DESIGN AND DEVELOPMENT OF A FIXTURE FOR KELLY BAR MOUNTING

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DECLARATION

This report does not contain any material which has been accepted for the award of any other degree or diploma in any University or equivalent institution in Sri Lanka or abroad, and that to the best of my knowledge and belief, contains no material previously published or written by any other person, except where due reference is made in the text of this report.

I carried out the work described in this report under the supervision of Dr. N.D. Jayaweera,and Dr. H.K.G Punchihewa.

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Abstract

The Kelly bar is a bulky, long and heavy device that is used in piling. The Kelly bar surface is not smooth and contains ribs and grooves. The Drilling process makes many damages to the Kelly bar. These damages are required to be repaired in a workshop. Therefore,the gap of this research was the difficulty and the high cost associated with Kelly bar maintenance.The aim was to design a suitable fixture.The Objectives were to study the process and then create a new fixture and implement it in the workshop. In the methodology, the development process of the fixture and testing was explained. The research focused on the design and the development of the Kelly bar mount The. Kelly bar mount was required to do sliding and rotation both. This mount was required to be designed so as to prevent injuries to workers and damage to the environment, with low energy consumption.A Literature review was done.Thus,the main areas of the report were to identify a suitable fixture, to design and produce the mount and then test the mount. Next, a Project plan was developed and a project path was identified. Then a free hand sketch was identified. Then the optimal solution by design tree was shown and the conceptual design was obtaitend. Next, calculations for engineering strength were carried out. The material requirement plans and machine requirement plans were prepared. Afterwards,the model was designed,and carried out. So, the actual model was made. Based on this,the cost of production was analyzed . The investment and the cost saving points were discussed. After which the production was carried out. Next , testing was done.Then it was implemented in the workshop. Finally it was painted. For this research, the cost of production and opportunity cost were calculated. Based on this, a simple payback period as 29 days was calculated. Based on these results, finally,it was concluded that, implementing this fixture reduced the cost of operation massively in the workshop.

Key words:Kelly bar mount, Energy saving, Kelly bar project, Optimised Design, investment, safety and ergonomics. a

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Every effort has been made to trace all the publications, but if any have been inadvertently overlooked the publishers will be pleased to make the necessary arrangement at the first opportunity.

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1 Introduction

Construction industry shows a 70% gross domestic fixed capital formation and 8% from Gross Domestic products. Some key features mentioned are annual growth in construction industry in 2010 compared to 2009. and the Share of construction increased in 2010 compared to 2002. Growth was mainly by large scale projects in North and Eastern province and 7% of the total population for construction industry [1].

Piling is a primary need of huge constructions. To cast a pile, piling machinery is used. Pilings are very useful f or the construction industry and it is done by using very large Kelly bars. One Kelly bar weighs approximately 20 tons [2]. To drive in to the ground the hammer is used in axial direction and rotatable in relation by remote means. Locking dogs prevent slipping. The bush holds the pile[3].

Due to the bulkiness [4] of Kelly bars, maintenance of them is a daunting task for the industry. At the end of the Kelly bar an auger is fixed and there is a special control panel to control the Kelly bar movements[5].As such,the Kelly bar mounts are very useful for industries.The Kelly bar mount bench is a very useful device. This device helps to mount a Piling Kelly bar and to rotate and slide the caliper without much use of persons , energy and time. This mount saves the cost in economics of scale. These will save fuel, money, time and energy. Currently, they use tedious methods for the repair and maintenance of Kelly bars. From the point of view of a company this will create new production opportunities to the company which produces this mount, as the production cost will be at a much lower rate compared to the price if they purchase it in the open market.

1.1. Kelly bar Maintenance

The Kelly bar is maintained by the aid of experience of the technicians [6]. Mainly it uses the forklift and jacks,to rotate and slide the device. This requires to be rotated and repaired.

. This also needs to slide in longitudinal direction. In order to lift this at least four men are required. It also requires another 5th person to rotate and move it.

Figure 1: Worldwide mounting methods

Figure 1: Worldwide mounting methods show the Kelly bar mount and repair methods in some countries in the world. With this, it is clear that there is no proper mounting method anywhere in the world.

1.2. Existing related patents table

Table 1: Exsisitng systems patents

Patent Id	Authors	Title
1. US5263899	S. Nozaki, S. Ajiro, H. Kusumi, A. Kule, K. Miyata	Cylindrical telescopic Kelly bar apparatus
2. US 3367142 A	G. Wilson T, L Raymond F.	Slip spline assembly.
3. US3255612 A	M James R., T. Joe D.	Telescoping drilling device
4. US1895901	Smith Herman R	Kelly Bar
5. US5368083	August H. Beck	Telescopic Kelly bar apparatus and method
6. US5586610	James N. Sajatovic	Kelly bar having hardened flutes.
7. US3561545 A	Rassieur Charles L	Kelly bar and mounting means therefore

2 Aims and Objectives

The gap of this project is the high cost in Kelly bar maintenance due to unavailability of cheap Kelly bar mount fixtures. The aim is to design and develop a suitable fixture that can be used in Kelly bar maintenance.

In this pursuit the objectives are:

- To identify a suitable fixture type.
- To design the mount.
- To produce the mount
- To test the mount.

3 Literature Review

3.1. Piling the Kelly bar

Piling history goes to before Christ as the Bible mentions about the foundation of a house. This was evolved and new technologies were applied [5]. The Kelly bar is one of the most important parts in piling. Figure 2: Telescope Kelly Bar shows the most important parts in a Kelly bar. Some of them are Splines, Locking ribs, and Drive keys [5].

The Kelly bar can dig a wide range of Sarata including very soft silty clays, non-corrosive soils to soft rocks. Vertical load is applied in a difficult Sarata. The Kelly Bar can be single or telescopic. A Standard telescopic Kelly Bar can reach a depth of 55m. Extended Triple telescopic Kelly Bar can be 70m. Boring tools are provided with different Sarata [7].

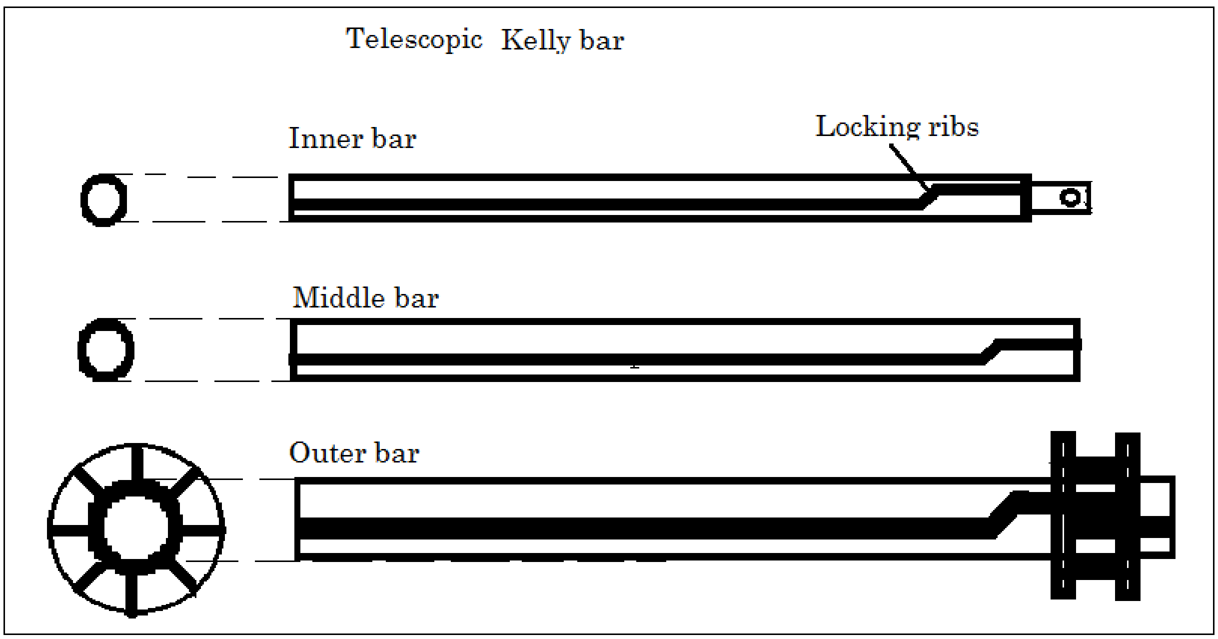


Figure 2: Telescope Kelly Bar

This Kelly bar involves heavy forces during the digging. This also involves rough conditions such as muddy water with dirt. The Kelly bar is also subjected to heavy torque during digging. The Kelly bar is also subjected to heavy friction forces moving up and down, such as hard rocks and metals inside the soil.

The Kelly bar is telescopic and one slides on another during the digging. This causes the friction between each Kelly bar piece.

The Kelly bar uses the ribs to insert torques. Some Kelly bars are square shaped [2]. But most of them are circular in shape. These ribs in the Kelly bar helps to lock the Kelly bar and move downwards without slipping. Usually these are long and rectangular in shape.

With time these ribs as mentioned above are subjected to conditions of wear and corroding. Hence,The ribs are required to be filled appropriately. In addition, if the Kelly bar is subjected to heavy torque, sometimes it may crack from the weak points. In that case, the cracks need to be filled suitably. These kind of defects need frequent short time motions, such as rotation of Kelly bar on one axis.

The Kelly bar can be maintained often by visual inspection. It may need to repair every circumference of a heavy bar. Frequently,the welders rotate this very heavy piece by the aid of heavy machineries. Hence this needs a separate machine to rotate and slide along with the current machineries.

The Kelly bar is not symmetric in center axis [2]. This is due to the fact that one side is slightly heavier than the other side. It also cannot be held and rotated on rollers due to the presence of ribs. Therefore a special device is required to rotate.

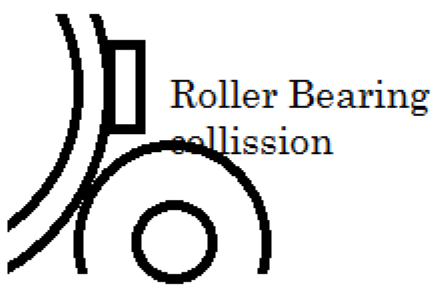


Figure 3: Ribs Collision

The Kelly bar is made of steel and most of the time , by drilling, the diameter increases from 12 in to 10ft diameter shafts.Bigger the diameter deeper the pit. The Bar is lifted with the cables which are attached to it.

The Kelly bar is also used for drilling tunnels. These are about 30ft in diameter and 200ft in depth.

Very often ,some defects can be observed. One is cracking of the bar. Another one is damaged ribs.Still another one is worn surfaces. See the figures 4, 5, 6 for defects.

Figure 4: Crack in circle

Figure 5: Crack in head

Figure 6: Damaged edge

3.2. Existing mountings

There are several mountings that were found. But these mountings are used for other purposes. Such as welding of cylindrical pipes.

In the workshop currently they use this kind of mountings (Figure 7).

Figure 7: Fix stationery mounting in workshop CML-MTD Construction Ltd.

These are roller mountings that can be used. Welding pipes involve about 150 tons. One is PEMA Windmill Tower Section Assembly Stations [8]. Figure 8, 9 show a design.

Figure 8: PEMA welding Mounts

Figure 9: PEMA welding mounts automated

Arc Matic is also producing the welding self-aligning roller which is similar in design but not for this purpose [9].Figure 10 shows an example of a design. This is automated by electric motors and have a control panel. Data are shown in table 2.

Figure 10: Arc Metic mounts

Table 2: Piling Kelly Bar properties

Model	Static Load 1 PF+1 Idler (tonne)	Turn Cap (Torque) (tonne)	Vessel Diam. Min-Max (mm)	Type Diam. Width (mm)	Drive Mode
AMT 20ASA	20	30	580-4500	Ø 457/177	Single Wheel
AMT 30ASA	30	40	580-4500	Ø 457/177	Single Wheel
AMT 40ASA	40	60	580-4500	Ø 558/203	Dual Wheel
AMT 60ASA	60	90	580-4500	Ø 558/406	Dual Wheel
AMT 90ASA	90	135	580-4500	Ø 558/609	Dual Wheel
AMT 120ASA	120	180	580-4500	Ø 558/812	Dual Wheel

There is a patent that can be adopt ed to this system but is used in wrapping the materials around the pipe line [10]. In the arrangement one,the shaft is attached to mounts. But this is permanent. If the arrangement is changed to any shaft mounting, then this can be used for our purposes with further improvements.

A Similar mechanism was found in India in Kamar Infrastructure pvt Ltd. See the Figure 11.This uses single thin wheels.

Figure 11: Kamasur infrastructure pvt Ltd

Figure 12: IMT Beijing Jitaihoile Techonology development co. Ltd

Figure 12 shows the part of the KDK device that can be adopted for the design.These parts are at high cost and hard to attach to the Kelly bar.

Figure 13: TRIS Kelly Bar mount

Figure 13 shows the Tris industries using the Kelly bar mount. It can be seen that it also uses the thin wheel which is there only to mount the device.

3.3. Relevant Technology

The Kelly bar was developed in the 19th century. Various patents are found for the development of the Kelly Bar and Drilling process. But it needs to be mentioned that it is still in the maturity state in my experience. In 1932 H. R. Smith invented a new mechanism to overcome the difficulties of continuous weight on depth on the Kelly Bar [5]. Furthermore, in 1939 Charles H Collett Walnut Park and Millman M. Ayres invented the Kelly Bar bushing.

REBA assessment is very useful in this project. Rapid Method Entire Body Assessment ("REBA") analysis identifies musculoskeletal risks through a sensitive postural analysis in a variety of tasks. The tool divides the body into segments that are analyzed individually in relation to the planes of movement. The result of this method is a score for muscular activities caused by dynamic postures, static postures, rapidly postural changes and unstable postures [11].

Arc Metric has developed the electric Welding roller mount [9]. This can be adopted for the current expected design.

It was obvious that welding is a repetitive task. The worker needes to hold it for a long period of time, sometimes for a couple of weeks. So it is important to design an ergonomic handle. This was studied under ergonomics. The Ergonomic handling of the welding torch [6]was one of them.

UFOARM technique is very useful in this kind of design. This concept hopes for a better design which functions and adheresto a standard[12].

Automation of the mount is an advancement in the future. This needs to be powerd by an external source and to sense the rotation. The product is in the introduction period of the development curve and I have a special method to overcome early Sunset. I hope to introduce the new improvements with time.

Recycle of waste products is the most important concept that I expected to use in this project. Mainly I used the scraps and available items in the workshop. I also considered the availability of the material in the market.

When designing the mount the aesthetic side is also a requirement. To make the piece of work attractive ,I hope to use the symmetry, blunt edges,attractive shapes of design,and finally the colour.

Designing the model is very important. In this CAD is a major task that will be handled by myself. I expect to use the SolidWork and Auto CAD advance features in this. But for the strength calculations I use the manual method.

3.4. Engineering value

Several questions are required to be answered. These are the main functions that need to be addressed. Thus the following Table 3 was prepared to answer the questions.

Table 3: Quality questions

Question	**Item**
Contribution to value	
Cost proportionate to usefulness	
All features need	
Better for intended use	
Low cost methods produce	
Standard product available	
Proper tooling	
Other suppliers selling for less value	
Those who buy for a lower value	

It is hoped to use the scraps available in the yard for the mount. Hence, there is no material cost involved to produce it. This is used frequently but the rotations are small in longer periods of time. So,there is no need for a high quality roller. The forces are very often static.

I expected to use the standard materials and items available. The opportunity cost of this is spending mainly on fuel for Forklift, extra labor , time spent to rotate, and ergonomic problems in repairing. These problems are expected to be addressed during the design.

Piling is a primary requirement of a huge building and large forces are involved. In Sri Lanka there are two Piling construction companies. Some are very old. we can see Piling work being carried out daily. These industries frequently use the Kelly bar. So, there is a huge place and demand for this kind of mount in Sri Lanka as well as abroad.

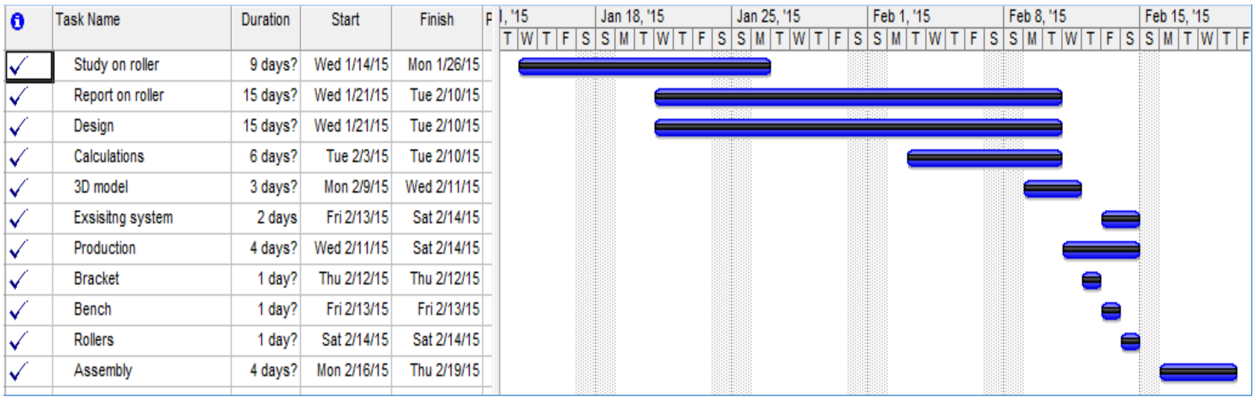
4 Methodology

At first the plan and sketch of the fixture is identified by the literature review. With this forces in the detailed design of the fixture that is subjected to Kelly bar during operation will be identified. From this, the conceptual design and the optimal design will be shown by a design tree. Then a detailed analysis of the fixture and other manufacturing plans and requirements of production will be identified.Next the model design will be done from which the actual design will be made. Then it will be produced and tested..

It will be required to produce new mounts and their designs, Hence it will be used in adaptive engineering techiniques.With this a suitable fixture can be made and also give an engineering value to the yard.

5 Development

5.1. Project Plan



Task Name	Duration	Start	Finish
Study on roller	9 days?	Wed 1/14/15	Mon 1/26/15
Report on roller	15 days?	Wed 1/21/15	Tue 2/10/15
Design	15 days?	Wed 1/21/15	Tue 2/10/15
Calculations	6 days?	Tue 2/3/15	Tue 2/10/15
3D model	3 days?	Mon 2/9/15	Wed 2/11/15
Exsisitng system	2 days	Fri 2/13/15	Sat 2/14/15
Production	4 days?	Wed 2/11/15	Sat 2/14/15
Bracket	1 day?	Thu 2/12/15	Thu 2/12/15
Bench	1 day?	Fri 2/13/15	Fri 2/13/15
Rollers	1 day?	Sat 2/14/15	Sat 2/14/15
Assembly	4 days?	Mon 2/16/15	Thu 2/19/15

Figure 14: Project plan

Figure 14 shows the project plan software GUI picture. In the project the time element was considered and each main and sub parts were calculated by the experience of the workers and observing the actual process of labour.The time available for the labour for the project was obtained,and this too was considered.

5.2. Sketch of the fixture

From the literatre review,the proper analysis of the mount was obtained. From this and from experience and adaptive engineering techniques, a sketch of the mount can be drawn.. Figure 15 shows the rotation method and Figure 16 has the sliding arrangnment.

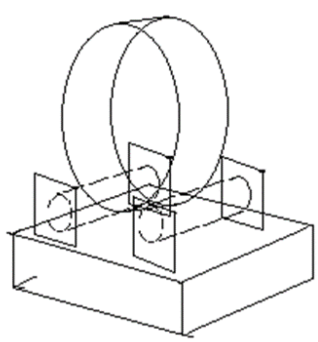


Figure 15: Sketch for mount rotation

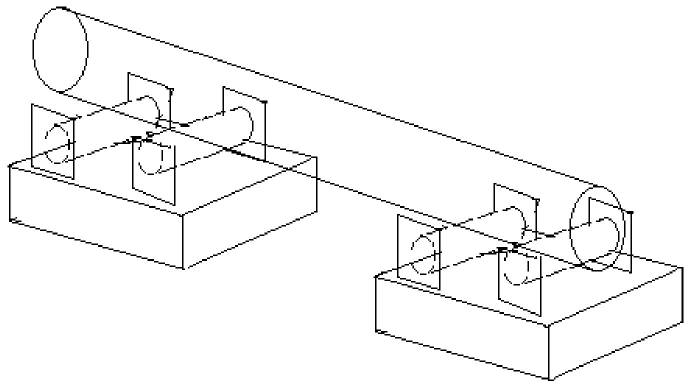


Figure 16: Sketch for Kelly bar slide

5.3. Engineering design

5.3.1. Problems identification

Primary problem

Currently Piling Kelly bar repair is hard work. In the maintenance of the Kelly bar a lot of energy is wasted. There was a request form the workers for a specially designed bench for the repair work. In the study a proper mount in the market was not available. It was found that the existing mount in the workshop was a fixed one and can not be used for the maintenance of the Kelly bar. Also it was found that the number of Kelly bars being repaired is increasing and time available was less. It was also found that there was a lack of space and equipement was scarce. In addion due to other workshop needs many workers were involved in other acivities. Furthermore, companies try to maximize the resources utilization .and even with the knowledge of workers and supervisors they are not in a position to design a suitable fixture for Kelly bar maintenance. In addition, with the changes and the beginning of new sections there was a total lack of everthing in all the areas.

Dependent problems

The Kelly bar is telescopic and has ribs around the bars. So direct clamping is not possible. The weight of the Kelly bar is 7 tons. So, it needs specialized roller bearings. Material selection is another problem. Also the Kelly bar is required to rotate frequently and takes several days to be repaired.Therefore it is required to be held for several days. Another problem is,it is required to slide only at the beginning of the process to separate each part. This is done by dragging it on the floor which makes a lot of damage. Sometimes it is found that the force needed for dragging is not sufficient. Thus,a new pulling fixture is required to drag it by man power. Another problem is the rotation of the bulky Kelly bar. A mechanisium was required to reduce the torque.

Secondary problems

Power supply for Rotation and Transport methods and Lifting methods is a problems. Also the ergomonic aspects of the workers were problems.. This is due to the worker performing the same job repeatedly for along time. It was found that the worker subjectd to this type of job gets sick. All these points are required to be considered in the designing.

5.3.2. Design Tree

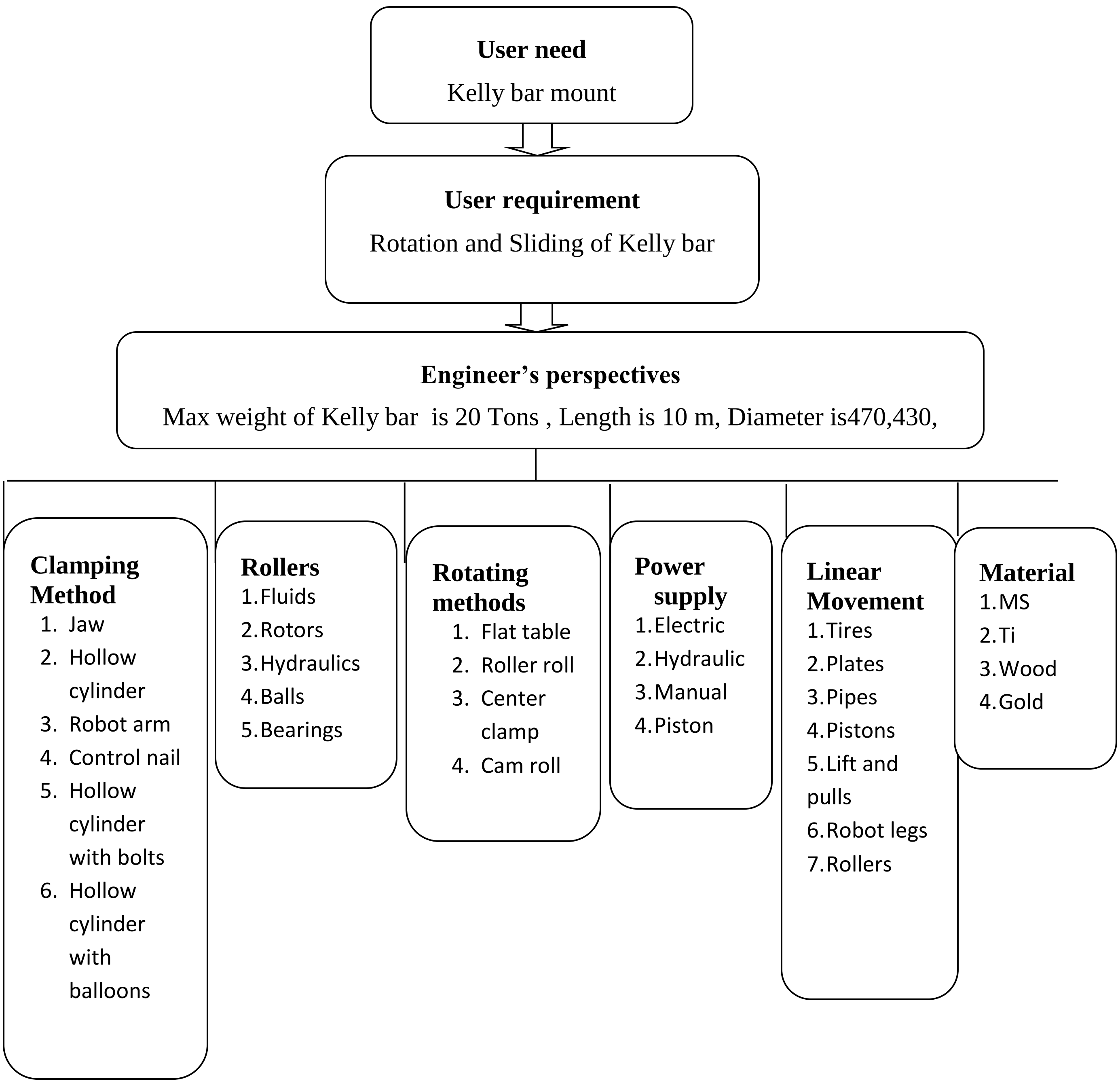


Figure 17: Design tree

5.3.3. Compatible Solution set

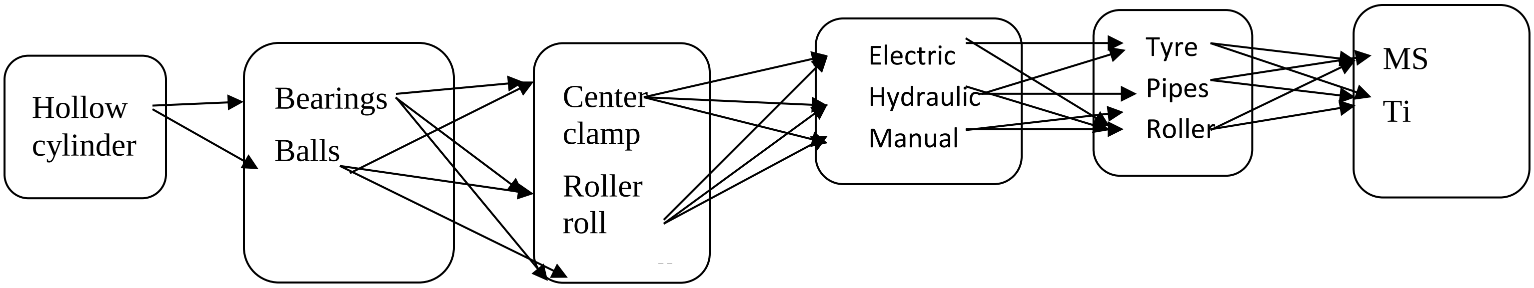


Figure 18: Compatible solutions set

No of Compatible solutions =1*1*3*3*3*2+1*1*2*3*3*2=45*2=90

5.3.4. Discussion of solutions

Clamping method

- Jaw Robots are not suitable due to the need of complex mechanical parts.
- Control nails cannot be attached to hollow Kelly bars
- Hollow cylinder with bolts Needs permanent flexible parts.
- Balloon which cannot take much load.

Rollers

- Fluids cannot take too much load
- Rotors and hydraulics are too expensive
- Balls are dangerous to use due to not being Neutral.
- Bearings are freely available

Rotating method

- Flat table is hard to rotate
- Center clamp cannot be used with Hollow cylinders.
- Cam roll is too expensive

Power supply

- Manual power is cheap
- No need of much power to rotate.
- No frequent rotations
- Small angle rotations.

Linear movement

- With reference to the above points, `rollers are used to Rotate.
- Therefore these rollers can be used for sliding without the use of extra materials and mechanisms.

Material

- Most of the time MS is used and it is available.

5.3.5. Feasible solution

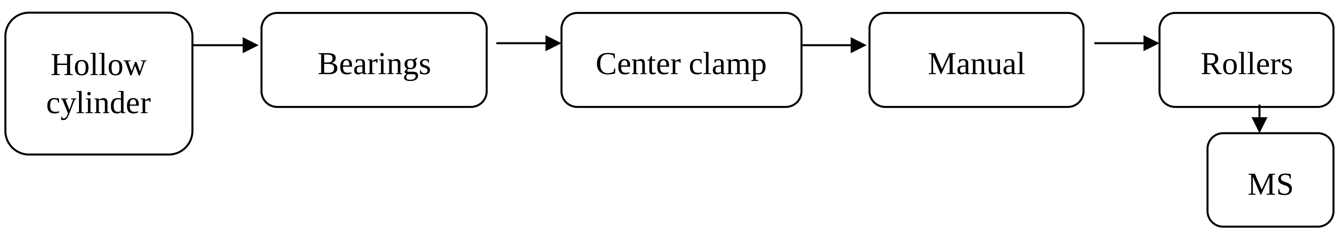


Figure 19: Feasible solution

This Figure 19 shows a feasible solution from the solution set derived from the design tree(Figure 17). For the clamping method the Hollow cylinder was going to be used. It can be clamped on the bearings by using center clamps. For power supply, man power was used and the linear movement was to be achieved by rollers. The material was steel.

5.4. Conceptual Model

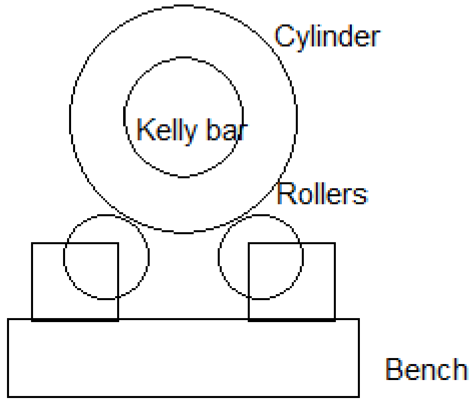


Figure 20: Conceptual model 1

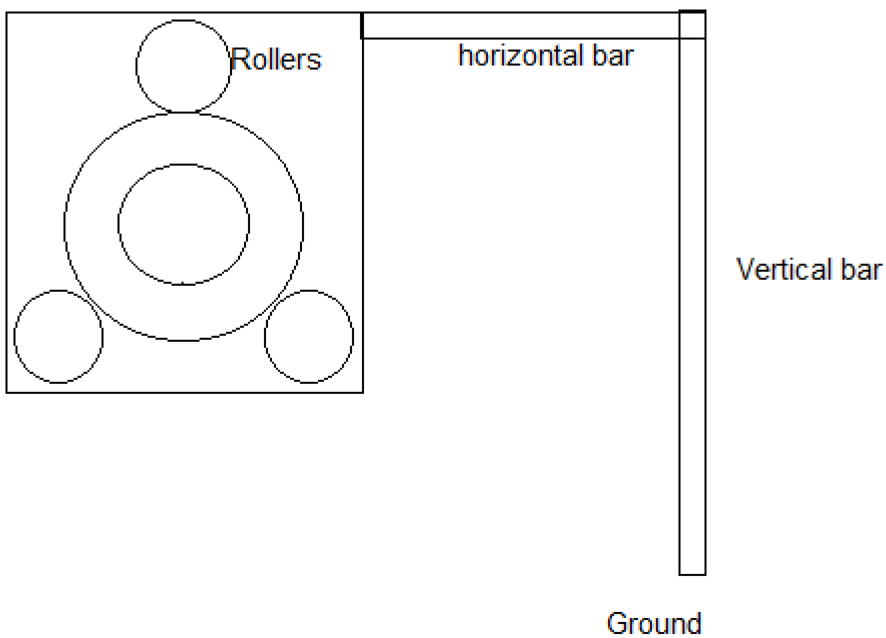


Figure 21: Conceptual model 2

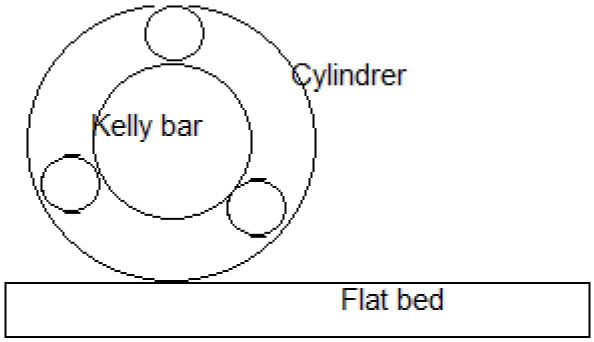


Figure 22: Conceptual model 3

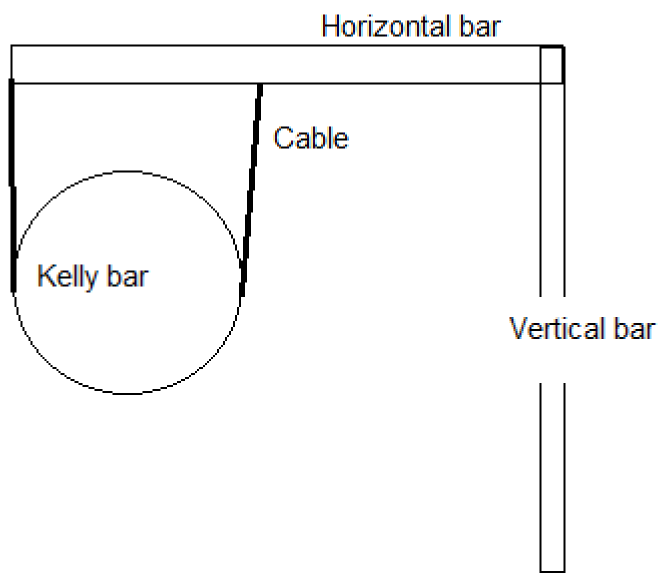


Figure 23; Conceptual model 4

The conceptual designs can be obtained from the optima solution. It was then drawn. Figure 20 shows the best arrangement. This was only to get the picture of the design arrangement..Figure 21 was more complex in design and it required more materials to design.

Figure 22 and Figure 23 were simple in design but cannot be used for sliding. Therefore these designs were abandoned.

5.5. Calculations

5.5.1. Strength calculations

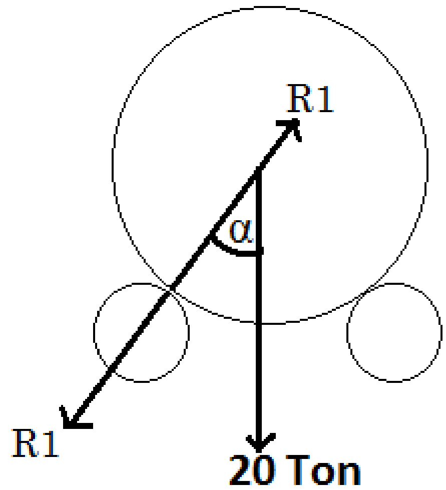


Figure 24: Force analysis of mount

- Weight of the caliper = 20 Ton (Given),[12],[13]
- Reaction force on roller(R1)(Figure 24)
  - =20*10*Cos(82.29')/2 kN=13.4kN
- Track Roller (Old track roller)
  - Weight can take= 50 ton(Given)
- Bolt (Old materials available)
  - Diameter 1.5cm
  - Number of bolts= 4
  - Shear stress on 4 bolt
    - R1*sin(82.29)/(4*A)= 18..7MPa<312MPa,[14],[12]
  - Therefore does not fail
  - SF=16.68
- Brackets (Old Pieces available)
  - No of Brackets =4
  - Tensile force=R1*Cos(82.29)=1.798 kN
  - Tensile Stress= 1798/A<390000000 Pa,[14],[12]
  - A>0.0004610m^2

- H beams(Old materials available)
  - Tensile Stress= R1*sin(82.29)/A< 390MPa,[14]
  - A>0.000304 m^2

- Ring(Available)
  - Shear stress=R1*Cos(82.29)/.0312=57.6kPa
  - SF=312/0.0005706=5416
- Welding thickness (Figure 25)
  - Bracket
    - Length of bracket=26.3 cm

      Does not to fail

      - Shear strength< Ultimate Shear strength,[12]
      - R1*sin(82.29)/(t*l)<312*10^6 where t=.707*s
      - t*l>4.4*10^(-5) m^2
      - We know l=26.3 cm, so t>0.1618 mm
      - Current t= 1 cm
      - Therfore safe in welding strength

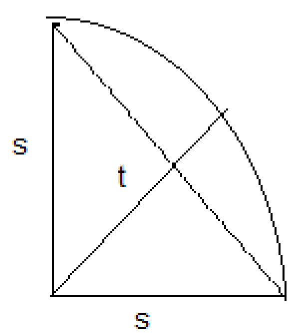


Figure 25: Welding thickness calculation drawing

REBA calculation

Exsistng methods

Ergonomics was required to be considerd in the designs. REBA analysis was very helpful in this aspect. In order to analyze the postures properly ,REBA calculation was done. The REBA values in each situation were considerd.

Figure 26: REBA analysis of exsisting method 1

In the current method the worker's posture is shown in the Figure 26 and Figure 27. They are required to work long hours in this position.

Table 4: REBA of exsisting method 1

Neck	3	Lower arm	2
Leg	4	Upper arm	4
Trunk	5	Wrist	3
Score A	9	Score B	5
Score C	10		
Activity	1		
Total	11		

With reference to Table 4 above, it can be seen that Score A is 9 and Score b is 5. This implies that the worker performs many movements from the upper parts and the legs . Therefore this is a method which has a high expenditure of energy.

Figure 27: REBA analysis of exsisting method 2

Table 5: REBA of exsisitng method 2

Neck	2	Lower arm	2
Leg	2	Upper arm	1
Trunk	3	Wrist	3
Score A	5	Score B	3
Score C	4		
Activity	1		
Total	5		

Another method that the worker follows is the repairing actions as shown in the Figure 27: REBA analysis of exsisting method. In this, score A and Score B are lower, compared to Table 4: REBA of exsisting method. This implies that the worker performs fewer motions from the upper and lower parts of the body,than the other parts.

Figure 26 and Figure 27 show the current postures. It is seen from Table 4 and Table 5 they have values of REBA 11 and 5.

Expected method Fixture

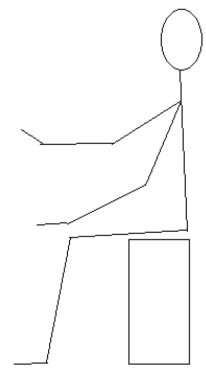


Figure 28: REBA analysis of expected method

Table 6:REBA of expected method

Neck	1	Lower arm	1
Leg	4	Upper arm	1
Trunk	1	Wrist	2
Score A	4	Score B	2
Score C	4		
Activity	0		
Total	4		

Figure 28 shows the posture of the worker in the expected design. From Table 6 it gives REBA score A value as 4 and Score B values as 2 which is lower than any other. Which implies that he spends less amount of energy compared to any other methods.

Moreover, Figure 28 has REBA value as 4, which is the lowest of all the values. Therefore, this posture is the best of all.

Height Calculation

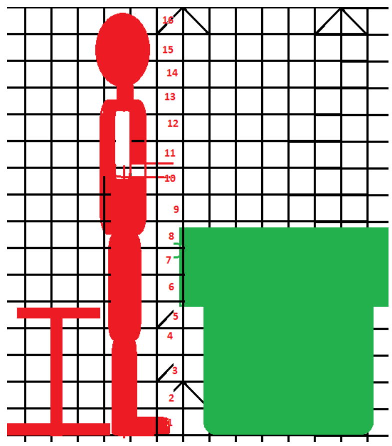


Figure 29: Design height analysis

Figure 29 shows the expected height of the mount and the expected height,of the user analysis. This helps to identify a clear picture of the mount used in the long run.

5.5.2. Process analysis

Table 7: Process Analysis shows the process analysis of the mount. In value calculation this is very useful to identify the business and the value of the added parts of each process. The following table explains that each part has to be considered in designing.

Table 7: Process Analysis

Process	BNVA	VA	NVA	BVA
Study of mounts			X	
Designing the Mount		X		
Documenting			X	
Manufacturing				X
Painting				X
Marketing				X
Material				X

5.6. Material Requirements

Bill of material

Table 8: BOM for mount

Mount	Bench	1,0d
	Bracket	4,2d
	Rollers	2,1d
	Paint	1,2d

Table 9:BOM for Bench

Bench(2d)	85cm	2,.5d	H beam	0.25,2d
			Oxygen	0.5,1d
			Acetylene	1,1d
	60cm	2,.5d	H beam	0.25,2d
			Oxygen	0.5,1d
			Acetylene	1,1d
			Weld rods	1,1d

Table 10: BOM for Bracket

Bracket(2d)	Top	1,1d	MS plate	225,1d
			Oxygen	0.5,1d
			Acetylene	1,1d
	Side	3,1d	MS plate	56,1d
			Oxygen	0.5,1d
			Acetylene	1,1d
	Middle	1,1d	MS plate	364,1d
			Oxygen	0.5,1d
			Acetylene	1,1d

Table 11: BOM for paint

Paint(2d)	Thinner	1,1d
	Primers	0.5,1d
	Outer	0.5,1d
	Sand papers	4,1d

Table 8 to Table 11 show the material required and the days required for each process [15]. Each process was extracted and calculated. It also indicates the dimensions of each part.

Project path

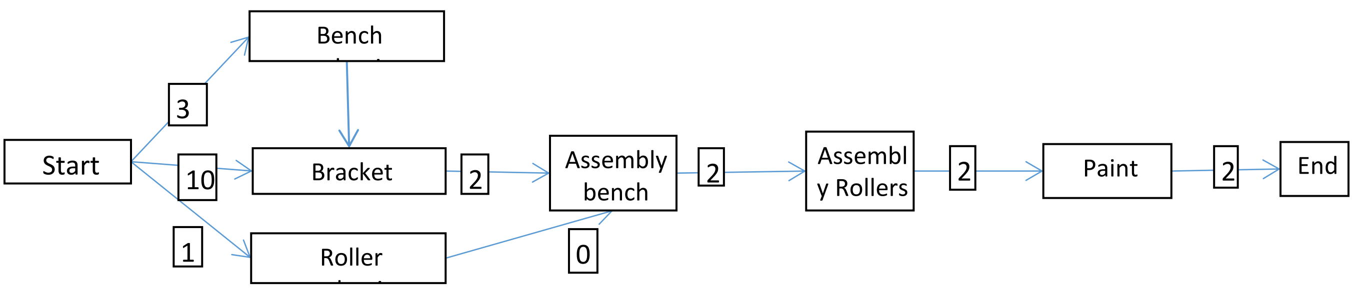


Figure 30: Project path graph

Project path is shown by the Figure 30. Bench, brackets, and rollers were produced and obtained first and ,the assembly of the bench was carried out. Next the roller assembly and finally the painting were done.

Max path=41d(S-B-D-E-F)

The maximum duration of the path from start to finish in41 days.

Machine requirement

Table 12: Machine requirement

	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
Welding generator														
Demand	2		2											1
Supply	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Balance	9	11	9	11	11	11	11	11	11	11	11	11	11	10
Gas cutter														
Demand			2	3										
Supply	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Balance	4	4	2	1	4	4	4	4	4	4	4	4	4	4
Spray gun														
Demand														1
Supply	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Balance	2	2	2	2	2	2	2	2	2	2	2	2	2	1
Grinder														
Demand														1
Supply	23	23	23	23	23	23	23	23	23	23	23	23	23	23
Balance	23	23	23	23	23	23	23	23	23	23	23	23	23	22

5.7. Production feasibility model

Figure 31: Model of mount

Figure 31 shows the model to be produced, to identify the production feasibility.This is the first step of the production [16] .This was done by papers. It was done to the scale of the mount.It was done in order to check the feasibility in manufacturing and to optimize the model at the same time.

5.8. Actual 3D design

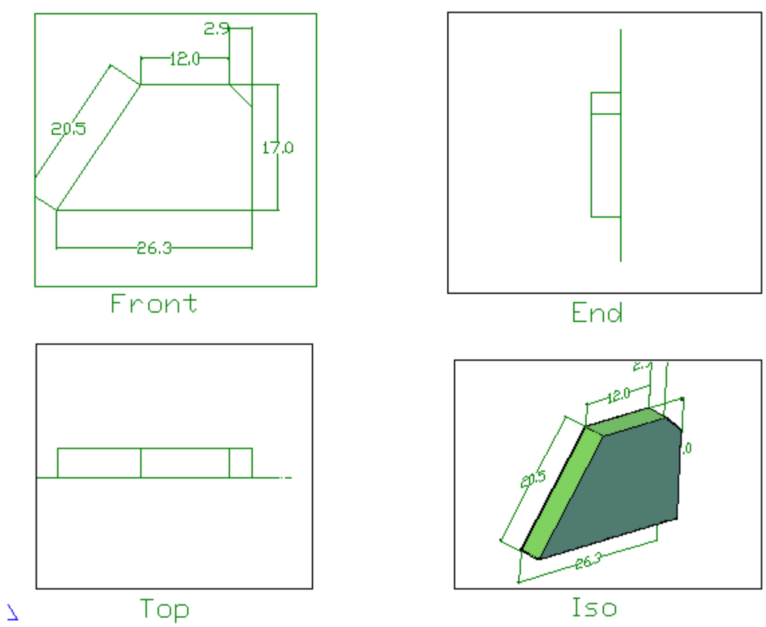


Figure 32: Side bracket of mount

The Figure 32 above shows the side bracket of the mount. This had the ability to withstand the long reaction force [17]with its trapezoidal shape. Its thickness was selected in such a way that it does not fail by compression or by shear. The thickness of the plate was 12 mm.

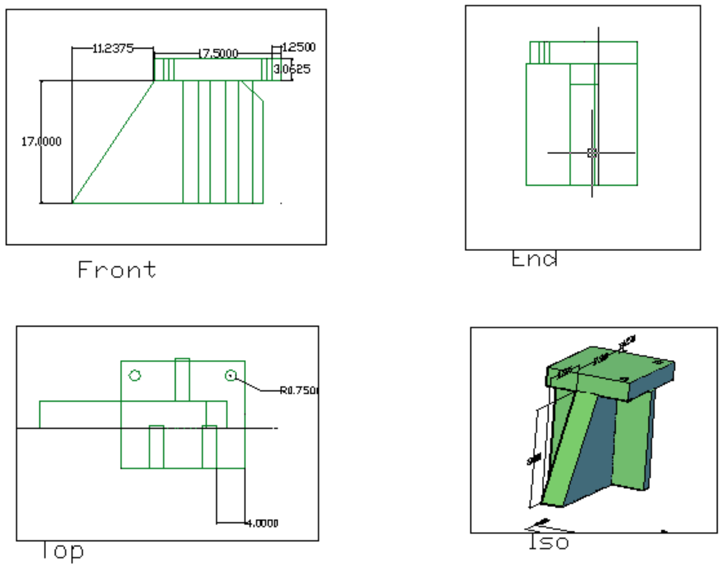


Figure 33: Side bracket assembly

This arrangement shows the side bracket assembly (Figure 33). There were two supports that prevent the top plate from falling and moving. The top plate was attached to the roller. There were two holes on the top plate, so that the roller can be changed after wear and tear.

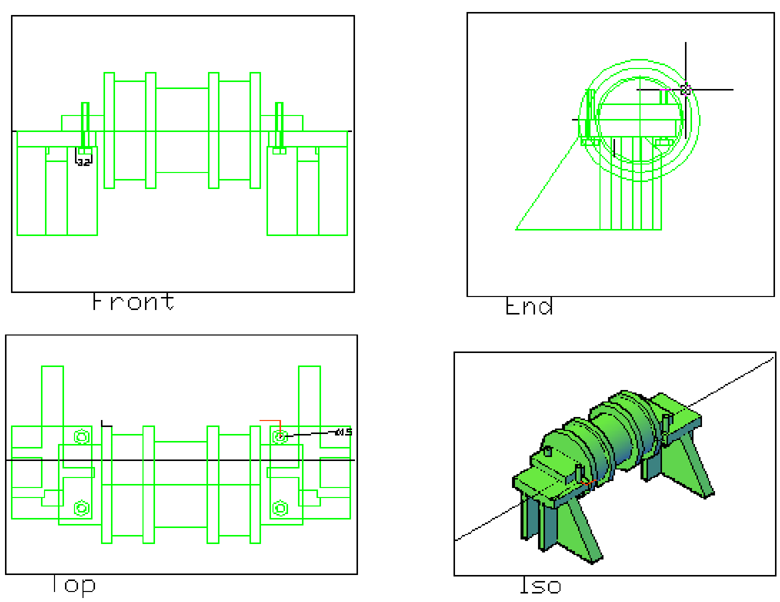


Figure 34: Side mount assembly

This shows the side roller with brackets (Figure 34). The rollers were attached with brackets from bolts of 12 mm diameter. This was taken from the calculation.

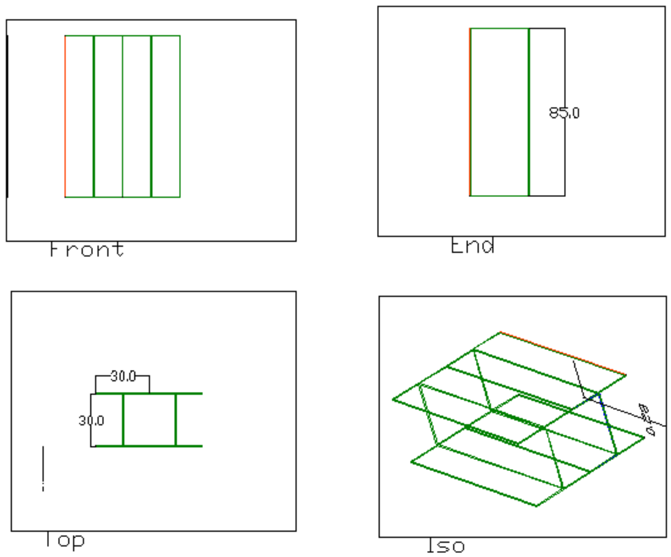


Figure 35: Frame Assembly

In this H beams and the standard parts were produced by DFM implementation. So that it can be manufactured easily at low cost.

Figure 32 to Figure 35 show the actual CAD design. This was drawn according to the actual length of the mount. The dimensions were obtained from calculations. Then Figure 33 shows the completed bracket with supportives to increase the structural strength. Figure 34 shows the assembly of bracket with the roller bearing. Figure 35 shows the base manufacturing and dimensions.

Roller

Excavator track roller ,Medium excavators from 20-35 metric tons

Figure 36: Roller type 1

Figure 37: Roller type 2

Figure 38: Roller type 3

Figure 36 to Figure 38 show the suitable roller types available in the market. Each had unique features.

Lifting bracket design

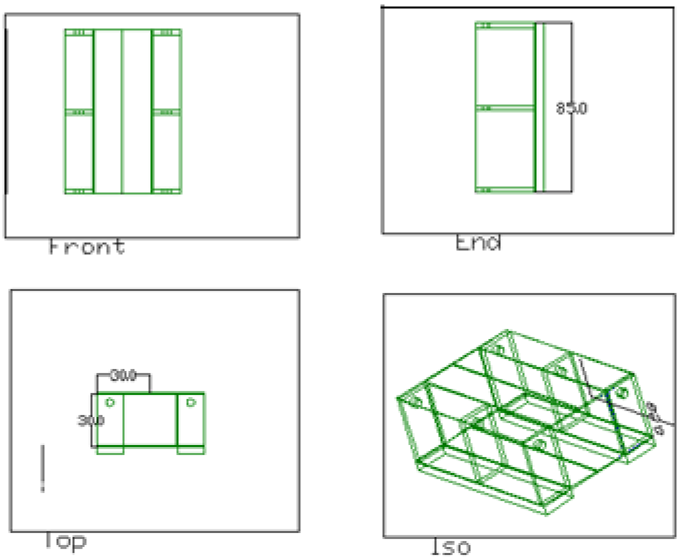


Figure 39: Lifting and Crane mechanism

The mount is required to lift and move with transport.Hence this feature was added to the design. Side bracket attached to the frame was drilled toinsert a belt and a hook. Figure 39 shows the design

Centering Puller design

There was a need for centering the Kelly bar in the design. Therefore these pulleys were designed. Figure 40 shows the design.

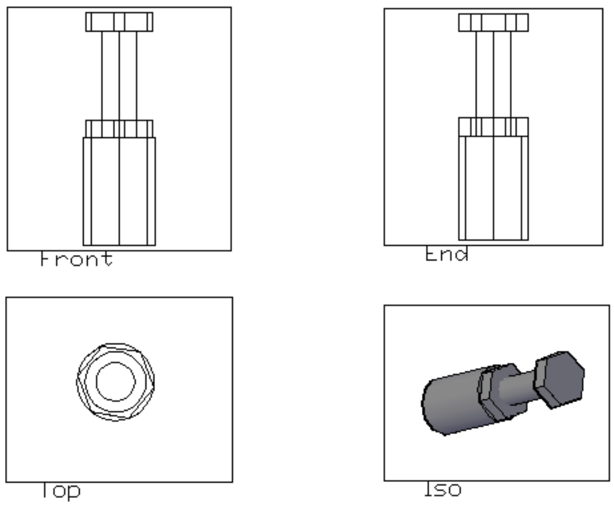


Figure 40: Centering Pullers design

5.9. Finite Element Analysis report

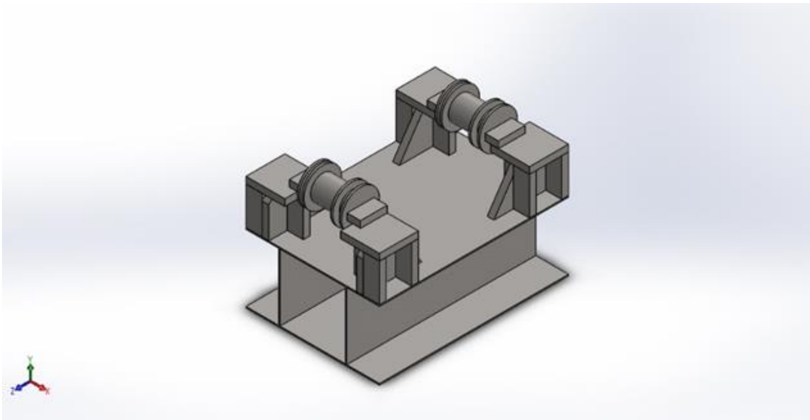
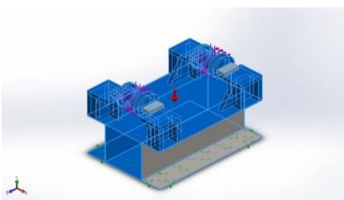


Figure 41: Actual design tested

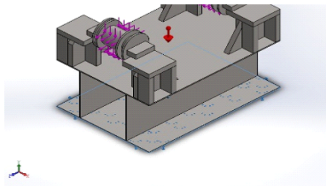
Figure 41 shows the actual figure that was subjected to ananlysis. The Design was made according to real dimensions.

5.9.1. Simulation of Base and Bracket

Model Reference	Properties	Components
	Name: **AISI 1020** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **3.51571e+008 N/m^2** Tensile strength: **4.20507e+008 N/m^2** Elastic modulus: **2e+011 N/m^2** Poisson's ratio: **0.29** Mass density: **7900 kg/m^3** Shear modulus: **7.7e+010 N/m^2** Thermal expansion coefficient: **1.5e-005 /Kelvin**	**SolidBody 1(Mirror1)(Base1_1-1),** **SolidBody 1(Boss-Extrude1)(Bracket1_1_4-1),** **SolidBody 1(Boss-Extrude1)(Bracket1_1_4-2),** **SolidBody 1(Boss-Extrude1)(Bracket1_1_4-3),** **SolidBody 1(Boss-Extrude1)(Bracket1_1_4-4),** **SolidBody 1(Boss-Extrude1)(Bracket1_2_12-1),** **SolidBody 1(Boss-Extrude1)(Bracket1_2_12-10),** **SolidBody 1(Boss-Extrude1)(Bracket1_2_12-11),** **SolidBody 1(Boss-Extrude1)(Bracket1_2_12-12),** **SolidBody 1(Boss-Extrude1)(Bracket1_2_12-2),** **SolidBody 1(Boss-Extrude1)(Bracket1_2_12-3),** **SolidBody 1(Boss-Extrude1)(Bracket1_2_12-4),** **SolidBody 1(Boss-Extrude1)(Bracket1_2_12-5),** **SolidBody 1(Boss-Extrude1)(Bracket1_2_12-6),**

In the model figure the material was AISI 1015 Steel and it had yield strength 351 MPa and tensile strength 420 MPa. Model type is linear elastic isotopic.

5.9.2. Load and fixture

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	12.6555	3145.22	-3.73662	3145.25
Reaction Moment(N.m)	0	0	0	0

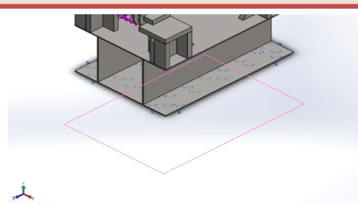
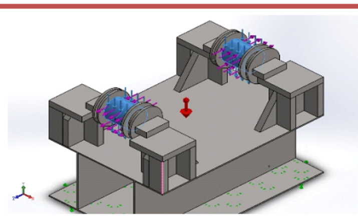
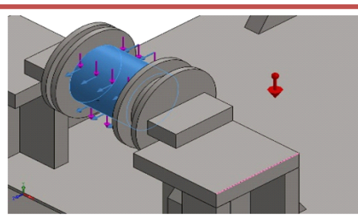
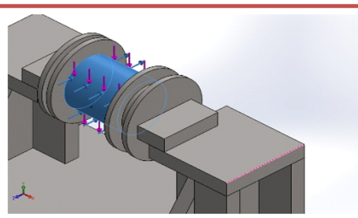
Load name	Load Image	Load Details
Gravity-1		**Reference:** Top Plane **Values:** 0 0 -9.81 **Units:** SI
Force-1		**Entities:** 2 face(s) **Reference:** Edge< 1 > **Type:** Apply force **Values:** ---, ---, 1000 N
Force-2		**Entities:** 1 face(s) **Reference:** Edge< 1 > **Type:** Apply force **Values:** ---, ---, 13000 N
Force-3		**Entities:** 1 face(s) **Reference:** Edge< 1 > **Type:** Apply force **Values:** ---, ---, -13000 N

Figure shows the fixed image. The bottam face was fixed and the top rollers were subjected to load.

In the figure the load was taken as 20 ton(200kN). This value was shown in the load details. This was selected in order to test the mount in the analysis. But the actual value was less than this. It was equally distributed among the brackets due to symmetric features in application.

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	43.4753 mm
Tolerance	2.17376 mm
Mesh Quality	High
Remesh the failed parts with the incompatible mesh off

Mesh information – Details

Total Nodes	18046
Total Elements	8984
Maximum Aspect Ratio	127.07
% of elements with Aspect Ratio < 3	26.3
% of elements with Aspect Ratio > 10	4.37
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:11
Computer name:	AF9

Figure 42 shows the meshed model. 4 point Jacobian(mathematical model) was used. Standard mesh type was selected. Total number of nodes are 18046 and total elements are 8984.

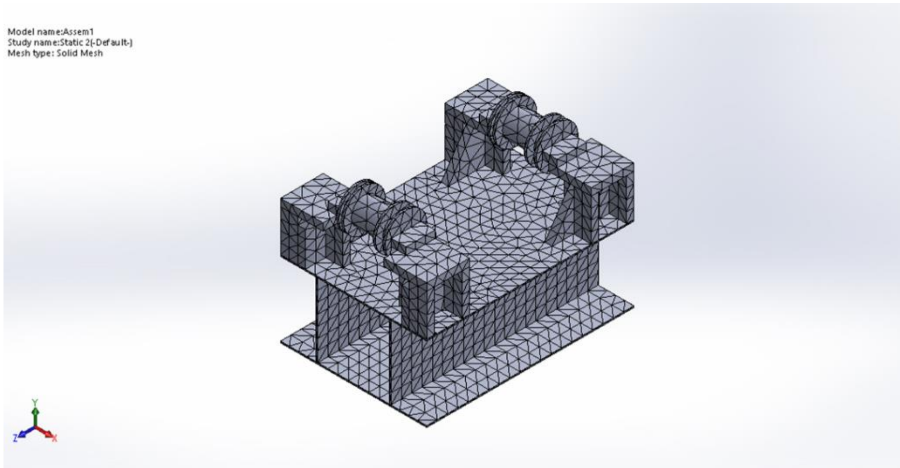
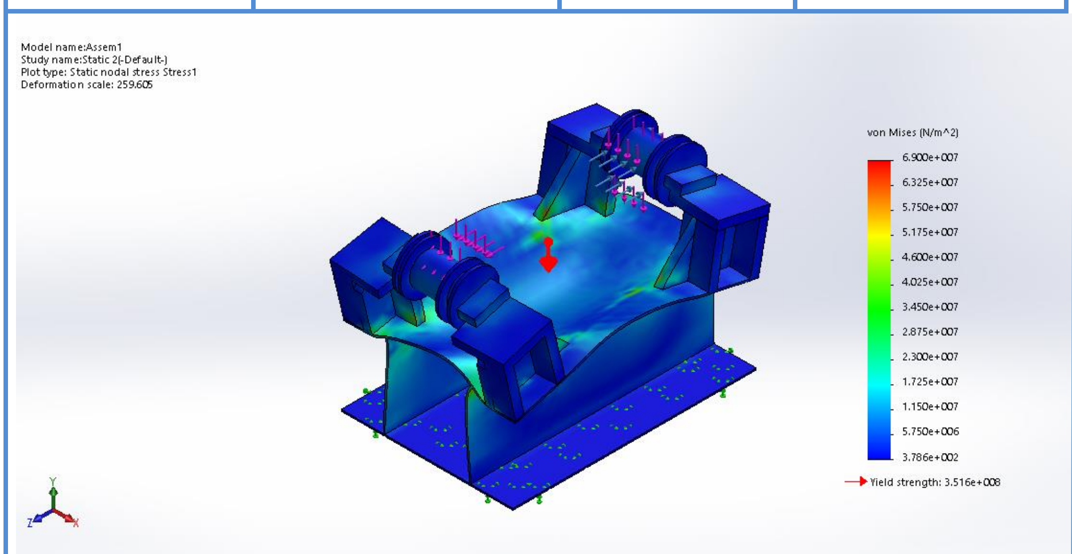


Figure 42: Meshed model

Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	378.595 N/m^2 Node: 5529	6.89991e+007 N/m^2 Node: 12268



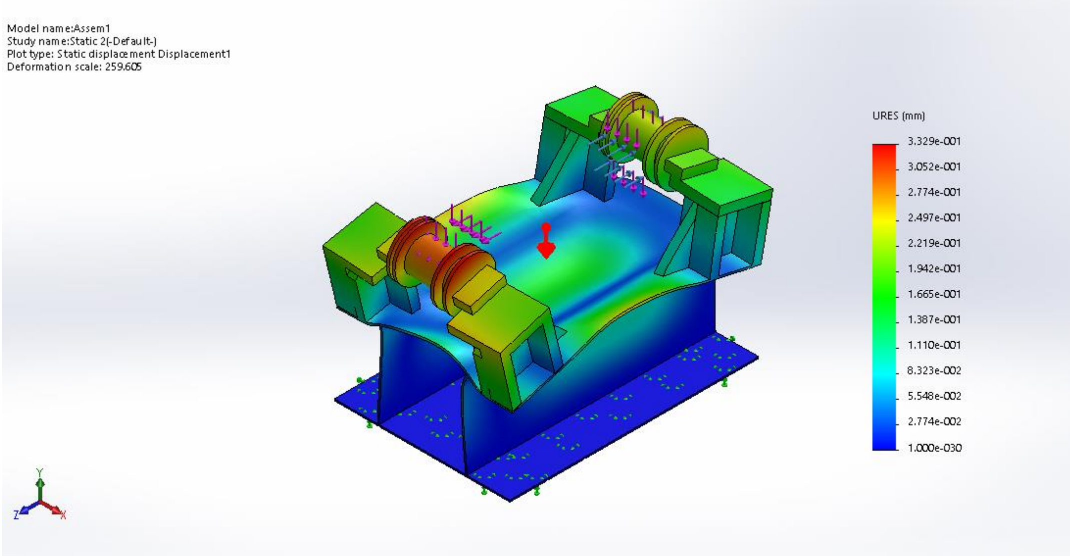
Assem1-Static 2-Stress-Stress1

Figure 43: Stress analysis of mount

Stress values are shown in the Figure 43. It shows the maximm value at 20ton was 6.89991e+007 Pa at Node: 12268. In a real case the value of load per mount will be about one roller for10 tons. So this is safe.under Stress due to Yield stress(3.5176e+008 Pa) is higher than the maximm stress.

Base and Bracket1-SimulationXpress Study-Stress-Stress

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 641	0.332904 mm Node: 16733

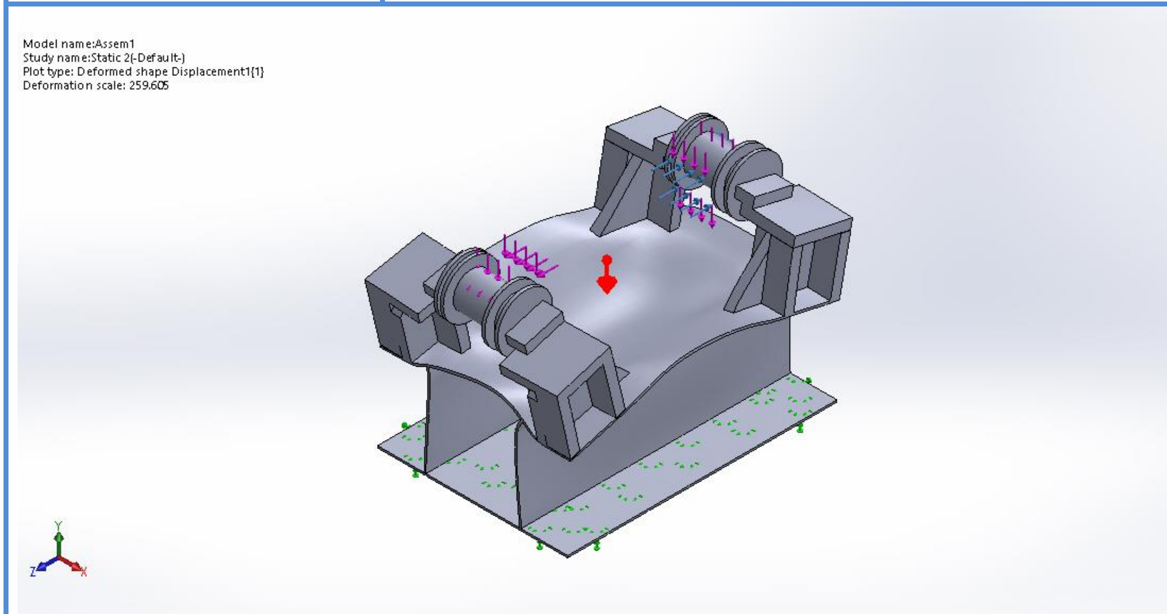


Assem1-Static 2-Displacement-Displacement1

Figure 44: Displacement analysis of mount

Figure 44 shows the displacement.. Maximum is about 0.332904 mm at Node: 16733. In the actual case the load was low.

Name	Type
Displacement1{1}	Deformed shape



Assem1-Static 2-Displacement-Displacement1{1}

Figure 45: Deformation of mount

In Figure 45 deformation is shown and it bends to sides. No damage to the motion of the rotation or sliding at loaded condition.

For the factor of safety,the minimum vaule is 5.099 . But in actual case this will be higher.. It is clear that the fixture will not fail by manual calculation.

Hence, In overall FEA is an approximation. [18] It can be proved that given the same condition to computers they give two different results .With the shape and size of the node,the stress values change.

5.10. Final design

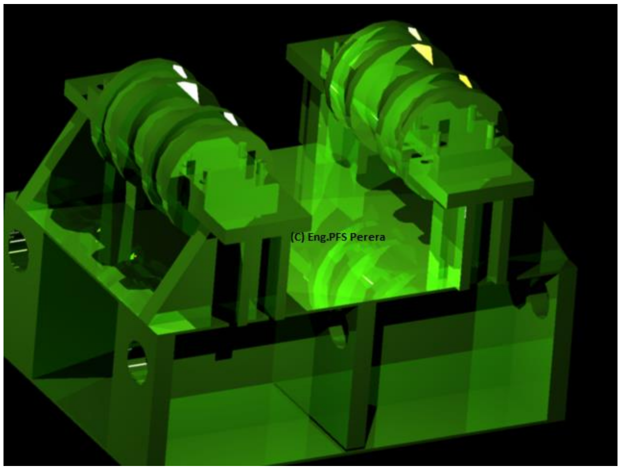


Figure 46: Final CAD Design

Figure 46 shows the final CAD design of the mount. This was the final design of the mount and this was used to produce the mount.

5.11. Proto type of mount

To show the design, it was 3d printed. The mount was designed in the Solid work and STL file was created. After which the prototype was printed. Figure 47 shows the 3d printed model.

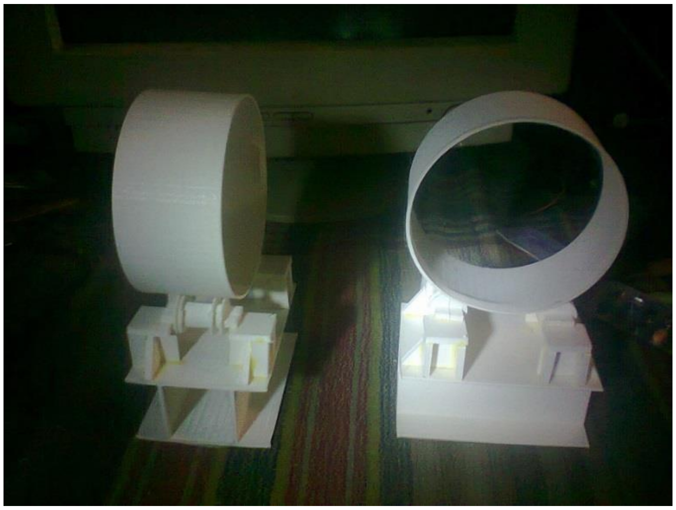


Figure 47: 3D printed model

5.12. Automation & Further development

External power supply mechanism

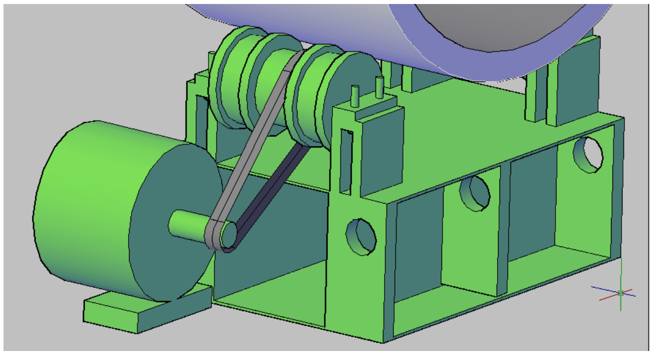


Figure 48: External power supply

Figure 48 shows the external power supply by electricity,if required The Motor was coupled to the rollers. The gearbox was with the motor shown.. Belt was used to prevent slipping in the case of getting stuck. SCR[19],[20] with Arudion circuit or on off switch can used for control the AC motor[21],[22].

5.12.1. Calculations for sliding

Power = Torque*speed; [23]

Torque = I*(Change of speed)/time+ Friction

=.5*9000*.2^2*(1-0)/1 + Friction ; Assume final speed is 1 rad/sec

=180Nm + Friction

Motor power

= Torque * Speed

= 180W + Friction

Drawing mechanism for sliding

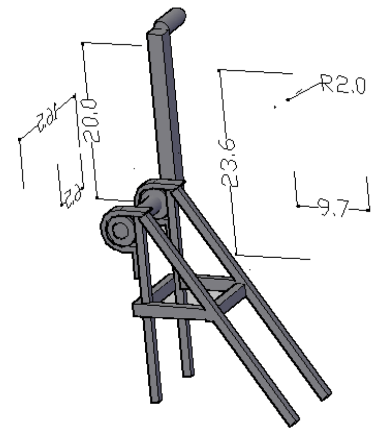


Figure 49: Drawing mechanism

Sliding required a drawing mechanism to pull the Kelly bar. This was designed to pull the Kelly bar by a long rope attached to the Kelly bar. Figure 49 shows the design.

Calculation

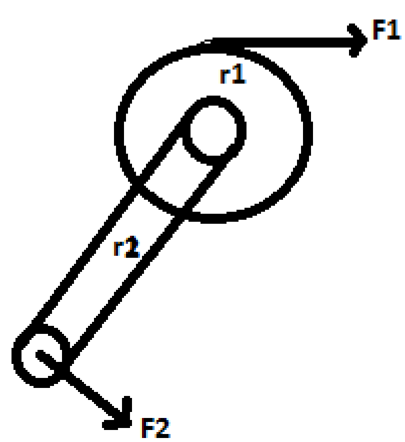


Figure 50: Sketch of drawing mechanism

Force to drag (F1)= HP of Forklift/Speed ;(Figure 50: Sketch of drawing mechanism)

=2235N

Force apply=263.52N

F1xr1=F2xr2

r2/r1=8.481

T/r=r/Ip

Not to twist (Figure 51: Twist calculation)

Tmax=Πw^3/32; [23]

=38kNm

T=2235*.025=55.875Nm < Tmax

thus , safe to twist

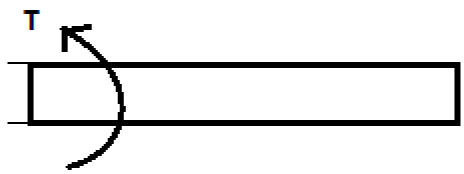


Figure 51: Twist calculation

Not to shear,

2235/A< 78x10^9

A>2.81/10^2mm

5.13. Production

5.13.1. Final design during production

Figure 52: During production

Figure 52 shows the final design during production. This had to be completed by welding the piece.

6 Validation

6.1. Testing

Sliding test

4 ton Kelly bar

- Load was taken by one roller.
- For the same 4 rollers the load was safe.
- See video (https://www.facebook.com/video.php?v=10153028739692368&pnref=story)

Figure 53: On 4 ton weight

11 ton Kelly bar

Figure 54: On 11 ton weight

- Load was taken by 2 roll.
- See video (https://www.facebook.com/video.php?v=10153033297612368&pnref=story)

Rotation testing

Figure 55: Roll test

The mount was tested for 4 ton and 11 ton sliding and rotation. Each was shown in the Figure 53 to Figure 55.

Figure 56: Implementation of roll

Figure 56 shows the ergonomic aspect considered .The worker performs the repair method. It can be seen that this is more convenient..

Figure 57: Manual Rotation of Kelly bar by workers

Implementation of the mount is shown in Figure 56 and Figure 57. This was done in the workshop.Figure 57 shows the rotation of the Kelly bar without any external power supply but by using man power only.

6.2. Production cost

Table 13: Cost calculation

Description		**Cost(Rs)**
Study on Roller		5000
Report on roller	Design	5000
	Calculation	2000
3D model		5000
Existing system		1000
Production	Bracket	200
	Bench	500
	Roller	200
Assembly		5000
Materials	1”x8’x4’ MS plate	22350
	300x300 H beam	45000
	Roller	34000
Labor	7*1200*2	16800
Total		142050
Tax Vat	11%	15625
NBT	2%	2841
Total cost		160156

From Table 13 It is clear that brand new material cost is Rs.101350.00. But this is not so in an actual case. All materails were freely available in the yard(old srcap parts).

7 Discussion

Figure 58: Final production

The Figure 58 shows the final and painted product. The standard engineering color code was used for painting.

7.1. Research analysis

7.1.1. Data collection

[24]

Informal method; [25]

Fork fuel =112.50x5/day=Rs. 562.50/day

Labor cost =1200/day x 2 = Rs. 2400 /day

Formal;[25]

Cost of production of mount = Rs.84150.00 (From the production cost table)

7.1.2. Data evaluation

Opportunity cost of Mount =Rs. 2962.50/day;

Simple Payback period = 84150/2962 days=29 days

7.1.3. Analysis and interpretation of data

Erogonomic analysis

Figure 59: Worker performing repair

Table 14: New ergonomic method

Neck	1	Lower arm	1
Leg	4	Upper arm	1
Trunk	1	Wrist	2
Score A	4	Score B	2
Score C	4		
Activity	0		
Total	4		

The implemented mount was tested for ergonomic performing method.It is shown in the Figure 59. It was revealed that this was comfortable in the long run by Table 14.

This fixture (Figure 58) was capable of fulfilling the need for reduction of cost associated with maintenance. This was tested and implemented in the workshop. The design fulfilled the engineering design requirements.

The following solutions were observed in the designed mount:-

- Low cost
- Rotatable due to being axisymmetric
- Can slide
- No need for extra machineries to operate.
- Less time consuming
- Ergonomic aspects
- Aesthetics
- Less labour required
- Easy to operate
- Less energy consuming

It should be mentioned that mounts of new designs were not only rotatable but also were able to slide to the axial direction. This was made with rollers in bearings.

From the above review it is obvious that the Kelly bar surface is not smooth. It had ribs and other shapes. Some were square and some were hexagonal while some were round. All these shapes were considerd in this design.

Considering the waste generated in the workshop this kind of project will give more profits to workshops and will result in environmentally friendly production of this product as it reduces the expenses and generates an income. In the future, if the project is successful, it will be a revenue generating medium to any company.

To produce the mount ,only the labor associated cost was required. The material was freely available in the yard and most were scrap items that could be reused (3R). Therefore secondly ,only electricity and welding costs were important.

From the above cost analysis it shows that this is cost effective in production and gives a better quality product to the customer to satisfy [26] his need. Therefore there is a need for this kind of mounting in every country.

7.2. Novelty

Table 15: Innovation analysis table shows the innovations [12] and its analysis. It shows each part and innovation type. This shows the expansion of parts and further details.

Table 15: Innovation analysis table

Description	**Innovation type**
Sketches	Inventive
Conceptual designs	Inventive, Adaptive
Model design by paper	Adaptive
Rotation method	Inventive
Sliding method	Inventive
Ergonomic design	Adaptive
Aesthetic aspects	Adaptive
Production techniques	Adaptive, Inventive
Automation	Inventive
Drawing mechanism	Inventive
Prototype	Adaptive

7.3. Future work

The design was produced as an answer to a request by the workers and implemented in the workshop. The request was only to rotate manually. In the future this can be extended to many fields. For example ,ship mount, rocket mount and many other heavy equipement mounts. This mount considered the ergonomic aspects. In that stream,it can be further developed to fully automated damage scan system and fully automated welding robot continuously for long hours. Futhermore, the rotaion of the mount can be automated and SCADA system can be used to observe the performance of the sub workshop by a central office. This mount can be devolped and improved to many other uses by careful study.

8 Conclusions

From the above discussion it is clear that a potential gap was addressed. This was a specially designed Kelly bar mount for the repair and maintenance of the Kelly bar. This was due to a drastic need in the exsisitng system. Therefore this fulfills the gap. It was easier for the worker to use it for a long period of time in repeated motions.

This had a specific understanding of the Kelly bar process and functions and solved the primary problem of the Rotation and Sliding of the Kelly bar. All the other secondary and dependent problems were considered such as the power supplies and ergonomic aspect in designing the product. By Table 15: Innovation analysis table, it is clear that this is an inventive innovation due to the existence of several inventive sub innovations.

From the research data it was shown the Opportunity cost of mount was = Rs 2962.50 per day. Simple payback period = 29 days. So this reduced and saved the cost with the use of scraps with an environmentally and economically friendly method.

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10 Appendix

9.1 DFM

Design for manufacture is a concept used in manufacturing engineering in order to define the better design for manufacture of a product.

9.2 UFOARM

User need, Functionality & Reliability, Operation and maintenance, Aesthetics, Retirement, Manufacturing ease. This is a concept used in designing a product.

9.3 Weight calculation

One Roller capable of taking a 250 tons+ load. Total load per mount is 500+ tons.

9.4 3R

Concept for waste material usage in an efficient way.

9.5 FEA

Finite element analysis is a method used in structural analysis of a component. Computer software is used for this.

9.6 SCR

Silicon Control Rectifier is a semiconductor electronic component that is used to control the motors and other electronic components. Mostly this can be used with alternative current.

9.7 Arudino

A circuit module that can be programmed by computer is used for electronic devices where complex motions and sensors are used.

9.8 GUI

Graphical User Interface is a computer picture showing the status of the data in a user friendly manner.

9.9 REBA

Rapid body assessment is an ergonomic tool used to evaluate the posture in action.

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