PROJECT REPORT

Mecanum Wheels based platform for Industrial Forklifts

UME801 Mechanical System Design

(January – May 2015)

Submitted to

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Contents

Acknowledgement

We have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and the University. We would like to extend my sincere extend to all of them.

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We would like to express our gratitude towards our parents & Mechanical Engineering department for their kind co-operation and encouragement which help us in completion of this project.

- Jayant Mittal
- Kashish Kanyan
- Kashish Goyal
- Maninder Singh
- Munish Arora

Chapter 1

1.1 Problem Definition & Introduction:

Omni-directional platform has a huge advantage over conventional platform in terms of mobility in congested environment. These environments are commonly found in factory shop-floors, offices, hospitals and warehouses.

The **Mecanum wheel** is one design for a wheel which can move a vehicle in any direction. It is sometimes called the Ilon wheel after its Swedish inventor, Bengt Ilon, who came up with the idea in 1973 when he was an engineer with the Swedish company Mecanum AB

It is a conventional wheel with a series of rollers attached to its circumference. These rollers typically each have an axis of rotation at 45° to the plane of the wheel and at 45° to a line through the centre of the roller parallel to the axis of rotation of the wheel.

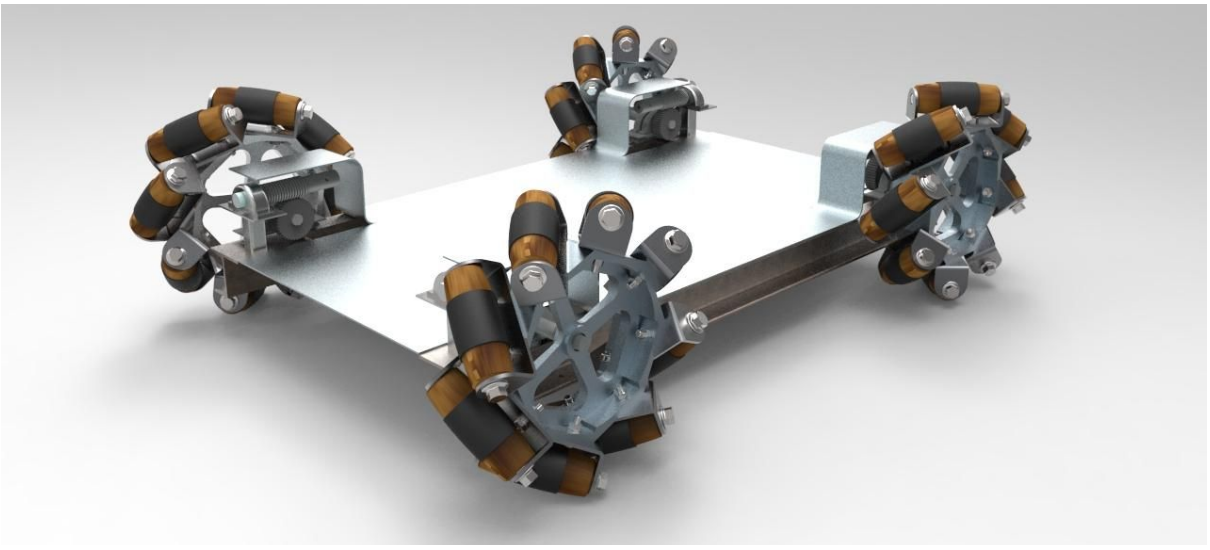


Fig. 1 Conceptual CAD Model

By alternating wheels with left and right-handed rollers, in such a way that each wheel applies force roughly at right angles to the wheelbase diagonal the wheel is on, the vehicle is stable and can be made to move in any direction and turn by varying the speed and direction of rotation of each wheel. Moving all four wheels in the same direction causes forward or backward movement, running the wheels on one side in the opposite direction to those on the other side causes rotation of the vehicle, and running the wheels on one diagonal in the opposite direction to those on the other diagonal cause sideways movement. Combinations of these wheel motions allow for vehicle motion in any direction with any vehicle rotation.

Fig. 2 Final Fabricated Product

1.2 System Detailing:

Need:

Omni-directional platform has a huge advantage over conventional platform in terms of mobility in congested environment. These environments are commonly found in factory shop-floors, offices, hospitals and warehouses.

Constraints:

The load carrying capacity of the platform is designed for 1 ton which is based upon US Standards for Forklifts. While the size was chosen according to the space provided for walk paths on shop floors (4ft). This product is designed for use on plane surfaces but can work on uneven surfaces as well. This product, at present, cannot be used under bad weather conditions. This Product derive its power form 4 AC Motors which requires a 220V, 60 Hz supply to work. The power port should be in a range of 20 ft. from the switch board.

Criteria:

The biggest challenge for us was to make this product economical & available to masses at convenient prices. As the product only needs electricity supply, (or Battery supply if DC Motor is used which is costly.) Environmental pollution will come under control. Thus making it a sustainable product. The Wheels are Self-locking thus no brakes were used for stopping the vehicle and this also makes it safe to use. The material used is easily available in the market and is also very cheap. Not much consideration was given to aesthetics due to cost constraints related to the project. As this product will benefit the society and reduce our dependence on fuels, 85% of which is imported, it is politically beneficial.

Specifications:

The Specifications of the product are as follows:

Power transferred by each Motor = 94 W

Gear Reduction from Motor to Wheel = 40:1

Load Carrying Capacity = 1 Ton

No. of Independent Drives = 4

RPM = 1360

Working:

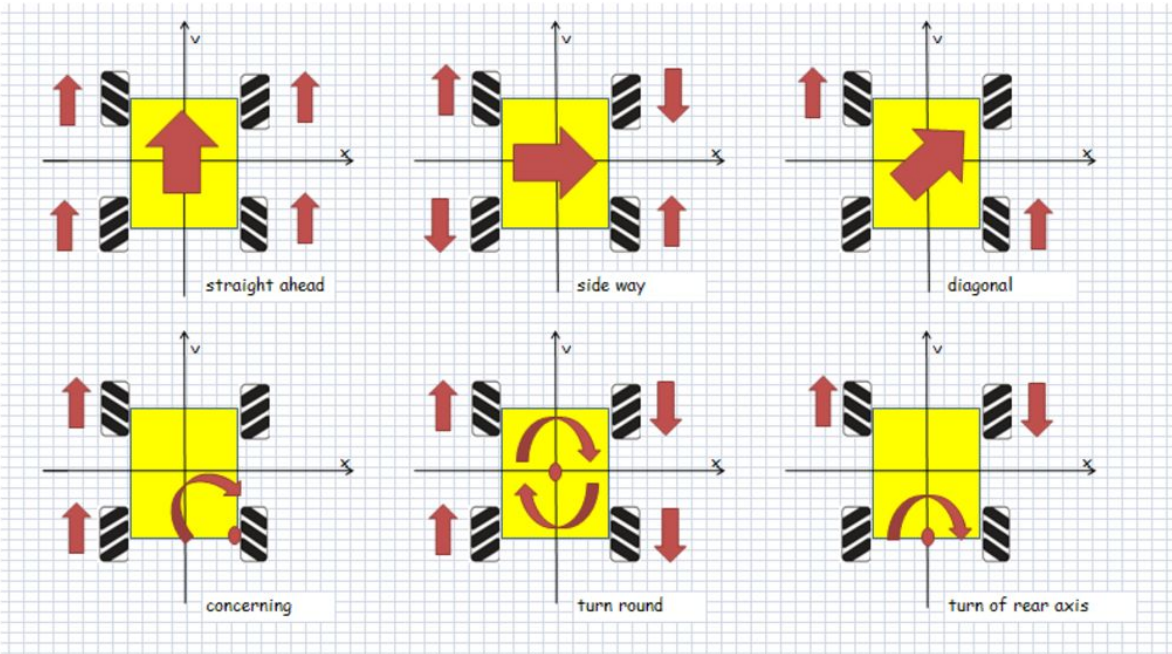


Fig. 3 Different Motions produced by changing orientation of rotating wheels

Components:

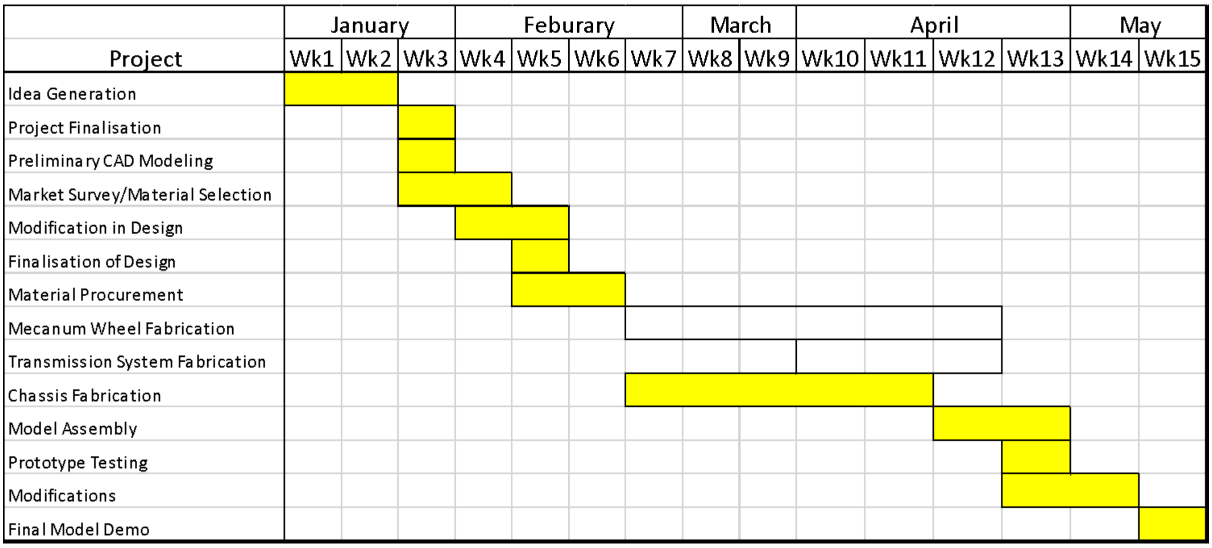
The components of the platform are as follows:

1. Rim
2. Rollers
3. Brackets (Used to Connect Rollers with Rim)

4. Chassis
5. Shafts
6. Worm Gears
7. Angular Taper Bearings
8. Motors

Planning Gantt chart:

Gantt chart for Jayant Mittal



Chapter 2

2.1 Shaft Design

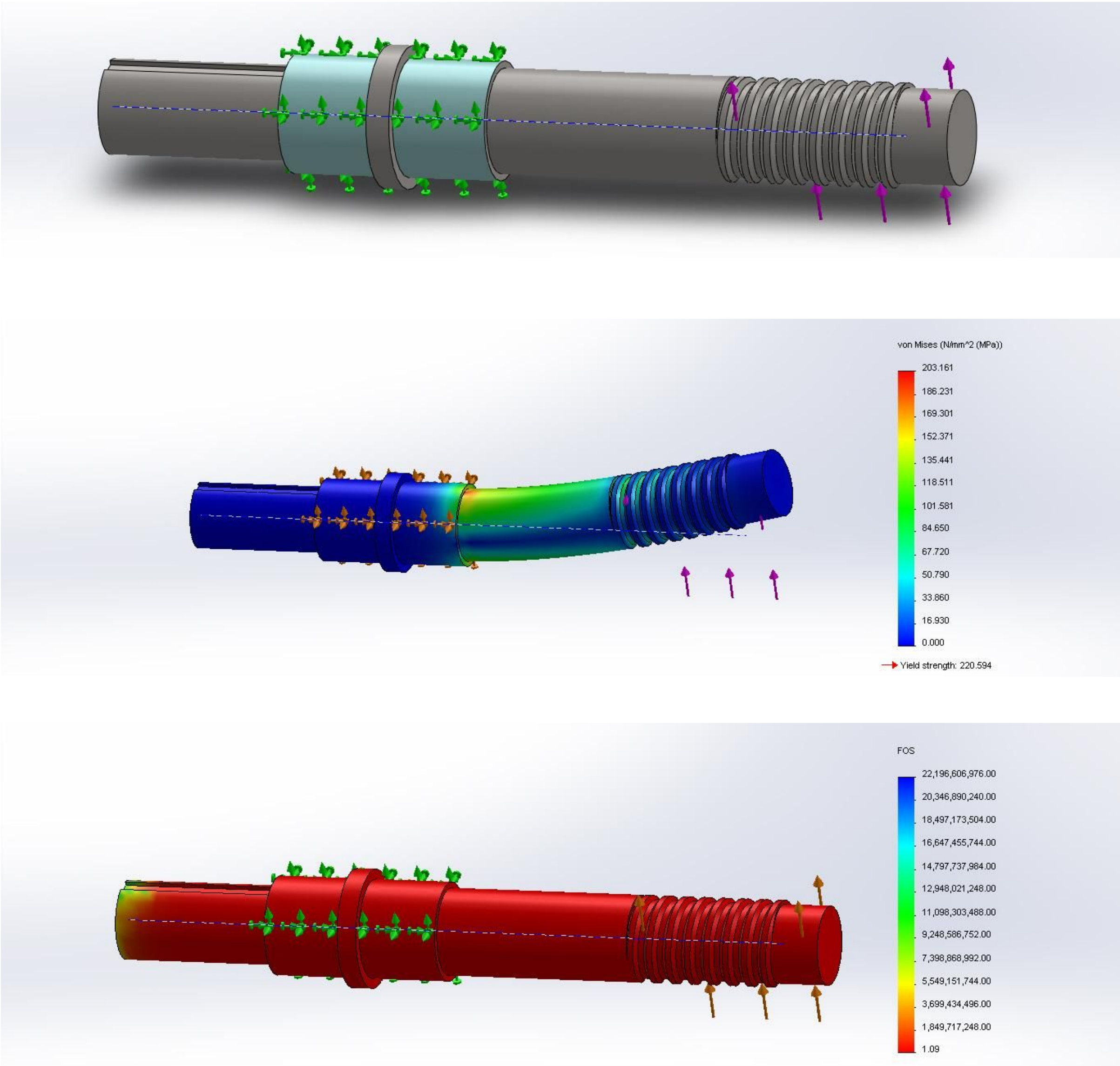


Fig. 4 Load Analysis, Stress Analysis & FOS Simulation of Drive Shaft

Market Surveying & Material Procurement:

Fig. 5 Market Survey

2.2 Design: Chassis Design

The most important objective for designing the chassis was to meet industrial standards to carry load like forklifts. Industrial Forklifts starts from load capacity of 1000 kg. So, our target was to design a chassis which could bear a load of 1000 Kg. In order to do that we started will the following designing consisting of sq. pipes of Cast Iron which are easily available in the market & also are easy to fabricate. Fig. 6 shows our initial design of chassis.

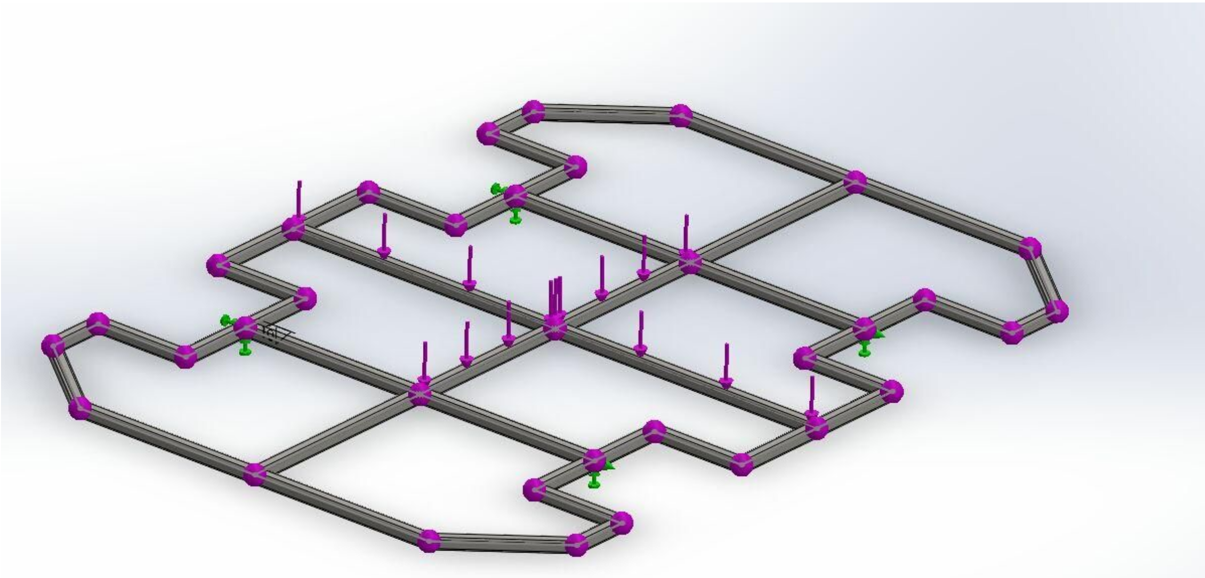


Fig. 6 Initial chassis design

The problem with this design was that it was unable to fulfil the load criteria. (As shown in fig. 7)

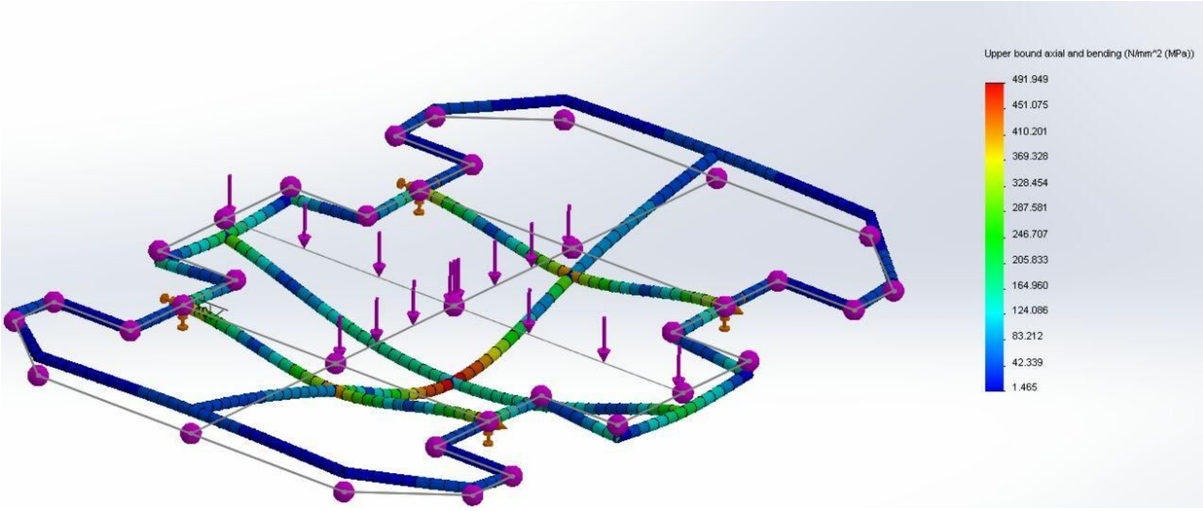
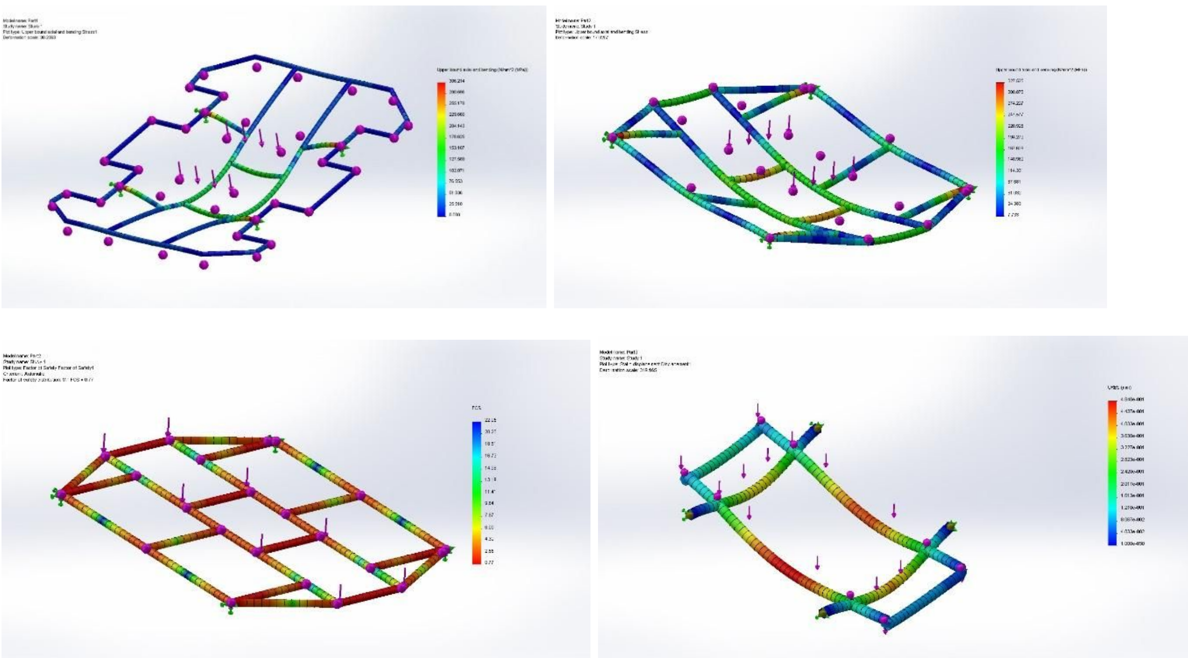


Fig. 7 Load analysis of the design.

A few iteration were made, but the result wasn’t sufficient to fulfil our requirements.



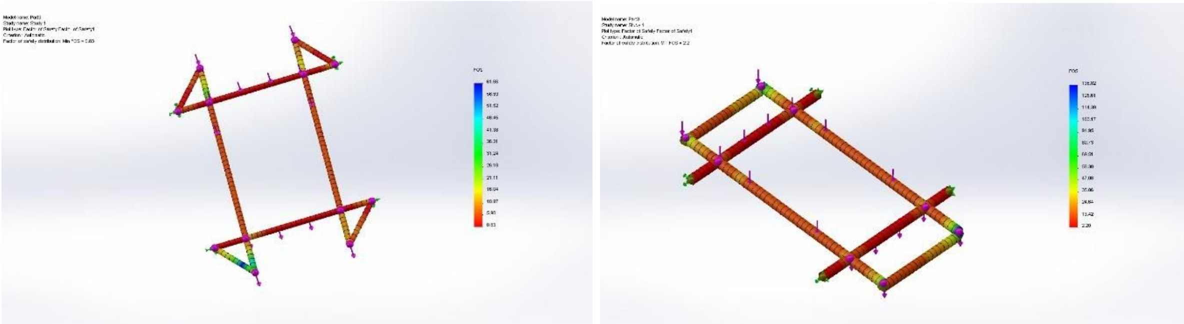


Fig. 8 Analysis of Iteration

So, we discussed the problem with our Course instructor, Prof. AS Jawanda and were able to achieve a new and better design based upon his suggestions.

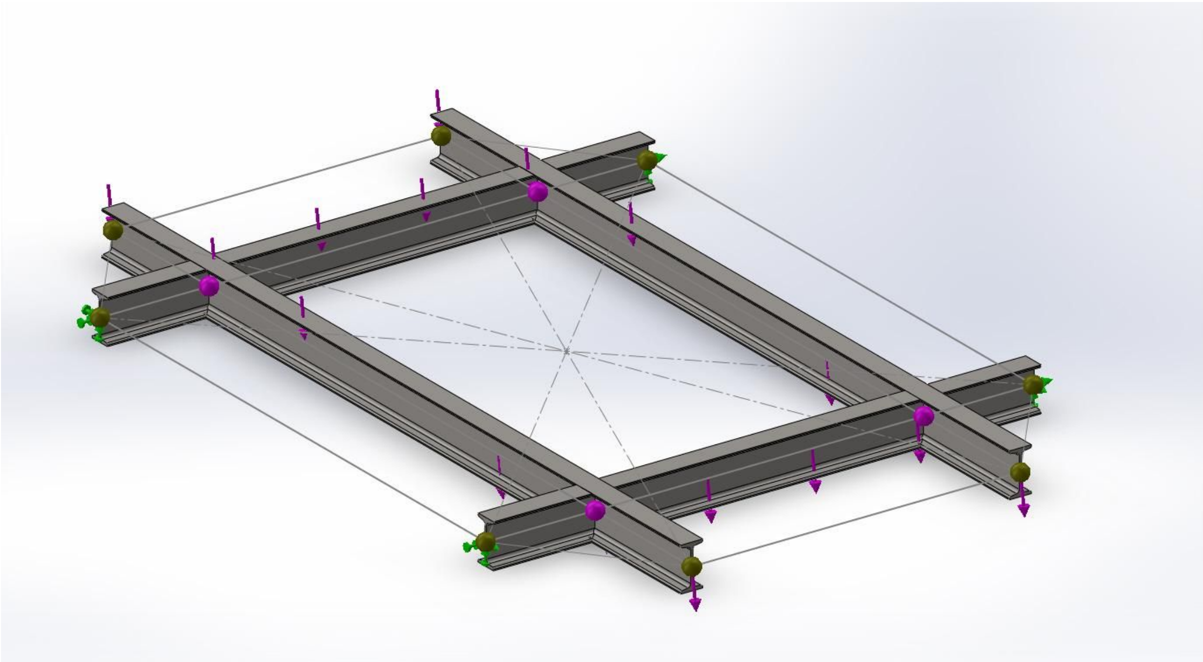


Fig. 9 Chassis based upon I-beams.

2.3 Design: Rim Design

The Objective while designing the rim was to reduce weight without affecting the functioning of the original design of the Mecanum wheel. So, basically we started with the original design (as shown in fig. 10)

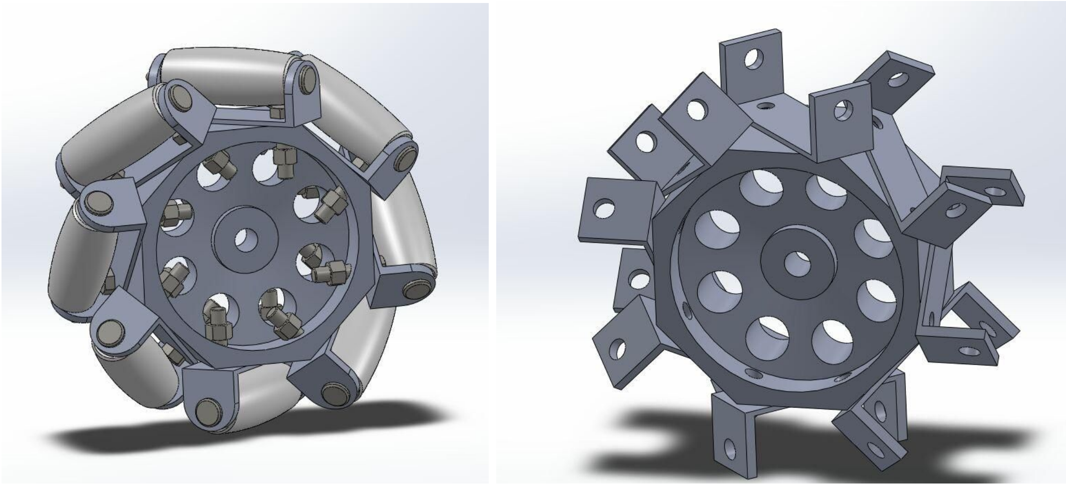


Fig.10 Original Design of Mecanum Wheel

Looking at the Fig. 10, two things were observed. First, reduce the size of the bolts connecting the rollers to the rim & second to increase the hole diameter or merge two or more holes.

The iterations made are as shown below (Fig. 11).

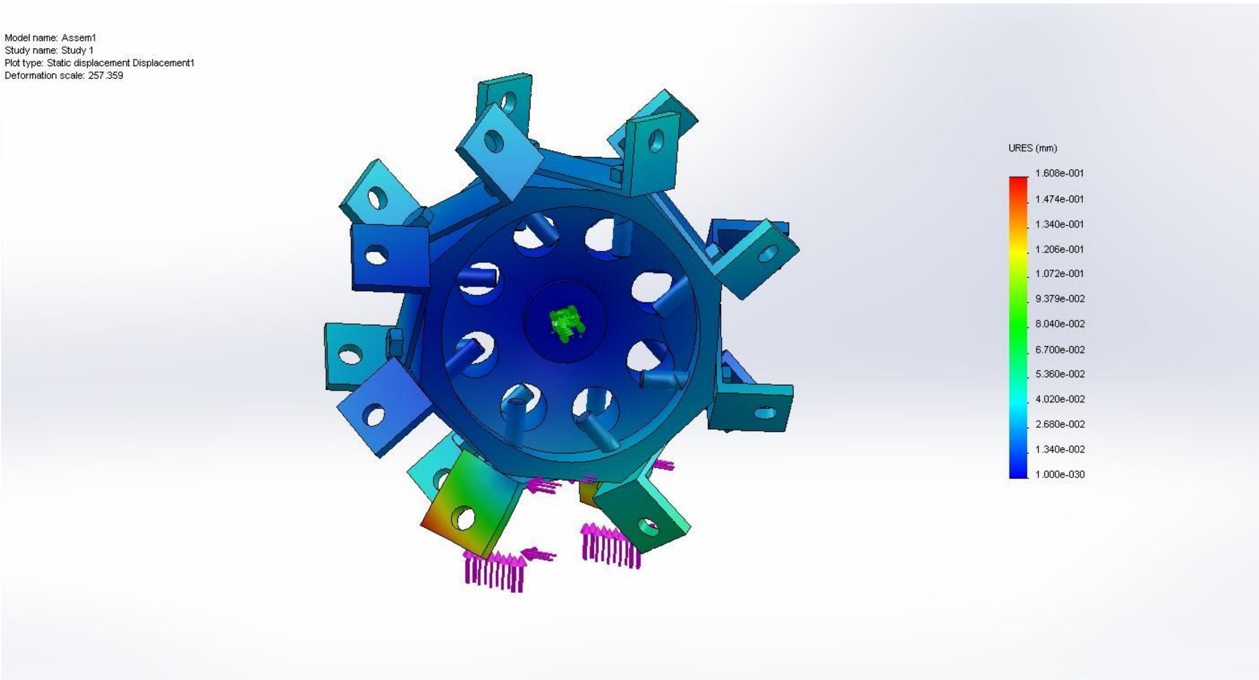


Fig. 11 a) Displacement Study

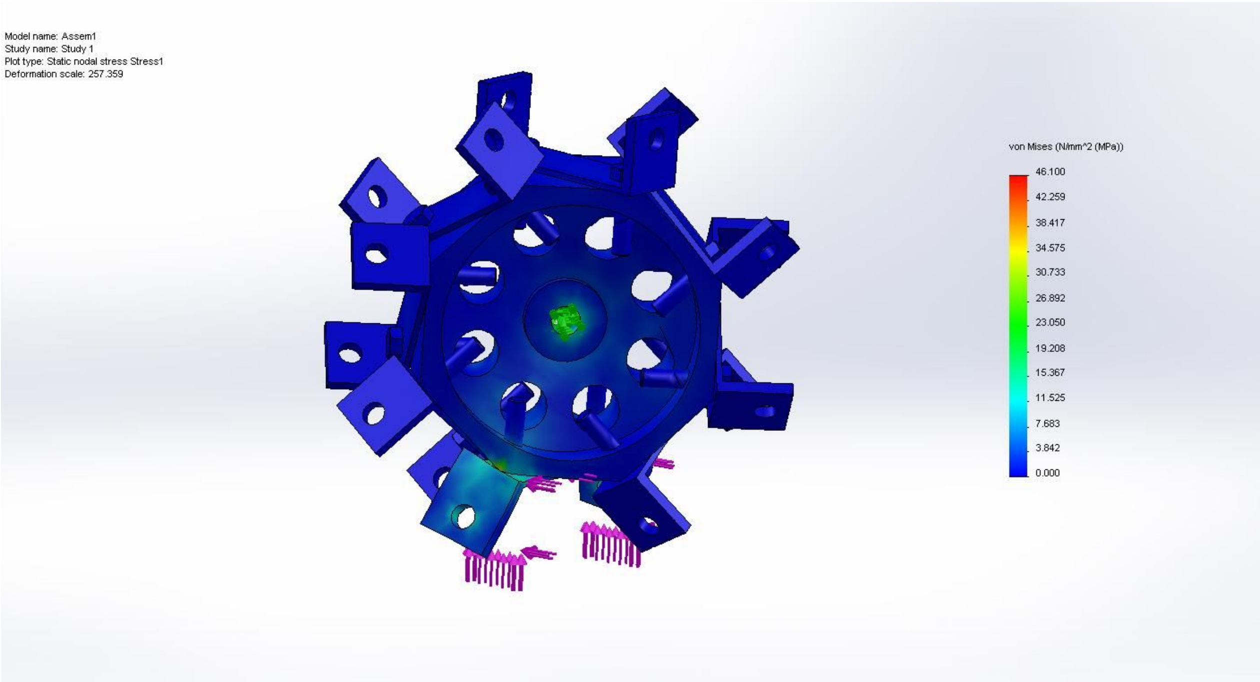
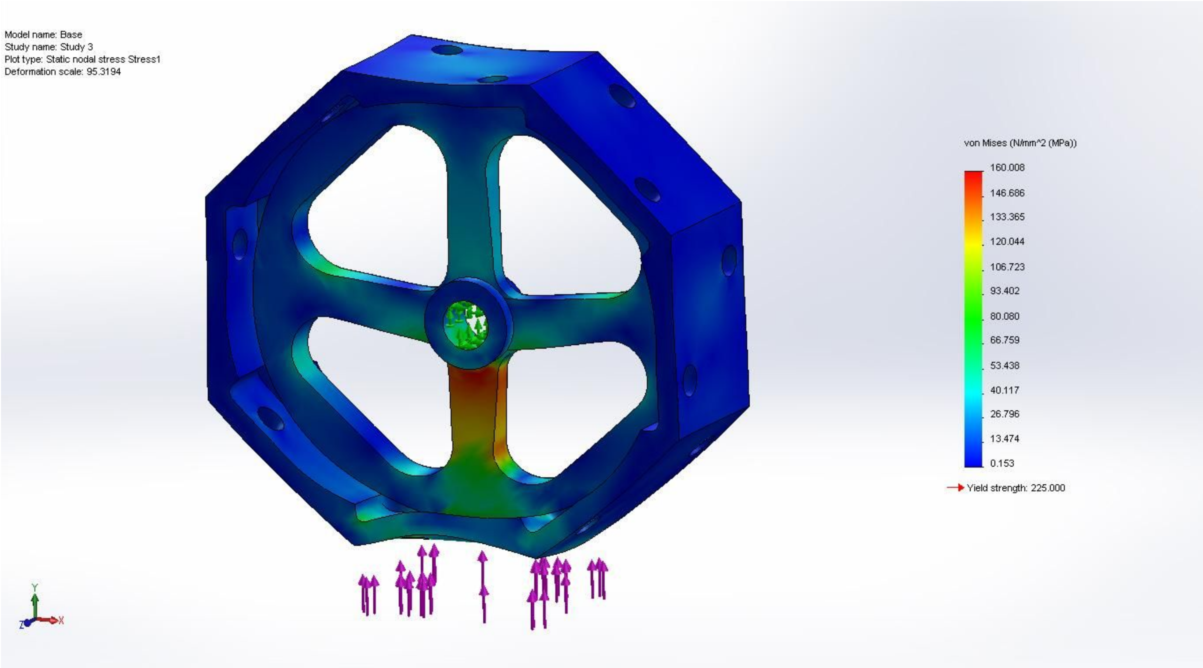


Fig. 11 b) Static Stress Analysis



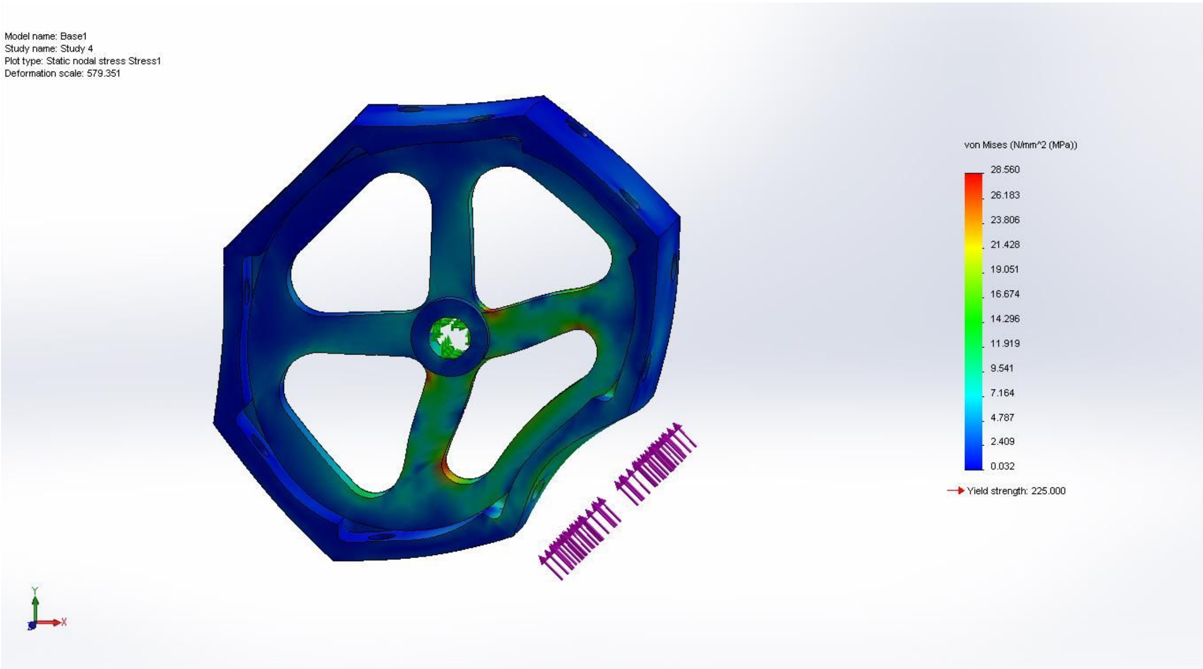


Fig.11 c) Modified Design Stress Analysis

So, as shown in Fig. 11 c), the modified design was obtained.

Power Transmission:

For power transmission we required high torque at low speeds. So we had the following options.

1. Spur Gears
2. Planetary Gear System
3. Worm & Worm Wheel Gear
4. Direct Motor Transmission

A Comparative analysis was done to choose the best option.

	Spur Gear	Planetary	Worm & Worm Wheel	DMT
Size:	Huge	Huge	Small	NA
Speed Reduction:	6:1	8:1	40:1	No Reduction
Ease of Manufacturing:	Easy	Complex	Moderate	Easy
Cost:	Low	High	Low	Low
Torque Amplification:	Yes (Low)	Yes (Moderate)	Yes (High)	No
Maintenance	Low	Moderate	High	Low

Table 2 Comparative Table

On the basis of above table, Best Suitable option is Worm & Worm wheel Gear.

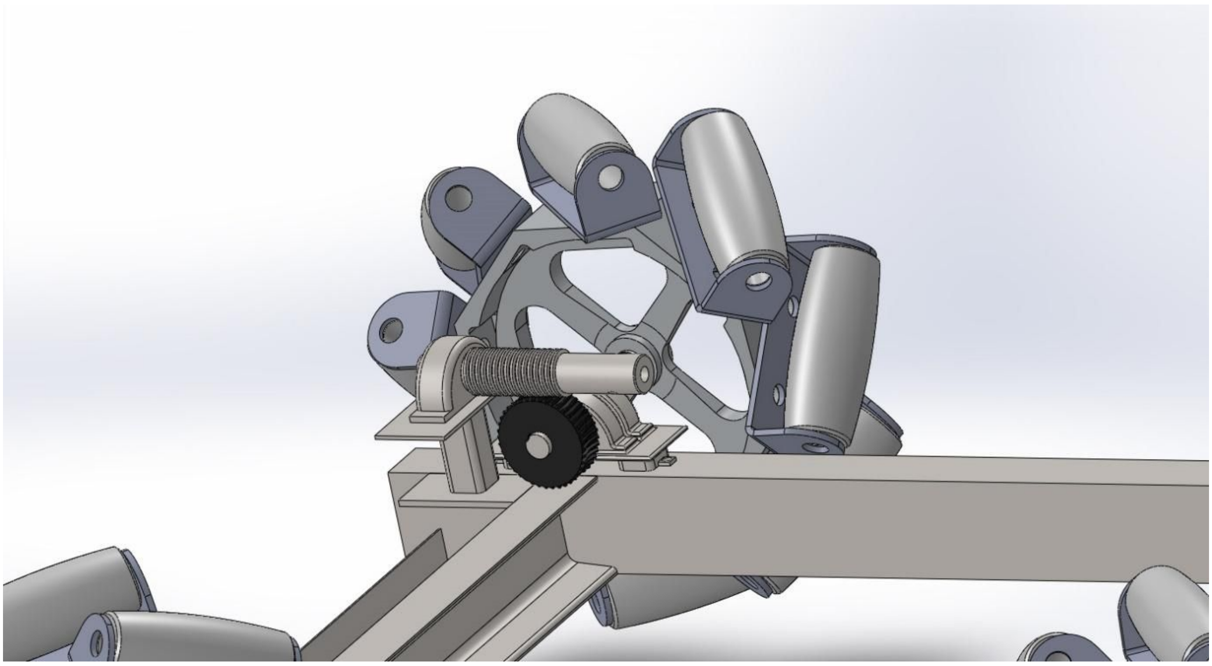


Fig. 12 Worm Gear & Worm Wheel on Chassis

2.4 Design: Roller Design:

There were two options available to us to have contact between the rollers and the rim. Either to have pin joint which will make it easy to replace the rollers if damaged or to have permanent joint which will require to change the section holding the roller with rim to be replaced as well. Shown in fig. 13 are both the options.

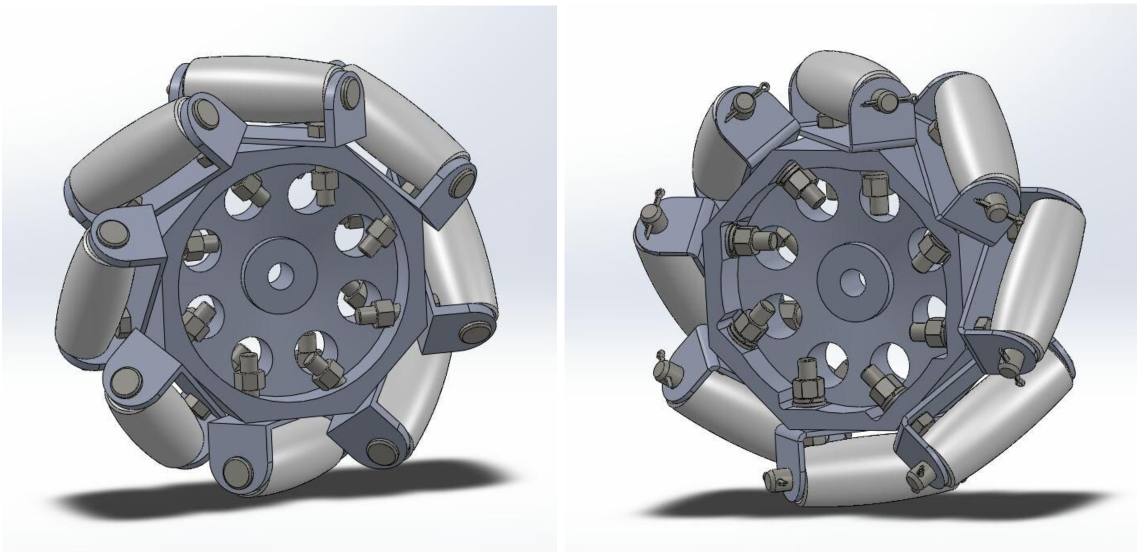


Fig. 13 a) Option for permanent joint **b)** for pin type joint

Also, we had two type of rollers, as shown in fig. 14. We chose option 2 because of the ease of manufacturing.

Fig. 14 Options for Rollers

2.5 Individual Contribution of Munish Arora

Design: Brackets

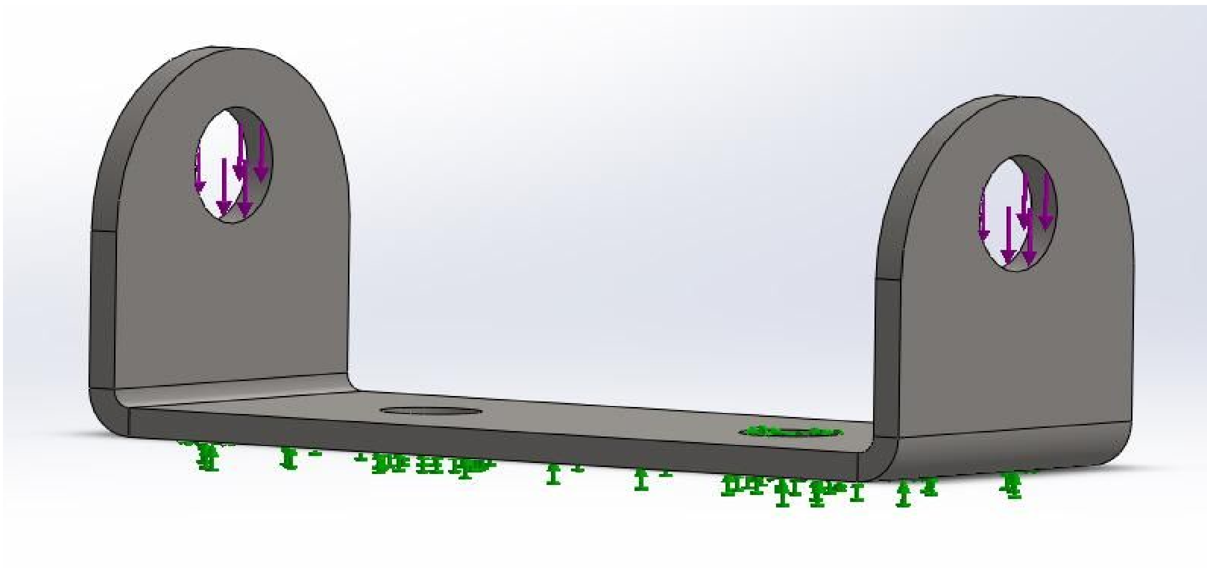
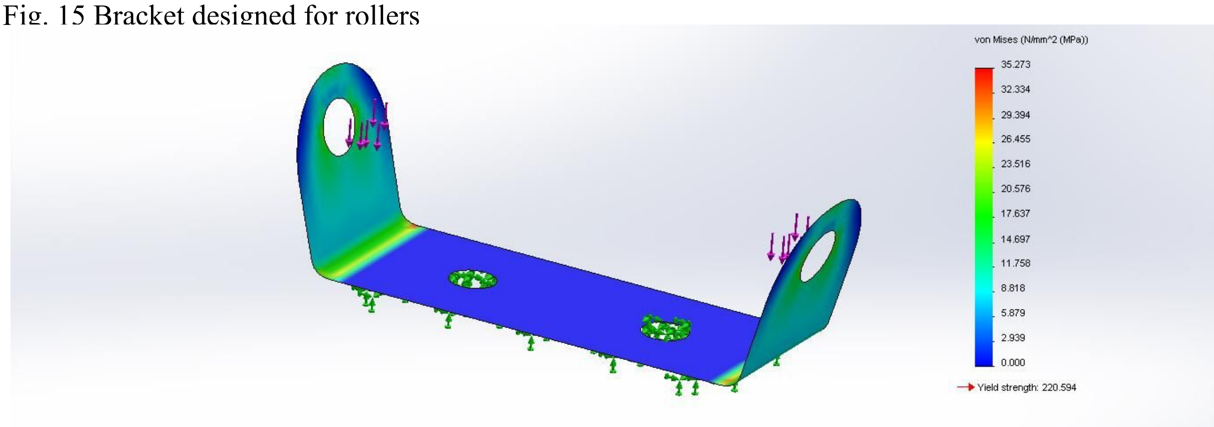
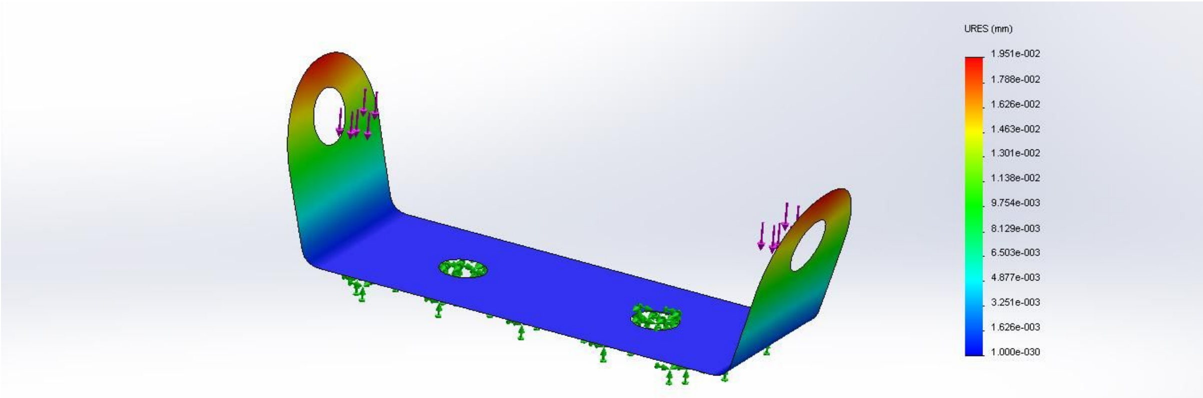


Fig. 15 Bracket designed for rollers





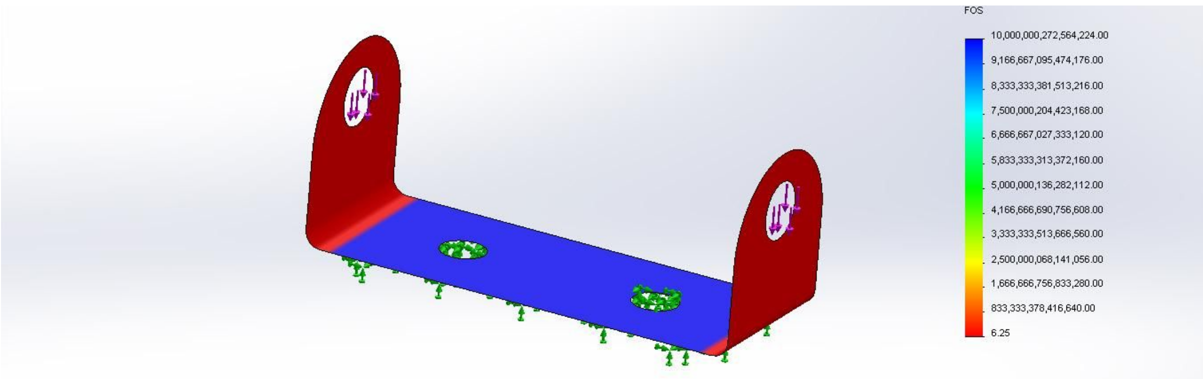


Fig. 16 Load Analysis, Stress Analysis & FOS Simulation of Bracket

2.6 Fabrication

The manufacturing of Wheel Rim. The process is as follows.

1. **Pattern Development**
   after Purchasing the wood block, moisture content was determined before making the pattern.
   After that,
   Rough Cutting, Tolerances, Final Cut & Finishing was done.

2. **Molding Box Preparation**

   Mold Box was prepared.

3. **Sand Preparation**

   Sand was first filtered for removing impurities,

   then molasses was added with ratio of 1:10

   Sand was mixed & finally prepared.

4. **Mold Preparation**

   Mold was prepared & baked with blow torch (using Kerosene oil) till the core became hard.

5. **Aluminium Melting**

   First, Aluminium chipping was done.

   Then, Al was melted in furnace using coke.

   Borax was added to remove slag.

6. **Metal Pouring**

   Al was poured and the mold was kept for cooling.

7. **Extraction of casting**

   Casting was extracted from the mold after cooling it for two days.

8. **Defect Analysis**

   various defects were encountered during the process.

Fig. 17 Wood Block used for pattern development

Fig. 18 Rough Cutting of wood Block

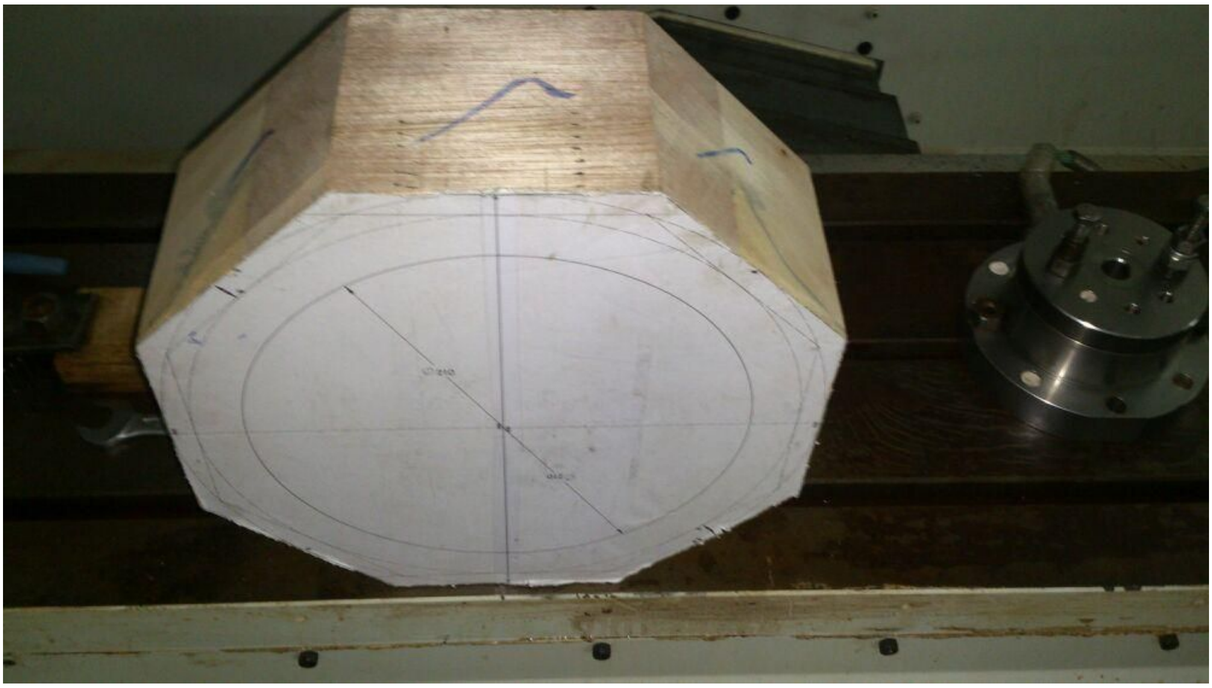


Fig. 19 Loading on CNC Machine

Fig. 20 Smoothening & Finishing of pattern.

Fig. 21 Sand collected for Sand Preparation

Fig. 22 Filtering of Sand before Sand Preparation

Fig. 23 Addition of molasses in sand (1:10 ratio)

Fig. 24 Mixing of Sand & Molasses; Molasses being applied inside moulding box.

Fig. 25 Pattern inside mould box

Fig. 26 Preparation of mould

Fig. 27 Ramming of Sand

Fig. 28 Baking of Core

Fig. 29 Coke burning and Aluminium chipping

Fig. 30 Melting of Aluminium

Fig. 31 heating of core after Al pouring & Breaking of hardened core after cooling.

Fig. 32 Defects occurred in casting

Fig. 33 Modification in Pattern

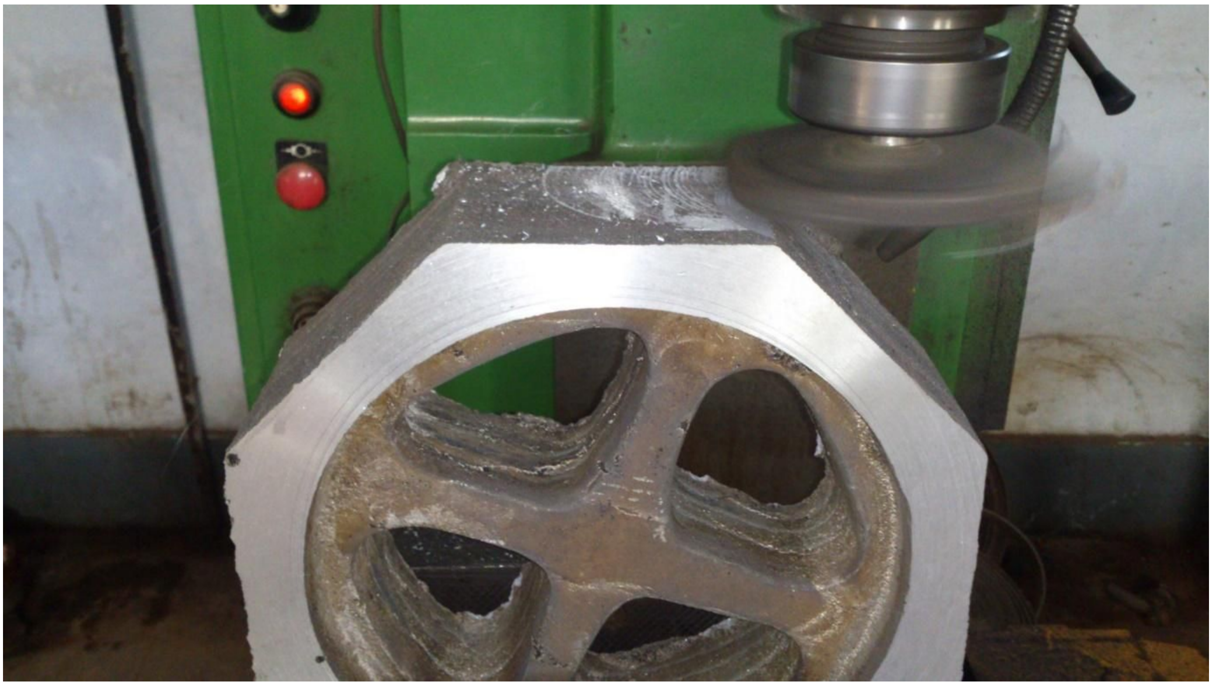


Fig. 34 Milling Operation on Rim

Fig. 35 Lathe Operation on Rim

Fig. 36 Shafts produced after turning, facing & centre-drilling operation.

Fig. 37 Brackets after bending operation

Fig. 38 a) 14mm Drilling on brackets b) Drilling operation during Roller fabrication

Fig. 39 wiring being done.

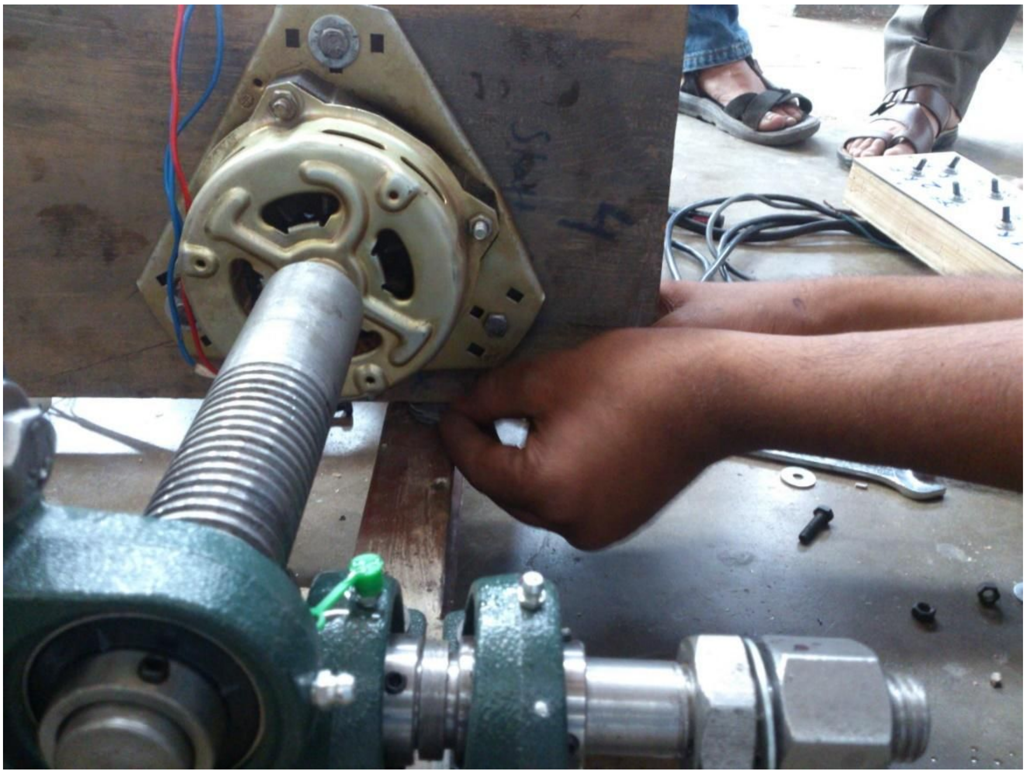


Fig. 40 Alignment of Motor with shaft for smooth operation.

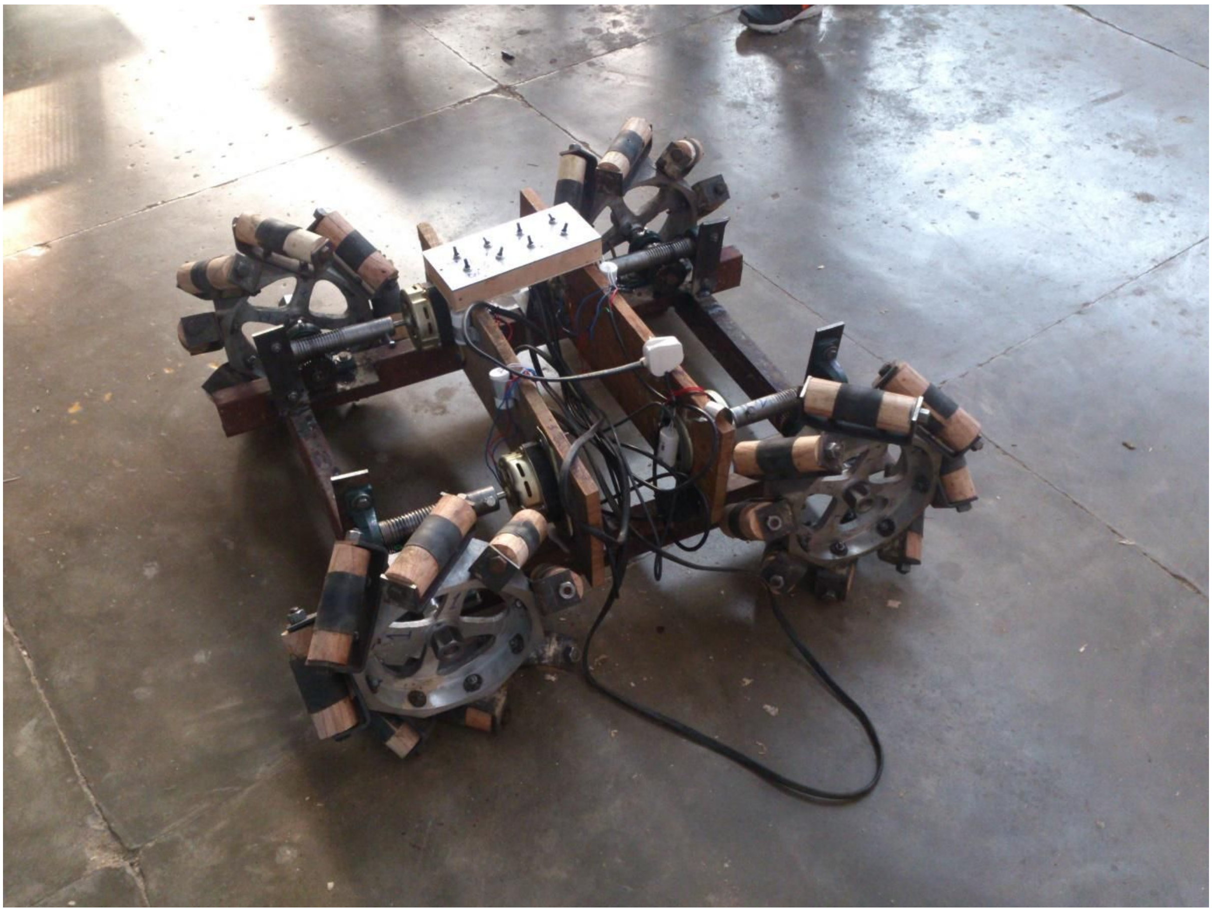


Fig. 41 Final Product

Chapter 3

Learning:

The sole motive of this 6 months project is to give an idea what a real life application of engineering is all about and getting first-hand experience for a market plus production situation is definitely a thing to be proud of. During training we learnt how to identify real life difficulties and solve them with brainstorming. The Initial brainstorming sessions were undertook only to create an entrepreneurial skill among us all. Designing and analysis helped us to get the hands on experience on the techniques and key-points followed for a quality product. Real life fabrication, taking place out of this 15 inches computer screen is a real challenge presented to us by this project.

Improvements:

1. Alloy wheel design of Rim is preferred over flywheel type
2. Rollers used are of Point contact instead of Line contact.
3. To minimize the jerk rubber tube are used.
4. Angular contact bearings UCO205 of 13 degree are installed.

Scope of future Work/Shortcomings:

1. Roller of nylon can be used for optimum performance
2. Shaft alignment
3. Motor of half hp is to be used.
4. A shock absorbing mechanism to absorb unwanted shocks.
5. If more budget is provided DC Motors can be used thus providing mobility.

Overall Conclusion:

Mechanical System design course has been highly successful in imparting to us a detailed idea of how a product is developed in industry. We, beginning from scratch and then arriving at a final product have learnt tremendous practical concepts throughout or journey. This project has familiarized us with the various CAD/CAE software. We now have an overview of the industrial design and are capable of taking new initiatives. As far as the manufacturing part is concerned, we had the opportunities to use most sophisticated as well as the most basic of machines. The understandings and learnings that came with this were tremendous.

Apart from the common everyday ideas which were worthy of tentative projects, we counted on various ideation techniques which would give us an idea that is a combination of innovation, improvement, applicability as well as being able to be manufactured with given resources. We gathered major info through internet (YouTube, Wikipedia, etc.) and looked for recently published research papers which had a scope for MSD. Before deciding on the project topic, we intended to tabulate the applications as well as the different populations our project will affect. When we finalized the industrial application of Mecanum, Wheel, we considered it for a forklift design and thus built the prototype for a capacity of 1ton.

The project is an innovation. It takes the concept of a wheel to a whole new level. This project bears the capacity to shatter our perception that like conventional wheels, all wheels move in just one direction. It is encouragement to budding engineers as well as researchers to think beyond the given horizon and generate new ideas. We learnt about new materials (majorly in plastics) like Teflon, Nylon, PVC, etc. This information was majorly banked on our industrial exposure as well as researches carried out on the internet. Mecanum wheel is relatively unexplored field. Due to this fact majority of the population including our teachers are unaware of this and are oblivious to its working. This made us carry out our own research and go through with the project.

The project has made us capable of undertaking any new innovation on our own. Although we may need to add the fact that nothing is perfect in the first attempt and thus several iterations are necessary to achieve the optimum result.

Final Gantt chart:

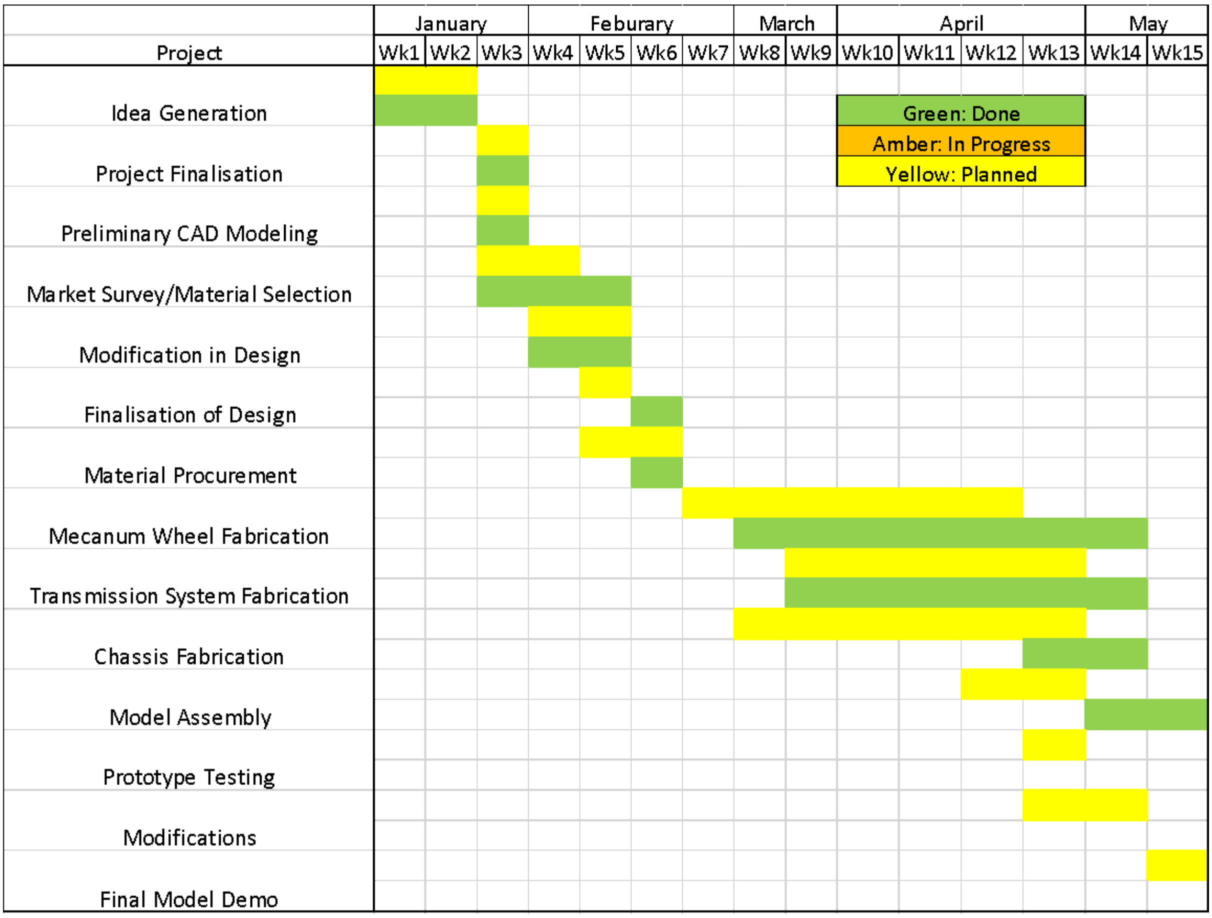


Table 4 Final Gantt Chart

Brief Notes:

1. **What sources of information did your group explore to arrive at the list of problems which could be taken as the project?**

Apart from the common everyday ideas which were worthy of tentative projects, we counted on various ideation techniques which would give us an idea that is a combination of innovation, improvement, applicability as well as being able to be manufactured with given resources. We gathered major info through internet (YouTube, Wikipedia, etc.) and looked for recently published research papers which had a scope for MSD.

2. How many needs were explored to form possible projects? How were the needs analyzed to from criteria, constraints, specifications for separate project proposals?

How many models (alternate designs) were considered to formulate solutions to the need? Briefly describe them.

Before deciding on the project topic, we intended to tabulate the applications as well as the different populations our project will affect. When we finalized the industrial application of Mecanum, Wheel, we considered it for a forklift design and thus built the prototype for a capacity of 1ton.

For the Mecanum wheel project we considered two separate designs but the second one fell through in feasibility analysis due to cost and manufacturability factors.

3. What analytical, computational and/or experimental methods did your project group use to obtain solutions to the problems in the project?

For Design problems we referred to our design course material. Worm gear and Drive was the result of several failed reduction methodologies. We also carried out design optimizations using CAE but still this was base level. Manufacturing problems required an upper hand in experience which was countered with the help of Workshop Staff.

4. Did the project give an opportunity to applying mathematics learnt in earlier courses in the form of differential equations, linear algebra, multivariate calculus, numerical analysis, optimization, etc.? How.

Although major portions of Egg. Mathematics were not used, still we had a chance to use optimization techniques. For future scope statistics come into picture when ergonomics of the vehicle are taken into consideration.

5. Did the project demand demonstration of knowledge of fundamentals, scientific and/or engineering principles? How.

Our project simple works on the principle of angular/ inclined traction force. Rollers mounted on the wheels do this job. The drives are just through electrical motors.

6. Where did you applying scientific and/or engineering principles towards solving problems in the project?

Chassis design was the crucial area where the concepts of Twisting, Bending, etc. had to be take into account. Loading of the chassis was done under several different conditions. The wheels are also completely optimized under different loads like direct compression, twist etc.

Major failure criteria were analyzed for each component and the studies were carried on further from there.

7. Was applying statistical methods in analyzing data necessary any stage in the design, analysis, testing?

Ergonomics is the area where statistics comes into picture for our project. Anthropological data is to be taken into account and the design for 95th percentile is carried out.

8. How did your group shares responsibility and communicate the information of schedule with others in team to coordinate design and manufacturing dependencies.

This was majorly carried out in the MSD tutorial hors where each of the groups sat together and shared their individual progress with the class. This is where the problems faced came to light and synonymous solutions applied.

9. What ethical issues occurred in the course of the project work? What professional codes of ethics were used to resolve the conflicts?

There was a major motion to get the project completed from an external mechanic/ source. Even when majority of the groups bowed on this decision our group remained firm and though good or bad, we still carried out each and every piece of manufacturing within the campus workshop itself.

10. List the societal and global changes that this project may cause.

The project is an innovation. It takes the concept of a wheel to a whole new level. This project bears the capacity to shatter our perception that like conventional wheels, all wheels move in just one direction. It is encouragement to budding engineers as well as researchers to think beyond the given horizon and generate new ideas.

11. What are the economics tradeoffs in your engineering design? What would be the cost if they were not made?

The foremost tradeoff will be the capacity of the drive motor. Due to budget constraints, 1/8 H.P. motor was used which is not capable of driving the vehicle under all circumstances. At least 2 H.P. motor is mandatory and this sliver of a change would have cost us around Rs. 10000 for a set of four motors.

The other tradeoff was the material for different components like the rollers. Ideally they would have been made of Teflon but due to cost issues we had to come down to wood itself.

12. Evaluate the environmental factors in the engineering design of this project.

Environmental factors have relatively low effect. Only consideration is the fact that this vehicle is designed for industrial use and thus ground conditions were taken into account. Rubber padding was thus provided to aid traction.

13. What resources did you use to learn new materials not taught in class for the course of the project? Which of these resources, references and new learnings would you keep for future use / anticipate would be useful in future?

We learnt about new materials (majorly in plastics) like Teflon, Nylon, PVC, etc. This information was majorly banked on our industrial exposure as well as researches carried out on the internet.

14. What has this project taught you about the use of self-learning? Does it prepare you for the future to undertake new and unexplored engineering problems using self-learning?

Mecanum wheel is relatively unexplored field. Due to this fact majority of the population including our teachers are unaware of this and are oblivious to its working. This made us carry out our own research and go through with the project.

Yes, the project has made us capable of undertaking any new innovation on our own. Although we may need to add the fact that nothing is perfect in the first attempt and thus several iterations are necessary to achieve the optimum result.

15. Does the project make you appreciate the need to solve problems in real life using engineering?

Yes. We made vehicle designed for optimum space utilization. It can work in congested spaces, industrial environments. Hence, it is a fact that our problem solving skills have improved.

16. What was the environmental impact, energy requirement / saving / regeneration of your project? Did the project make you appreciate the impact of engineering decisions on energy resources?

Our project did not skew towards the energy field. We were more concerned with automobile aspects.

17. List the engineering equipment, hardware which this project has made you able to use effectively?

Though the list is very long, we would still like to mention the major few.

Lathe Machine, Milling Machine, Drill Machine, CNC Lathe Machine, CNC Milling Machine, Reciprocating Band saw, Circular band saw, Planer Machine, Press Brake machine, Shear Bending Machine, Welding Equipment, and So on…

18. Where was programming of CNC machines, computer programming required in the project?

We used the CNC machines to fabricate our first pattern for casting wheel rims. Circular pockets and surfacing was done using CNC Milling machines. Photographs are attached in the report.

19. List the software tools used to analyze engineering problems in the project.

SolidWorks2012, ProEngineer, KeyShot5, Microsoft Excel, Microsoft Word, Microsoft PowerPoint, etc.

20. How has the project made you able to use solid modeling software for engineering applications?

Rigorous design changes and optimizations along with simulation tools and other CAE products have made us fluent in CAD modelling. Different special purpose modules of these software were also used to carry out design.

Chapter 4

Production and Assembly Drawings:

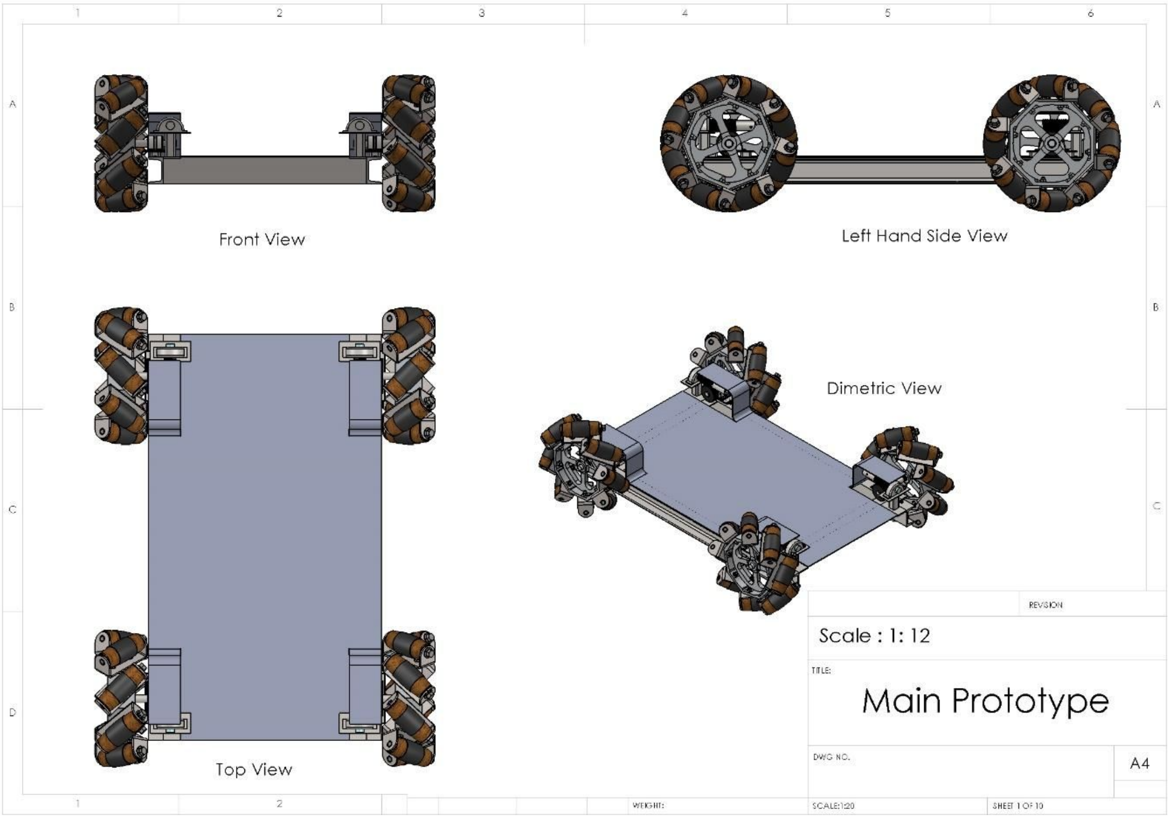
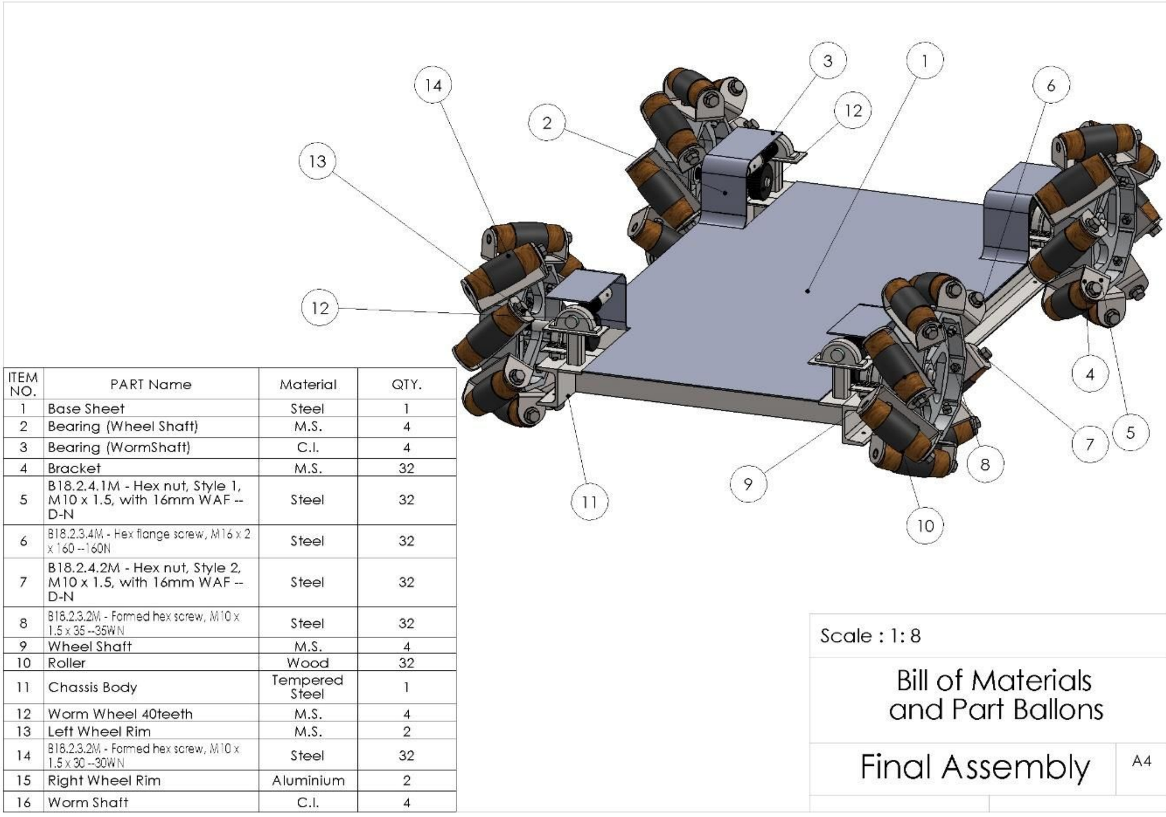


Fig. 42 Main Prototype



ITEM NO.	PART Name	Material	QTY.
1	Base Sheet	Steel	1
2	Bearing (Wheel Shaft)	M.S.	4
3	Bearing (WormShaft)	C.I.	4
4	Bracket	M.S.	32
5	B18.2.4.1M - Hex nut, Style 1, M10 x 1.5, with 16mm WAF --D-N	Steel	32
6	B18.2.3.4M - Hex flange screw, M16 x 2 x 160 --160N	Steel	32
7	B18.2.4.2M - Hex nut, Style 2, M10 x 1.5, with 16mm WAF --D-N	Steel	32
8	B18.2.3.2M - Formed hex screw, M10 x 1.5 x 35 --35WN	Steel	32
9	Wheel Shaft	M.S.	4
10	Roller	Wood	32
11	Chassis Body	Tempered Steel	1
12	Worm Wheel 40teeth	M.S.	4
13	Left Wheel Rim	M.S.	2
14	B18.2.3.2M - Formed hex screw, M10 x 1.5 x 30 --30WN	Steel	32
15	Right Wheel Rim	Aluminium	2
16	Worm Shaft	C.I.	4

Fig. 43 Final Assembly

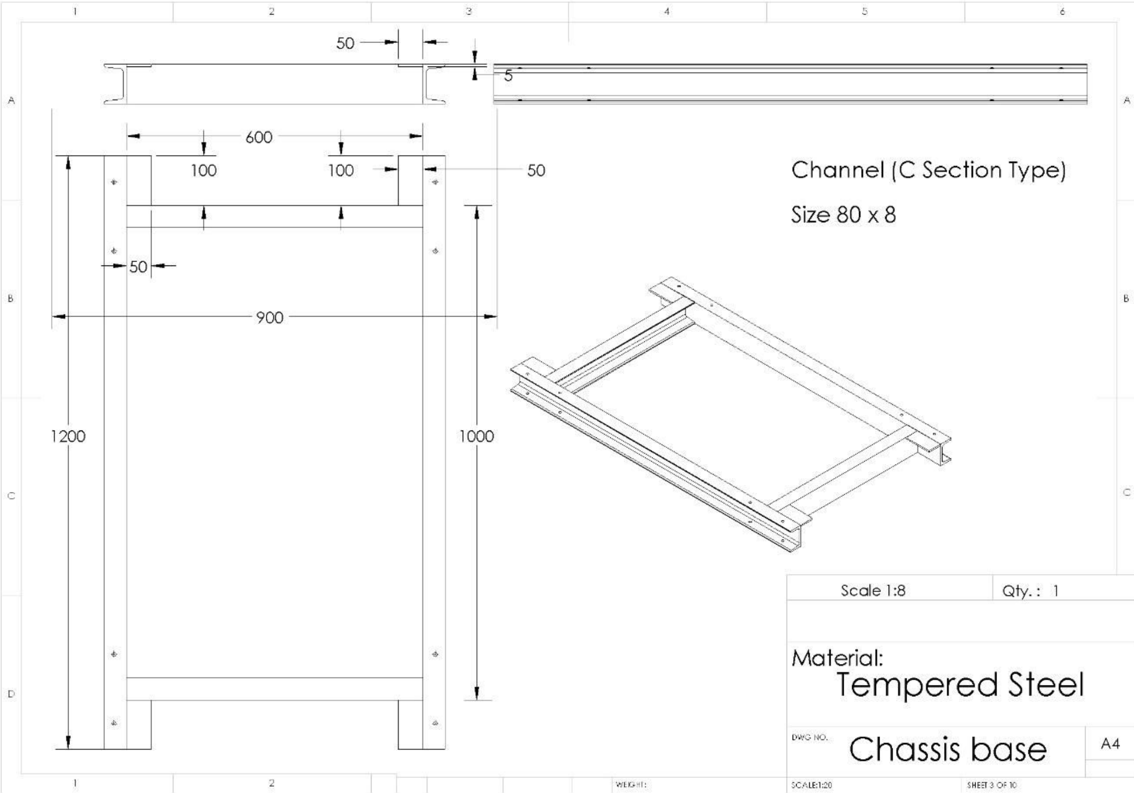


Fig. 44 Chassis

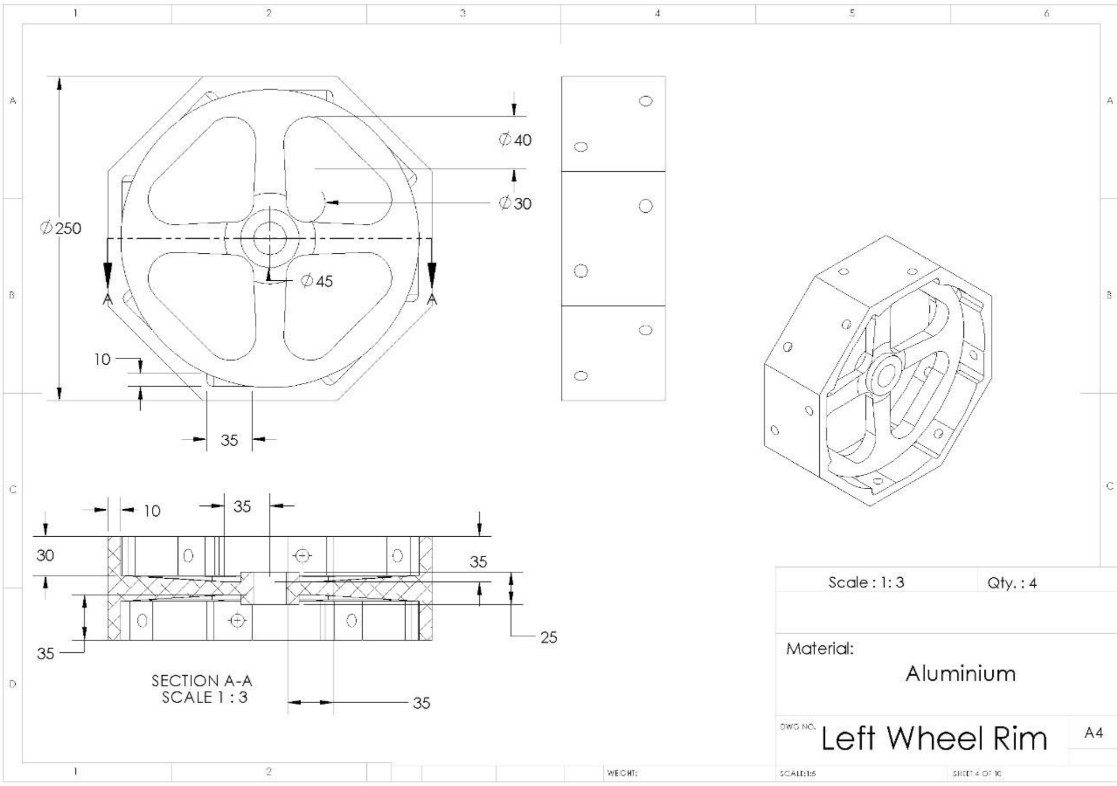


Fig. 45 Wheel Rim

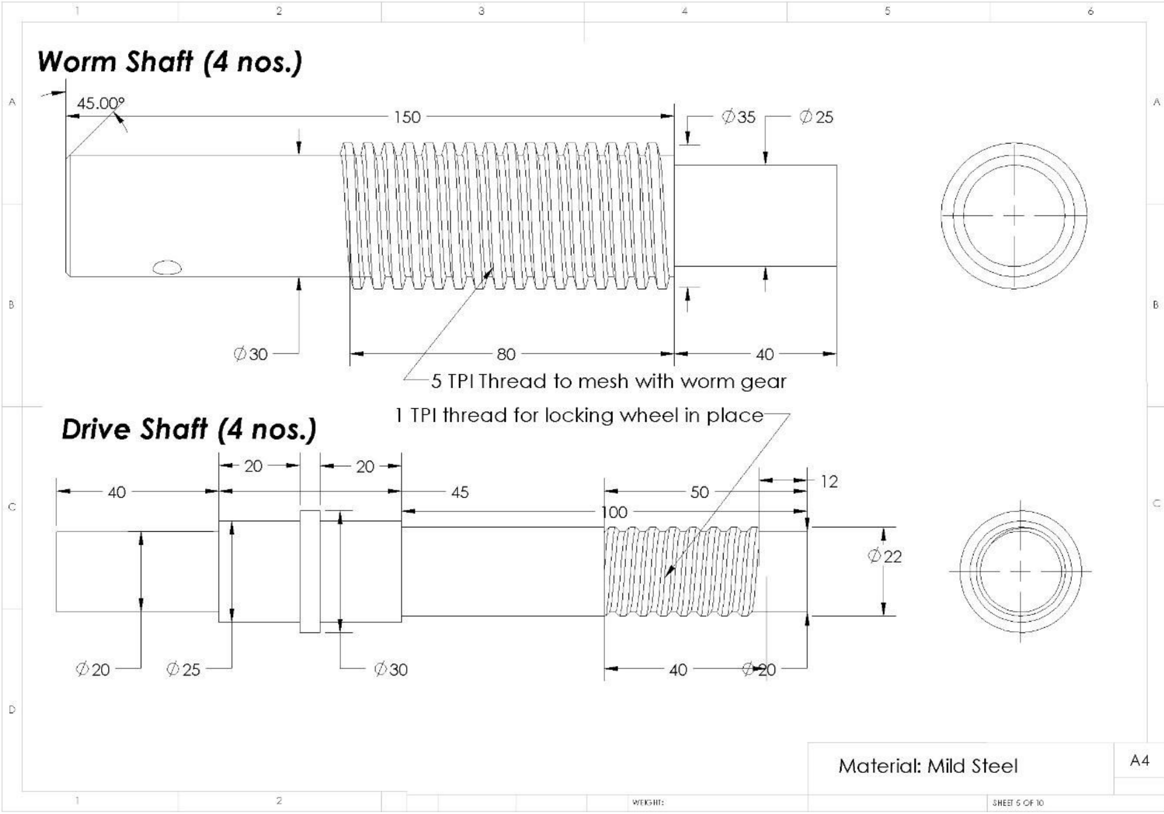


Fig. 46 Worm Shaft

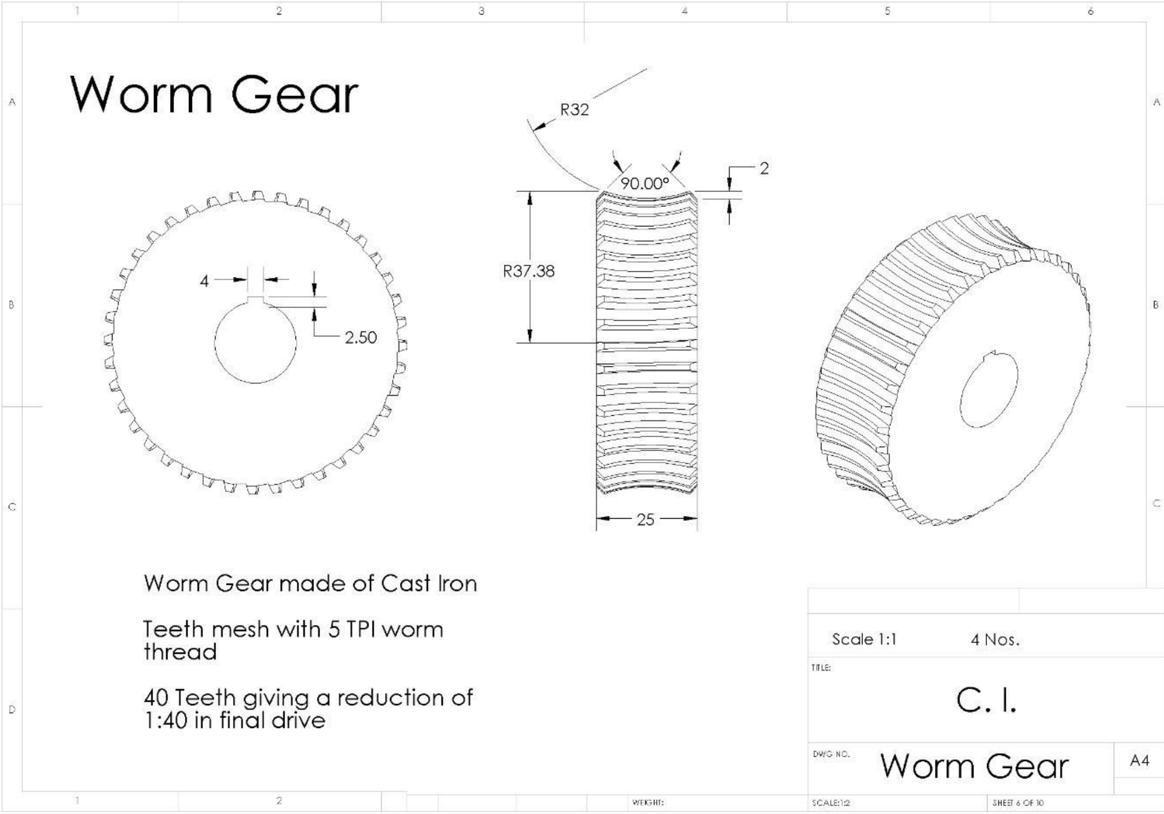


Fig. 47 Worm Gear

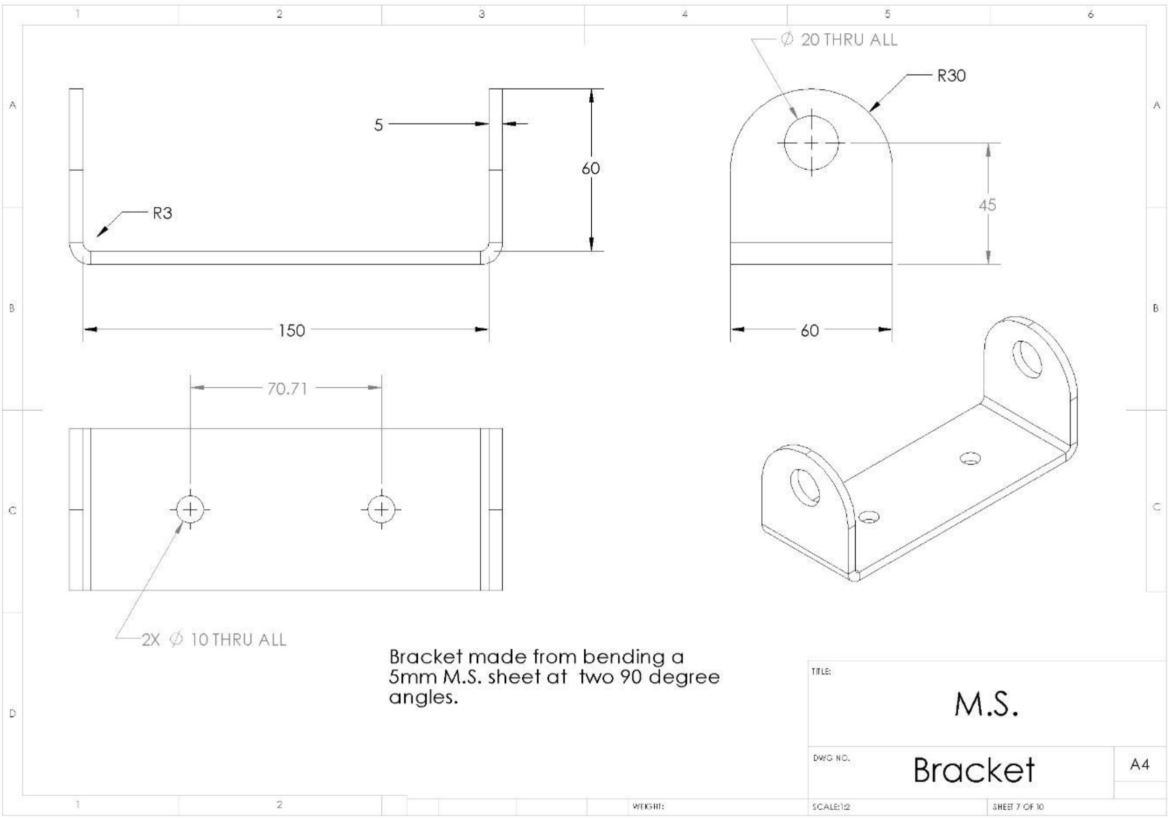


Fig. 48 Bracket

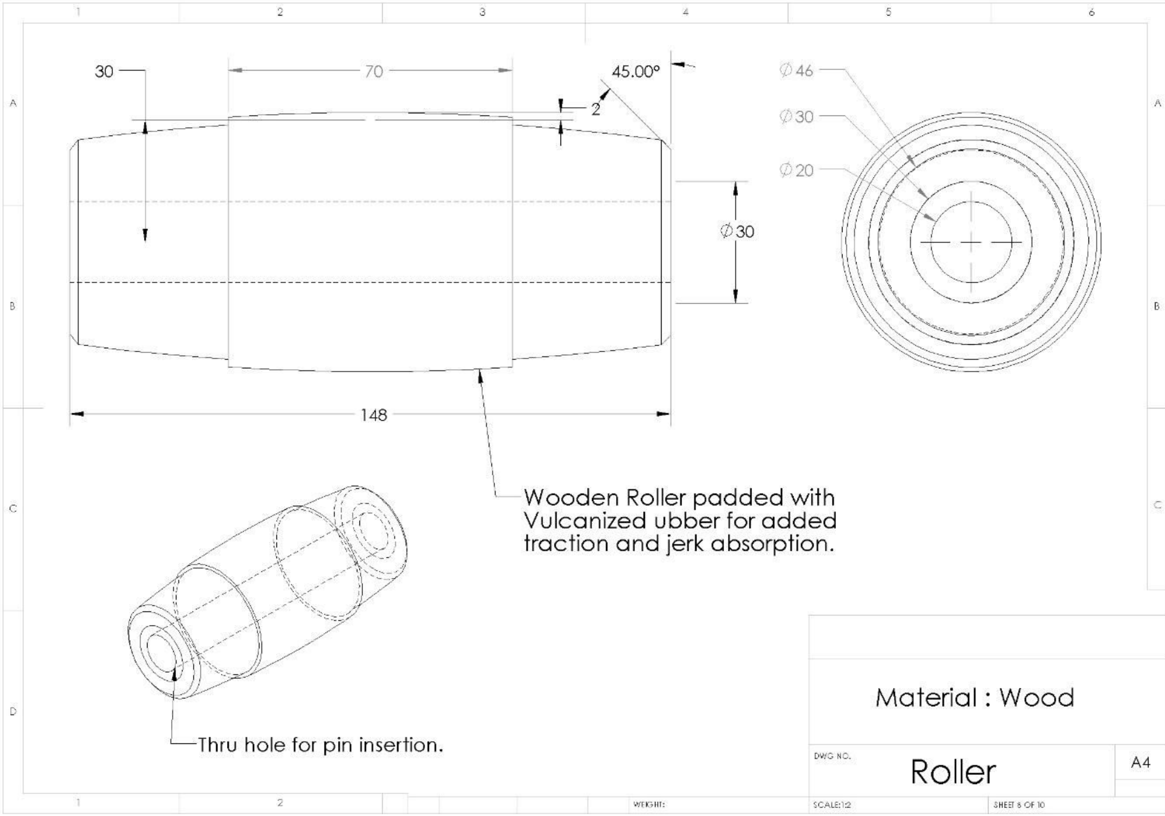


Fig. 49 Rollers

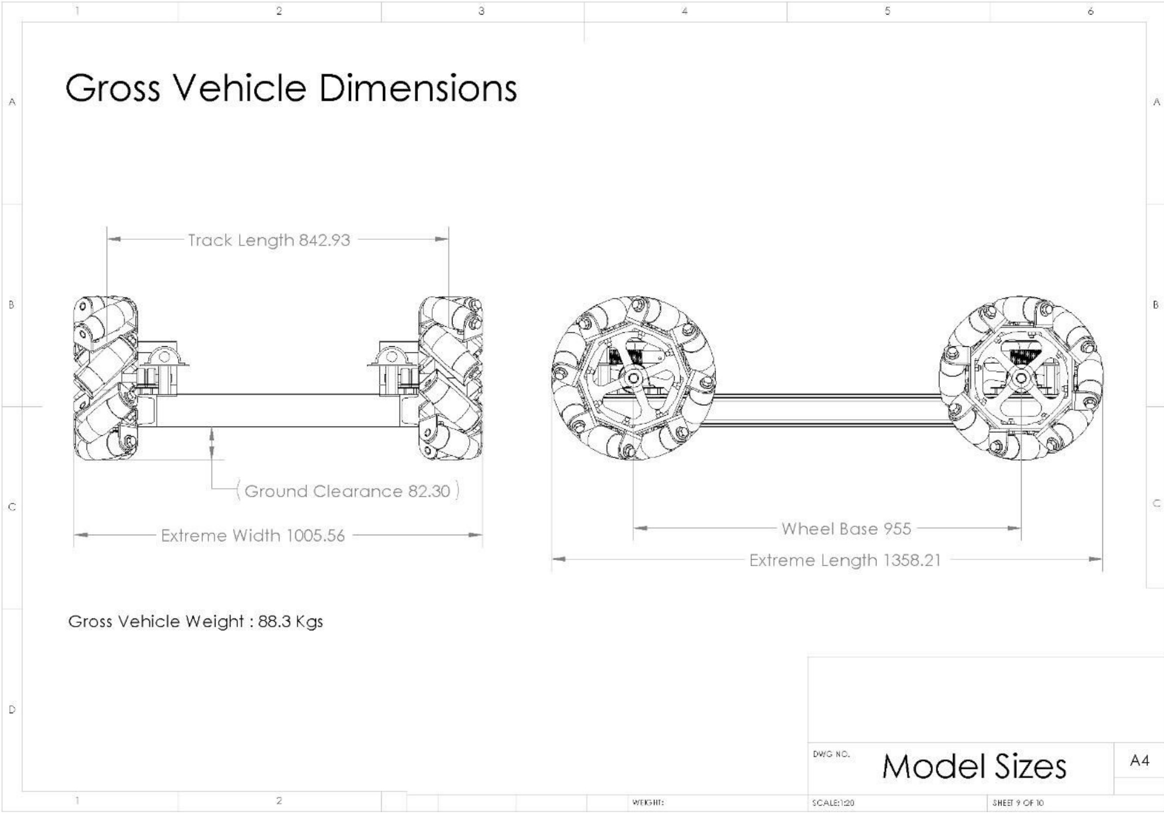


Fig. 50 Dimensions of final product

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