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Design, Analysis and Fabrication of Macanum Wheel

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Abstract - A Mecanum Wheel has been re-designed for better performance and utilization by Helical Robotics. Mecanum Wheel is a complex "Omni-Directional" wheel that currently contains several drawbacks. The drawbacks include complex design, usage of hobby grade material, bumps in rollers, etc. A comprehensive design of the Mecanum wheel is being presented using Computer Aided Software, CAD and analysis tools, such as Finite Element Analysis, FEA. The different concepts were hand sketched using various parameters and then implemented in a CAD software - CATIA. The Mecanum Wheel's feasibility was thoroughly studied through ANSYS software. Load analysis was performed using various materials and several manufacturing processes carefully, to check the achievability of the wheel. In conclusion, the Mecanum wheel was successfully re-designed and manufactured to meet the requirements and specifications of Helical Robotics.

***Key Words*:** CAD,CATIA,ANSYS,FEA

1.INTRODUCTION

The purpose of this thesis is to re-design the Mecanum Wheel produced by a company called AndyMark. Mecanum Wheels produced by AndyMark are currently being used by the company Helical Robotics for its Robots. Different wheel plates have been designed keeping the requirements and specifications in mind. These wheel plates were re-designed by AndyMark to avoid any legal complications from the patented wheel plates already being designed and used by a competitor. To make the re-designed wheel stand out from the current one, some of the dimensions of the wheel were significantly improved upon. The combinations of several different manufacturing processes along with different materials helped in concluding the best design which will be later covered thoroughly in this thesis. Load analysis was performed on the wheel to check feasibility. A significant amount of research was concluded and taken into account regarding wheel efficiency.

Omni-directional wheels have been used in robotics, in different industries and in logistics for many years. The first Omni-directional wheel was patented in 1919 by J. Grabowiecki in US, which was allows for in- place rotation which prevents ground friction to a great extent and results into low driving torque. Mecanum Wheels allow a robot to achieve Omni-directional movement while supporting large weights. A Mecanum-style wheel drive consists of two main components which are visible in Figure1.1 below [not famous. Mecanum Wheels were first invented in 1973 by Swedish inventor Bengt Ilon [1]. This wheel is designed in such a way that, the rollers are mounted around the circumference of the wheel at 45 degrees to the wheel plane. This design of wheel [2]

Fig.1: Mecanum Wheels Mounted on Robot Manufactured by Helical Robotics

Mecanum-style drive uses 4 wheels from which, 2 are “left” wheels and 2 are “right” wheels. One right and left wheel is on each side of the robot. Each wheel is driven independently which requires 4 individual motors [3]. The Figure 1.1 shows the magnetic climbing robot manufactured by Helical Robotics. This robot is lightweight and portable and the magnet used by the robot also does not touch the work surface. It can climb up to 7 ft. height without using any wireless components. This thesis study only concentrates on the designing of the Mecanum Wheel and analyzing its manufacturing process and material.

2. PROBLEM STATEMENT

One of the main problems faced by Helical Robotics in using Mecanum Wheel manufactured by AndyMark is that the wheel is not of expected quality and is unable to withstand high loads. The rollers have been reportedly performing poor. The material on the rollers has been reported to be ripping away after some usage.

Some of the common typical problems with the Mecanum Wheel are:

- Unable to perform smooth motion.
- Roller supports, bolts, nuts, etc. which are closed to hard rolling surface suchthat very small bumps and ledges when vehicle translates sideways.
- The current weight of the wheel is a serious concern.
- The complex design of the wheel has too many individual components

3. MECANUM WHEEL DESIGN DEVELOPMENT

3.1 Design Procedure for Rollers

As mentioned, rollers are designed in part design. The following steps describe the roller design procedure:

1. First, using the sketch feature outer roller body isdesigned.
2. Shaft profile is designed in part design workbench which is then generated as a full solid.
3. A circle is then created and after that pocket feature is used to create hole by removing material.
4. Roller is rotated at an angle of 45 degrees. Circular pattern is createdwhich generates 16 rollers in total.

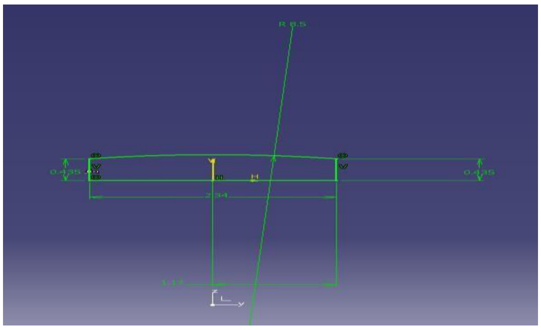


Fig 2: Roller Profile Designed in CATIA

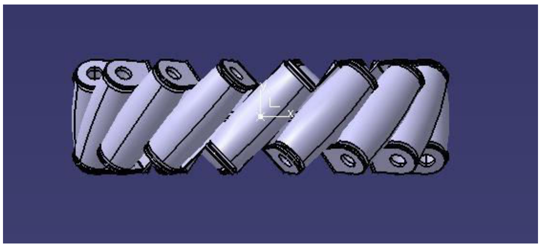


Fig 3: Circular Pattern of Rollers Created in CATIA

The design profile of roller in CATIA is shown in Figure 2

As seen in diagram the roller dimension are as follows:

Width: 11 mm.

Length: 60 mm.

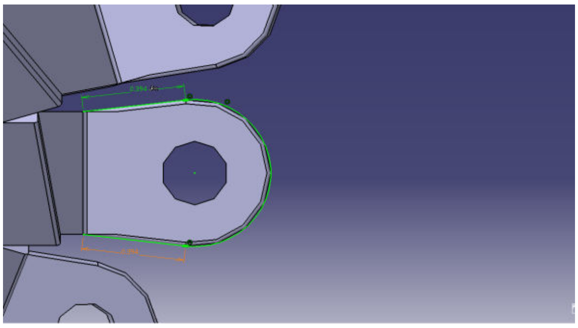
Radius of curvature: 216mm.

After generating the roller pattern it is realized that there is overlapping of rollers which is not desired in Mecanum Wheel. Efficiency of wheel decreases because of bumpiness which occurs due to the overlapping of rollers. This overlapping of the rollers is corrected by affinity feature which is available in CATIA. This feature has been used to reduce the overall size of the rollers by 33%. This value of reduction has been selected after trying different values and has also proved to be beneficial as overlapping could be eliminated. Figure 3 represents the circular pattern of the rollers which does not involve overlapping.

3.2 Design Procedure for Pate

Flange is circular patterned keeping the instance same as the number of rollers which is 16. The Figure 4 shows the design of flange along with its dimensions from which it can be noticed that the length is 10mm and the dimension of the hole is 3.2mm. Pad is created in part design of same thickness as that of plate. A quadrant is created on padded area and pocket feature is used to remove the material. It is then circular designed to have 4 such quadrants. The design and the dimension of the pad is shown in Figure 4. which mentions that the circle is of dimension of 76mm. diameter and also the radius of curvature of the quadrant is of radius 38mm which is also shown in the Figure 5

Fig 4: Design of the Flange Along with its Dimensions in CATIA



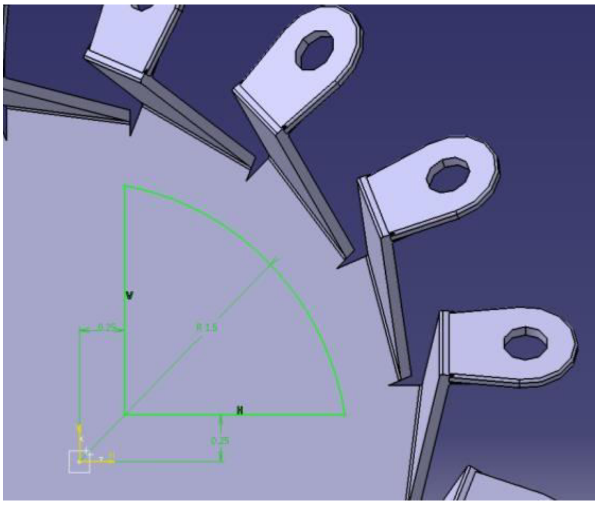


Fig 5: Design and Dimension of Pad and the Dimension of the Quadrant

After creating all these parts in product design all parts like rollers, flange and plate are assembled. 16 rollers are placed in assembly design feature and the plate is attached while aligning the holes in the plate to the holes in the rollers. A similar plate is also placed at the bottom surface and then aligned with the holes of the bottom part of the roller. The 4 view of the Mecanum Wheel plate is shown in Figure 6:

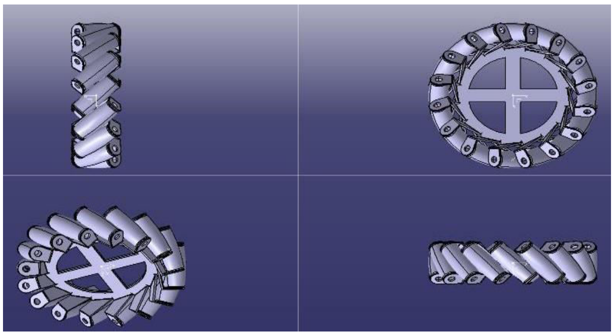


Fig 6: 4-View of Mecanum Wheel Designed In GSD WORKBENCH

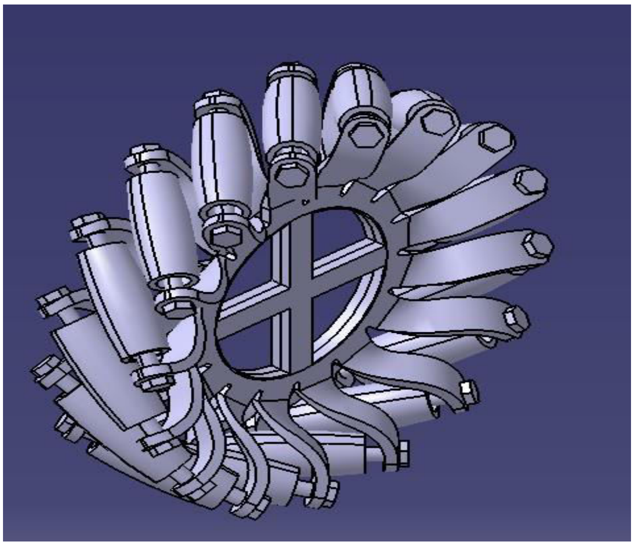


Fig 7: Modified Mecanum Wheel 1 Designed in CATIA

4. FINITE ELEMENT ANALYSIS OF MECANUM WHEEL

Structures designed tend to fail by applying larger loads. They can undergo various modes of failure such as, buckling, brittle fracture, ductile fracture, impact, creep, thermal shock, wear, etc. as well as stress and strain failures [16]. In order to check the feasibility of the structure FEA analysis was performed on the different designs of the Mecanum Wheel by following the steps mentioned below.

The main aim is to check the feasibility of the Mecanum Wheel under different loads and conditions. The feasibility of the wheel is checked considering two different materials i.e Structural Steel and Aluminum Alloy. Analysis is performed on the main designs of the wheel. The first analysis is performed on the wheel design that has been modeled in GSD workbench. After importing the geometry, it is actually generated as it is transferred from CATIA to ANSYS. Analysis done on wheel modeled in GSD.

Details of "Geometry"

Definition	
Source	P:\final hopefully_files\dp0\Geom\DM\Geom.agdb
Type	DesignModeler
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	7.0195 in
Length Y	4. in
Length Z	6.6497 in
Properties	
Volume	34.47 in^3
Mass	3.4495 lbm
Scale Factor Value	1.
Statistics	
Bodies	34
Active Bodies	34
Nodes	80543
Elements	41062

Fig 8: Parameters for Structural Steel

Details of "Geometry"

Definition	
Source	P:\final hopefully_files\dp0\Geom\DM\Geom.agdb
Type	DesignModeler
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	7.0195 in
Length Y	4. in
Length Z	6.6497 in
Properties	
Volume	34.47 in^3
Mass	9.7756 lbm
Scale Factor Value	1.
Statistics	
Bodies	34
Active Bodies	34
Nodes	80543
Elements	41062
Mesh Metric	None
Basic Geometry Options	

Fig 9: Parameters for Aluminium Alloy

Details of "Force"

Scope	
Scoping Method	Geometry Selection
Geometry	5 Faces
Definition	
Type	Force
Define By	Components
Coordinate System	Global Coordinate System
X Component	0. N (ramped)
Y Component	0. N (ramped)
Z Component	7000. N (ramped)
Suppressed	No

Fig 10: Force Parameters Used For Wheel Center

4.1 FEA Using Structural Steel

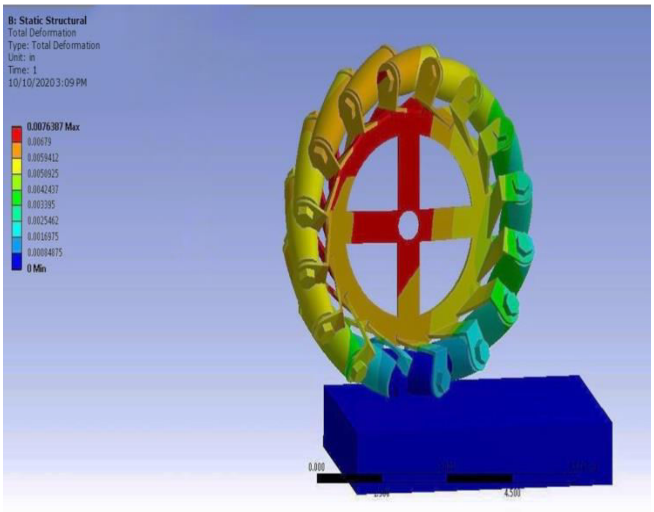


Fig 11: Deformation in Structural Steel

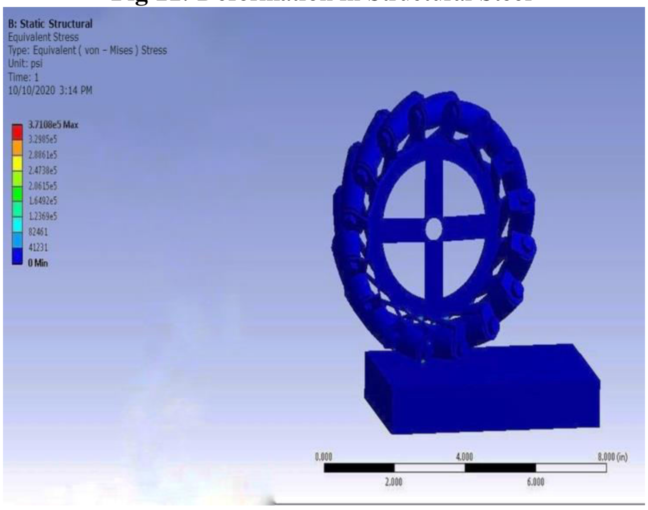


Fig 12: Equivalent Stress Distribution in Structural Steel

4.2 FEA for Modified Design Using Structural Steel

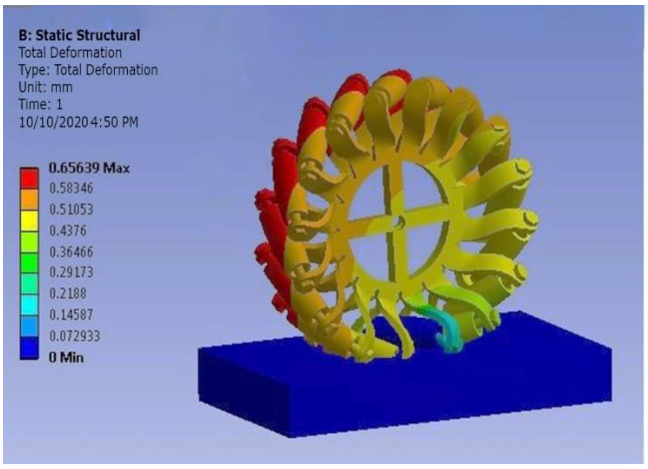


Fig 13: Deformation Undergone By Structural Steel

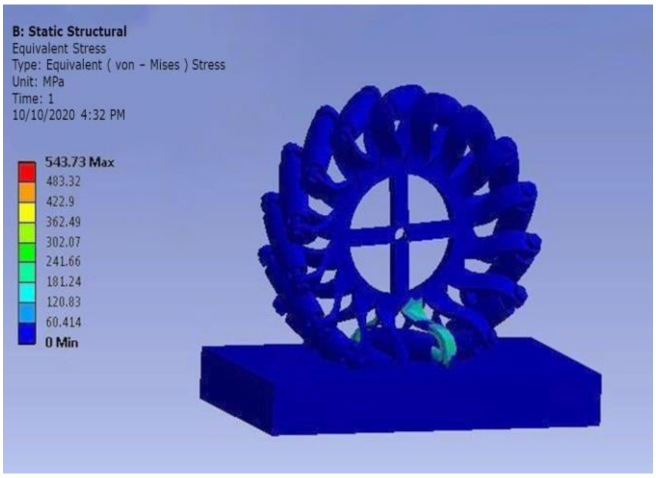


Fig 14: Equivalent Stress Distribution in Structural Steel

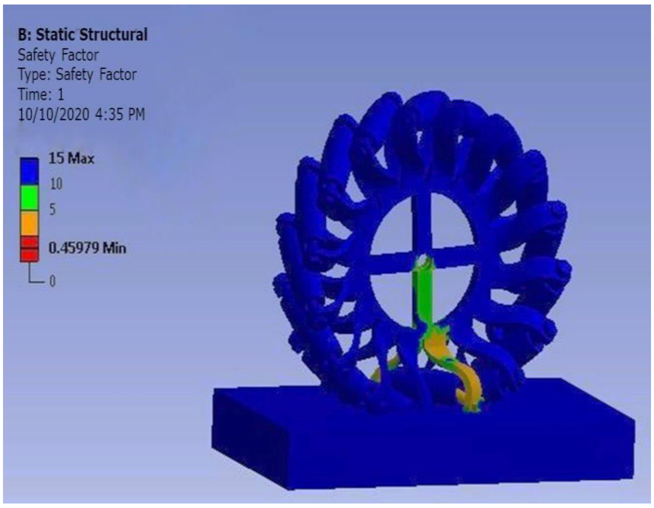


Fig 15: Safety Factor Noticed in Wheel for Structural Steel

4.3 FEA for Modified Design Using Aluminium Alloy

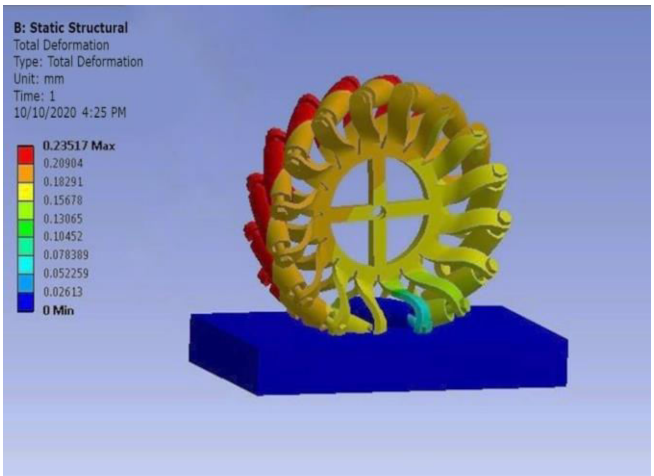


Fig 16: Deformation Undergone By Aluminium Alloy

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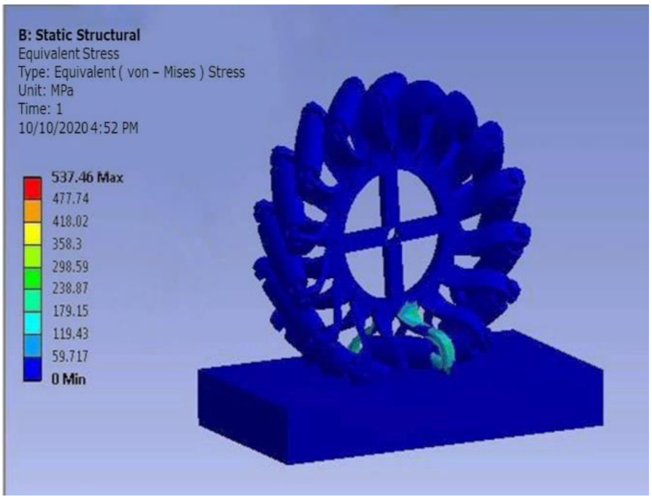

Fig 17: Equivalent Stress Distribution in Aluminium Alloy

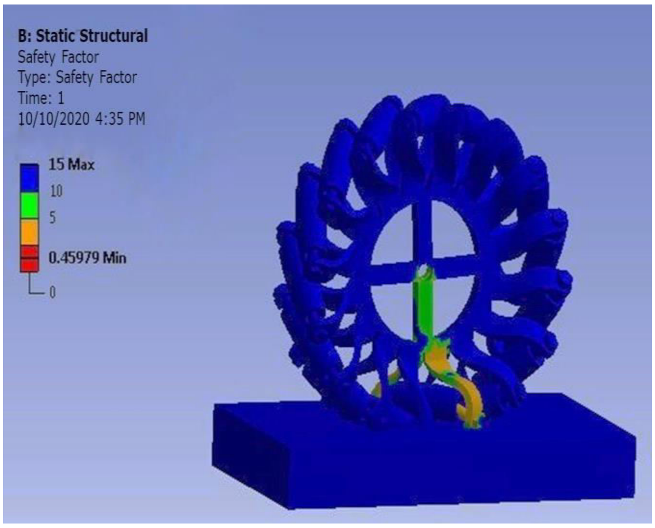

Fig 18: Safety Factor Noticed in Wheel for Aluminium Alloy

4.4 Result Comparison

Type of Wheel	Deformation (mm)		Equivalent Stress (MPa)	
	Min	Max	Min	Max
Structural Steel	0	0.1940	0	689.47
Structural Steel using Modified Design	0	0.6564	0	543.73
Aluminium Alloy	0	0.2351	0	537.46

5. MANUFACTURING PROCESS AND MATERIAL FOR MECANUM WHEEL

5.1 Manufacturing of Rollers

Rubber rollers are manufactured through many different methods such as the plying method, extrusion method, press method and cast method etc. Using plying method or calendaring method, a sheet is covered on to the iron core which is not widely used. Extrusion method uses rubber on the iron core using an extrusion machine. Press method uses rubber which is filled into a metal mold and pressed with heat and pressure. Casting method uses liquid resin which is filled into a metal mold and heated in oven.

Material used for manufacturing roller is as follows:

- Viton rubber.
- Silicone.

Specification of rollers mentioned below:

- Weight: 0.159 kg.
- Length: 38mm .
- Diameter: 19mm.

5.2 Manufacturing of Wheel Plate

Wheel plate can be manufactured using many different methods. Most wheels have been manufactured using Aluminum/Steel stamped plates alone; spot welded Steel stamped plates, riveted Steel plates, plastic or nylon core between the plates for structural reinforcement. The main idea is to manufacture the wheel as a one part using stamping method, which is one of the most prominent methods that can be used.

5.2.1 Stamping Method:

This technique utilizes level sheet metal which is either in clear or loop structure. This sheet metal is put into a stamping press where an instrument passes on surface structures of the metal into a foreordained shape. Other manufacturing process such as punching, banking, embossing, bending, flanging and coining can also be done on sheet metal using stamping.

Stamping is also a single stage operation in which the desired form of sheet metal part is formed by every stroke of the press or could be done through a series of stages. Stamping is usually done on cold metal sheet. It has also replaced die forging and machining. Also, progressive stamping can be used for metal working method that includes punching, coining, bending and other modifying process combined with an automatic feeding system. Each station performs one or more operations until the part is made.

Rotary plate stamper is one of the equipment that is used to stamp the parts instead of using the stamping press. The surface speed of the stamping wheel is synchronized with the speed of the plate using a friction drive between the plate and the drive wheels. This wheel is actuated by a PLC signal, which is also in constant contact with the plate. The marking wheel rises automatically when once the entire plate hasbeen stamped. A manual stamping mode can be used for additional marks on long plates[31].

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Fig19: Working Model of Mecanum Wheel

6. RESULT AND CONCLUSION

The main aim of this thesis was to re-design the Mecanum Wheel as desired by the company Helical Robotics. The idea behind designing the wheel structure was to have a design which is different from the design proposed by AndyMark, which is known for their Mecanum Wheels. Along with coming up with different designs, it was also important to have the most optimum and feasible design while reducing the current flaws. Some of the problems along with their solutions are described below:

1. Bumpiness is sometimes noticed while the wheel is in motion:

To overcome with this problem it is very necessary to set the roller radius in such a way that it does not experience bumpiness. If the rollers overlap they cause problems and even gap between them causes discontinuous motion which results into bumpiness of the wheel. For this thesis as per the new design the radius of roller is assumed as 13mm. This was assumed by trial and error process.

2. Material used by both rollers and the wheel plate:

To overcome this problem, different materials for both rollers and wheel plate are uesd. For the wheel plate it is beneficial to use Steel or Aluminum. Based on the Durometer and hardness Scale, two of the materials that are suggested to use are Viton rubber and Silicone . With using both of rollers and wheel plate, Weight is also reduced from 862 gm to 472 gm. And from result comparison we can say that stresses are also reduced.

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