UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled “ Automated Guded Vehicle “ is written by Huzairi Bin Hashim . I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Signature

Name of Supervisor: EN MOHD FADZIL FAISAE

Position: LECTURER

Date: 20 NOVEMBER 2009

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

Signature

Name: HUZAIRI BIN HASHIM

ID Number: MH06030

Date: 20 NOVEMBER 2009

Dedicated to my parents, lecturer and all my friends

ACKNOWLEDGEMENTS

At last, this project finally finished and had been done successfully. A lot of effort and time had been spent for this project. I would like to express a very warm appreciation and thank you to my supervisor En Mohd Fadzil Faisae for helping me to complete this project. Without all his guidance and knowledge this project may not complete on time.

I would also like to give my gratitude to my university, Universiti Malaysia Pahang and also to the Mechanical Engineering Faculty for giving me this opportunity to do this project and gain new knowledge from it and not forgeting Universiti Malaysia Pahang Library for all their relevant literature that I use for this project.

Thank you to my family for all their care and endless support they had given to me. To all my friends who had helped me, thank you for all your support. Last not least, I would like to thanks to all people that involve directly or indirectly with this project. I hope this project give a lot benefit to the human knowledge and make world a better place to live.

ABSTRACT

Automated Guided Vehicle or AGV is one of material handling equipment that has been widely used in most manufacturing industry today as it provides more flexibility to the systems. The basic concept of the AGV incorporates battery-powered and driverless vehicles with programming capabilities for path selection and positioning. Nowadays, the AGV are equipped to navigate a flexible guide path network that can be easily modified and expanded.

This project include the designing and assembling on the base structure for this AGV. Using software SOLIDWORKS 2006, the design of the vehicle can be done with the respect of specification needed. In designing, the weight of the vehicle must be taken into consideration. After the designing, the choices for material must be taken into notice as it may resulting as a dead weight for the vehicle. Next step in this project is, analysis using software to validify the project. The software used for analysis in this project is FEMPRO V22. It is used to find the displacement for this AGV when the load is apply to the base structure and othe components.

In this project, the design of this AGV has to be done properly in order the maximum usability of this AGV project. For this project, the mechanical part or system of this AGV will be incorporated with the guidance system done by other students. The choice of the material for the structure is also important as it will compromised the weight to power ratio of this vehicle. The steering system also will be one of the importants of AGV as it will contribute to the radius of turn angle and also the design of the AGV.

Through this report, the types of AGV, the basic concept, the classifications of the AGV and the steering mechanism that usually used in common AGV will be reviewed. Then, this report will be focusing on the mechanical design concept of the AGV which combines knowledge on mechanical parts such as the electric motor, gears, wheels, structure of the AGV and others mechanical parts that are essential for this project.

ABSTRAK

Kenderaan tanpa pemandu atau AGV merupakan salah satu peralatan penanganan material yang telah banyak digunakan di industri pembuatan saat ini kerana menyediakan lebih banyak fleksibiliti untuk sistem penyimpanan. Konsep asas untuk kenderaan ini adalah menggabungkan bertenaga bateri dan kenderaantanpa pemandu dengan keupayaan pengaturcaraan untuk pilihan perjalanan. Saat ini, kenderaan ini dilengkapi untuk menelusuri pemanduan yang fleksibel yang boleh dengan mudah diatur dan diperluas.

Projek ini meliputi perancangan dan pemasangan struktur asas untuk AGV ini. Penggunaan software SolidWorks 2006, rekabentuk kenderaan boleh dilakukan dengan rmengikut spesifikasi yang diperlukan. Dalam merancang, berat kenderaan perlu dipertimbangkan. Setelah rekabentuk, pilihan untuk bahan harus diambil ke dalam perhatian kerana boleh menyebabkan berat berlebihan untuk kenderaan. Langkah seterusnya dalam projek ini, analisis menggunakan perisian untuk memperakukan projek. Perisian yang digunakan untuk analisis dalam projek ini adalah FEMPRO V22. Perisian ini digunakan untuk melihat kemampuan kenderaan yang direkabentuk untuk bertahan apabila dikenakan beban.

Dalam projek ini, rekabentuk kenderaan ini harus dilakukan dengan betul agar kegunaan maksimum kenderaan ini. Untuk projek ini, bahagian mekanikal atau sistem kenderaan ini akan digabungkan dengan sistem navigasi yang dilakukan oleh pelajar lain. Pilihan bahan untuk struktur juga penting kerana akan mengurangkan berat nisbah kepada kuasa kenderaan ini. Sistem kemudi atau navigasi juga akan menjadi salah satu daripada kepentingan kerana akan memberikan sumbangan pada jejari pusingan dan juga rekabentuk kenderaan.

Melalui laporan ini, jenis kenderaan, konsep asas, pengelasan untuk kenderaan dan mekanisme kemudi/ navigasi yang biasanya digunakan dalam AGV umum akan ditinjau. Kemudian, laporan ini akan memfokuskan tentang rekabentuk mekanik AGV konsep yang menggabungkan pengetahuan tentang bahagian-bahagian mekanik seperti motor elektrik, roda gigi, roda, struktur mekanikal kenderaan dan lain-lain bahagian yang penting untuk projek ini.

TABLE OF CONTENTS

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

ρ	density
v	Total strain, Bandwidth parameter
μ	Friction coefficient
α	Angular accelaration
δ	Deflection
I	Moment of inertia

LIST OF ABBREVIATIONS

AGV	Automated Guided Vehicle
Al	Aluminium
ASRS	Automatic Storage And Recovery System

CHAPTER 1

INTRODUCTION

1.1 Introduction

Basic Automated Guided Vehicle (AGV) technology is not a new technology. Fifty years ago when AGVS were first entered the market and industry were called driverless systems. Going through the years of development, advances in electronics have led to improvement in automated guided vehicles. Nowadays, the technology of AGV is widely used in industrial environment to perform variety of task that involves automation. Mikell P.Groover. (June 2000)

The automatic guided vehicle is highlighted as a flexible transport vehicle for existing lines in variety industrial fields. An automatic guided vehicle (AGV) is a vehicle that is equipped with automatic guidance system either electromagnetic or optically. This vehicle is capable of transportation of material, sorting and material handling work also handling dangerous material. An AGV consists of one or more computer controlled wheel based load carriers (normally battery powered) that runs on the plant floor (or if outdoors on a paved area) without the need for an onboard operator or driver. As it names was automated, this vehicle is programmed to handle operation on its own. Jünemann and Schmidt (2000)

Material handling systems using automated guided vehicles (AGVs) are commonly used in facilities such as manufacturing plants, warehouses, distribution centers and terminals. The automatic guided vehicle is highlighted as a flexible transport vehicle for existing lines in variety industrial fields. An automatic guided vehicle (AGV) is a vehicle that is equipped with automatic guidance system either electromagnetic or optically. G.A. Bekey (1996). This vehicle is capable of transportation of material, sorting and material handling work also handling dangerous material. An AGV consists of one or more computer controlled wheel based load carriers (normally battery powered) that runs on the plant floor (or if outdoors on a paved area) without the need for an onboard operator or driver. As it names was automated, this vehicle is programmed to handle operation on its own. The increasing needs for more efficiency and cost savings production had made this vehicle is a popular substitute for manual labors. Groover(2001).

1.2 Problem Statement

The increasing needs for more efficiency and cost savings production had made this vehicle is a popular substitute for manual labors. Technological developments have given AGVs more flexibility and capability in performing its tasks. These AGVs is widely used for its advantage which is the ability to move from one place to another without proper supervision by human or operators. This advantage can increase the productivity and efficiency in manufacturing process of certain product. Cho,C.G and Tanchocho,J.M.A (1991)

The structure of AGV has to be design properly. This is to ensure that the space are used to the maximum. This is ensuring maximum usability of the vehicle. The material selection of material for structure is also important. Material for base structure of the AGV can give significant impact. The lightest material and strongest material will be chosen as the best material for this AGV. In order to get a better weight to power ratio, the material selection have to make to choose the best material. Instituto Superior Técnico (1995)

The steering system is also one of the considerations; the AGV that will be design must operate successfully. The steering system is considered by location for the used of AGV, path taken by the AGV and capability of the project itself. Graham and McGowan (2004)

1.3 Project Objective

In order to achieve the project, the objective of this project must be stated as a guide for the project. The objective of this project is stated below:

i) Design the model preparation of the AGV prototype using computer software

ii) To design mechanical system for an automated guided vehicle.

iii) To perform analysis based on the design automated guided vehicle using calculation and software

.

1.4 Project Scope

For this study, the scope that the project limited to is stated below:

i) This design of automated guided vehicle is limited to the maximum load that can be transported. The maximum load for this design is 10 kg equivalent to 98.1 N.

ii) The maximum loads are related to the motor that are supplying the vehicle to move.

iii) The application of this system is limited to laboratory area for Faculty of Mechanical University Malaysia Pahang.

iv) This vehicle application is limited to the flat land and smooth road.

v) The mechanical system including size of the structure, gear, bearing, shafts and other mechanical systems.

1.5 Arrangement of Thesis

In the overview of the chapter is firstly is the introduction. As for introduction, the objective, problem statement, project scope for this Development of Automated Guided Vehicle (Mechanical System) thesis will be discuss in this chapter. In literature review, discussion deeper in knowing the function of AGV and other system related for this project. In the methodology for this thesis, the procedure had done from designing the vehicle to the analysis step will be discussed into matter. As for the results chapter in this thesis will present the overall results in the analysis step and the manual calculation for this thesis. In the results and discussion of this thesis were to discussed and the comparison with objective if this thesis has achieved.

CHAPTER 2

Literature Review

2.1 Introduction

In this chapter, we will discuss more about Automated Guided Vehicle System, its classification, the vehicle load capacity, the vehicle itself and the application of the vehicle in material handling and industry. This chapter is to enhance the knowledge of student about the project.

2.2 Automated Guided Vehicle System (AGVS)

Material handling systems using automated guided vehicles (AGVs) are commonly used in facilities such as manufacturing plants, warehouses, distribution centers. The performance of the material handling system directly affects the performance of the whole facility. Material handling in manufacturing system is becoming easier as the automated machine technology has improved. One of the material handling methods that has been widely used in most industry nowadays is the Automated Guided Vehicle System or better known as the AGVS. It has become one of he fastest growing classes of equipment in the material handling industry. (Tanchoco and Bilge, 1997).

Until today there are many researchers that have shown interests in improving the system in order to achieve more productivity and flexibility in manufacturing environments. According to Groover (1987) an Automated Guided Vehicle System (AGVS) is a materials handling system that uses independently operated, self propelled vehicles known as the automated guided vehicle or AGV that moves along defined pathways between delivery points or stations. A typical AGV will consist of the, batteries, electrical system, drive unit**,** steering, on board controller and work platform.

2.2.1 AGVS Classification

Modern AGV systems differ from the classic ones as described for instance in the books of Jünemann and Schmidt (2000) and Tompkins et al. (2003) in several respects. Rather than using fixed paths, many modern AGV are free ranging, which means the path of the vehicle are software programmed and can be change relatively easy when new stations or even flows are added. Modern technology also allows the vehicle to make decisions on its own compare to the past when control was perform by the central controllers. This leads to adaptive, self-learning system of the AGV (Tuan Le-Anh and De Koster). In this section, AGVS classification according to the journal by Peters et *al* will be described.

According to the journal, the automated guided vehicle system can be divided into three basic levels such as below:

i). Guide path determination

- a) Static path
  - i. Unidirectional
  - ii. Bidirectional
- b) Dynamic path

ii). Vehicle capacity -

- a) Single unit load
- b) Multiple loads

iii). Vehicle addressing mechanism

a) Direct address

b) Indirect address

2.2.2 Vehicle Load Capacity

In automated guided vehicle system, the vehicle can be classified based on its load capacity, which is either single load or multiple load vehicles. System that use single load vehicle is known as single load system and if multiple load vehicles are used, it is known as the multiple load system. In a single load system, an empty vehicle will be assigned for a task for example taking a load and deliver it. From its current position; it will then travel to a station to pick up the load and then travel to the desired position to drop off the load. During performing its task, it is not in tempted with another assignment and will only move in path to pick up and drop off the load. In multiple load system, the task of the vehicle is more complicated where the vehicle may be interrupted while performing its task. It may stop to another station to pick up another load. In this type of system, the planning and scheduling functions of the controller might be difficult as the plan and schedule must integrate the new tasks into previously assigned tasks. (Peters et *al 199l).*

2.3 Automated Guided Vehicle (AGV)

According to (Groover, 1987), Automated Guided Vehicles (AGV) can be grouped into three categories as below:

1. Driverless train
2. Pallet trucks
3. Unit load carriers

2.3.1 Driverless Train

Driverless train basically consists of towing vehicle, which is the AGV that pulls one or more trailers forming a train. This type of AGV is used when heavy payloads involve and the loads need to be travel in large distances like in a warehouse. The task usually involves intermediate pick-up and drop-off points along its path. (Groover,2001).

Figure 2.1 Driverless train

2.3.2 Pallet Trucks

This type of AGV is used to shift palletized loads along programmed path. In its application, the vehicle is backed into the loaded pallet by act of human operator that steers the truck and uses the forks to lift the load vaguely. The human operator will then drive the pallet truck to its route, program its destination and the vehicle will then automatically travel to the preprogrammed destination for unloading. (Groover, 2001).

Figure 2.2 Pallet trucks

2.3.3 Unit Load Carriers

This type of AGV is also used for transferring loads from one station to another and usually set for automatic loading and unloading of pallets by devices that built into the vehicle deck such as powered rollers and moving belts. The unit load carriers varies from light load AGVs, which are small vehicle that usually can withstand light load capacity; to assembly line AGVs, which are designed to carry a partly completed subassembly through a series of assembly workstations to complete a product (Groover,2001).

Figure 2.3 Unit load carrier

2.4 AGV Applications

According to Groover (2001), Automated Guided Vehicles are widely used for variety of applications. Such applications can be grouped into five categories such as following:

i) Driverless train operations.

This type of applications usually involves transferring of large quantities of loads over large distances.

ii) Storage distribution systems.

For this type of applications, unit load carriers and pallet trucks are used. In this application, materials in unit loads are moved from or to specific locations. The system usually involve interface with other automated handling or storage system, for example the automated storage/retrieve system (ASIRS).In such interface, the vehicle will pick up or drop off unit loads from receiving dock to the ASIRS, which then placed them in storage.

After that, upon request, the ASmS will of the floor, applying a narrow photo sensitive chemical strip on the surface of the floor, applying a narrow photo reflective tape on the surface of the floor or embedded wire just below the surface of the floor. In the technique that uses wire embedded in the floor, wires that have varying frequencies are used. AGV will then select a path at a control point according to the assigned frequency. AGV using this type of system usually equipped with sensor underneath the vehicle, usually a small antennae consisting of magnetic coils. With presence of current that flows, a magnetic field surrounds the buried wire. The closer the buried wire to the antennae, the stronger the field will be.

The other three type of fixed AGV path is also known as the optical guide path technique. For these types of AGV paths, AGV will move by focusing on the beam of light reflected from the paints strip or reflective tape. It follows the path by measuring the reflected light. These methods require a sensor mounted under the vehicle, which able to detect the presence of the surface mounted path. Of course, the purpose of the sensor is to keep the AGV correctly over the guide path. (Frog Navigation System, 2004)

2.5 Steering Consideration

Wheel plays an important role as it enables the AGV able to move according to the preprogrammed path in its memory. It is the first decision to be made in designing a mobile robot or AGV. There are a few possible configurations of wheels and / or casters that would work for this purpose. In this section a few types of wheel configurations for steering mechanism of the AGV will be explained. According to Graham and McGowan (2004), the steering methods that usually used in mobile robots or AGV are steered wheel systems, skid-steered system and differential drive system. According to Miles (2002), there is also another type of steering method that usually used in mobile robots, which is the Ackerman steering method

2.5.1 Steered Wheel System

In this system, usually only drive motor and a controlled steering wheels or set of wheels are needed to make it works. This steered-wheel system can be used either in a tricycle or four wheel configuration, usually used in most automobiles. In this system, steering wheel can be the front wheel or the rear wheel. If the rear wheel is used as the steering wheel, tighter and faster steering will be obtained but it is quite difficult to control compare to front wheel as the steering wheel. Four wheel configurations is slightly different compare to tricycle configuration but it offers more stability where the additional wheel prevents the vehicle from tipping over. This type of system offers simplicity but vehicle using this system cannot turn in a complete circle around its own axis and wider turning circle or radius is required compare to other type of systems (Graham and McGowan, 2004).

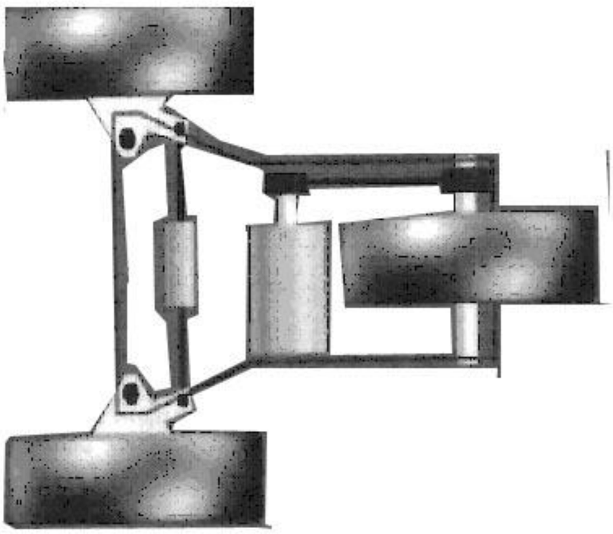


Figure 2.4 Steered wheel system in tricycle configuration (Front driven) (Graham and McGowan, 2004)

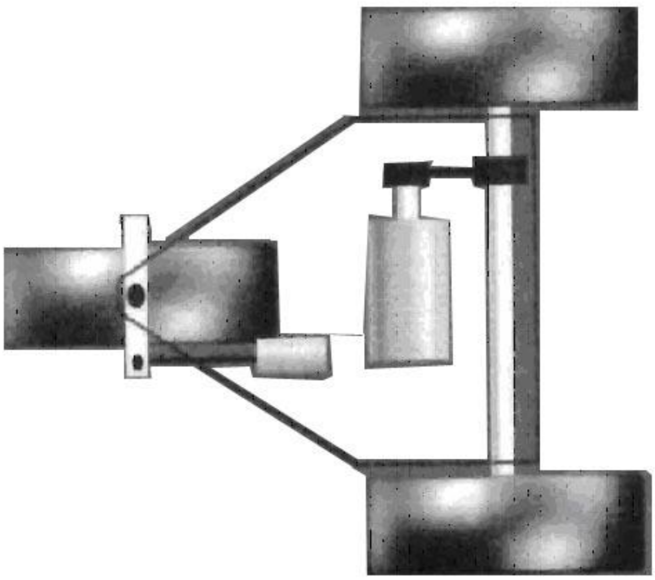


Figure 2.5 Steered wheel system in tricycle configuration (Rear driven) (Graham and McGowan, 2004)

2.5.2 Ackerman Steering System

Ackerman steering system is another type of system that usually used in mobile robot. In this system, only one drive motor is needed to drive the vehicle forward and reverse and another motor or servo to control the steering system. This system usually is used in large assembly area and need to move fast. The drawback of this system is that it can't spin around; it has to do a U-turn or 3 point turn. The minimum turning radius is a function of sharpest turning angle of the front and the wheel base of the vehicle. (Miles, 2002)

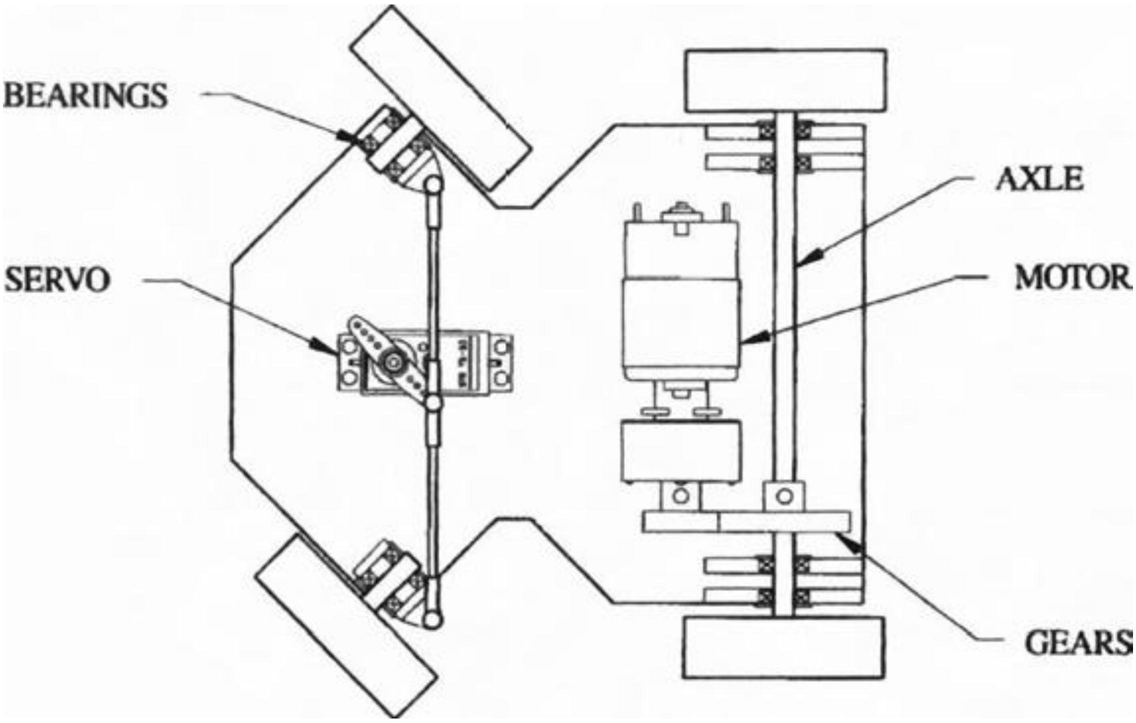


Figure 2.6 Schematic of a robot using Ackerman Steering System (Miles, 2002)

2.5.3 Differential Drive System

For this project, the differential steering mechanism will be used as it is the most common steering method. This type is also ideal for maneuvering in small areas and it is also easiest steering method to be implemented. Therefore, in the next section, the feed back control system for the differential steering method will be explained.

This type of steering method is the most common configuration used in most mobile robot or AGV. The term "differential" itself is used to describe the way the vehicle steers, which is by turning one of the drive motor on one side of the wheels at a different speed than the other in order to make the vehicle turn. In other words steering a vehicle in this system is just a matter of varying the speed of the drive wheels. But if both drive wheels turn in tandem, the vehicle will move in straight line (Lucas, 2001).

From Figure 2.7, it can be seen that each wheel on the side is controlled by individual drive motor. From the same figure, it can be seen that there is only one main drive wheel on each side of the vehicle. This feature prevents the wheels from skidding around a corner (Graham and McGowan, 2004).

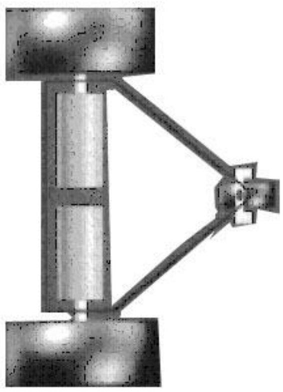


Figure 2.7 Differential Drive Systems (Graham and McGowan, 2004).

2.6 Conclusion for literature review

From this study of extensive literature reviews, some of the point has been taken from the study into consideration for the use in this AGV project. The point taken from the literature review is listed below:

i) Type of AGV
ii) Steering system
iii) Vehicle Load Capacity

In term of type of AGV, for this project a unit load carrier AGV is to be carried out. The reason for this type of AGV chosen is this project is about prototyping an AGV thus a unit load carrier is suitable. With a design for small load capacity, it is appropriate as been discussed in the literature review. According to Groover (2001) the unit load carriers varies from light load AGVs, which are small vehicle that usually can withstand light load capacity; to assembly line AGVs, which are designed to carry a partly completed subassembly through a series of assembly workstations to complete a product.

As for the steering system, the differential drive system has been chosen to be the best and ideal first step steering system compare to other steering systems. This system is suitable for new learner as it is easy to set up and design. This system is also ideal for maneuvering in small areas and it is also easiest steering method to be implemented. For this project it will used a four wheel as to prevent the vehicle tilting.

Lastly the vehicle load capacity, as this AGV may be implemented and incorporated with other AGV project in future, it is can be turn into an automated storage and recovery system that is highly valuable assets for a place with limited and tight storage place.

CHAPTER 3

METHODOLOGY

3.1 Introduction of Methodology

This chapter discuss about methodology of the project. Besides that, this chapter will show the time line of this project from the start until the project is finished successfully. For this project, the time line starts when receive the project title and start it with some briefing session with supervisor.

3.2 Flowcharts

To achieve the objectives of this project, a methodology has been constructed (see figure 3.1). The methodology flow chart is purposed to give guidelines and directions to successfully accomplish the main goal of this project. The following is the summary methodology flow chart.

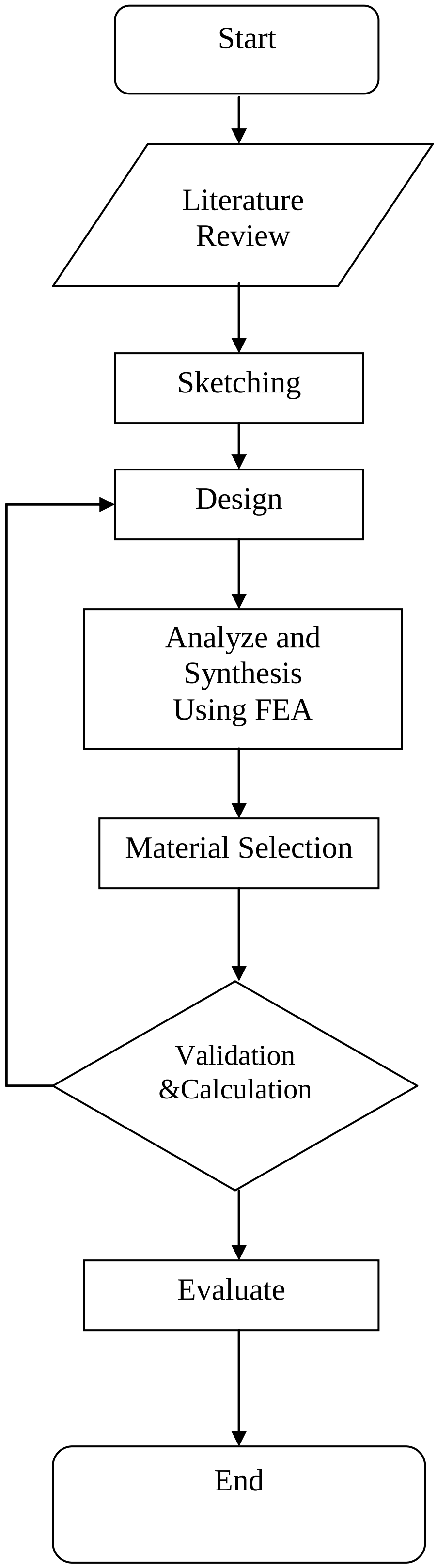


Figure 3.1 Methodology Flowchart

3.3 Drawing

Drawing is one of the steps in designing the vehicle, without a proper drawing the consequences is the outcome of the design.

3.3.1 Drawing Consideration

The drawing of the AGV must achieve all of the objectives desired. So the drawings must be as complete as possible and can be fabricated perfectly without any errors on the middle of the fabrication process. This is to keep track of time and not to be late of schedule.

The consideration for the drawing is for it firstly to be movable, in sketching, the measurement must been taken to get the suitable size for the AGV.

3.3.2 Drawing Method

In this project, the software that will be used to draw the model is Solid Works 2006. The Solid Works software is mechanical design automation as a computer aided design (CAD). This software is chose as it is possible for designers to sketch their ideas of the design, experiment with features and dimensions and produced models and detailed drawings. Solid Works enables to draw the models much more quickly and precise. Solid Works designs are defined by 3D design and are based on components. To draw the design of the quenching tank it must have some steps that must be followed. It includes:

i) **Sketches**: Create the sketches, dimensioning, where to apply the objectives needed.
ii) **Features**: Select the appropriate features, determine the best features to be applied.
iii) **Assemblies**: Select the components to be mate, what types of mate to apply in the drawing.

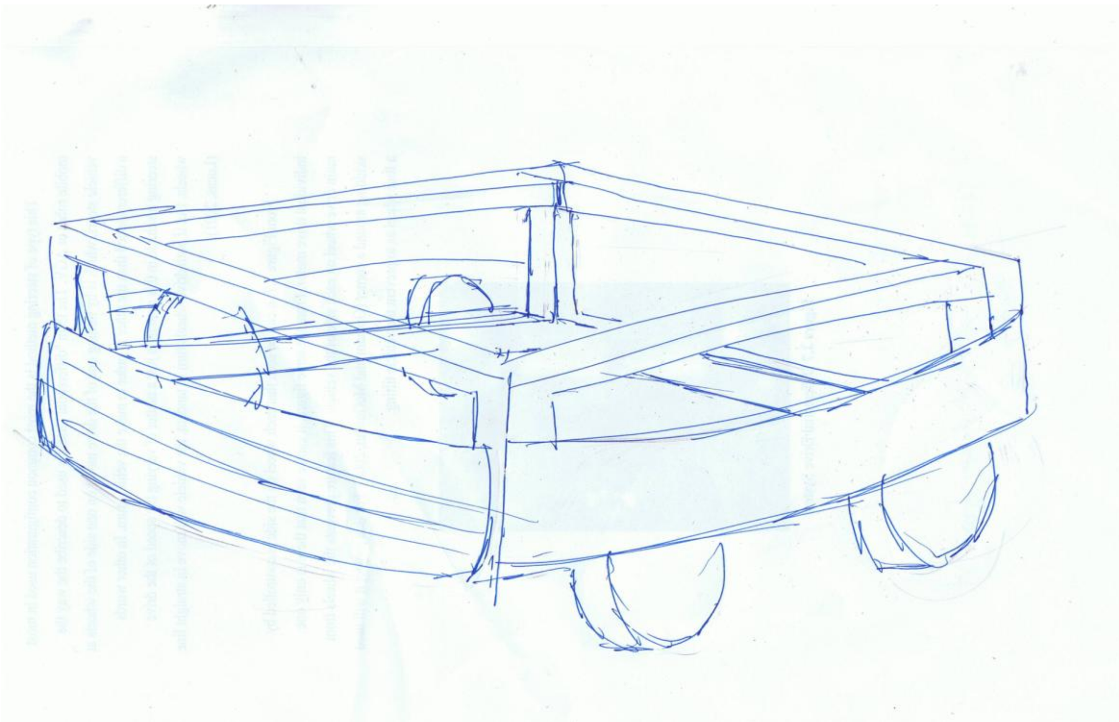


Figure 3.2 Initial Sketches

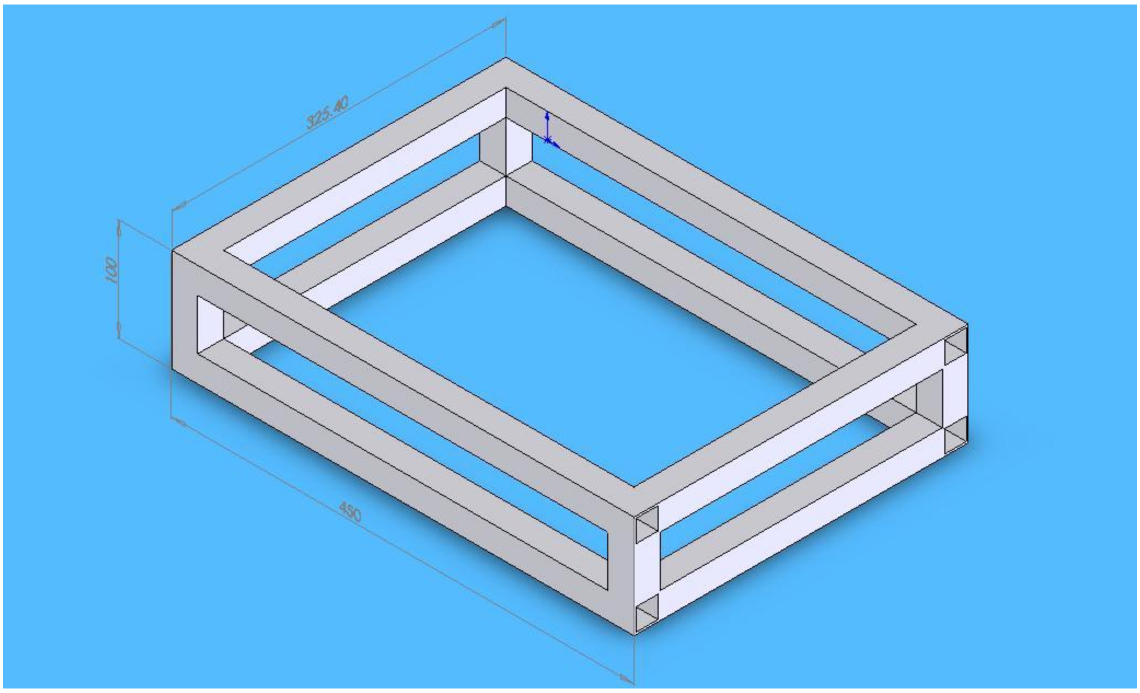


Figure 3.3 Base Structure

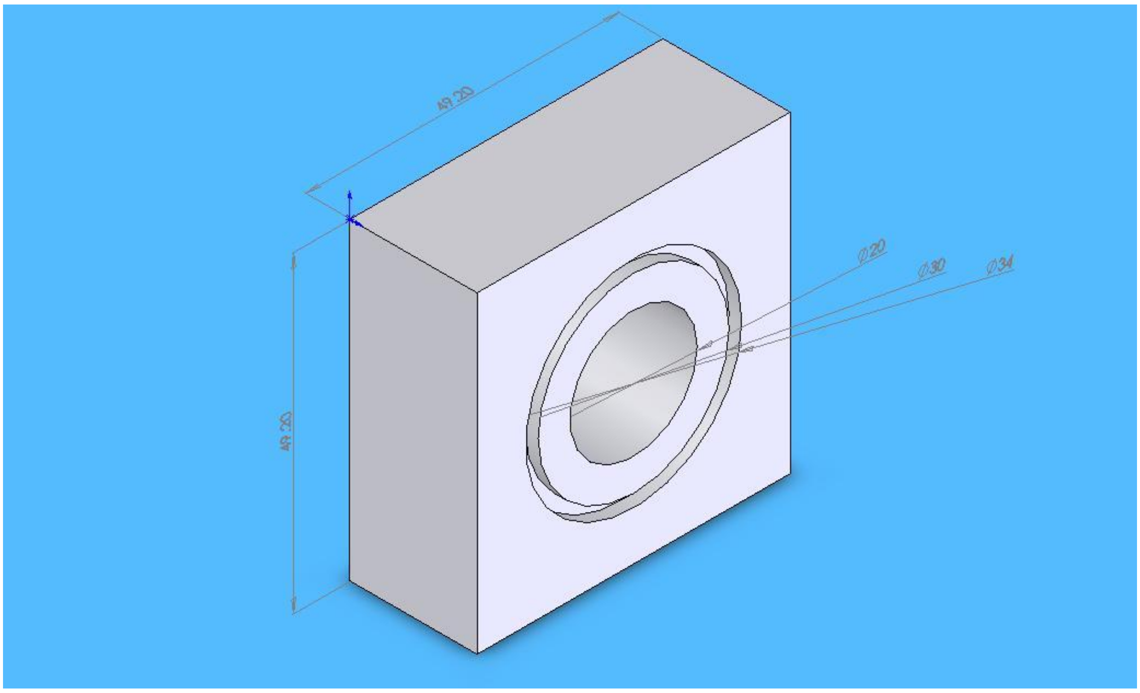


Figure 3.4 Bearing with holder

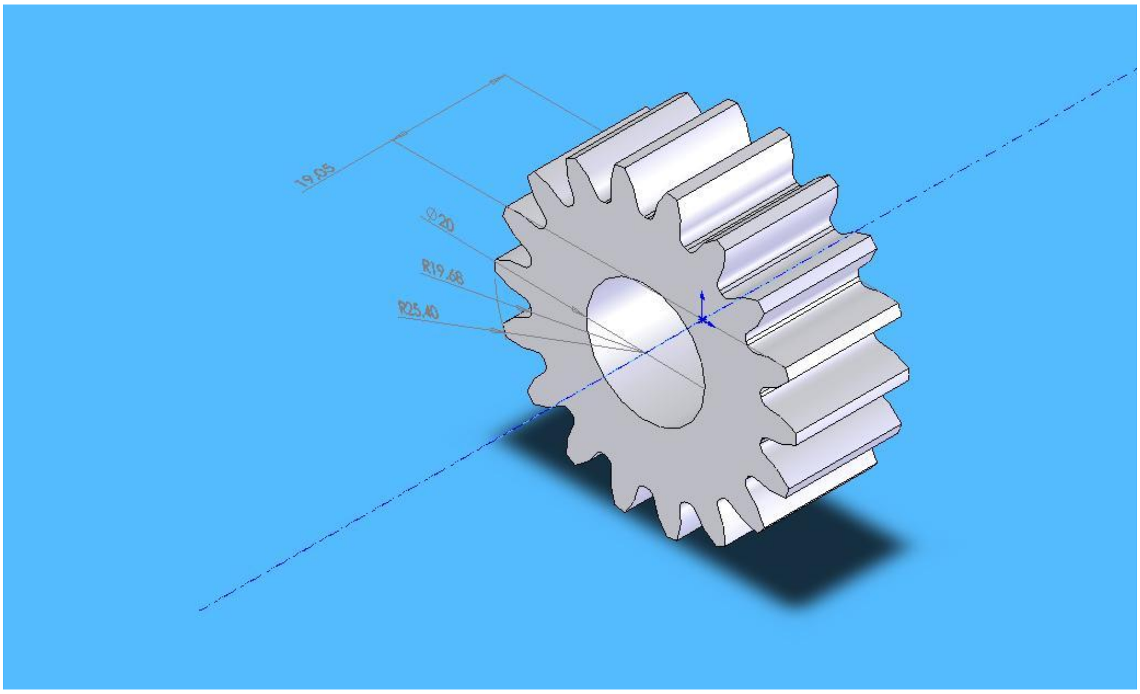


Figure 3.5 Gear 18 teeth

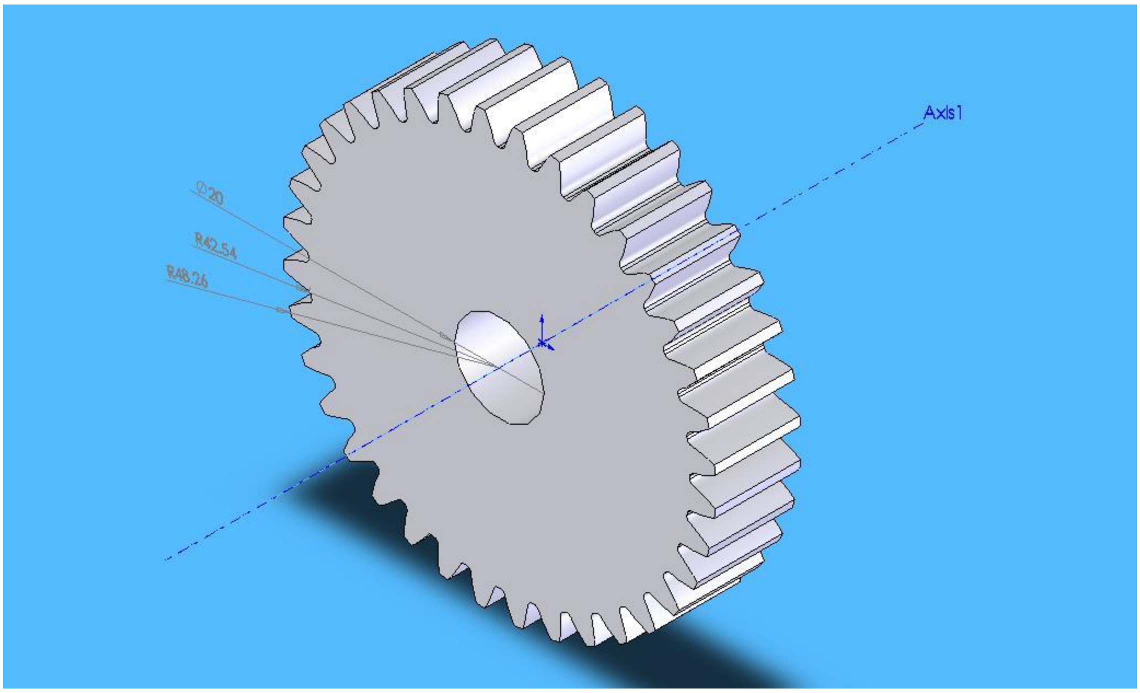


Figure 3.6 Gear 36 teeth

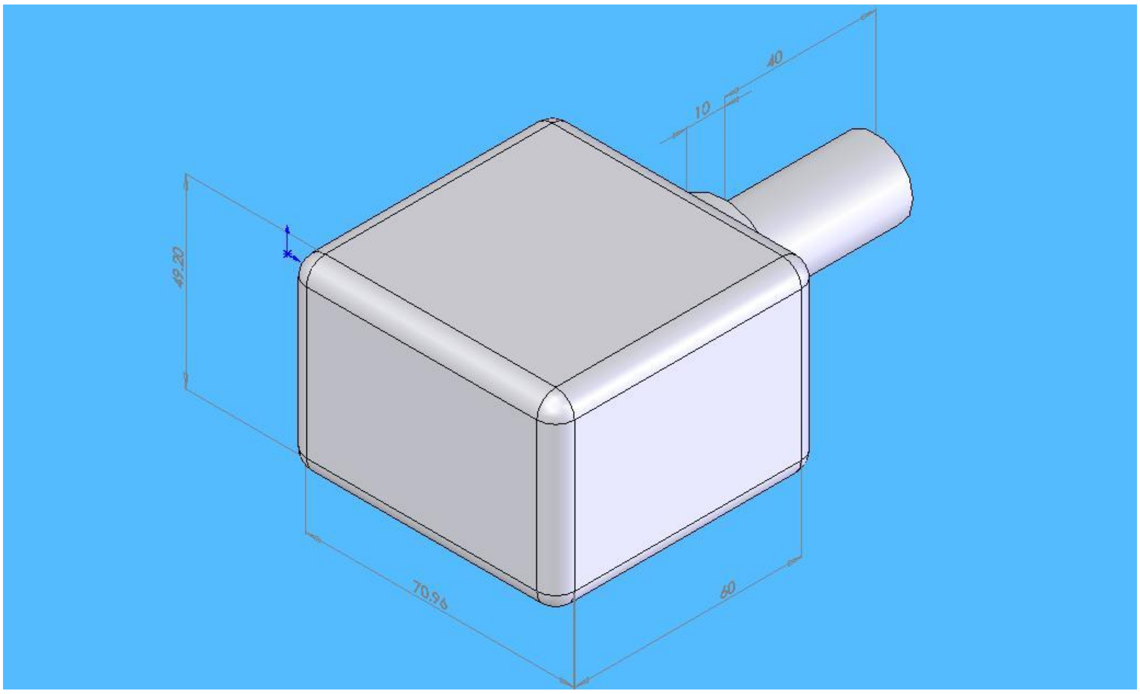


Figure 3.7 Motor

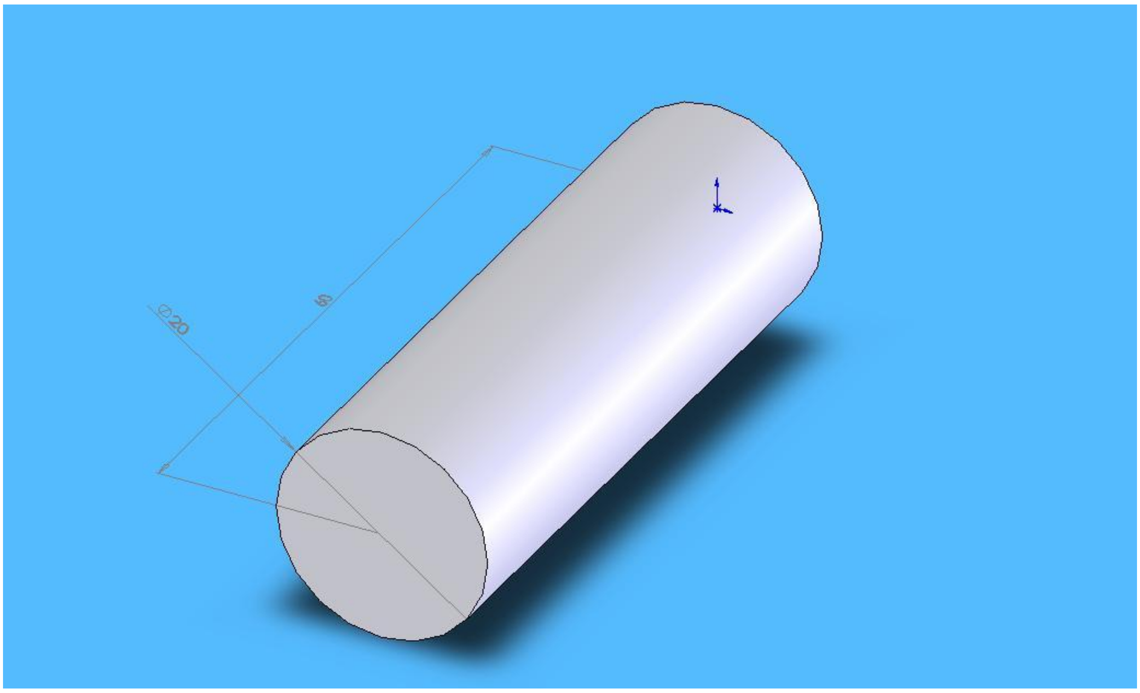


Figure 3.8 Rear shafts

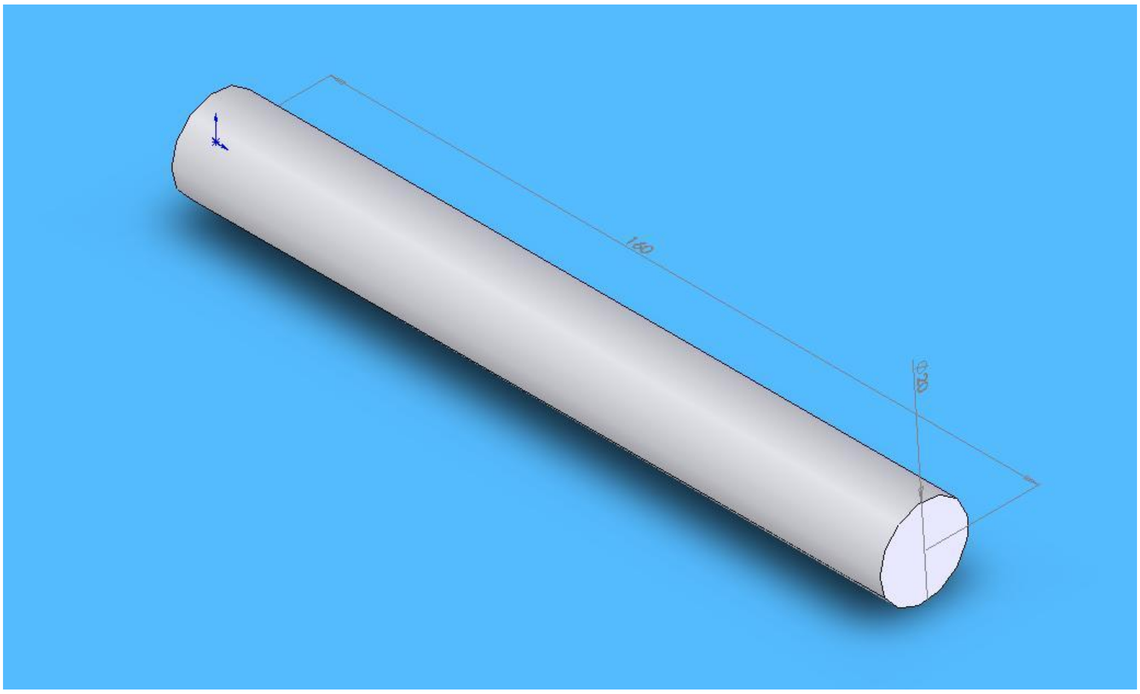


Figure 3.9 Front shaft

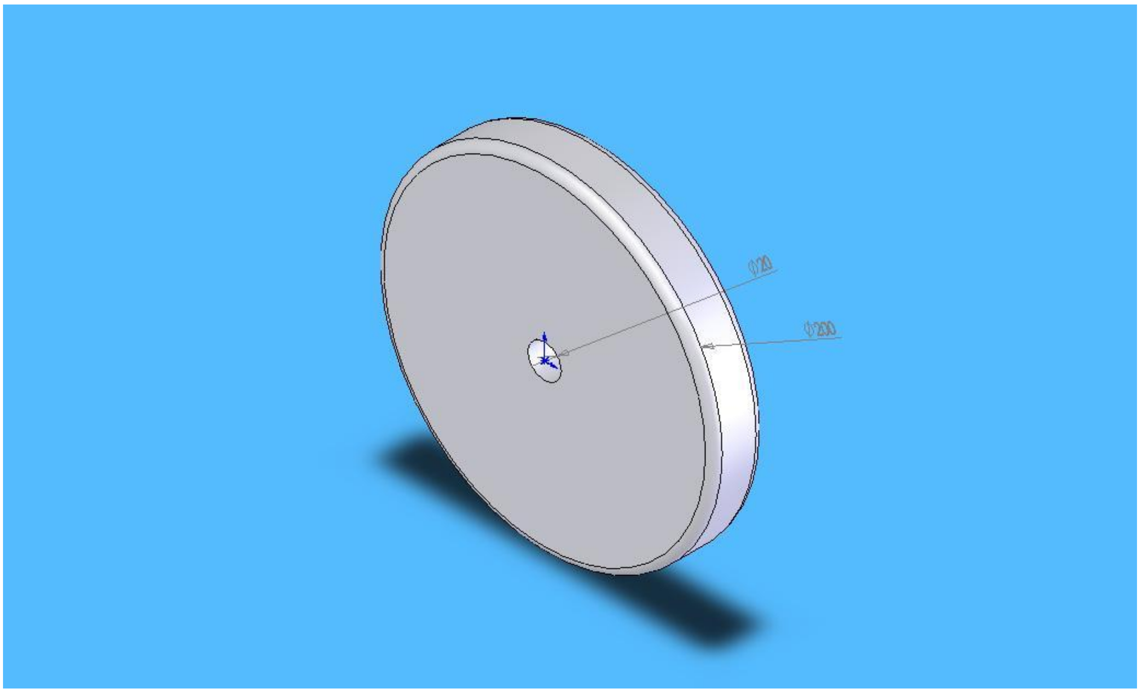


Figure 3.10 Tire

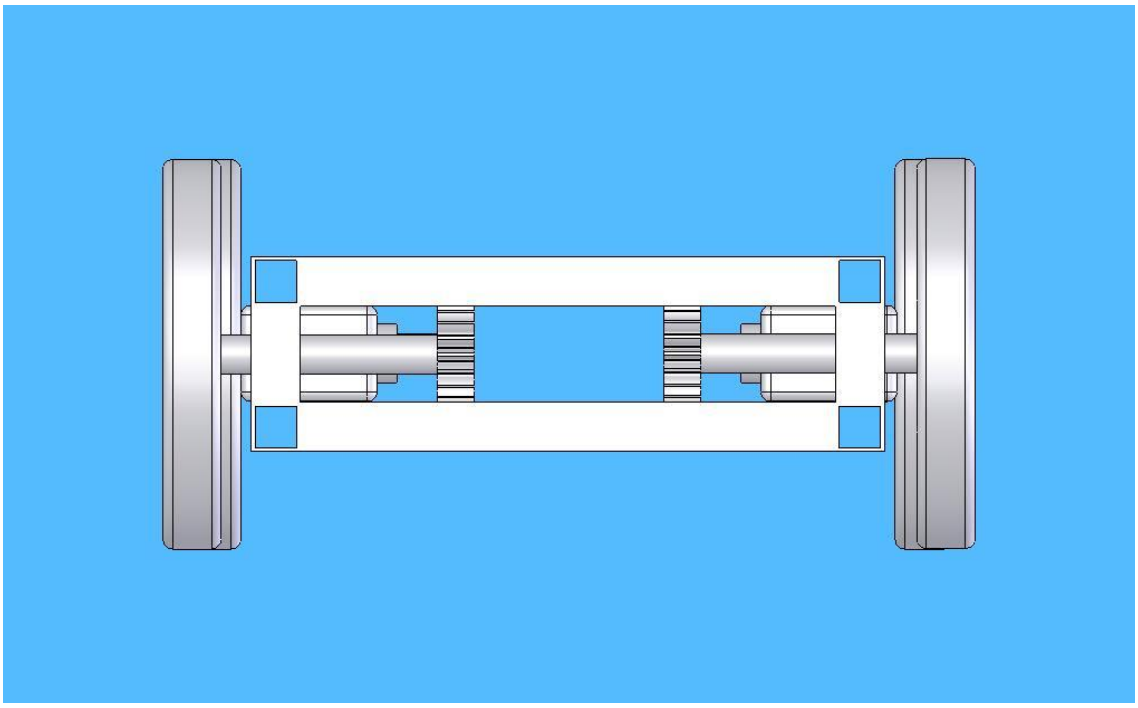


Figure 3.11 AGV Prototype (Front view)

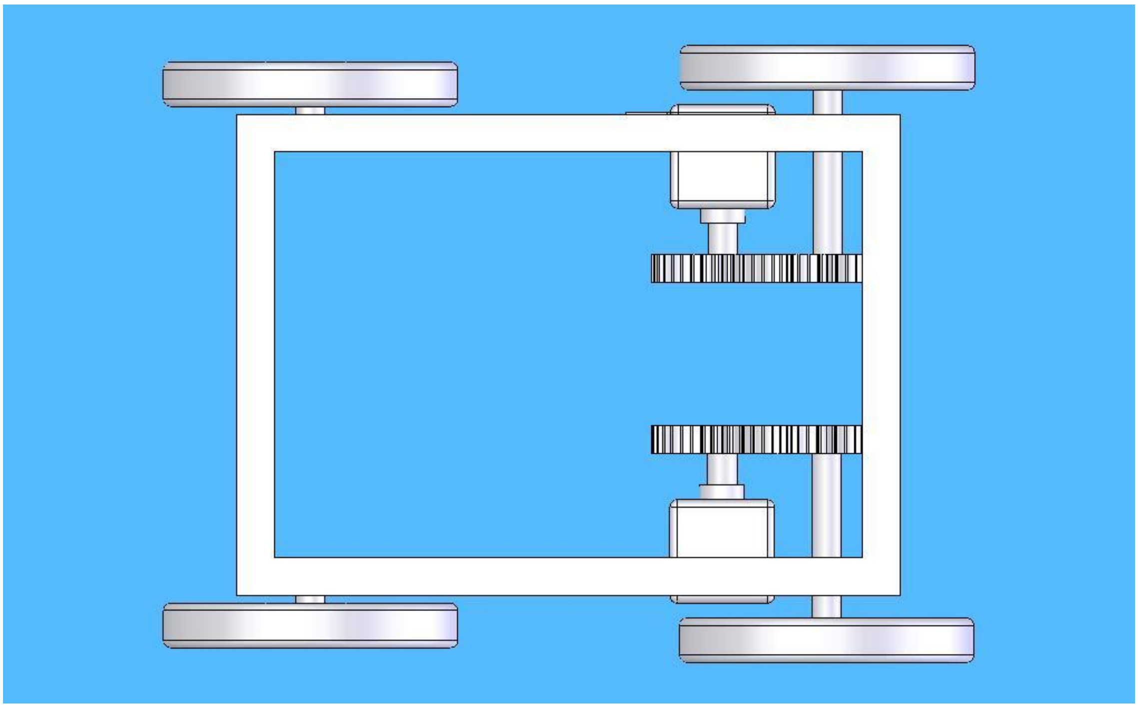


Figure 3.12 AGV Prototype (Top view)

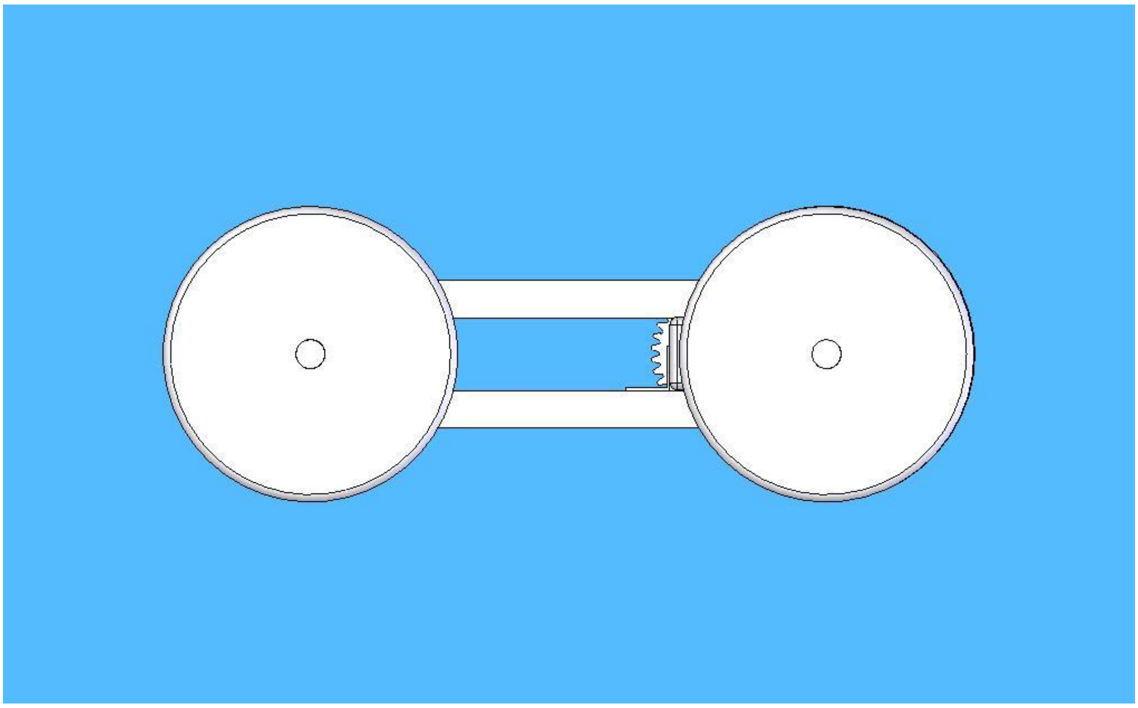


Figure 3.13 AGV Prototype (Side view)

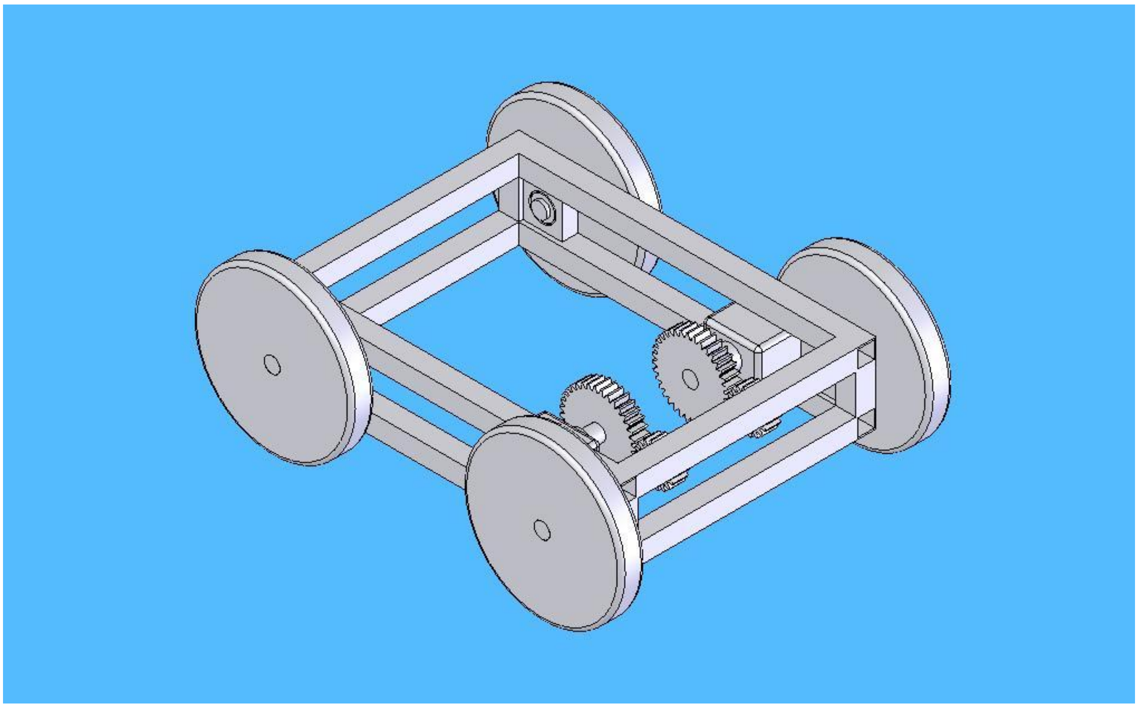


Figure 3.14 AGV Prototypes (Isometric View)

As for other parts such as gear, the use of specific software. Camnetics GearTrax 2003 software was used and was integrated with the SolidWorks 2003 software. The use of Camnetics Gear Trax had significantly reduced the time needed for design and calculation of the dimension for gear.

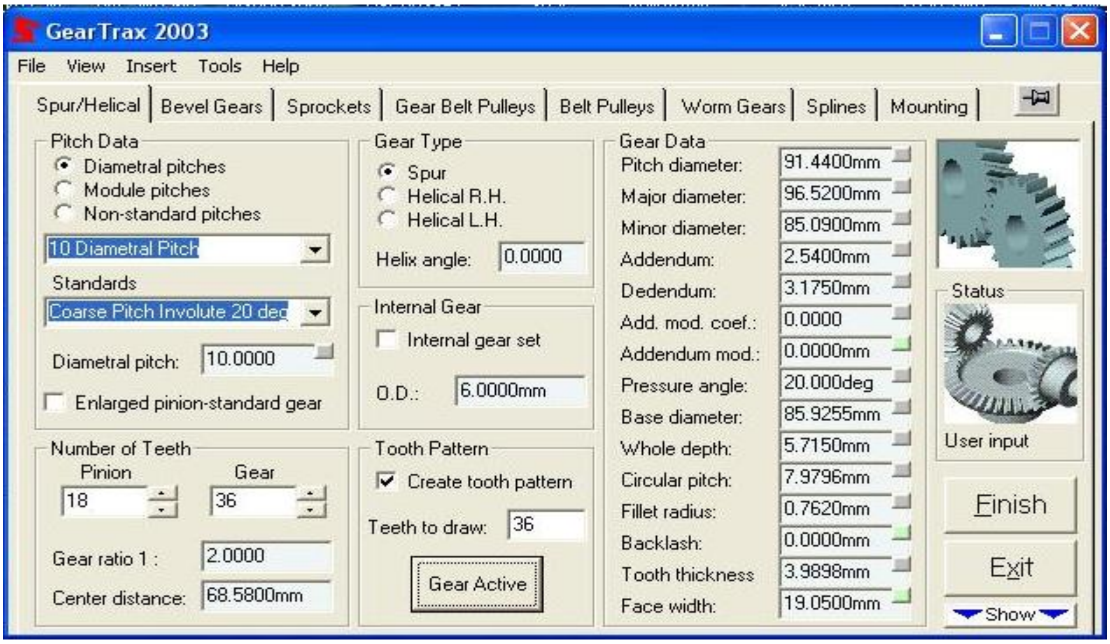


Figure 3.15 Camnetics GearTrax 2003 software

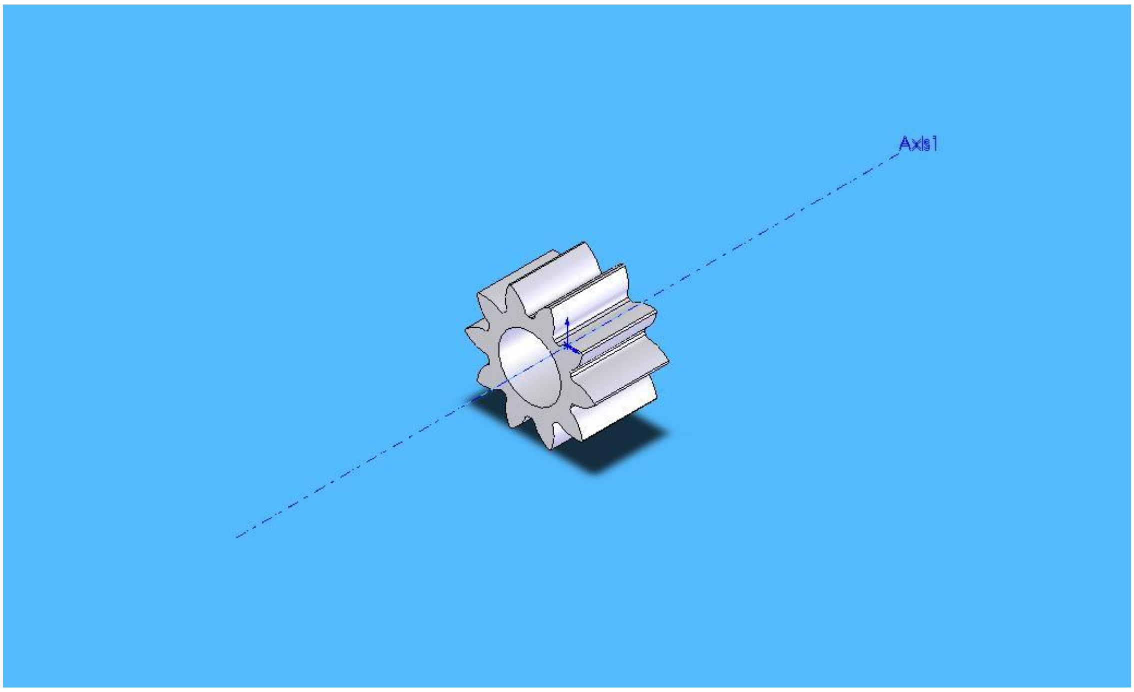


Figure 3.16 Gear model design by Camnetics GearTrax 2003 software

3.4 Analysis

The analysis of AGV total structure has been done using ALGOR 22 software. ALGOR 22 software is a general-purpose finite element analysis software package developed by ALGOR. After finish the analysis using this software, problems and errors can be reduced in order to improve the design.

3.4.1 Analysis Step

In order to validate the design, analysis must be made by using software. In this design, the analysis that were taken into consideration is the displacement of the model after force and load were taken into consideration

Below is the step for analysis:

1. Create model using Solid Work 2006 and save work as .IGES.
2. Open IGES file using FEMPRO V22.
3. Model mesh setting
4. Modify all condition according to specific requirement.
5. Start Analysis using the traffic light button
6. Take data from the result and see displaced model

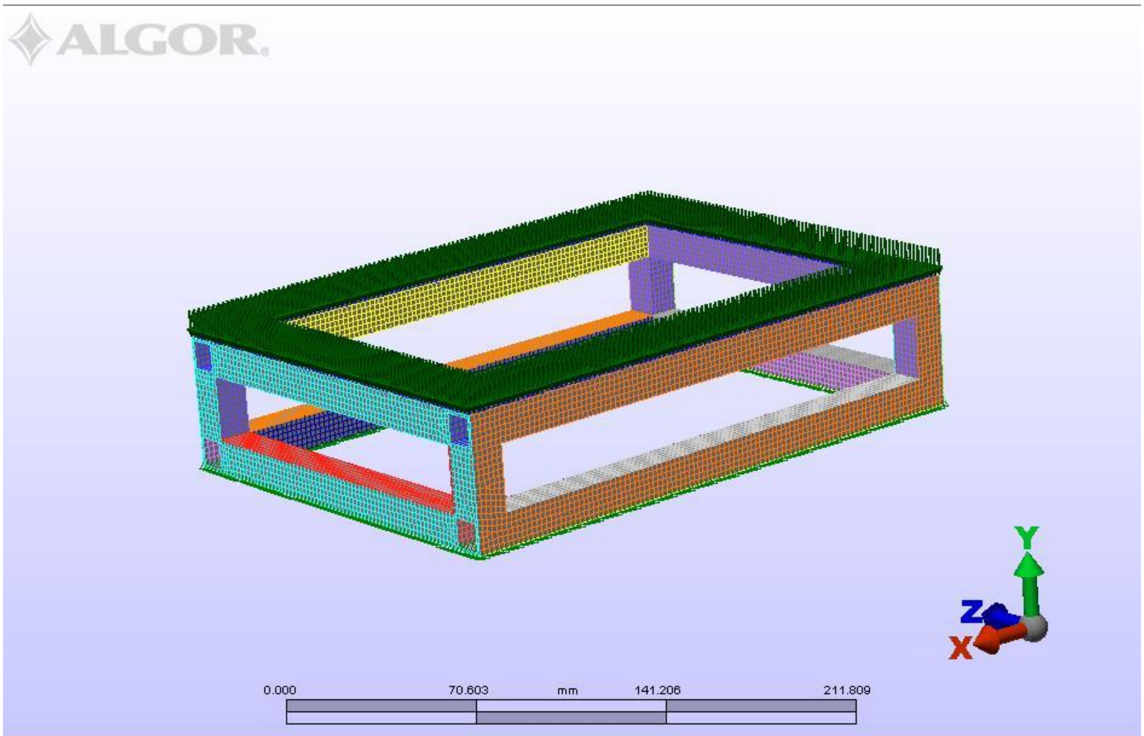


Figure 3.17 Applied force and fixed boundary condition

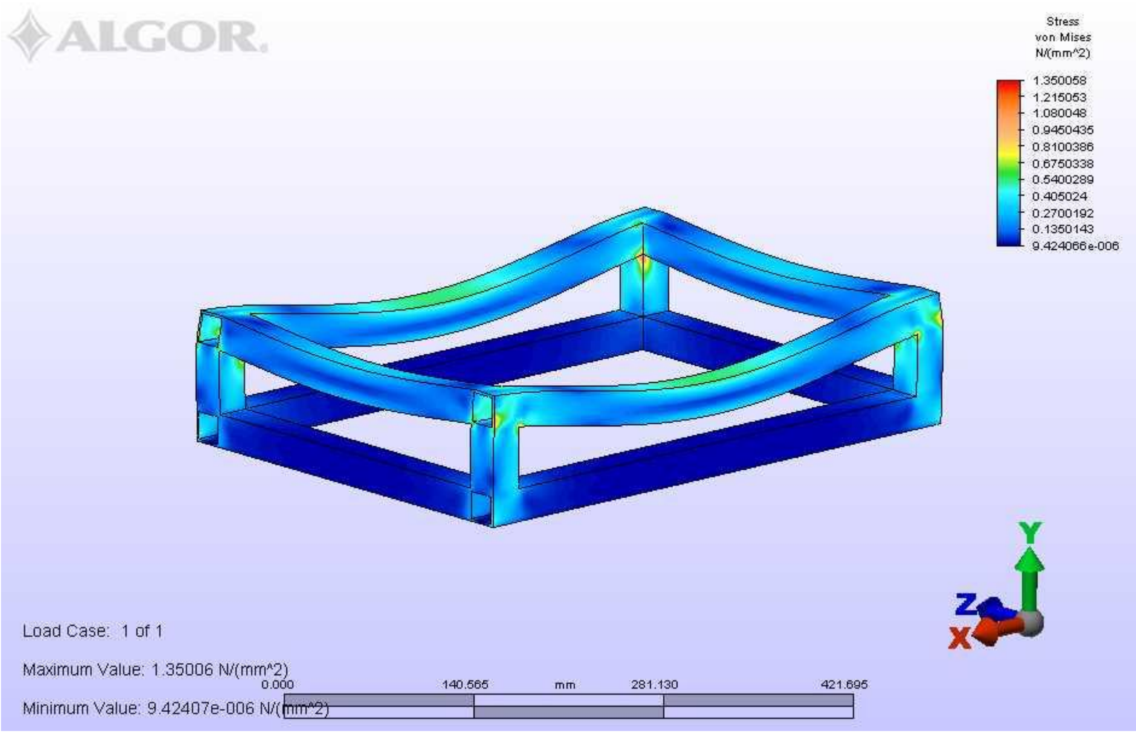


Figure 3.18 Result of Von Mises stress

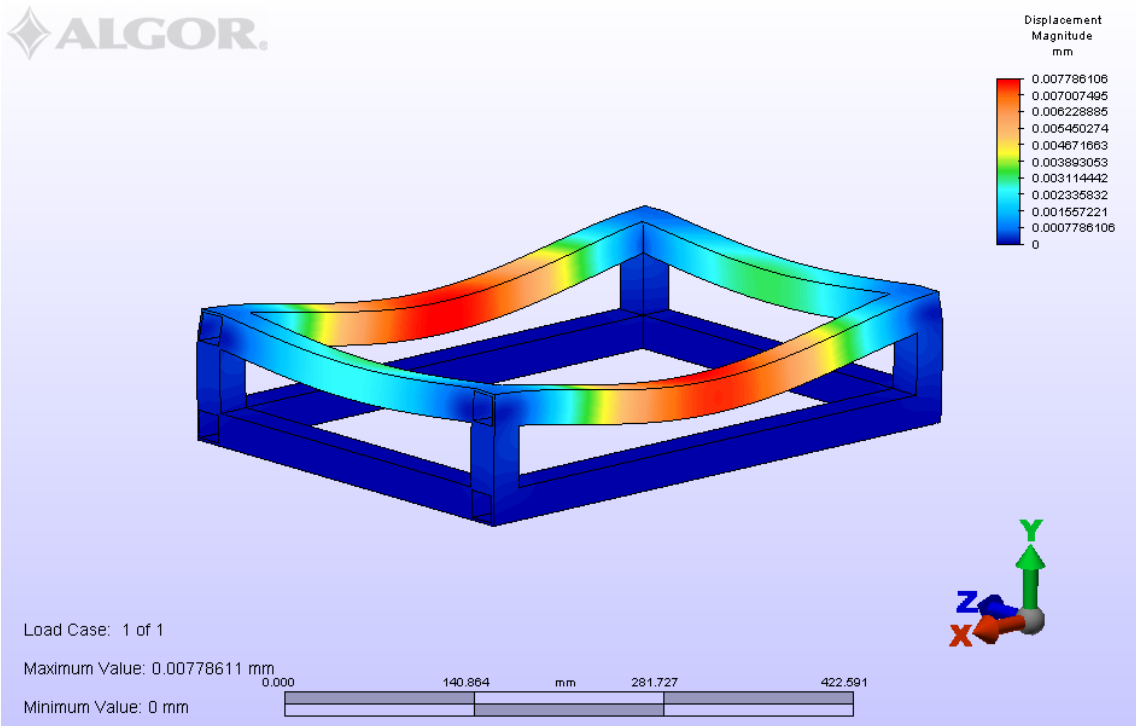


Figure 3.19 Result of displacement

3.5 Material Selection

Comparison must be made in order to choose the best material for the vehicle. Consideration that were taken:

i) Density of material
ii) Displacement of model
iii) Von Misses Stress value

The materials that were comparing are Aluminium and Steel. Both of this material is widely used for chassis of vehicle and in construction.

3.6 Validation and Calculation

Method in validation is using manual calculation and comparing result in table. The importance of validation is to prove the result from software analysis thus validating the project itself. Validation include manual calculation, selecting component such as bearing, tire, gear and other mechanical component that were needed to complete the project.

Validation and calculation also include the calculation for specification of motor needed to move the vehicle. The requirement speed for the AGV is 1m/s. Thus calculation for motor torque, revolution per minute and angular acceleration of motor needed to be done in order to choose the AGV motor.

3.7 Evaluate

Method in evaluate is considering data collected from software is compared with manual calculations. This step is important in order to accept all the data from software. The data that were collected then were compare to a manual calculations.

CHAPTER 4

RESULTS

4.1 Introduction

All the things about this chapter are the findings got from the analysis and calculations explained in the previous chapter. In this chapter will show all the results and data that can be used to achieve the objective of this project. In this chapter will include the schematic diagram of the vehicle, parts of the vehicle and built of material for the vehicle. Next this chapter will show the manual calculation for vehicle motor specification and data of comparison between steel and aluminium. Last in this chapter is the validation of software data and manual calculation. Other than that this chapter will discuss all about the results and finding for the project. All the data will be thoroughly discuss so that at last part of this project, it can be concluded and any recommendation to improve this project can be given.

4.2 Design of Automated Guided Vehicle

After completing the sketching, using SolidWorks 2006 software the sketches were put into development. After consideration, there are six important parts needed in this vehicle. The six main parts are listed below:

1. Chassis of the vehicle
2. Bearing
3. Gear
4. Motor
5. Shafts
6. Wheels

These five main parts are the backbone of this vehicle. Without the design and analysis these parts this project will end failure.

4.2.1 Automated Guided Vehicle

This automated guided vehicle must support the load that was specified for it. For the design, consideration of all the masses supported by the chassis must be accounted as it will exert stress for chassis. In this project, the design of AGV is simplified to a rectangular shape. The rectangular shape can give support to a longer load and also wide load.

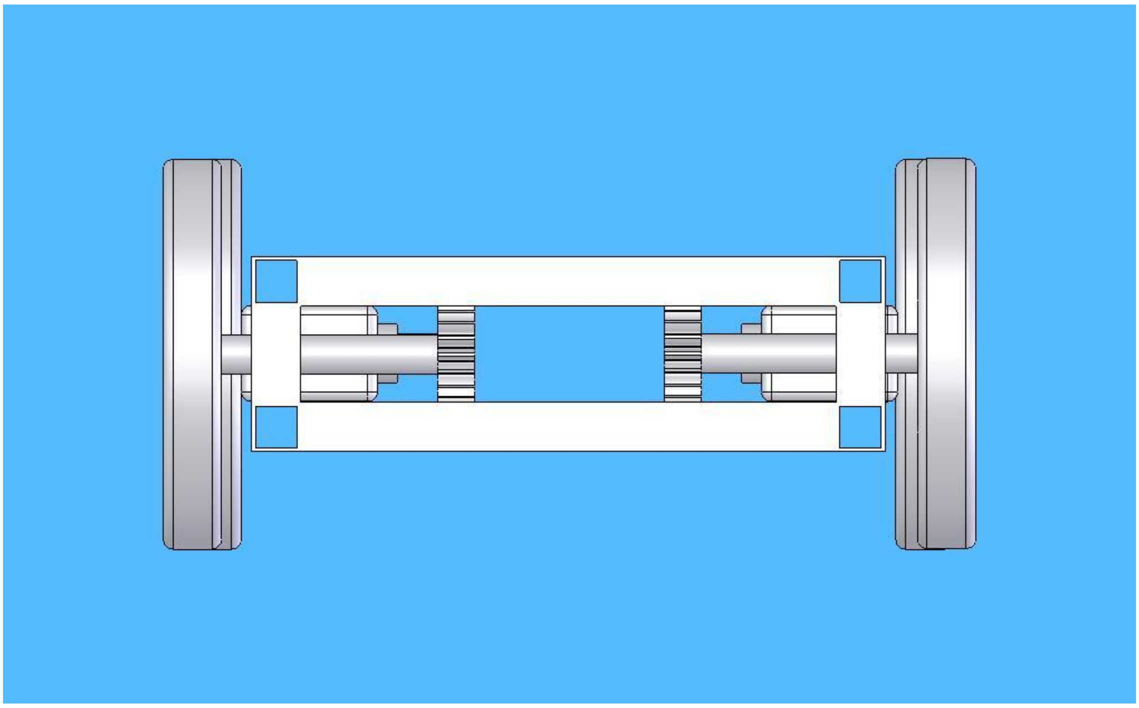


Figure 4.1 Front View of AGV

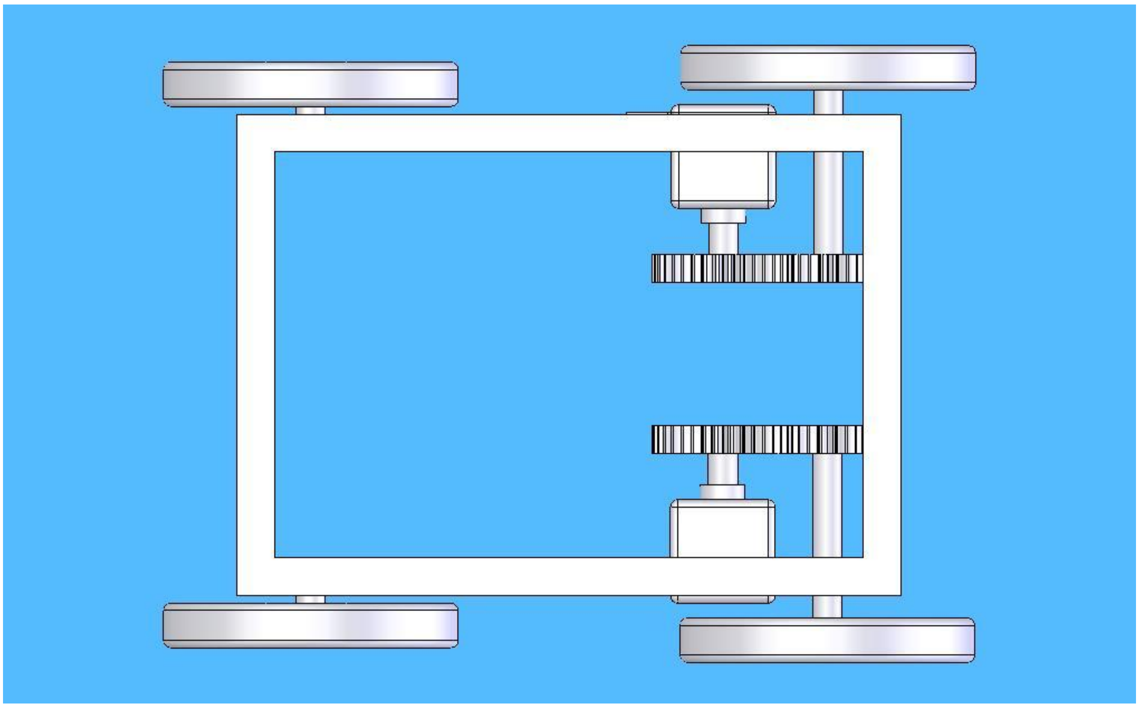


Figure 4.2 Top View of AGV

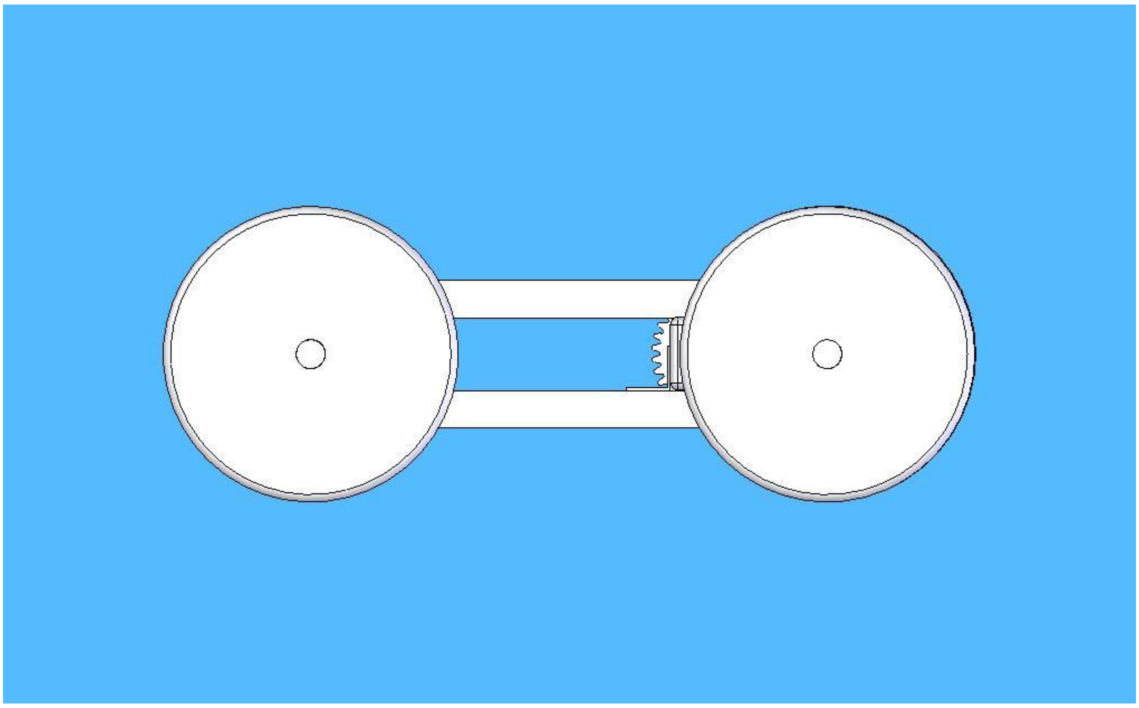


Figure 4.3 Side View of AGV

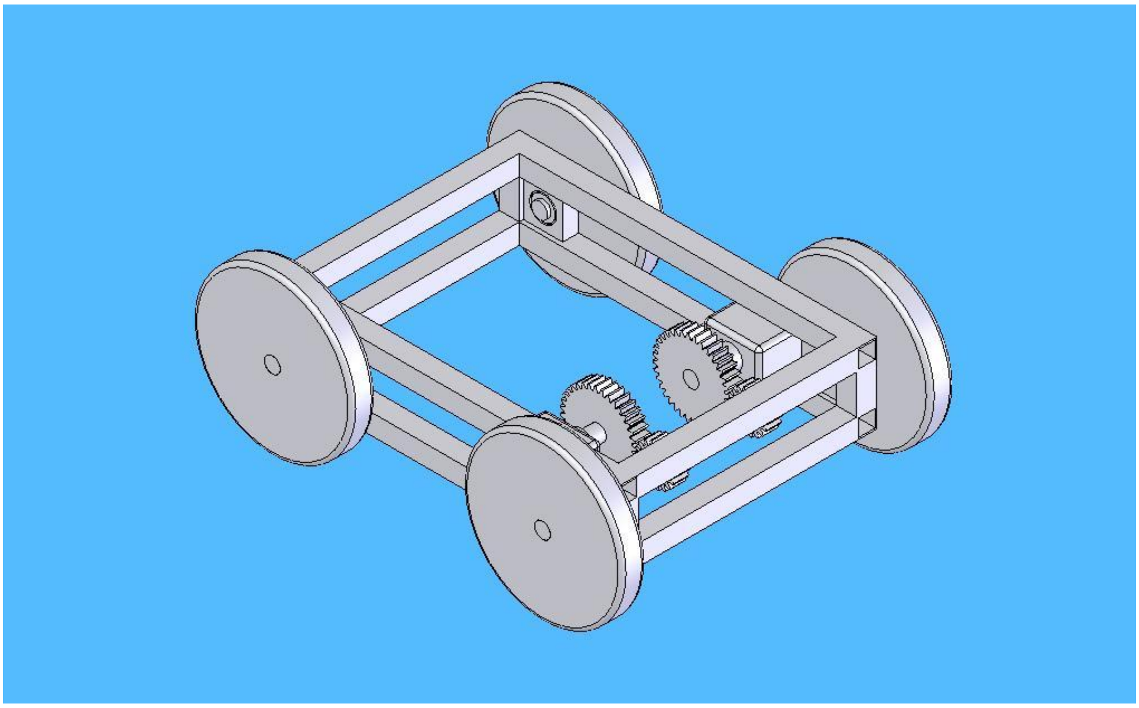


Figure 4.4 Isometric View of AGV

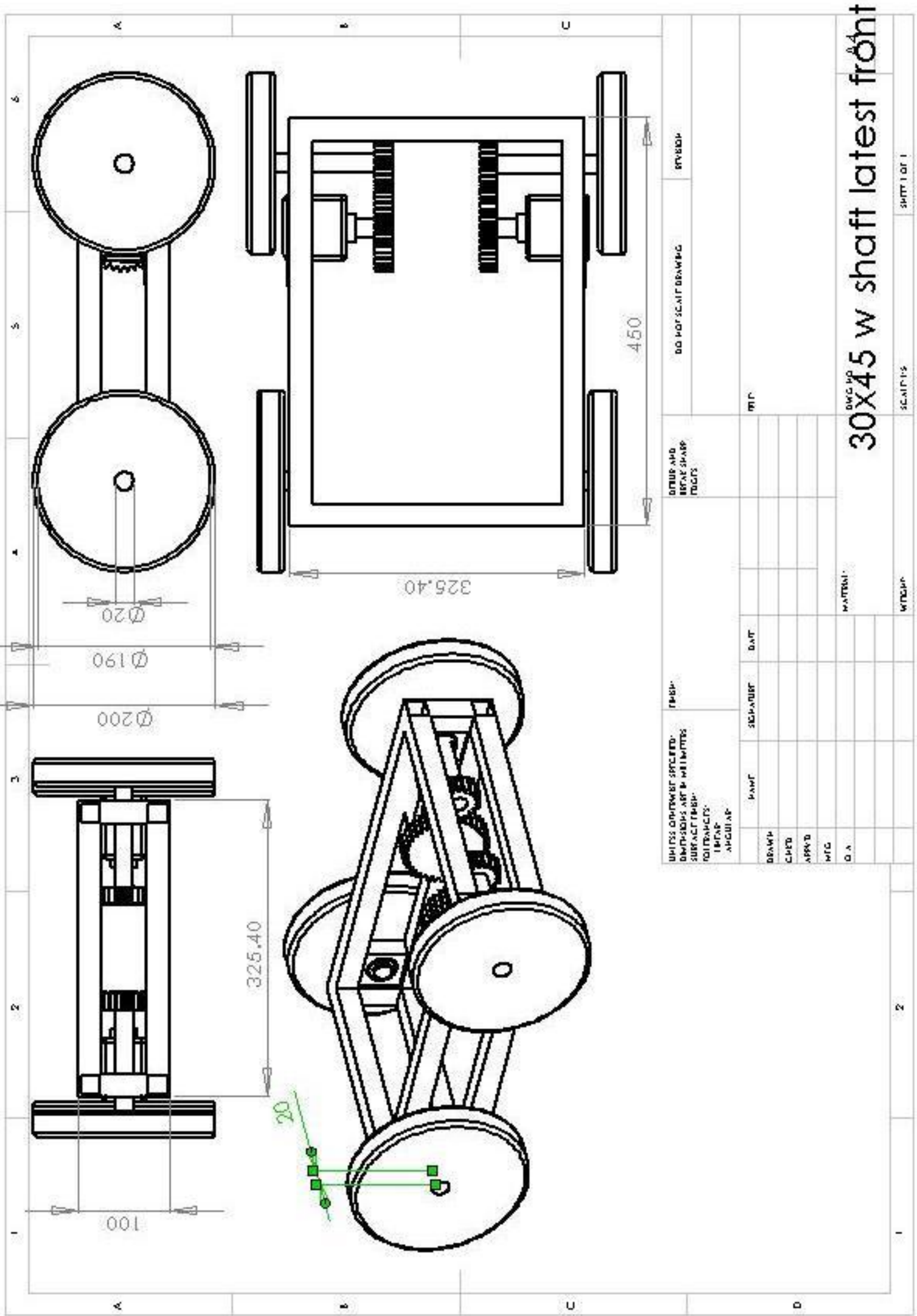


Figure 4.5 Schematic Diagram of Vehicle

In this design, the vehicle is a front driven vehicle with all the motor were situated at the front of the chassis. This is for easier turning and a sharper turn. This will help the vehicle to navigate through a condensed place easier. The empty space at the rear of the vehicle is for battery placement. The weight of batteries and weight of motor and driving part will cancel each other thus weight and stressed on the vehicle will be almost equal between front end and rear end. The schematic diagram for other parts are in appendix.

The wheel chosen for the vehicle is a 200 mm diameter vehicle. This is ensuring the vehicle has a high clearance of the ground. The high clearance of the vehicle is for getting through obstacle that may occur on the road such as rocks and debris.

4.2.2 Built Of Material

In this built of material, it is stated all the required parts for the AGV.

Table 4.1 Built of Material for AGV

Name	Material /Part	No. of Unit
Chassis 450mm X 325.4mm X 100 mm (LXWXH)	Aluminum 2024	1
Wheel (Diameter = 200mm)	Steel and rubber	4
Bearing for Shafts (Bore 20mm O.D 42mm)	6004-2RS	4
Gear 18 teeth & 36 teeth	Steel	1 each
Motor 4.21 Nm	351-4726	2
Shafts 160mm X 20 mm & 60mm X 20 mm (L X Dia)	Steel AISI 1018	2 each

The part for motor the recommendation is motor from RS Malaysia direct current motor catalogue.

The most suitable bearing used the current chart and catalogue in determining by comparing the size of bore for shaft that had in the design that is 20 mm. From the table,

Table 4.2 Extra Light Bearings

Number	**Bore**	**O.D.**	**Thickness**
6000-2RS	10	26	8
6001-2RS	12	28	8
6002-2RS	15	32	9
6003-2RS	17	35	10
6004-2RS	20	42	12
6005-2RS	25	47	12
6006-2RS	30	55	13
6007-2RS	35	62	14
6008-2RS	40	68	15
6009-2RS	45	75	16
6010-2RS	50	80	16
6011-2RS	55	90	18
6012-2RS	60	95	18
6013-2RS	65	100	18
6014-2RS	70	110	20
6015-2RS	75	115	20

4.3 Analysis on Automated Guided Vehicle

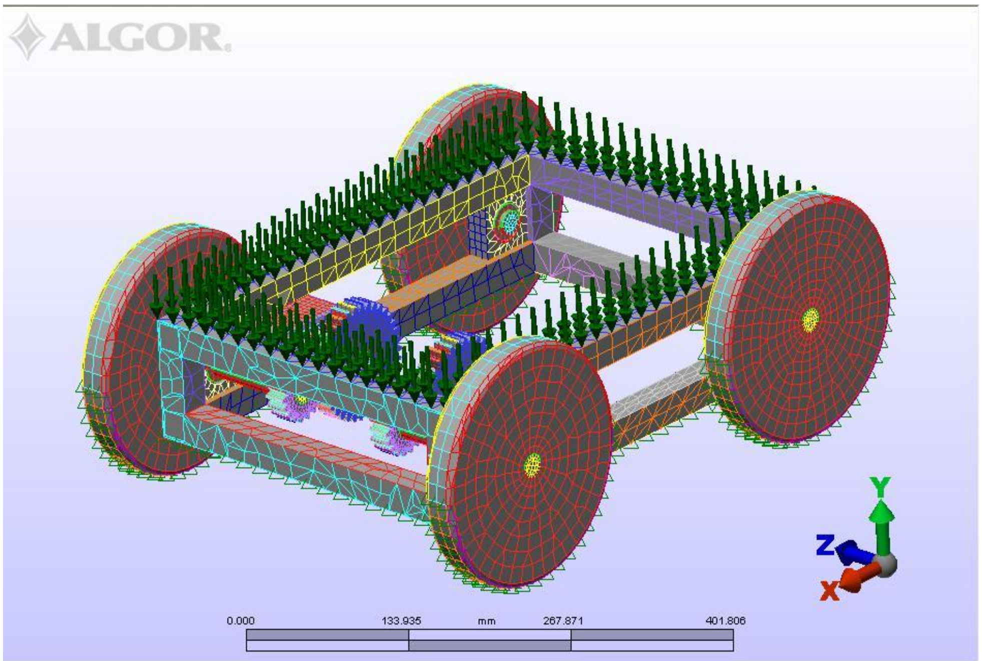


Figure 4.6 Diagram of analysis

The first step in analysis for ALGOR 22 software is by meshing the design. The meshing is for preparing the design for the next step that is doing the analysis. In this analysis, the vehicle top body is applied force of 98.1N equivalent to a 10 kg. This is to simulate the vehicle being applied load of 10 kg.

In order to simulate the tire is on the ground, the tire has to be fixed in all direction. As all the properties have been selected, the last is to consider all the joints and connecting parts as welded. This will give extra strength as a welding could be.

The material that has been selected is Aluminium 2024 for the chassis of the vehicle. As material for gear part and shaft is Steel AISI 1018. The material for wheel is selected as Steel AISI 1018.

Finally, after all the properties have been selected, the analysis can be start by pressing the traffic light button.

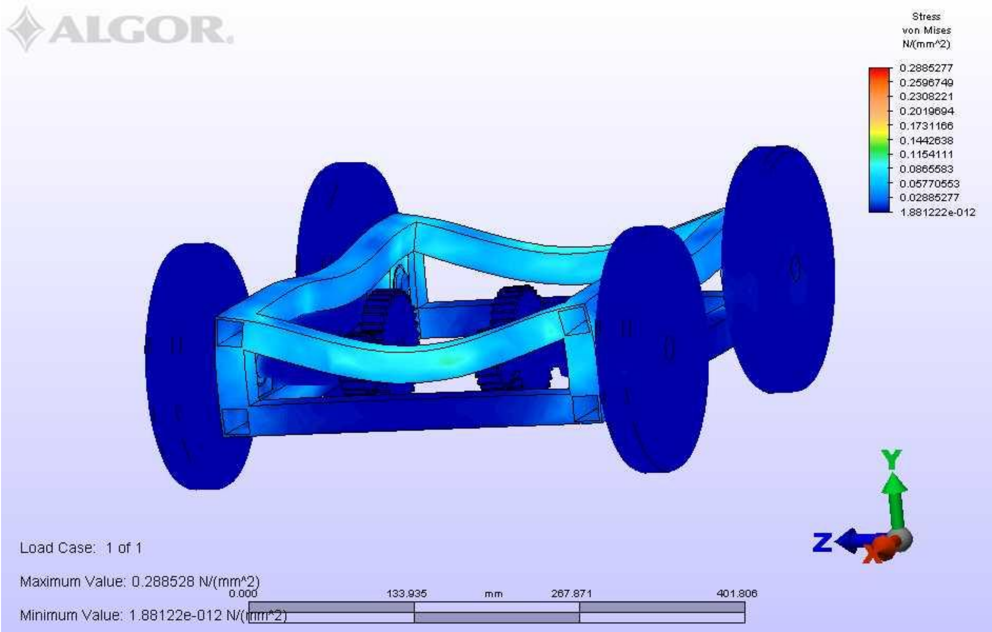


Figure 4.7 Analysis of Von Mises Stress

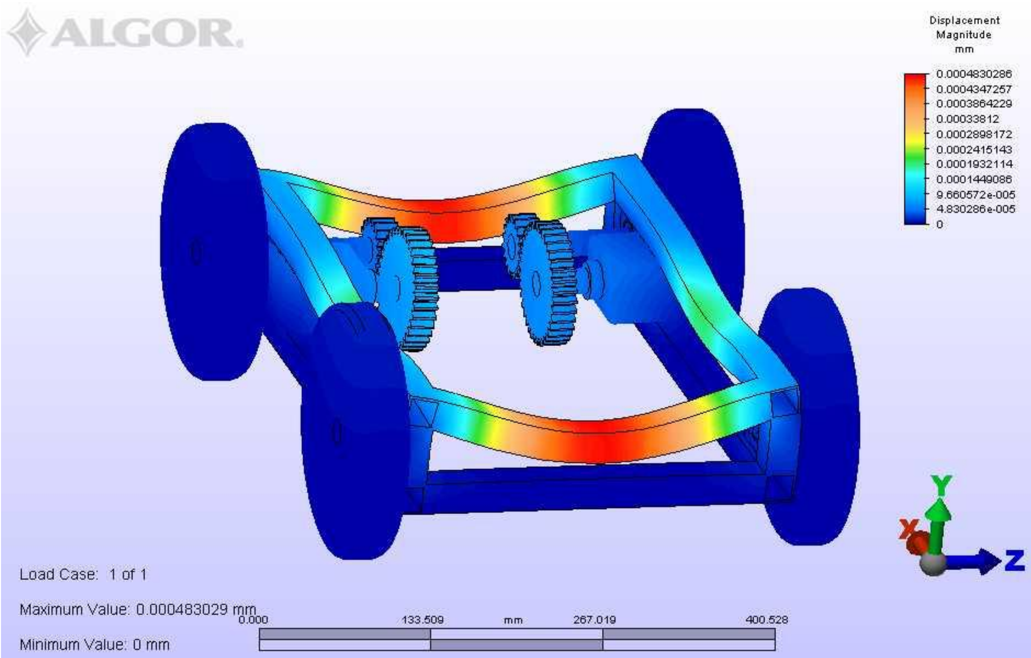


Figure 4.8 Analysis of Displacement

4.4 Material Selection

In order to get the best result, comparison of material has to be done. The material that has been chosen for comparison is the most use materials in industry, which is aluminium and steel. The chosen aluminium is Aluminium 2024 while the steel is Steel AISI 1018. The result of comparison between the two materials is stated in the table below.

Table 4.3 Comparison of Material

Material	Mass	Maximum Stress	Displacement
Steel AISI 1018	4.75 kg	0.58 N/mm^2	0.0003 mm
Aluminum 2024	1.66 kg	0.29 N/mm^2	0.0004 mm

4.5 Manual Calculation

The automated guided vehicle operates using motor thus calculations has to be done in order to find the specification of the motor. Below is the calculation made to find the motor for AGV specification:

Vehicle Volume without Load

$A = 2.54^2 - 2.14^2 = 1.872\ cm^2 = 1.872 \times 10^{-4}\ cm^2$

$\rho_{\text{aluminium 2024}} = 2780\ kg/m^3$

$1.872 \times 10^{-4}\ cm^2 \times 32.54\ cm \times 2 = 121.83\ cm^3$

$1.872 \times 10^{-4}\ cm^{2\ x}\ 39.92\ cm \times 2 = 149.46\ cm^3$

$1.872 \times 10^{-4}\ cm^2 \times 10\ cm \times 2 = 74.48\ cm^3$

$V_{total} = 6.175 \times 10^{-4}\ cm^3$

$M_{Veh} = \rho \times V = 1.72\ kg$

Mass Calculations:

$Mass_{Total} = M_{Veh} + M_{Batt} + M_{Gear} + M_{Motor} + M_{Misc}$

$= 1.72 + (2 \times 1.5) + 1 + (2 \times 1.5) + 1.5$

$= 10.22\ kg$

$Mass_{Total} + Mass_{Load} = 10.22 + 10$

$= 20.22\ kg$

With factor of safety,

Factor of safety: 1.25

M = M. FoS

M = 20.22 x 1.25 = 25.275 kg

Calculation of the speed requirements

Total wheel outer diameter, $D_{0} =$ 200 mm = 0.2 m

Speed requirement = 1 m/s

$$S_1 := 2 \cdot \pi \cdot \frac{D_o}{2}$$

S_1= 0.628 m in one revolution

Number of revolution to get up to speed $= S_v / S_1$

$= 1/0.628$

$N_r = 1.59\ s^{-1} = 95.4$ rpm

Calculation of the required torque

The motor has to overcome two forces:

They are,

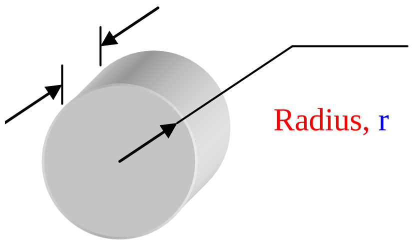
1) The frictional resistance due to the self weight of the machine
2) The inertial resistance offered by the wheel

Calculation of the resistance due to inertia of the wheel

(Based on Dr. Hall and Brad Mathews's design of steering wheel **(Feb. 8, 1994)**)

$$\rho := 1 \cdot \frac{kg}{m^3}$$

$$dh := 1 \cdot m$$



Design Explanation

Figure 4.9 Wheel Design

$$d\theta := 1 \cdot deg$$

$$dr := 1 \cdot m$$

For the above solid cylinder of radius, r, thickness, h and density, ρ,

$$dv := r \cdot dr \cdot d\theta \cdot dh$$

$$dm := \rho \cdot dv$$

Where,

$$J := \int_0^r r^2 \, dm$$

$$J := \int_0^h \int_0^{2\cdot\pi} \int_0^r r^2 \cdot \rho \cdot r \, dr \, d\theta \, dh$$

$$h := 1 \cdot m$$

$$J := h \cdot 2 \cdot \pi \cdot \rho \cdot \left(\int_0^r r^3 \, dr \right)$$

$$\theta := 1 \cdot deg \qquad \rho := 1 \cdot \frac{kg}{m^3}$$

$$r := 1 \cdot m$$

$$J := \frac{\pi \cdot \rho \cdot (r)^4 \cdot h}{2}$$ .... (Equation 1.0)

Now, assuming the tire we use to be as follows,

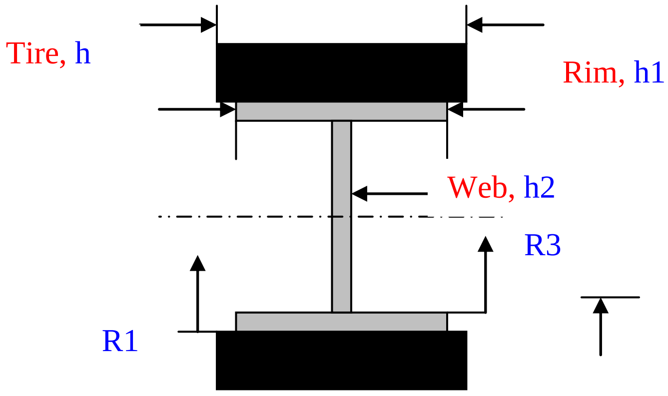


Figure 4.10 Shafts and Wheel

Let, as shown in the figure,

R1 - be the radius of the rim,

R2 - be the radius of the tire,

R3 - be the radius of the web,

h1 - be the thickness of the rim,

h - be the thickness of the tire,

h2 - be the thickness of the wheel,

Then,

$R_1 := 1 \cdot m$

$R_2 := 1 \cdot m$

$R_3 := 1 \cdot m$

$h_1 := 1 \cdot m$

$h_2 := 1 \cdot m$

The total inertia equals the sum of the inertia of the rim, tire and the web.

$h_3 := 1 \cdot m$

If the density of rim, wheel be R1 and tire be R2,

$$\rho_1 := 1 \cdot \frac{kg}{m^3}$$

The inertia due to the rim, say J_{rim}, would be,

$$J_{rim} := \frac{\pi \cdot \rho_1 \cdot h_1 \cdot \left(R_1^{\,4} - R_3^{\,4}\right)}{(2 \cdot g)}$$

From equation 1.0

$$J_{web} := \frac{\pi \cdot \rho_1 \cdot h_2 \cdot R_3^{\,4}}{2 \cdot g}$$

From equation 1.0

$$J_{tire} := \frac{\pi \cdot \rho_1 \cdot h_2 \cdot \left(R_2^{\,4} - R_1^{\,4}\right)}{2 \cdot g}$$

From equation 1.0

$$J_{total} := J_{rim} + J_{web} + J_{tire}$$

Now, let us substitute the values we have:

The density of steel varies between 5700 kg/m^3 to 5950 kg/m^3

In order to over-design, assume, ρ = 5950 kg/m^3

The density of tire-rubber varies between 400 kg/m^3 to 865 kg/m^3

In order to over-design, assume, ρ = 865 kg/m^3

Thus;

$$J_{Total} = J_{Web} + J_{Tire} + J_{Rim}$$
$$= 2.29 \times 10^{-5} + 1.23 \times 10^{-3} + 7.74 \times 10^{-4}$$
$$= 2.023 \times 10^{-3}$$

Calculation of the force required to overcome self-weight.

The co-efficient of static friction, between rubber and concrete varies between:

$$0.6<\mu<0.9$$

Over designing the vehicle, assume,

$$\mu := 0.9$$

Estimated mass of the vehicle, M is :

M= 25.275 kg

Force required to overcome friction is given by,

$F_{friction} = \mu.\ M.\ g$

$= 0.9(25.275\ kg)\ g$

$= 223.15\ N$

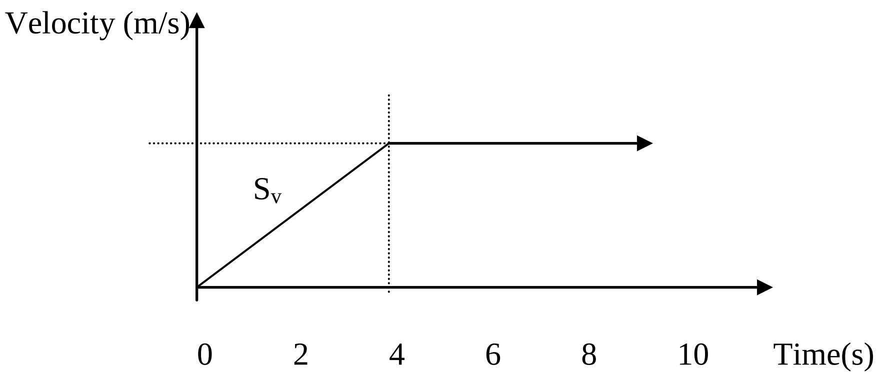
Or

Therefore the torque to be supplied at the end of the wheel to overcome the limiting value of the static friction is:

$T_{friction} = F_{friction}.\ R_2$

$= 22.315\ Nm$

Determination of Angular Acceleration Required in Motor



Where, S_V is the required maximum speed of the vehicle

$S_v = 1$ m/s

So, the maximum speed is achieved in t seconds:

t= 4 seconds

Therefore, the required acceleration a is

$$a := \frac{S_v}{t}$$

a= 0.25 m/s^2

Thus:

$$\alpha := \frac{a \cdot 2 \cdot \pi}{S_1}$$

S_1= 0.628 m in one revolution

α = 2.5 rad/sec

Determination of the inertial torque, reflected through the gear train

N_r= 1.59 s^{-1} = 95.4 rpm

N motor = 200 rpm

From motor specified speed (selected later)

Then, the required gear reduction would be:

$$i := \mathrm{floor}\left(\frac{N_{motor}}{N_r}\right) + 1$$

i= 3.09, say i= 3

The reflected inertia through the gear train is:

$$J_{inertiaatmotor} := J_{total} \cdot \left(\frac{1}{i}\right)^2$$

$J_{\text{inertia at motor}}$ = 2.49 x 10^{-5}

The torque reflected through the gear train to overcome <u>static</u> frictional force

$$T_{frictionthrugear} := T_{friction} \cdot \left(\frac{1}{i}\right)$$

$T_{frictionthrugear}$ = 7.43 Nm

Determination of Total torque that the motor needs to overcome

The total torque required to move the vehicle can now be determined from:

$$T_{total} := \left(J_{motor} + J_{transmission} + J_{inertiaatmotor} \cdot a\right) \cdot \alpha \cdot 2 + T_{frictionthrugear} + T_{ftom}$$

Where,

T_{total}	= Total torque,
J_{motor}	= Inertia offered by the rotor,
$J_{transmission}$	= Inertia due to the power transmission. (Assumed)
$J_{inertiaatmotor}$	= Inertia of the wheel reflected at motor end,
a	= acceleration required,
α	= angular acceleration,
$T_{frictionthrugear}$	= Torque to overcome the static friction, reflected through power transmission
T_{ftom}	= Frictional torque of motor. (Assumed)
J_{motor}	= 0.2 $kg.m^2$ (Assumed)
$J_{transmission}$	= 0.001 $kg.m^2$ (Assumed)
$T_{frictionthrugear}$	= 7.43 Nm
T_{ftom}	= 0.001 $kg.m^2$ (Assumed)

a= 0.25 m/s^2

α = 2.5 rad/sec

T_{total} = 8.43 Nm $\qquad T_{mot} := \dfrac{T_{total}}{N_{mot}}$

T_{mot} = 4.21 Nm

4.6 Evaluate and Validate

As discuss in previous chapter, the need of evaluation and validation is to strengthen the analysis using the software.

Calculation

Using Stiffness Elements: Beams in Bending

We assume the beams are simply supported by the lower part of the chassis.

The formula given is:

$$F = K\delta_{\max}, \qquad \delta_{\max} = \frac{FL^3}{48EI}$$

$$K_b = \frac{48EI}{L^3}$$

Force used: 98.1 N

Length : (used the longest beam): 0.6 m

Material selected for beam

- AISI 1005 STEEL
- MASS DENSITY : 0.000000007872 Ns2 /mm/mm3
- MODULUS OF ELASTICITY : 200000 N /mm2
- POISSON RATIO : 0.29
- SHEAR MODULUS ELASTICITY : 80000 N /mm2

Calculating the maximum deflection for this beam is

$$I_x = \frac{bh^3}{12}$$

b = h = 2.5 cm = 0.025 m

I = 3.255 X 10^-8

Maximum deflection = 6.781 X 10 ^ -5 m

Maximum deflection from ALGOR V22 = 2.43 X 10 ^ -5 m

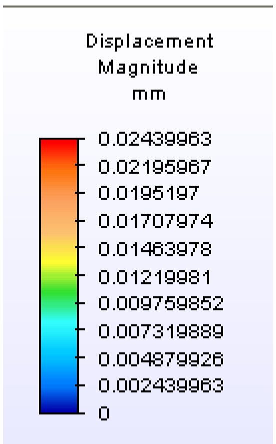


Figure 4.11 Data from ALGOR

CHAPTER 5

CONCLUSIONS

5.1 Summary

From this project, Automated Guided Vehicle is one of the material handling methods that has been widely used in most industry nowadays. As from the literature review, AGV is rated highly flexible material handling vehicle. From the results, the most suitable material for the chassis is the aluminium. The difference between the aluminium and steel in handling stress and displacement is almost the insignificant but aluminium is lighter thus is more appropriate material for this project. This project should be referring to a catalogue from companies. In this way, the cost of producing this AGV will be reduced as it will be built based on the existing line of product instead of manufacturing itself. The difference between the manual calculations and software data is caused by how the assumptions are made. As the difference is insignificant, the data from the software can be accepted. As referring to main objective, the design of Automated Guided Vehicle has been achieved by the design of the rectangular shape of the chassis.

5.2 Conclusions

For this project several objective had been set as a benchmark for this project. In order to complete this project, the objective of the project must be completed.

In this project, the objective requires designing the AGV and modeled it in computer software. For this objective, the project have certainly achieved the objective as the prototype of the AGV has certainly design and model in the computer software using the SOLIDWORKS 2006. The design has certainly meet the criteria for the AGV as it have its base structure, wheel, motor and other components needed for completion. Since the design of this AGV is simple the future project supposed to create a more advanced base structure as these were the prototype of the AGV.

As for the mechanical system, the system that were design for this project is the improvement of differential steering system as discussed in the literature review. The other mechanical design is the gearing system that is included as a velocity limiter. The completion of the mechanical system for this project has certainly achieved the objective for this project. Higher level of mechanical design for this AGV can be done and improve as the AGV has a large space for improvement.

Lastly, is the analysis using manual calculation and software. The manual calculations done are to validate the result from the software. Calculations also were done in order to determine the type of motor needed for this project. From this, the project has certainly achieved the third objective. The limit of this calculation done is that, calculations are done by assuming some of the parameters. Thus the calculation will slightly differ from the actual result using software.

5.3 Recommendation

After completing this project, there is some recommendation idea that can be use for further study in improvising this project. The idea recommendation will include the more advanced controller use a better type of chassis and lighter in weight.

The improvement that can make to the chassis is using plate type chassis. The plate type chassis is lighter than a tube type chassis. With a plate type chassis the design of the vehicle can be smaller.

Next improvement is add-on equipment such as stage lift. This stage lift can be more ergonomics to the users as the users doesn’t have to bend lower to pick up the load. This will increase the value of the AGV.

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APPENDICES A

GANTT CHART FOR FINAL YEAR PROJECT (FYP) 1

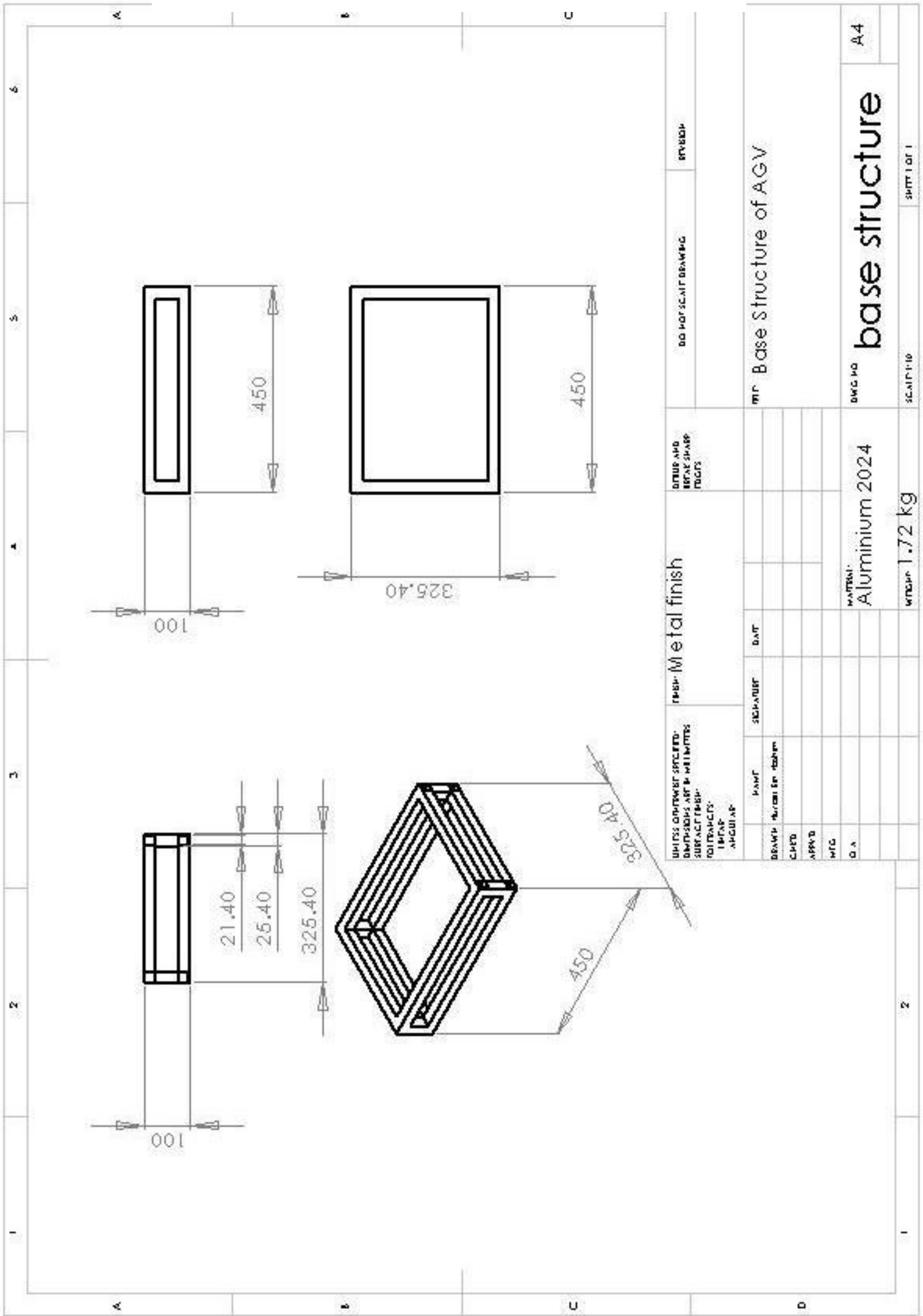
PROJECT ACTIVITIES	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project confirmation	■													
Literature study		■	■	■	■	■	■	■	■	■	■	■	■	
Identify problem			■	■										
Define objective and scope of study					■	■	■							
Methodology								■	■					
Make proposal										■	■			
Presentation preparation												■	■	
Presentation 1														■

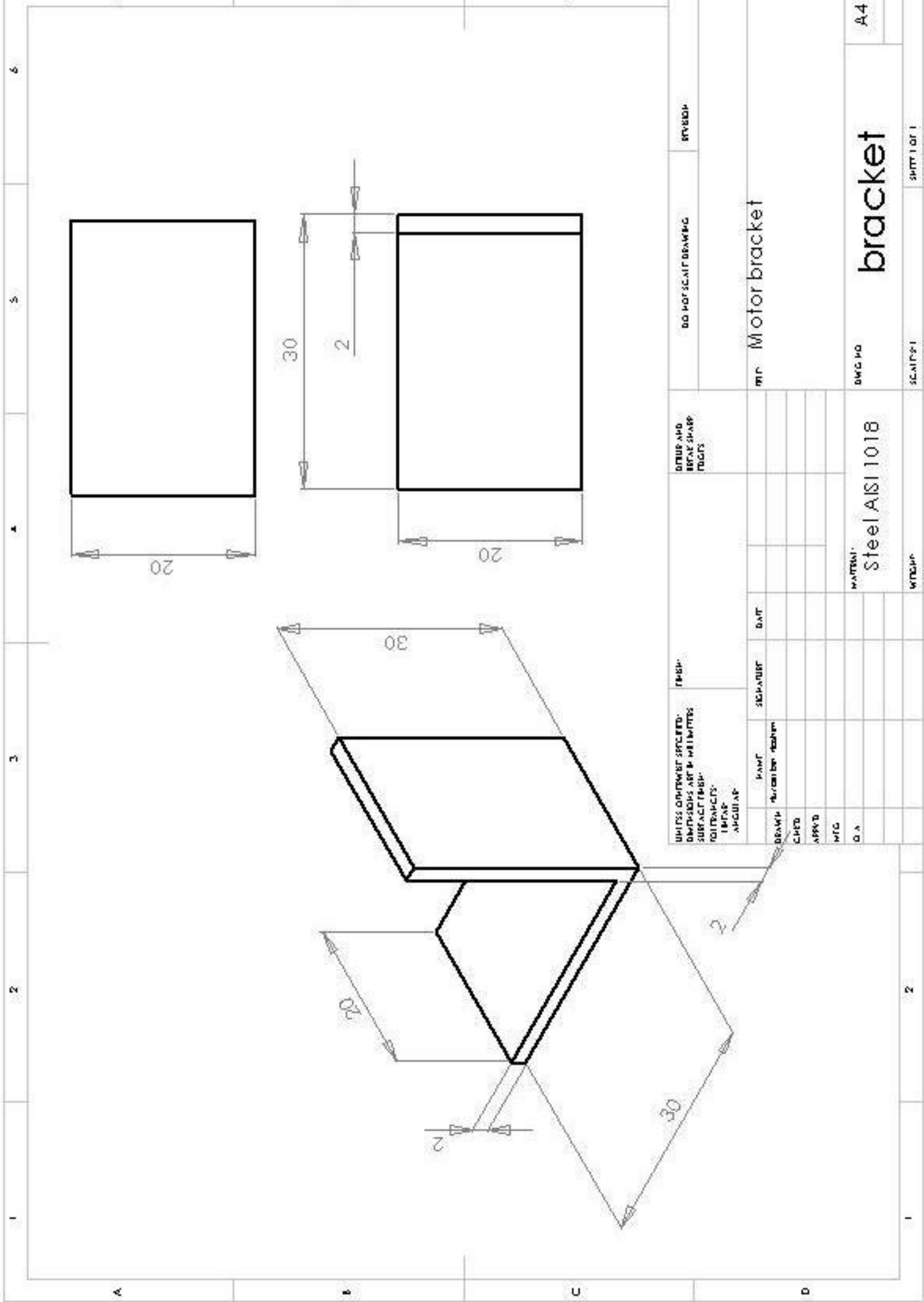
GANTT CHART FOR FINAL YEAR PROJECT (FYP) 2

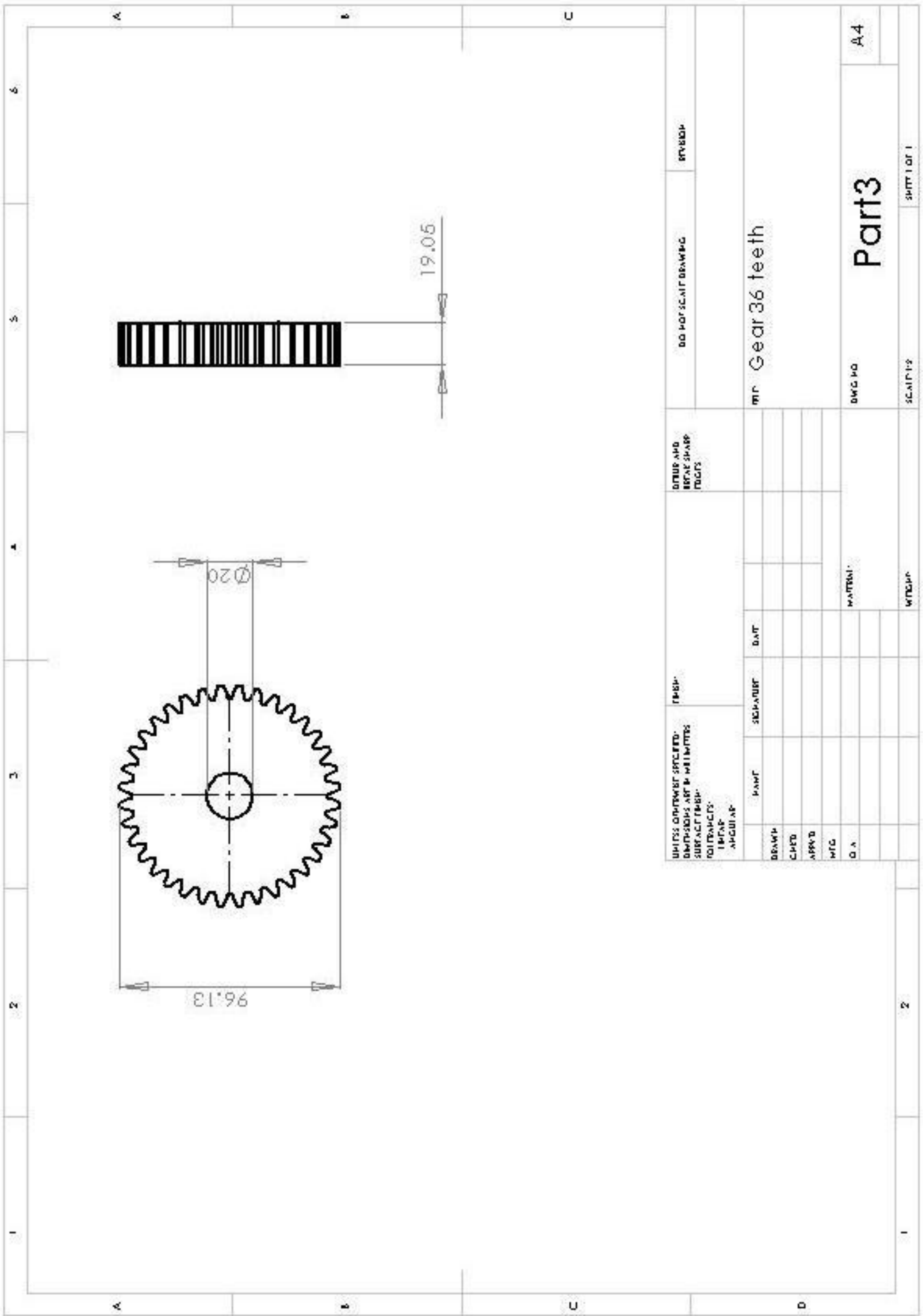
PROJECT ACTIVITIES	WEEK															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Finite element analysis	■	■	■	■												
Design analysis				■	■											
Result comparison					■	■										
Design optimization						■	■	■	■							
Discussion										■	■	■				
Conclusion												■				
Presentation 2													■			
Make final report														■	■	

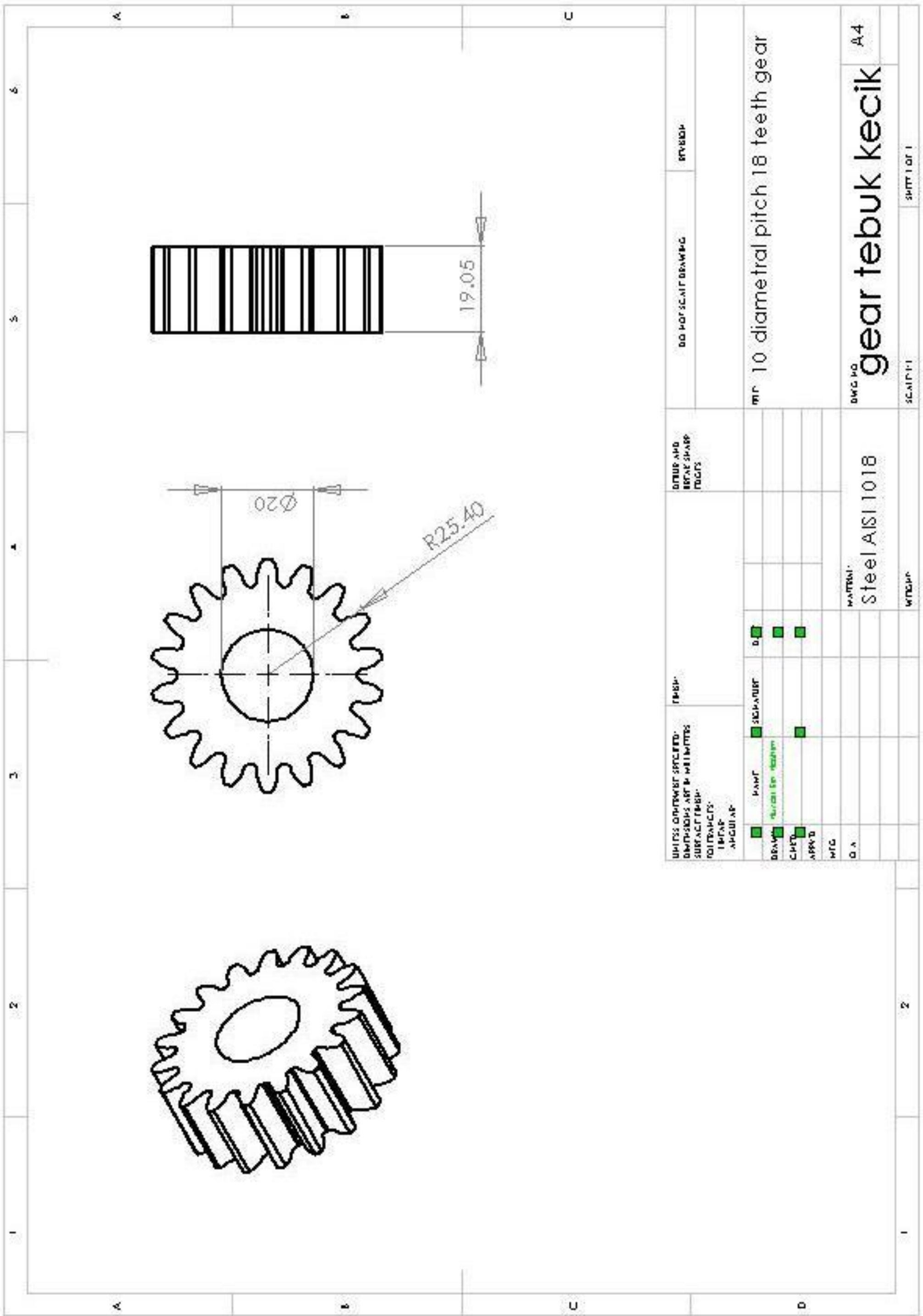
APPENDICES B

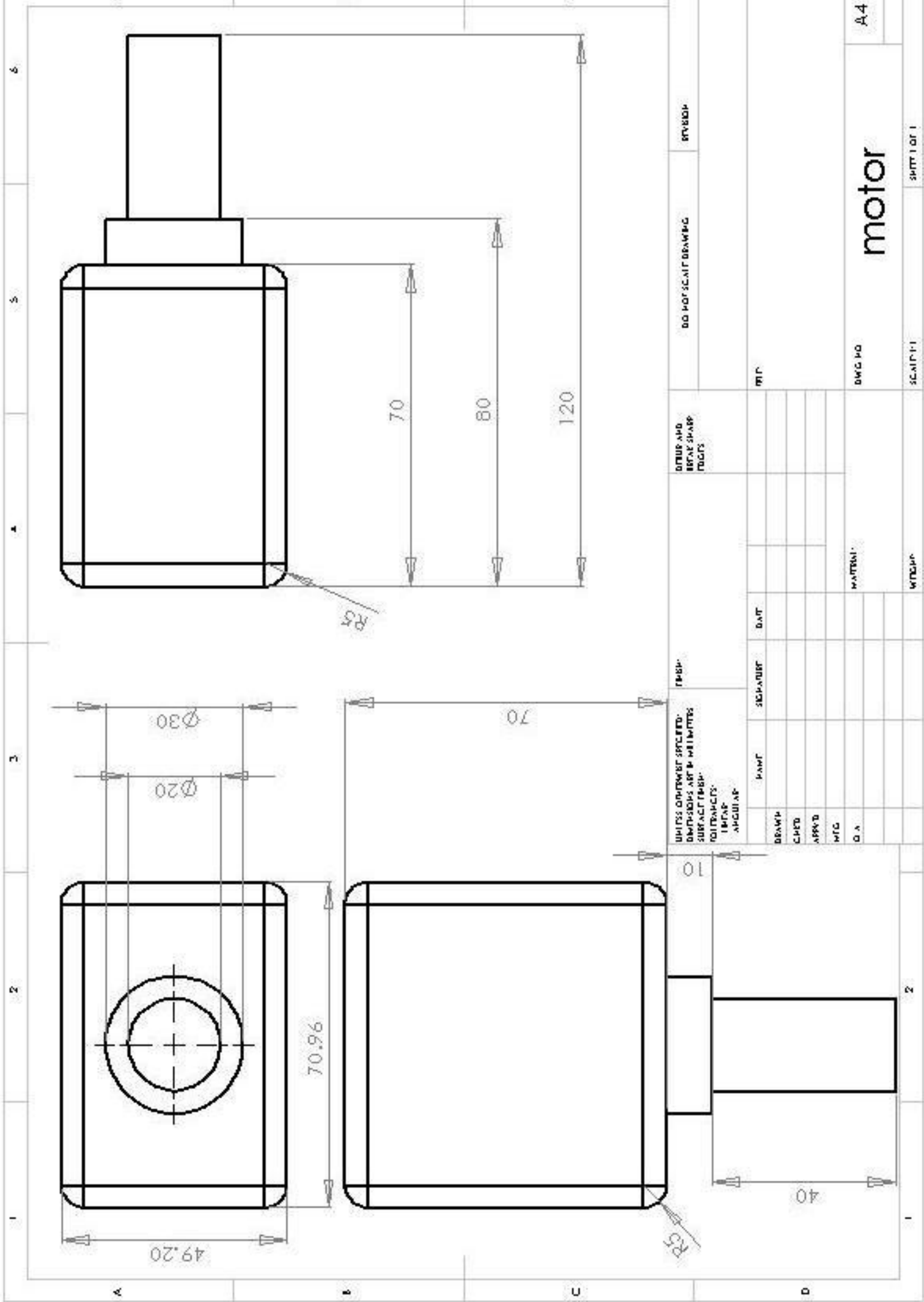
Schematic Diagram for AGV component



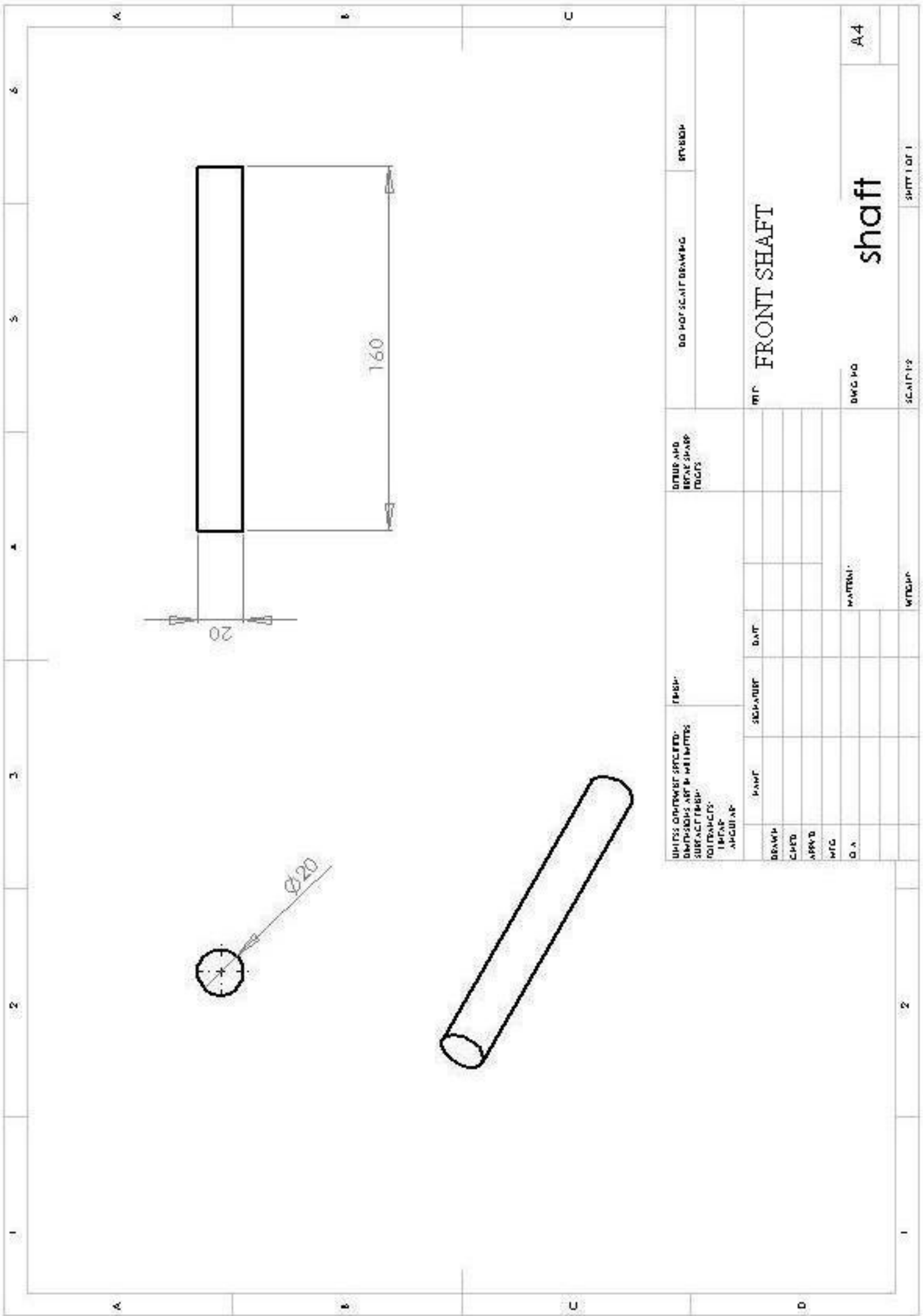

Motor bracket
bracket
Steel AISI 1018
A4
30
20
2
30
20
2
30
20
2

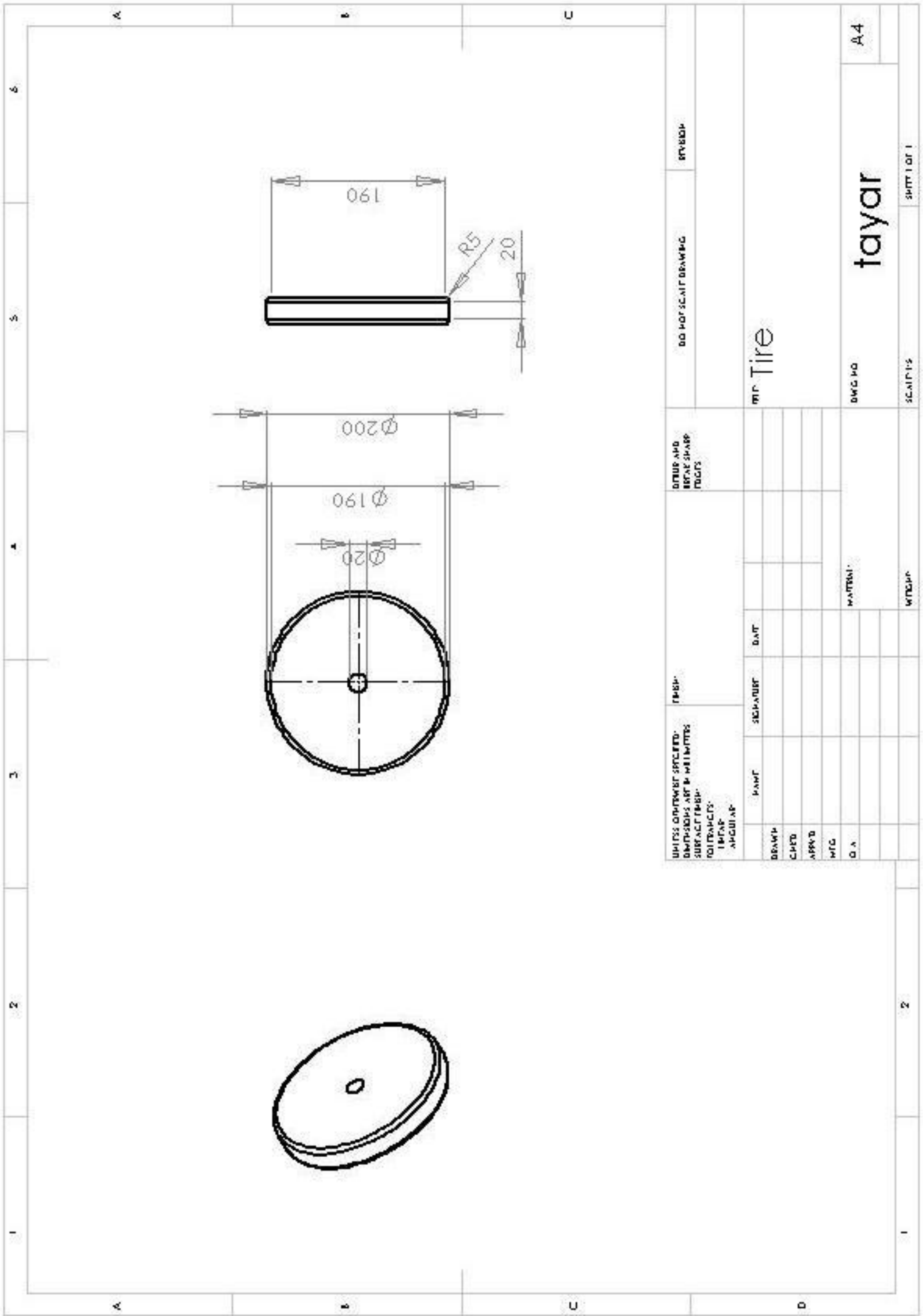

Gear 36 teeth
Part3
A4
19.05
Ø20
96.13

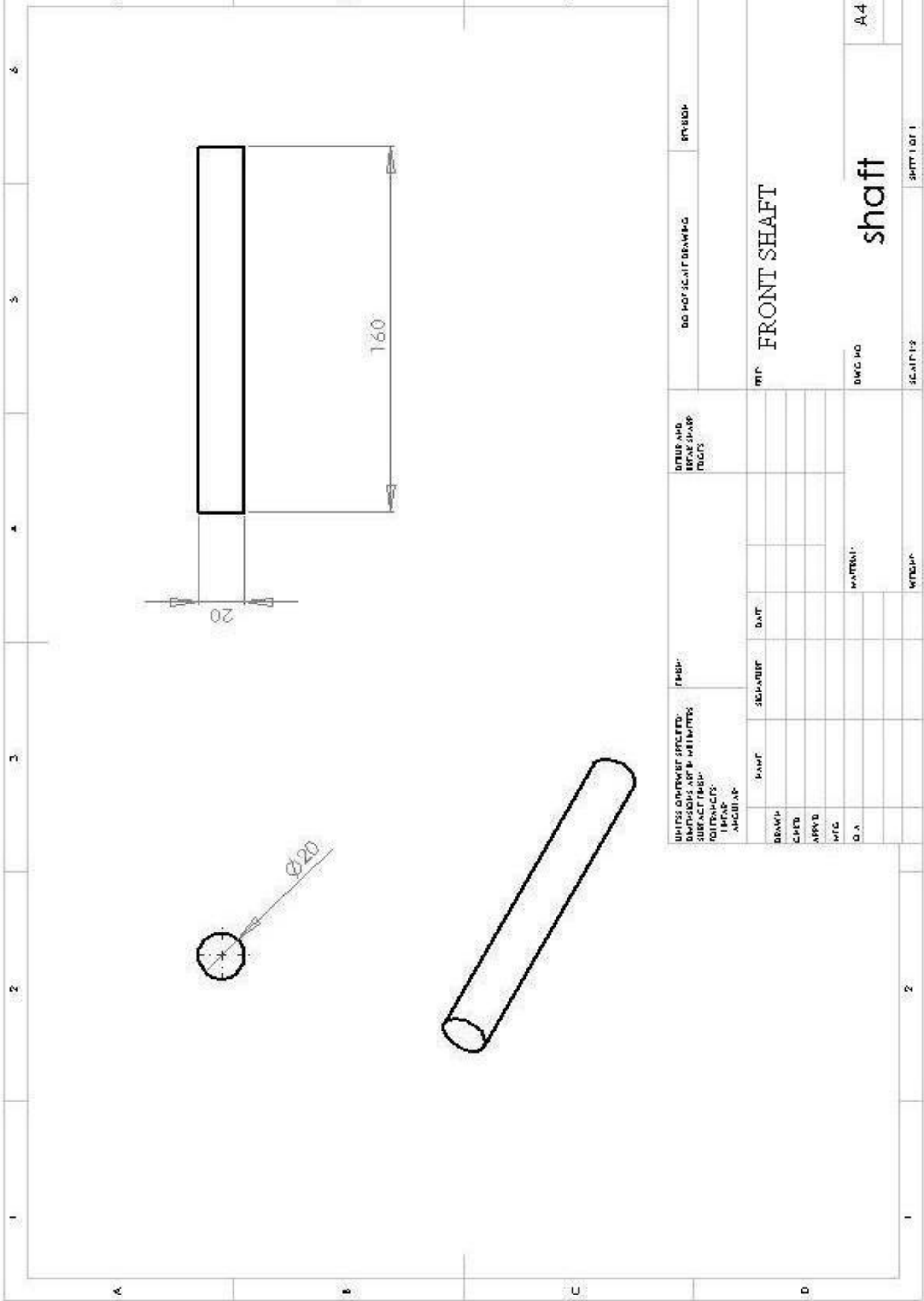

19.05
Ø20
R25.40
10 diametral pitch 18 teeth gear
gear tebuk kecik
Steel AISI 1018
A4



motor
A4
70
80
120
R5
Ø30
Ø20
70
10
70.96
49.20
40
R5


FRONT SHAFT
shaft
A4
160
20
Ø20


Tire
tayar
A4
Ø200
Ø190
Ø20
190
R5
20



160
20
Ø20
FRONT SHAFT
shaft
A4