that can lock the radio unit inside and rotate is 180°. But Later Box was replaced with a frame design to reduce the weight and size of the part. The frame is going to be rotated by the motor whose calculation is be described below. But for the frame design which made and analysis with both steel and Aluminium. Even though steel is providing us with much better results in stress handling but with aluminium, author is also getting the desired result shown in figure 27 below:

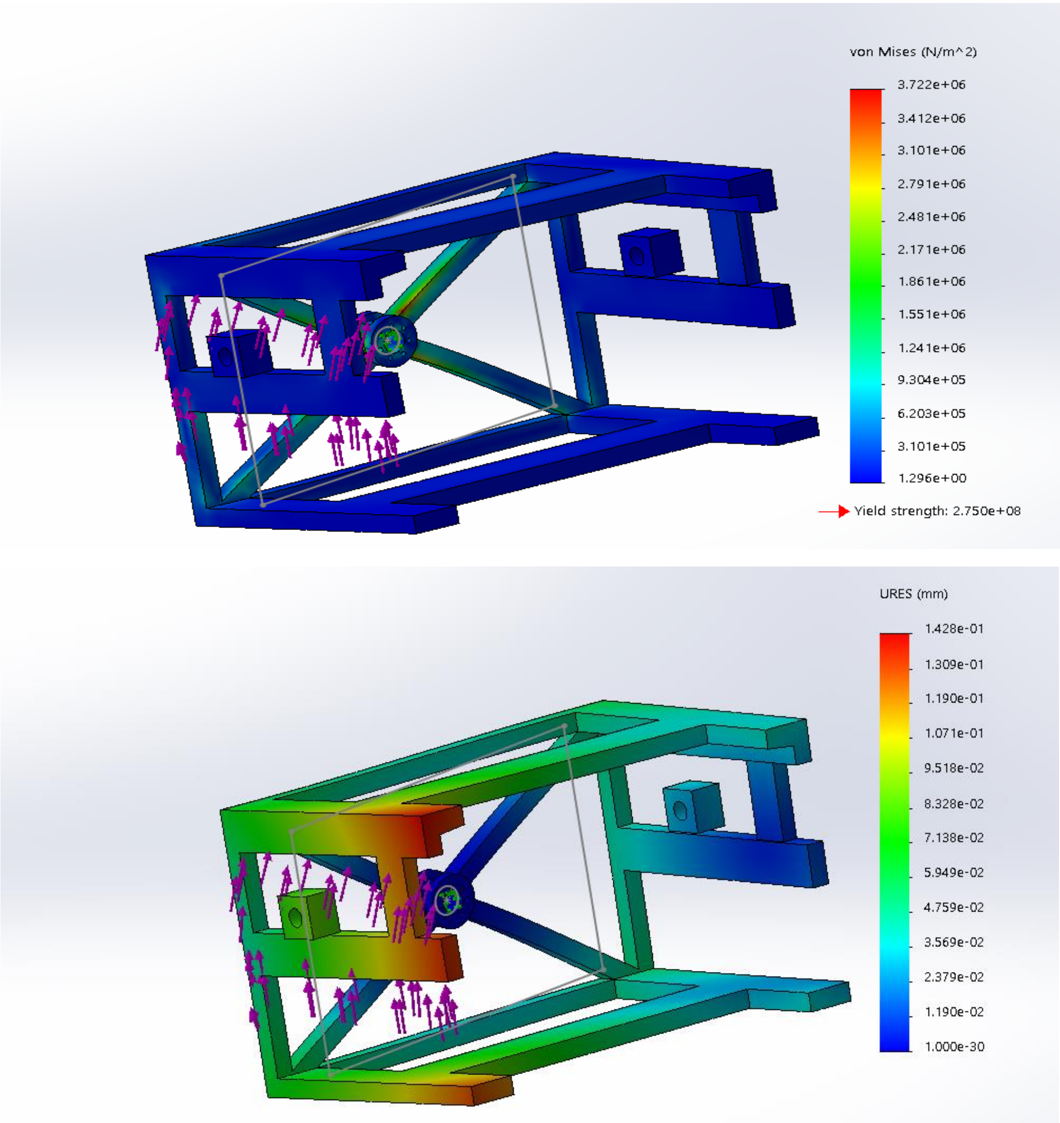

Figure 23 Solidworks simulation result on Frame

The frame is rotated by the motor and the torque required to rotate the frame and the unit is calculated below:

Motor Sizing [15]

Known Parameters

Mass = m = 100 kg (product + box)

Length = A = 420 mm (product + box)

Width = B = 300 mm (product + box)

System Efficiency = η = 95%

Operation Speed = 10 rpm

Load Inertia J_L $= (1/12)\, m \times ((A \times 10^{-3})^{2} + (B \times 10^{-3})^{2} + 12 \times (r \times 10^{-3})^{2})$

$= (1/12) \times (420 \times 10^{-3})^{2} + (300 \times 10^{-3})^{2} + 12 \times (5 \times 10^{-3})^{2})$

$= 2.222\ [kg \cdot m^{2}]$

Needed Torque

Acceleration Torque = $T_a = J_L\, (V_m / (9.55 \times t_1)) = 2.222 \times (10 / (9.55 \times t_1)) = 0.7757$ Nm

Load Torque = $T_L = ((m \times r \times 10^{-3})) \times g \times (1 / (\eta \times 0.01))$

$= ((100 \times 5 \times 10^{-3})) \times 9.8 \times (1 / (95 \times 0.01))$

$= 5.158$ Nm

Hence,

Needed Torque $T = (T_a + T_L)\ (\text{Safety Factor})$

$= (0.7757 + 5.158) \times 2$

$= 11.87\ \text{Nm}$

The calculated torque was applied on the frame to check the stress value and the maximum displacement and values the author got are:

Maximum stress = $3.722e^{6}$ N/m^{2}
Yield strength =$2.750e^{8}$ N/m^{2}
Maximum Displacement = $1.428e^{-1}$ mm

Our maximum stress is less than the yield strength which justifies that the system stable. the maximum displacement is 0.1428 mm which is very low to make any kind of harmful effect on the system.

5.1.2.7 Motorised Wheel

The whole design weight is approximately 250-280 kg without unit which is quite too heavy to move physically by a human. That's why author are using the motorized wheel which can move the object up to 400 kg. This wheel doesn't have any brakes, but the braking force is provided by the moment of inertia. The placement of the wheel is done in the middle of the design where mostly all the load is concentrated on the base as shown in figure 28. The wheels come with handles which provide high ergonomics.

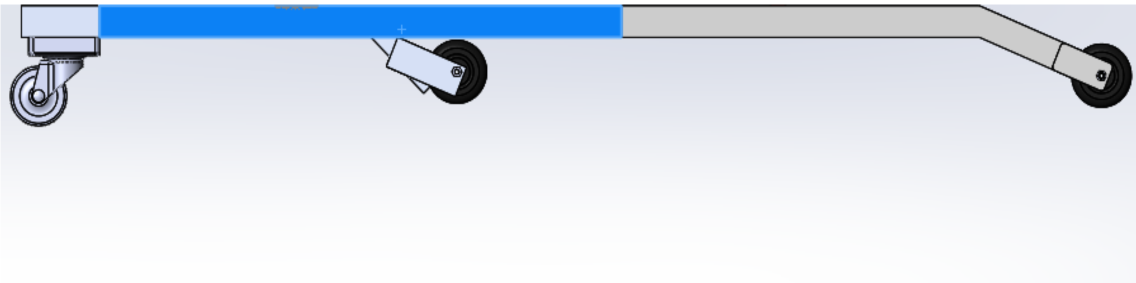

Figure 24 Motorised Wheel from Tente [16]

5.3.2.8 Locking Mechanism in Rotating Frame

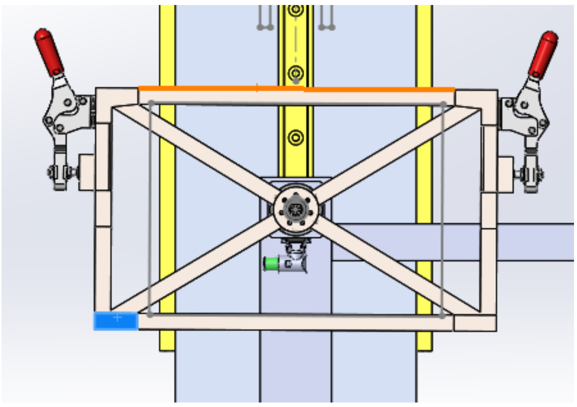

Figure 25 Locking system on the Frame for Unit

The frame must hold the unit inside. For which one locking mechanism was used which lock the unit inside. This mechanism is also the standard part. But currently, author is using the manual locking system what this will be changed to automatic in future if it is required.

6 Updated Mechanical Design

After the concept verification and analysis. The design was further modified to overcome the drawbacks of producibility and mechanical failure. The design base/frame now has been changed to Aluminium profile. To make it lighter and easy to manufacture. Below is the image of the updated Design.

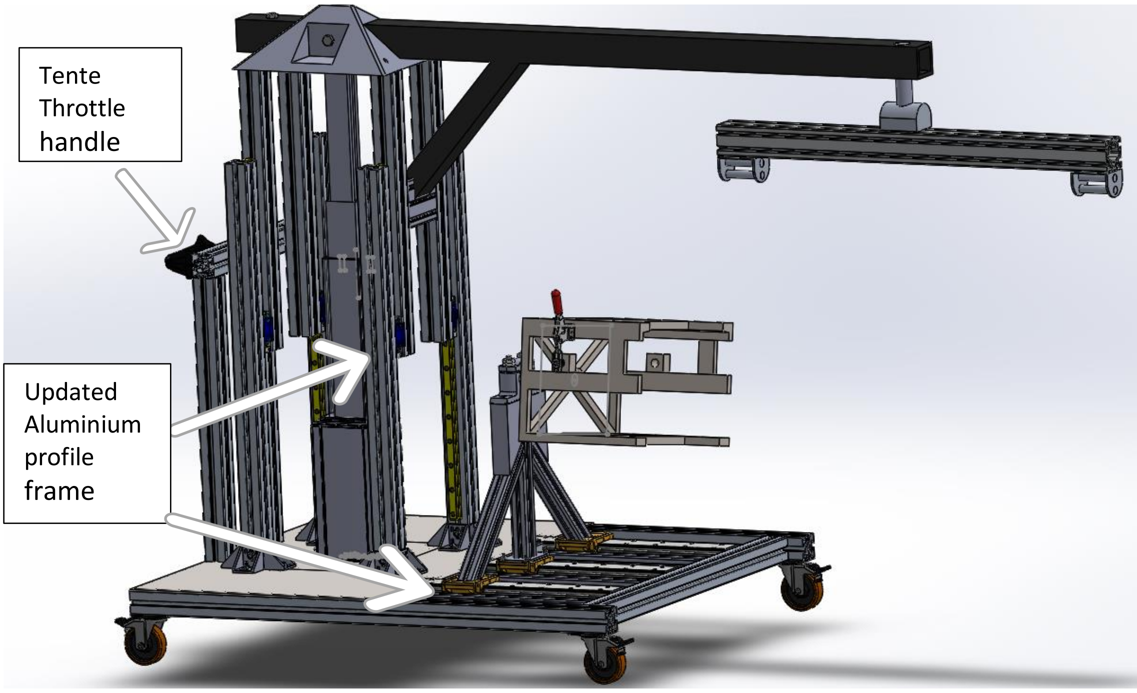

Figure 26 Updated Mechanical design

As visible from the figure above that design has been modified to lighter Aluminium profile [17] instead of solid heavy metal plates. Also, the from for rotating frame has been updated to increase the safety of the deaccelerating force produced during the rotation of the heavy radio unit. Instead of the 1 linear to move the rotating frame front back. Three linear rails have been introduced to distribute the force.

7 Safety

As this solution is going to be used in the production by the human also in the area where the humans are going to work along. Safety has to be the utmost important factor. The design is being developed to follow the CE and UL standards. But besides this as this going to be used in electronics production. This solution has to ESD free.

7.1 ESD Safety

To keep the Solution ESD free all the parts and equipment selection is done on the criteria that the there while being no electrostatic discharge which can damage the radio unit or any other production equipment [18]. Based on this criteria author had selected the "Electrostatic Dissipating wheel" the ohmic resistance is greater than 105 ohms shown in figure 36. Which is perfect to use on the machine which is going to be used in the discharge-Safe area. The wheels are crucial in ESD because the wheel isolate the contact of the machine from the ground and there will be no closed circuit for the flow of charge. Other than all the current generating equipment will be grounded to nullify the harmful discharge. [19]

Figure 36 ESD wheel

7.2 Locking in the Actuators

A second safety measure that the author took is to make the design accident safe. In case of any failure, the all the moving parts in the design will be locked in its place which nullifies the danger of sudden fall and any breakage in the machine also on the radio unit. To lock the electrical moving parts, the author had used the following techniques:

1. Limit switch (referred to 6.5)
2. Fuses (referred to as 6.6)

7.3 Safety in Mechanical design

The mechanical design has been made in an ergonomic way to reduce any kind prevent injuries which can arise due to uncomfortable design. Beside this for the safety of the unit locks (referred to 5.3.2.8) has been used mounted on the rotating frame which holds the unit in the desired position. All the human interaction has been reduced in this new design compare to current solution use in production which the largest contributing factor in any accidents.

8 Conclusion

The expected outcome of this thesis was to give an operational, safe and ergonomic solution. For which initial prototype has to be designed and build. This thesis involves almost all the step of product development which includes conceptualizing various solutions and combining them in one efficient design. The proposed design in this is a result of deep production process analysis, economic profitability and development of design from scratch. Development of the solution has shown in the clear way how knowledge of Mechatronics studies proved helpful in each step of the development. Starting from an understanding of the production process, which includes measurement, mechanism and technology involved in the production process. Later during the development of the semi-automatic product combination of the electronics with the mechanical possibility in a controlled system. This product development has also proved how the engineering creativity has to meet reality, which was realized mostly during the search and selection of standard parts which includes actuators, motors and mechanical parts etc. One of the biggest problems realised during this selection is mostly related to logistics, which showed how geographical place of the product development influence the development by influencing the cost, availability and time of transportation.

Besides this human competence and involvement plays a vital role in product development. The competence decreases the development time but still working in a team helps to find an efficient solution. All the projects in the world are developed by a group of people, which clarifies that working in a team is equally important to the along gaining technical skills. Because for better understanding clear communication within team and stakeholders is essential to come up with the product which will be profitable in the end.

Future of this product has a huge scope. As seen from mechanical design development with every update design can get lighter and stronger because of which more the development will be done better the outcome will be. Besides this as this thesis is only conceptual based, a lot of work and challenges has to solve during the prototype build. This prototype can't be achieved because of limitation in time and resources.

Learning aspects of this thesis are huge, the reason for that was the expected outcome. The solution/product is developed with a lot of constraints which includes practical feasibility, manufacturing feasibility and profitability. These constraints just didn't make the development harder, it also made it important to develop the product inefficient way.

Summary

The manufacturing site is one of the leading 5G radio manufactures. They're coming up with a lot of new radios. Many of them are going to be heavy up to 90 kg or more. This thesis is focused on these heavy radios, as these products quite weight for a human to lift and move around as required for the production, testing and now and again investigating. Presently, Manufacturing site is a fixed crane which provides all the arrangement yet in a restricted territory and in light of this the format of generation is improved to keep everything inside the compass of the crane and the comparable crane is introduced in the stockroom. In the event that the item should be picked and place in other creation corridor or far from the fixed crane it is absurd and in future, more items are accompanying comparative attributes. Thus, it is anything but an ideal or versatile arrangement which can be utilized in various creation lobby or circumstances.

The thesis is developing a conceptual solution to overcome the problem fulfilling all the requirements. To take care of the issue creator needed to think of various arrangements from the scratch, at that point creator ran a required examination on the answers for check the plausibility and the later creator contrasted those arrangements and one another. After examination, the creator showed those outcomes to our director and assembling/generation builds after which the creator chose one to move one with one arrangement and to additionally create it. For the improvement and refinement, the creator did advance the mechanical investigation and inquired about business sectors for answers for our plan issues and if necessary, the creator reached organizations to get the missing information. On the other, the creator was likewise dealing with the control arrangement of the lift and attempting to make it as straightforward as could be expected under the circumstances, which made the framework conservative, modest and simple to the commission. In the proposal, creator contacted all the part of "Item Improvement" which incorporates specialized and the executive's perspectives.

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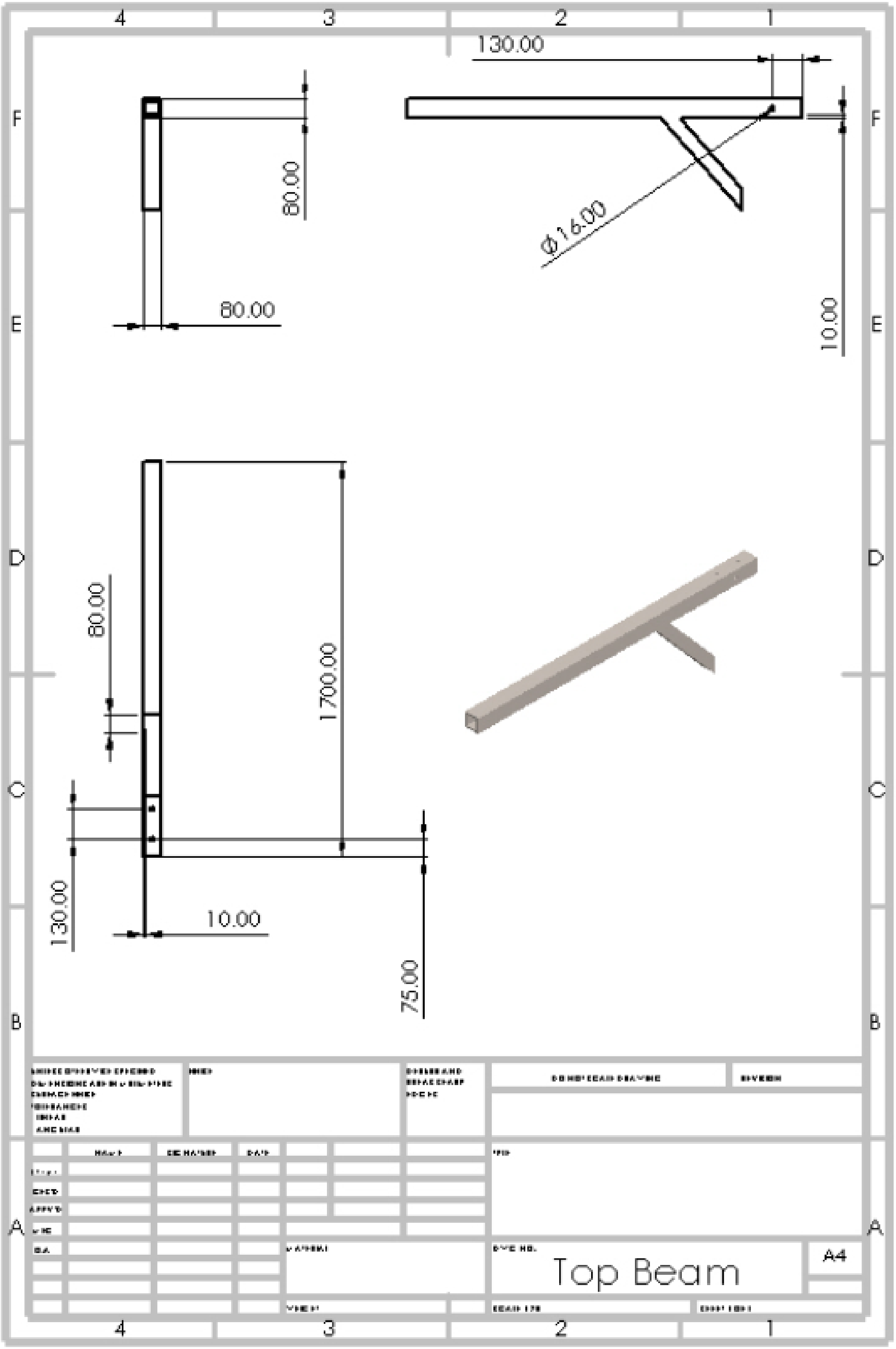
Appendix 1



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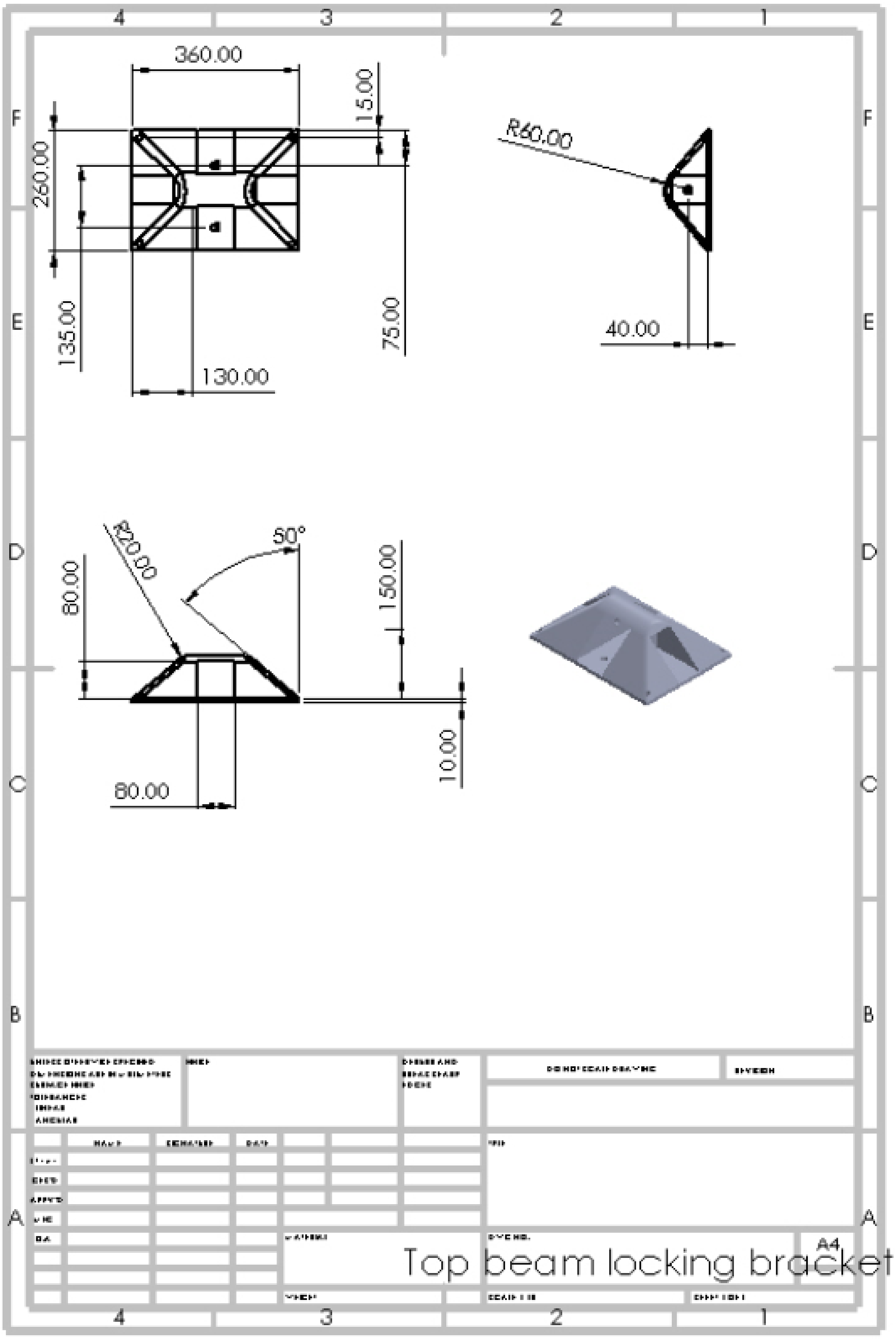
Appendix 2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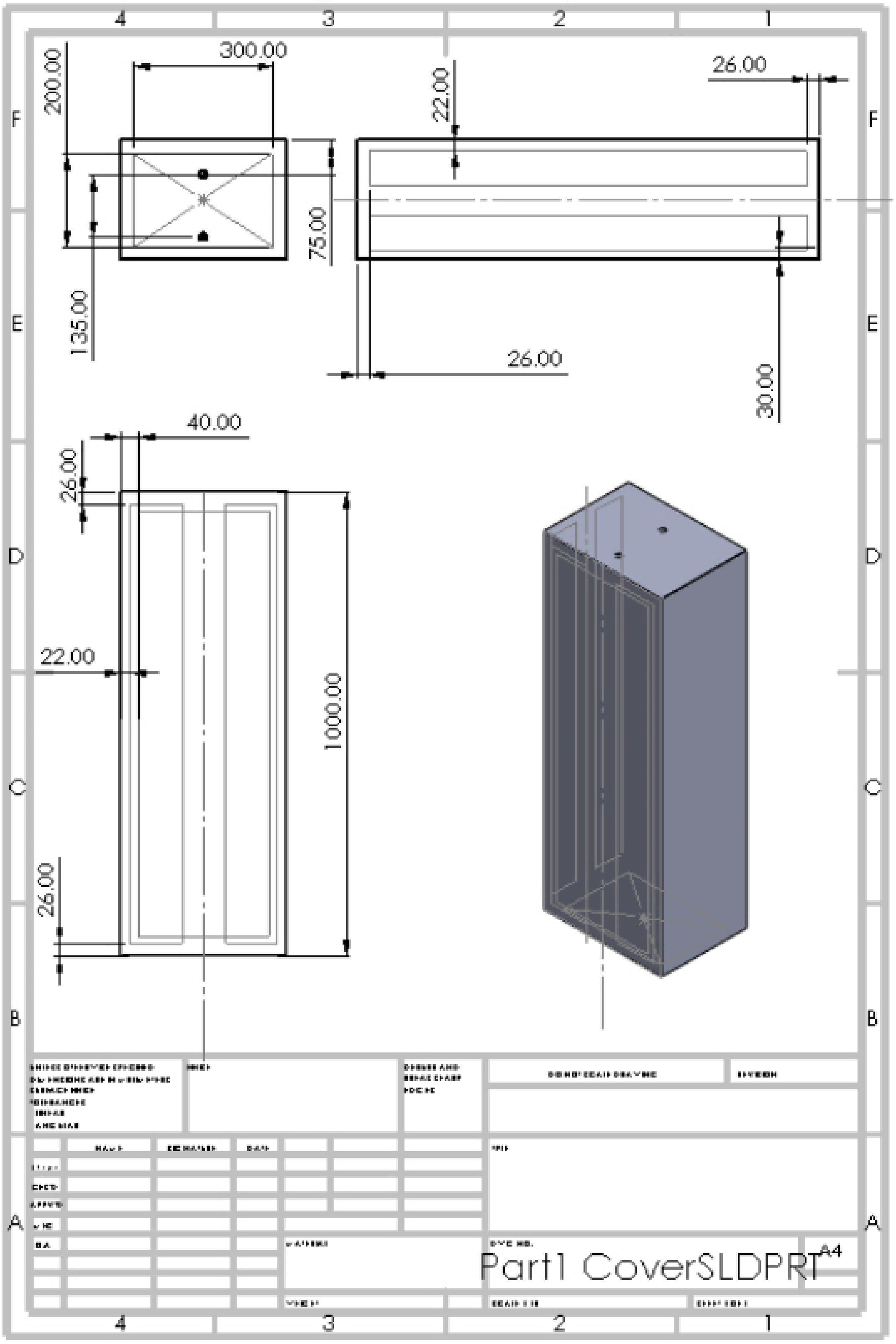
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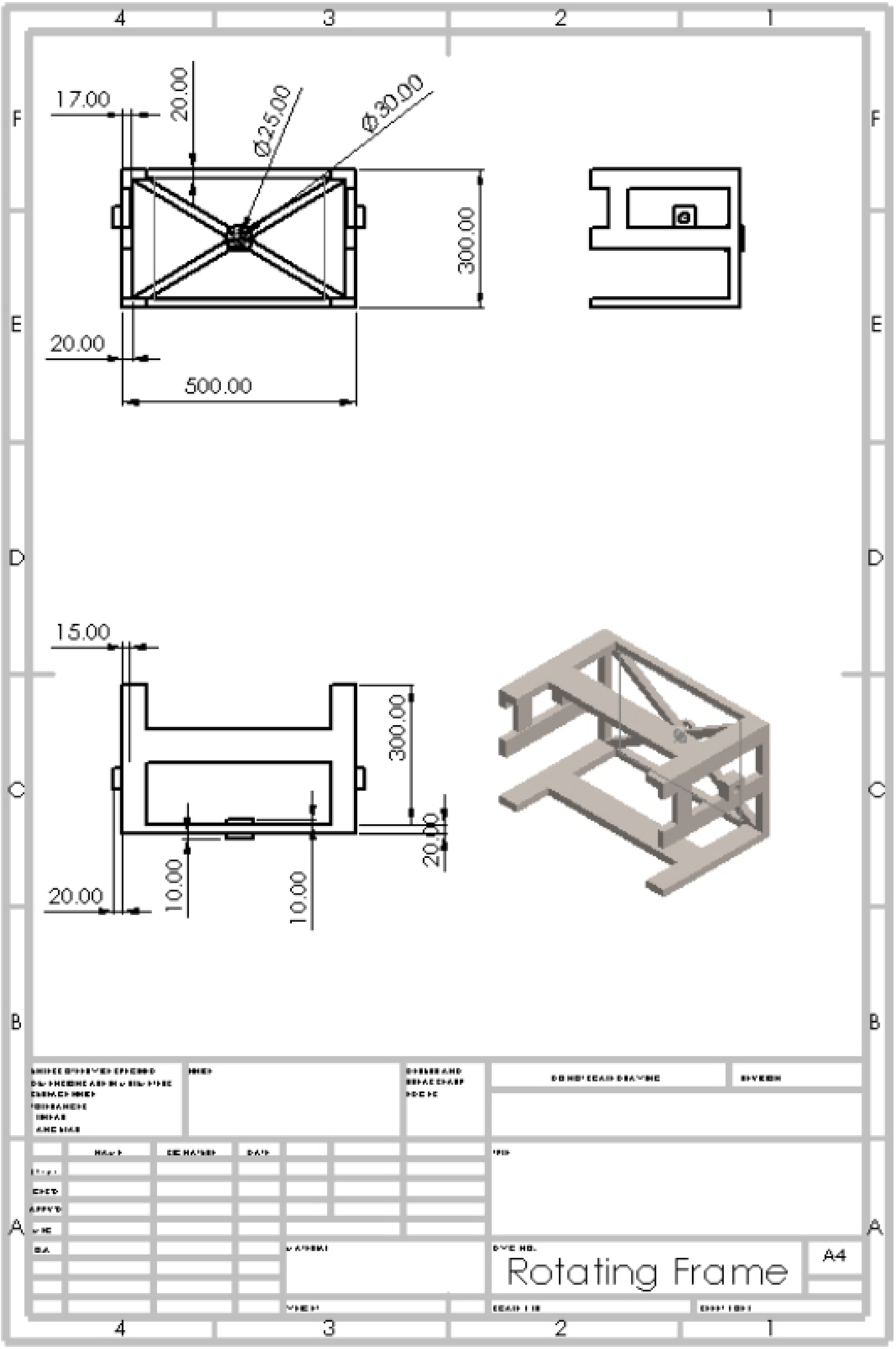
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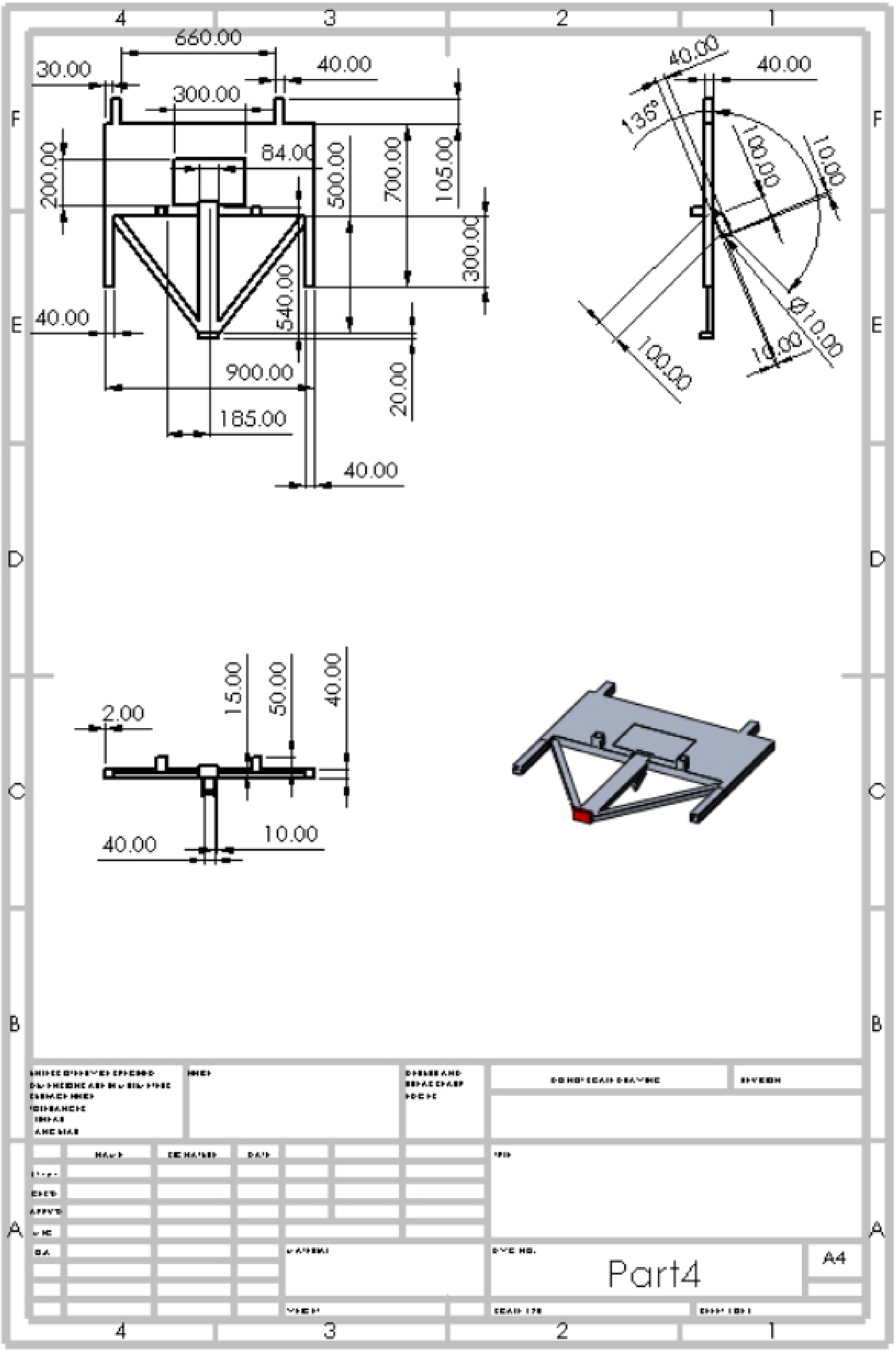
Appendix 5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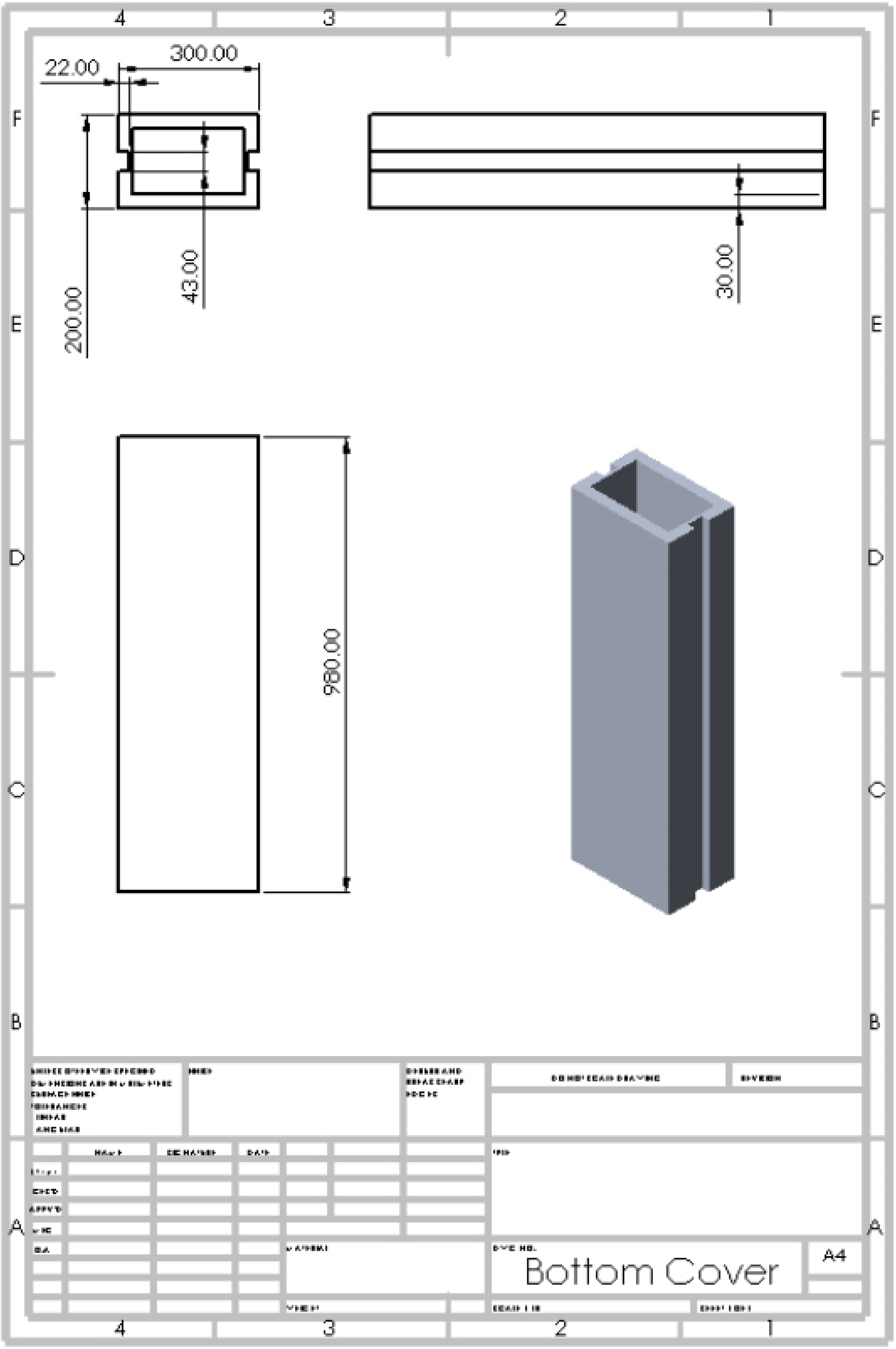
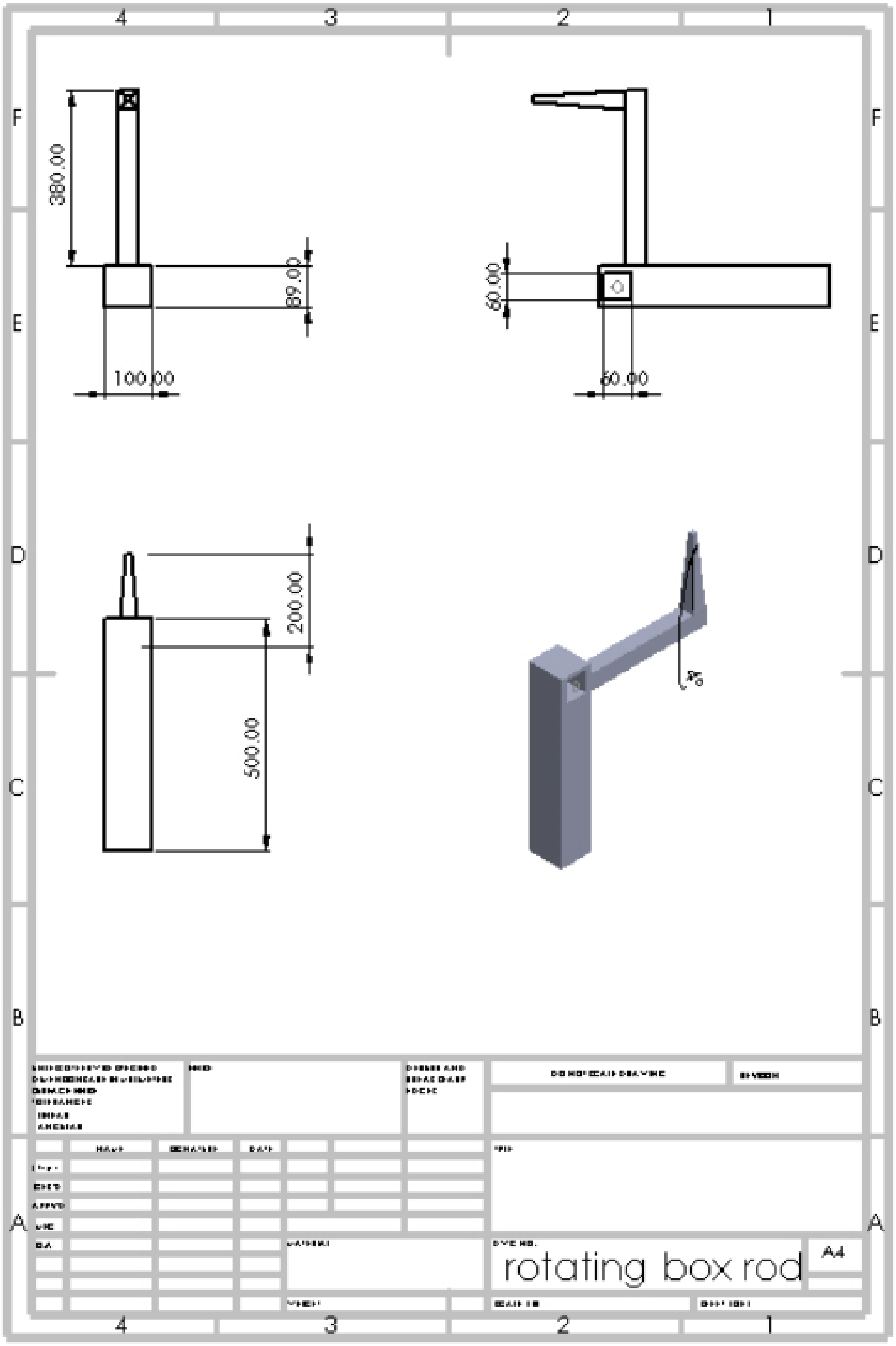


Appendix 7



Appendix 8 (Updated Mechanical Design)