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Introduction of AGV

Autonomous vehicles or automatic guided vehicles (AGV) are robotic vehicle which can perform desired tasks in unstructured environments without continuous human guidance. Many kinds of robots can be autonomous in different ways. A high degree of autonomy is particularly desirable in filed such as space exploration, cleaning floors, mowing lawns and waste water treatment.

Some modern factory robots are autonomous within the strict confines of their environment. It may not be that every degree of freedom exists in their surrounding environment but the factory robot's workplace is challenging and can often contain chaotic, unpredicted variables. The exact orientation and position of the next object of work and a fully autonomous robot has the ability to:

- Gain information about the environment.
- Work for an extended period without human intervention.
- Move either all or part of itself throughout its operating environment without human assistance.
- Avoid situation that are harmful to people, property, or itself unless those are part of its design specification.

1.1 Types of AGV

1.1.1 Forklift AGVs:

Fork Truck has the ability to service loads both at floor level and on stands. In some cases these vehicles can also stack loads in rack.

Fig 1.1 Forklifts AGV.

1.1.2 Unit Load AGVs

Unit Load Vehicles are equipped with decks, which permit unit load transportation and often automatic load transfer. The decks can either be lift and lower type, powered or non-powered roller, chain or belt decks or custom decks with multiple compartments.

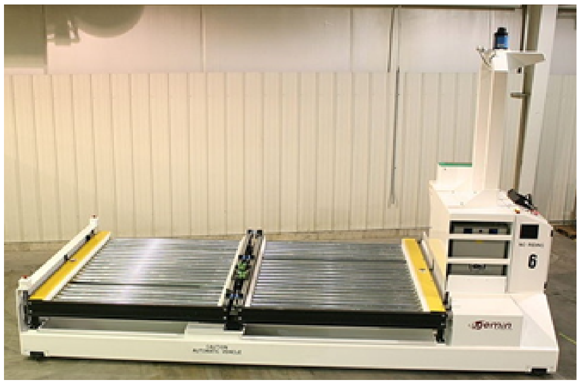

Fig 1.2 Unit load transfer AGV.

1.1.3 Hybrid Vehicles AGVs:

They are adapted from a standard CAT-style man-aboard truck so that they can run fully automated or be driven by a fork truck driver. These can be used for trailer loading as well as moving materials around warehouses. Most often, they are equipped with forks, but can be customized to accommodate most load types.

1.1.4 Clamp AGVS:

Automated guided vehicles with clamps for transport of rolls and palletized loads

1.1.5 VNA AGVs:

AGVs for automated material handling and storage in narrow aisles of warehouses

1.1.6 TUGGER AGVs:

AGVs for transport of carts with loads, manually or automatically with actuated hitch

1.1.7 CUSTOM-MADE AGVs:

Automated guided vehicles with special load handling devices for specific applications

Fig1.3 custom made AGV.

1.3 AGVs Components

AGVs use many different components to assist it in getting a load from point “A” to point “B”. These components range from sensors on the vehicle used to detect objects or people in the near vicinity to the control system that is used to control the actions of the vehicle as well as interface it with the server that receives the work requests.

1.3.1 Controller:

The controller typically consists of a microprocessor that is used to gather data and make decisions based on a program. The controller tells the vehicle how fast to go, where to go, where to turn, and when to stop. .

A controller will maintain communication with another PC/workstation that "supervises" all of the AGV controllers. The supervisor controls traffic, tells the AGV where the load is to be picked up and where to take it. When the routing of the vehicles must change, a user can install the program on the supervisor, and the supervisor can download it to the individual AGV controllers.

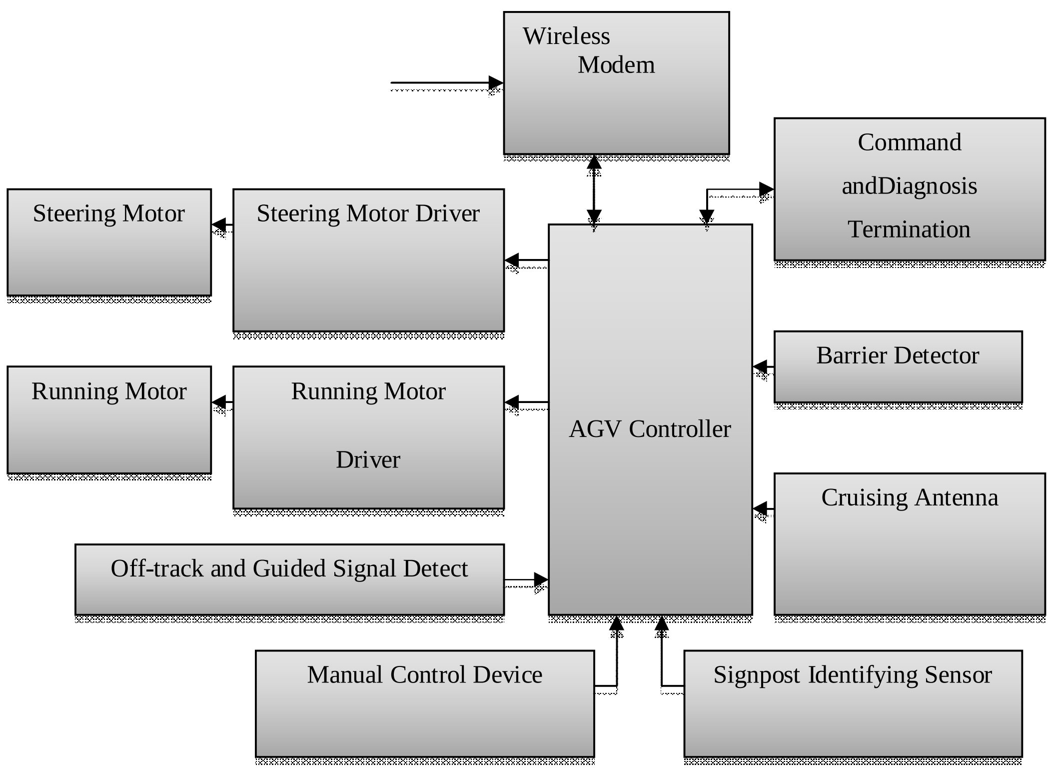

FIG 1.4 CONTROL CONFIGURATION.

1.3.2 Sensors

Sensors come in all shapes and sizes and have a variety of different uses from temperature sensors to proximity sensors. A temperature sensor on an AGV can monitor battery temperature to prevent the battery from being damaged. Proximity sensors can be used to determine if there are objects in the path of the AGV such as inanimate obstructions or personnel. Guidance systems use sensors to determine position by sensing targets on the wall, chemicals on the floor, magnets in the floor, etc.

1.3.3 RF Modem

Since AGVs are not wired directly to a “supervisor,” and the AGV must know where loads are and where to drop them off, an RF modem is typically used for communication between the controller on the AGV and the supervisor computer. Without this modem, the AGV would have to be controlled manually, which defeats a large portion of the purpose (reduction in manning) behind using AGVS.

1.3.4 Navigation system

The navigation is done by mounting reflective tape on walls, poles or fixed machines. The AGV carries a laser transmitter and receiver on a rotating turret. The laser is transmitted and received by the same sensor. This information is compared to the map of the reflector layout stored in the AGV's memory. This allows the navigation system to triangulate the current position of the AGV. Which is compared with map already stored and according to that steering is adjusted.

It has two types:

Modulated Lasers: The use of modulated laser light gives greater range and accuracy over pulsed laser systems. By using a modulated laser a system can achieve an angular resolution of ~ 0.1 mrad (0.006°) at 8 scanner revolutions per second.

Pulsed Lasers: A typical pulsed laser scanner emits pulsed laser light at a rate of 14,400 Hz which gives a maximum possible resolution of ~ 3.5 mrad (0.2°) at 8 scanner revolutions per second.

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2.1 Issues of wheel size

Wheel size:

In general larger the wheel, the larger the obstacle the vehicle can get over. In most suspension and derive train system, a wheel will be able to roll itself over an obstacle that is about the one third the diameter of the wheel. In a well-designed four wheel vehicle it can be increase a little, but the limit in the most suspension is something less than the half the diameter of the wheel.

Three wheels are the minimum required for the static stability, the three wheel robots are most common. Mobility and complexity is increased by further adding of the more wheels. Let's take a look on the wheel vehicles in through order. The most basic vehicle will have minimum number of wheels. It is also possible to make a one wheel vehicle but with a limited mobility.

2.2 Number of wheels in designing a vehicle

2.2.1Three wheel layout:

There are five possible layouts of three wheeled vehicle the most common and easiest to implement, but with, perhaps the least mobility is presented by a kid's tricycle. But powering by only one of the three wheel results in the lowering of net traction, which further lowers the motive force. In order to improve the mobility the three wheels all terrain cycle (ATC) was developed. In this the rear two wheels are powered through differential and the front steer.

Increasing the mobility of three wheel vehicle can also be accomplished by reversing the layout, putting the two wheels in front. This layout is works fine for low speed, but geometry is difficult to control at high speed as the force on rear wheel tends to make vehicle turn more sharply. Steering with the front wheels on the reverse tricycle removes the steering problem. But adds the complexity of steering and driving both wheels. This layout allows the placing the more weight on the passive rear wheel, significantly reducing the flipping over tendencies and mobility is moderate. The layout is still dragging around the passive wheel, however, and mobility is further enhanced if the wheel is powered.

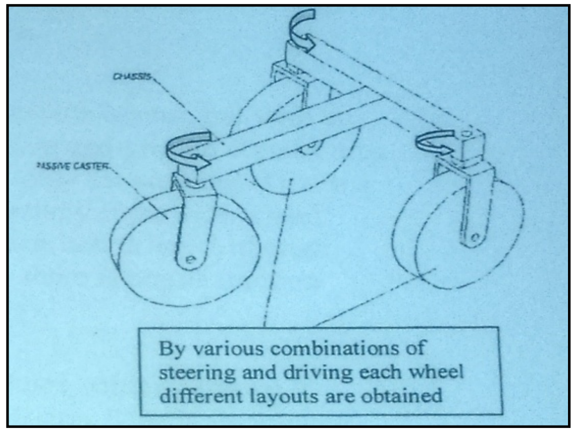

Fig 2.1 Three wheel layout

The most complicated and highest mobility three wheel layouts is one where the all three wheels are powered and steered as well. This layout is extremely versatile, providing motion in any direction without need of moving vehicle; this is called holonomic motion and is very useful in robotic motion.

2.2.2Four wheeled vehicles:

The most basic four wheel vehicle actually doesn't use differential. It has two wheels on each side that are coupled together and is steered just like a differential steered tricycle. Since the wheels are inline on each side and do not turn when a corner is commanded, they slide as the vehicle turns. The sliding action gives the steering method its name skid steering.

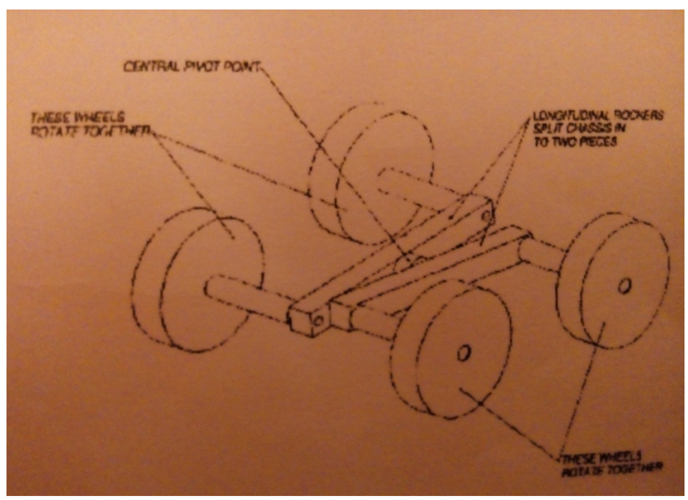

Fig 2.2 Four wheel layout.

The problem with skid steering non suspended drive is that as the vehicle goes over bumps, one wheel necessarily come off ground, this problem doesn't exist in two or three wheeled vehicles, but is more major to deal with on vehicle with more than three wheels

2.2.3 Five wheel layout:

This is basically the tricycle layout, but with an extra pair of wheels in a back to increase traction and ground contact area. The front wheel is not normally powered and is only for steering. This is a fairly simple layout relative to its mobility, especially if the side wheel pairs are driven together through a simple chain or belt drive. Although the front wheels must push over the obstacles, there is ample traction from all that rubber on the four rear wheels.

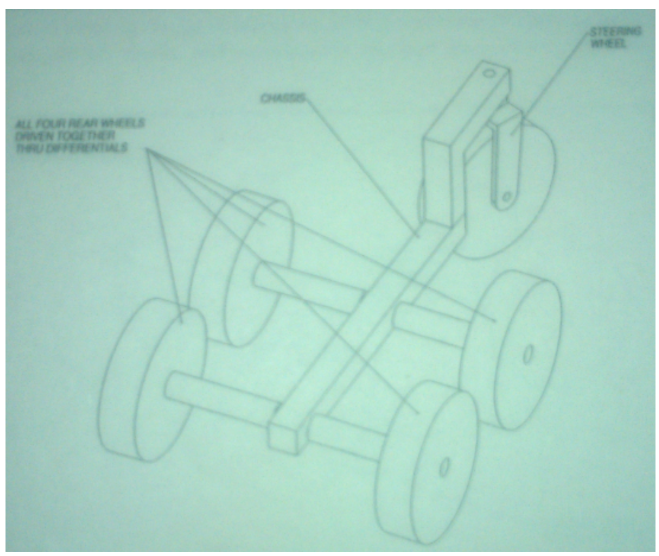

Fig 2.3 Five wheel layout.

2.2.4Six wheel layout:

The most common six wheeled vehicle shown in fig, is skid steered non-suspended design. This is very much like the four-wheeled design with improved mobility simply because there is more traction and less ground pressure because of third wheel on each side, the wheels can be driven by chain, belt or bevel gearboxes in a simple way, making for a robust system. An advantage of the third wheel in the skid-steer layout is that the middle wheel on each side can be mounted slightly lower than the other two, reducing the weight the front and rear wheel pairs carry. The lower weight reduces the forces needed to skid them around when turning, reducing turning power. The offset center axle can make the vehicle wobble a bit. Careful planning of the location of the center of gravity is required to minimize this problem.

An ever trickier layout adds two pairs of four-bar mechanism supporting the front and rear wheel pairs. These mechanisms are moved by linear actuators, which raise and lower the wheels at each corner independently. This semi-walking mechanism allows the wheel to negotiate obstacles that are taller than the wheels, and can aid in traversing other difficult terrain by actively controlling the weight on each wheel. Skid steering can be improved by adding steering mechanism to the front pair of wheels, and grouping the rear pair more closely together. The main problem with this layout is that one wheel is up on a bump, the lack of suspension lifts the other wheels up, drastically traction and mobility.

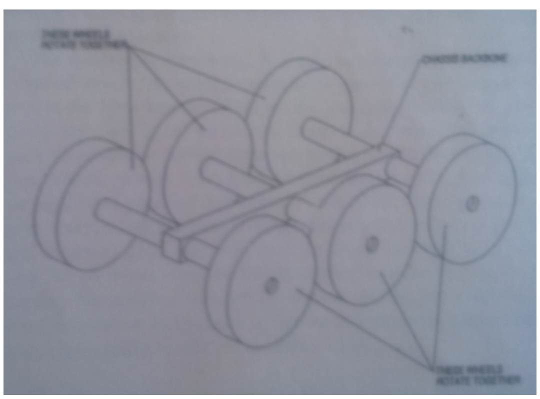

Fig 2.4 Six wheel layout.

2.2.5Tracked vehicles:

Tracked vehicles uses tacks in place of wheel to overcome the limitations of wheeled vehicles. The basic track formed by a drive sprocket, idler, and road wheels. Tracks simplify the problem somewhat and can climb stairs more smoothly than wheeled drive trains, allowing higher speeds, but they have difficulty staying aligned with the stairs. A tracked vehicle uses the differential steering to steer the vehicle.

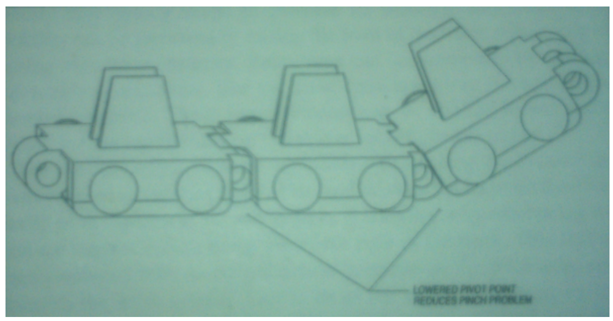

Fig 2.5 Tracked vehicles.

2.3. Method of steering

When a vehicle is going straight the wheels or tracks all point in the same direction and rotate at same speed, but only if they are all the same diameter. Turning requires some change in this system. This can be obtaining by many methods some popular methods are as follows:

2.3.1. Differential steering:

A differential wheeled robot is a mobile robot whose movement is based on two separately driven wheels placed on either side of the robot body. It can thus change its direction by varying the relative rate of rotation of its wheels and hence does not require an additional seeing motion.

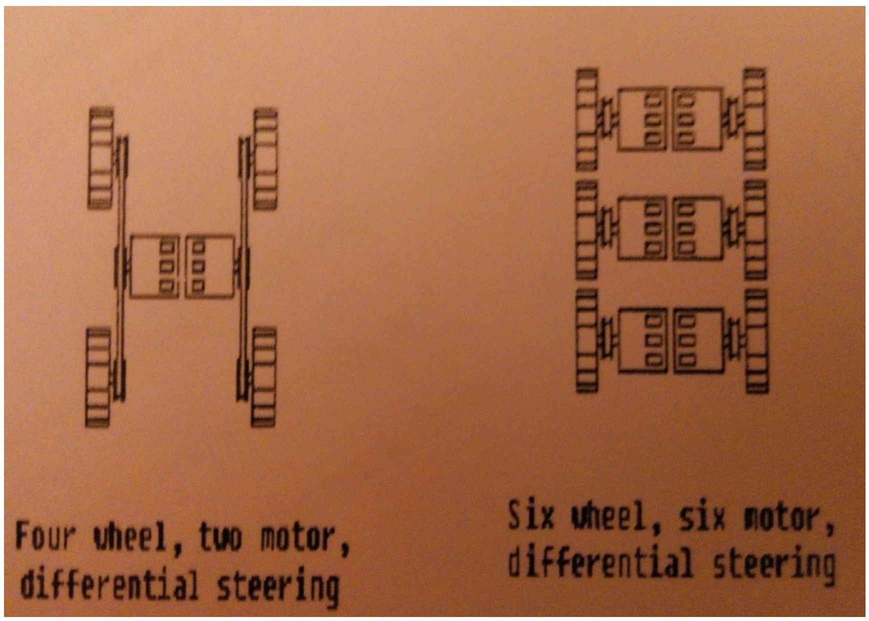

Fig 2.6 differential steering

2.3.2Skid steering

The most basic four-wheeled vehicle actually doesn't even use a differential. It has two wheels on each side that are coupled together and is steered just like differential steered tricycles. Since the wheels are in line on each side and do not turn when corners commanded, they slide as the vehicle turns. This sliding action gives this steering method its name-skid steer.

2.3.3 Tracked vehicle steering:

In order to steer a tracked vehicle, it is necessary to drive one track faster than the other, causing the vehicle to turn toward the slower track. This is called skid steering or differential steering.

2.3Omni directional vehicle and its need:

An Omni directional vehicle is one which can in any direction from any position without changing its orientation. Due to the less floor area and narrow path space the vehicle has to be holonomic, in, in order to quickly respond when commanded.

Omni directional is use to describe the ability of a system to move instantaneously in any direction from any configuration. Omni directional vehicle have vast advantage over a conventional vehicle in terms of mobility in congested environment. Path planning in general is a difficult task, especially when considering vehicle dynamics andmoving obstacles. Omni directional vehicles have some desirable properties:

1. They are very maneuverable, ableto navigate tight quarters.

2. Have few constraints on path planning.

2.3.1Caster type two wheels ODV:

Guiding mobile robots along desired trajectories is an important problem in mobile robot navigation the typical differential drive mechanisms used by many mobile robots, the current potion and orientation can be easily estimate. Two wheel caster type (TWCT) is specially serve as ODV. In this mechanism tricycle is powered by the two rear wheels and the differential steering is used to steer the rear wheels. This type of the vehicle provides the holonomic steering. So, all the three wheels can be rotate in a circle which center at the middle of the vehicle. This can be easily obtained by simply rotating the two rear wheels in opposite directions with a same rate.

2.3.2 Four wheel ODV:

The most basic four wheeled vehicle actually doesn't even use a differential. It has two wheels on each side that are coupled together and is steered just like differential steered tricycles. Since the wheels are in line on each side and do not turn when a corner is commanded, they slide as the vehicle turns. This sliding action gives this steering method its name-skid steer.

For turning the vehicle about its center we can use two methods:

1. By driving each wheel individually and keeping the direction of the wheels along the tangential direction.
2. Rotating the wheels with the same amount but the direction of the two same side wheels (one rear and other front) opposite to the direction of the two of the different side as shown in figure

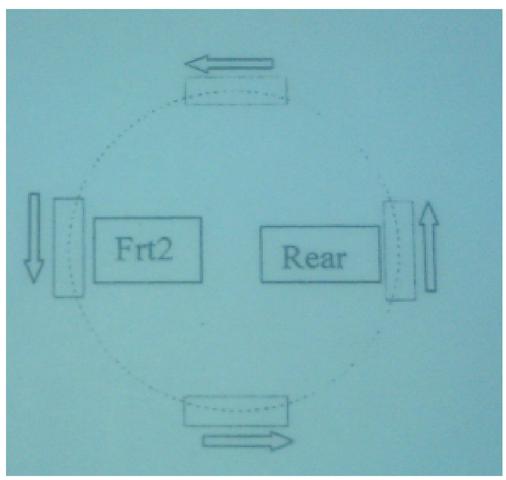

Fig 2.7 four wheels ODV

CHAPTER 3 – Report on Present Investigation

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3. 1 Selection of wheel configuration

In Quad configuration, two drive, steering wheels and four caster (supportive) wheels are used. Caster wheel will give the stability to AGV as it move or steer along the pre-defined path. Caster wheels located at each corner of chassis and drive wheels at center. The quad configuration of wheel for AGV is as shown in fig.

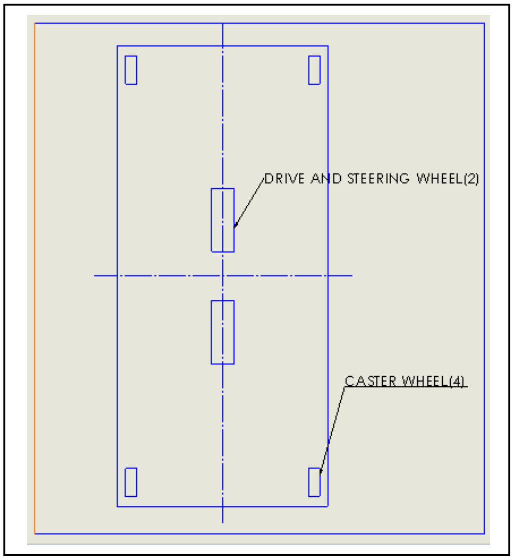

Fig 3.1 wheel configuration

Advantage:

1. Allows the vehicle to move in any direction.
2. Highest degree of maneuverability.
3. C.G. of vehicle always stays in center of guide path
4. Works well in areas where space constrains may be a concern.
5. Vehicle movement allows for loading and unloading most areas.
6. Recommended for use with laser navigation technology.

3.2 Assumption

All AVGs run using motors. Power supply to the motor is given by chargeable battery.

Gear head is use for transmission of proper torque and speed as per requirement.

1. Tasks in Drive and steering mechanism design:
2. Selections of motor as per the power requirement.
3. Selection of gear head.
4. Selection of external gear pair (if required).

Assumed specifications of AVG:

1. No of driving wheels=2.
2. Caster wheels=4.
3. Wheel Diameter =300mm.
4. Speed of vehicle (rolling) =1.5m/s

Assumptions made during calculations:

1. Since the speed is very less, friction due air flow (aerodynamic drag) is neglected.
2. Floor surface is smooth so there is no need of suspension.
3. AGV is working on concrete surface.

Chapter 4 – Design and Calculations

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4.3.3 DRIVE AND STEERING SYSTEM - TYPE III 40

Calulation of various parameters:

Total payload on vehicle	700kg
Total self-weight of vehicle	300kg
Total load of vehicle	700+300=1000kg
No. Of driving wheels	2
No .of supportive wheels	4

4.1Calculation of Drive:

Calculation of force:

Load acting on each wheel (P) =total load on vehicle/ no. Of wheels

=1000/2

=500kg.

=500×9.81

=4905

P =4905N

fr=coefficient of rolling resistance between vehicle tire and concrete=0.035

Rolling resistance force on each wheel (F) =P.fr

=4905×0.035

=171.675

F =171.675N

Calculation of angular velocity:

Diameter of wheel=300mm.

Radius of wheel(r) =150mm.

r=0.150m

Circumference of wheel=2πr

=2×3.14×0.150

=0.9425m

Velocity of wheel (v) =1.5m/s.

No. Of revolution/min (N) =$\frac{v\times 60}{2\pi r}$

=$\frac{1.5\times 60}{0.9\,425}$

=95.49

N=95.49rpm

Calculation of power:

Power (P) =F×v

=171.675×1.5

=257.51

P=257.51Watts

Calculation of torque:

Torque =F×r

= 171.675×0.150

=25.75

T=25.75Nm

Taking 40% extra torque for safety purpose (factor of safety=1.4)

T=25.75×1.4

=36.05Nm

So design torque must be more then calculated torque

4.2. Calculation of steering

Calculation of torque:

Consider uniform wear theory for calculation so

$$T=\frac{2}{3}\mu W \times \frac{(R1)^3-(R2)^3}{(R1)^2-(R2)^2}$$

Here R_2=0

μ=coefficient of sliding resistance between vehicle tire and concrete=0.035

$T=\frac{2}{3} \times \mu W \times R1$

$T=\frac{2}{3} \times 0.6 * 500 \times 9.81 \times 0.025$

=49.05

T=49.05Nm

Taking 20% extra torque for safety purpose (factor of safety)

T=49.05×1.2

=58.86Nm

So design torque must be more then calculated torque

Calculation of angular velocity:

Now consider the angular speed of for steering is as follow:

N=10rpm

Calculation of power:

Power of steering is given by

$$P=\frac{2\pi N\ T}{60}$$

$$P=\frac{2\pi\times10\times49.05}{60}$$

P=51.36 W

Table 4.1 Required parameter

Parameter	**For Driving System**	**For Steering System**
Speed(rpm)	95.49	10
Torque (Nm)	25.75	49.05
Power (watts)	257.51	51.36

4.3 Arrangement of assembly

We workout various arrangement of driving and steering system for AGV.Butmain aim is develop more compact system.

At last we founded three most suitable arrangements of drive and steering system for AGV, which is having less space consumption. The arrangements are as follow:

- Drive and steering system- Type I
- Drive and steering system-Type II
- Drive and steering system-Type III (Harmonic drive)

4.3.1 Drive and steering system- Type I

As per the load carrying AGV, we calculated force on each wheel, power and torque. Then for design safety, assuming factor of safety 1.4 for driving and 1.2 for steering.

In motor selection we selected brushless dc motor, because of high speed rang, high torque, no maintenance and for gear head we selected planetary spur gear head. AGV works on laser navigation system, so high precision motor and gear head needed. Therefore, we use parkar motor and gear head for drive system and maxon motor and gear head for steering system.

Both the wheels have independent drive and steering system. Advantage of independent drive and steering is, it works well in areas where space constrains may be a concern. In this arrangement drive system is rotating around the wheel and steering system fix on bracket. For bracket mild steel material is used.

As axial load acting on steering shaft is more, so prevent failure of shaft thrust bearing is put on steering shaft.

Selection of motor and gear head for drive system

Table 4.2 Selection of motor:

Make and model no.	Parkar motor(BE341J)
Type of motor	DC brushless motor
Rated Speed	5000rpm
Rated Torque	1.27Nm
Rated output Power	673watts
Motor weight	2.2kg
Motor length	112mm

Table 4.3 Selection of gear head:

Make and model no.	Parkar gear head(G55)
Reduction Ratio	55:1
Max. input torque	2.08Nm
Efficiency of gearbox	0.93
Gear head weight	3.45kg
Gear head length	101.6mm

Calculation ofmotor and gear head for drive system

1.for speed calculation:

i=$\frac{N1}{N2}$

Where

i=55, Reduction Ratio,

N1=Output Speed of Motor,

N2==Output Speed of Gear head,

55=$\frac{5000}{N2}$

N2=90.90rpm

2. for torque calculation:

i=$\frac{T2}{T1\times ή}$

Where,

T1=Output TorqueofMotor,

T2=Output Torque of Gear head,

ή=Efficiency of Gear head

55=$\frac{T2}{1.27\times 0.93}$

T=64.96Nm

3. for power calculation:

P=$\frac{2\pi\times N2\times T}{60}$

P=$\frac{2\pi\times 90.90\times 64.96}{60}$

P=618.36Watts

Selection of motor and gear head for steering system

Table 4.4 Selection of motor for steering:

Make and model no.	Maxon motor(223098)
Speed	4370rpm
Torque	0.186Nm
Output power	150watts
Motor weight	1.8 kg

Table 4.5 Selection of gear head for steering:

Make and model no.	Maxon gear head (G156)
Reduction Ratio	156:1 External gear head i=2.8
Max. output torque	60 Nm
Efficiency of gearbox	0.93
Gear head weight	3.45kg

Calculation of motor and gear head for steering system:

1. for speed calculation:

1.1Using gear head

$i=\frac{N1}{N2}$

Where

i= Reduction Ratio,

N1=Output Speed of Motor,

N2==Output Speed of Gear Box,

$156=\frac{4370}{N2}$

N2=28rpm

1.2 Using External Gear

Taking i=2.8

$$i=\frac{N1}{N2}$$

$$2.8=\frac{28}{N2}$$

N2=10rpm

2. for Torque Calculation:

2.1 Using gear head

$$i=\frac{T2}{T1\times\dot{\eta}}$$

Where,

T1=Output Torque of Motor,

T2=Output Torque of Gear Box,

$\dot{\eta}$=Efficiency of Gear Box

$$156=\frac{T2}{.186\times 0.93}$$

T2=21.7Nm

2.2 Using external gear

Taking i=2.8

$$i=\frac{T2}{T1\times\dot{\eta}}$$

$$2.8=\frac{T2}{21.7\times 0.93}$$

T2=60Nm

23 for power calculation:

$$P=\frac{2\pi\times N2\times T}{60}$$

$$P=\frac{2\pi\times 10\times 60}{60}$$

P=62.82Watts

Output of drive and steering system

Table 4.6 Output put of drive system:

Output power	618.36Watts
Output speed	90.90rpm
Output torque	64.96Nm

Table 4.7 Output of steering system:

Output power	62.82 Watts
Output speed	10rpm
Output torque	60Nm

Table 4.8 Selection of bearing:

As more thrust load acting on steering shaft, so to reduce the thrust load we need put thrust bearing inside the fix bracket.

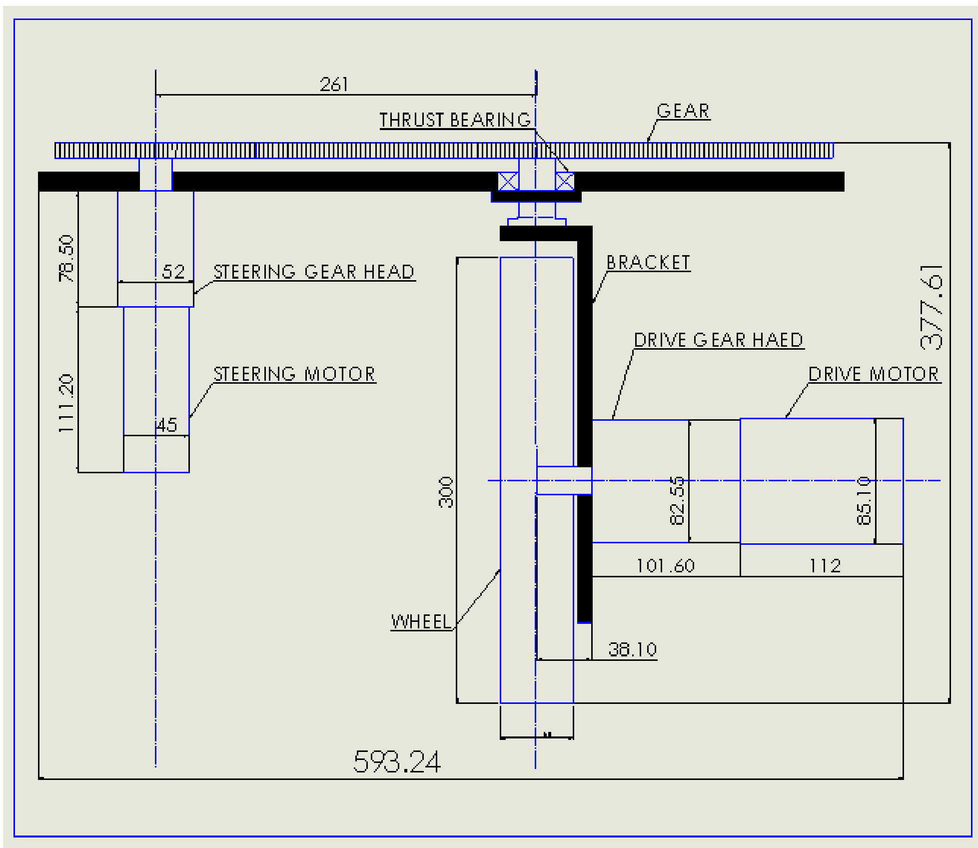
Make and model no.		K02513XP0 Four point contact bearing Series-13
Bore diameter		25mm
Diameter outside		51mm
Radial load	Static	696kg
	Dynamic	686kg
Axial load	Static	1293kg
	Dynamic	869kg
Moment	Static	96Nm
	Dynamic	96Nm
Weight (kg)		0.13kg

Drive and steering system type-1:

This is type-1 drive and steering system.

Total horizontal length of system=593.24mm

Total vertical length of system=377.61mm



ig5.1 type-1 2-d drawing

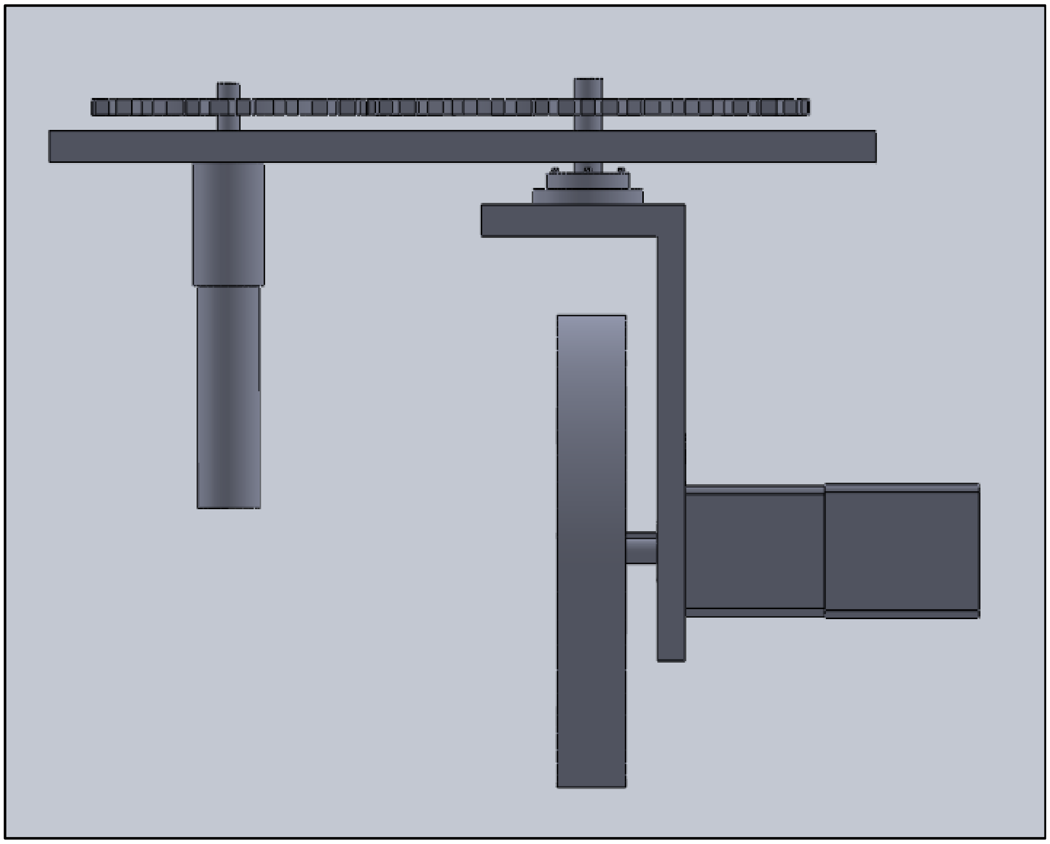


Fig 5.2 type -1 solid works 3-d model.

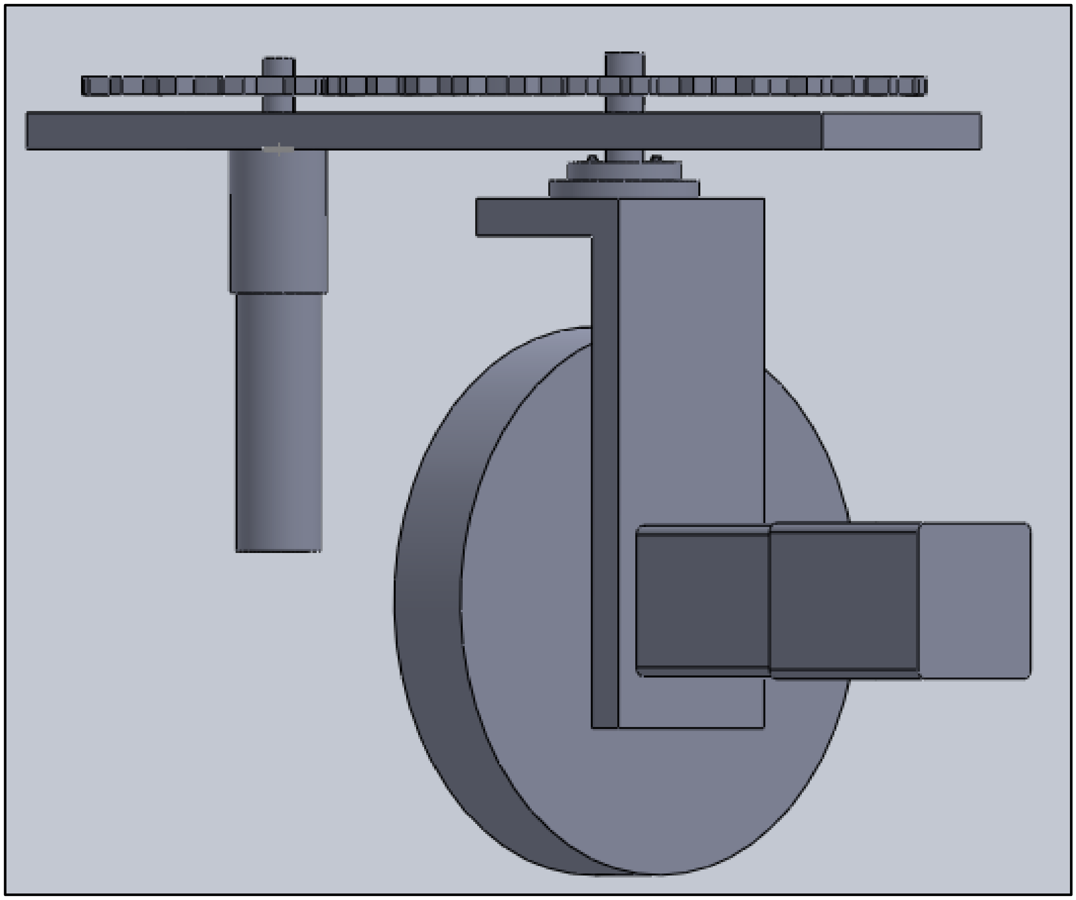


Fig5.3 type-1 solid works 3-d model

4.3.2 Drive and steering system-Type II

In this arrangement of drive and steering system same motor and gear head selected as of type- I. But our main aim to make compact the system, therefore we make wheel whole. So that gear head is partially inside the wheel. Gear head power is transmitted to wheel through coupling.

Here flange coupling is used. One of them flange is attached to shaft and another one is welded to wheel rim and both flange coupled with bolt.

Drive and steering system type-2:

This is type-2 drive and steering system.

Total horizontal length of system=427.96mm

Total vertical length of system=374.61mm

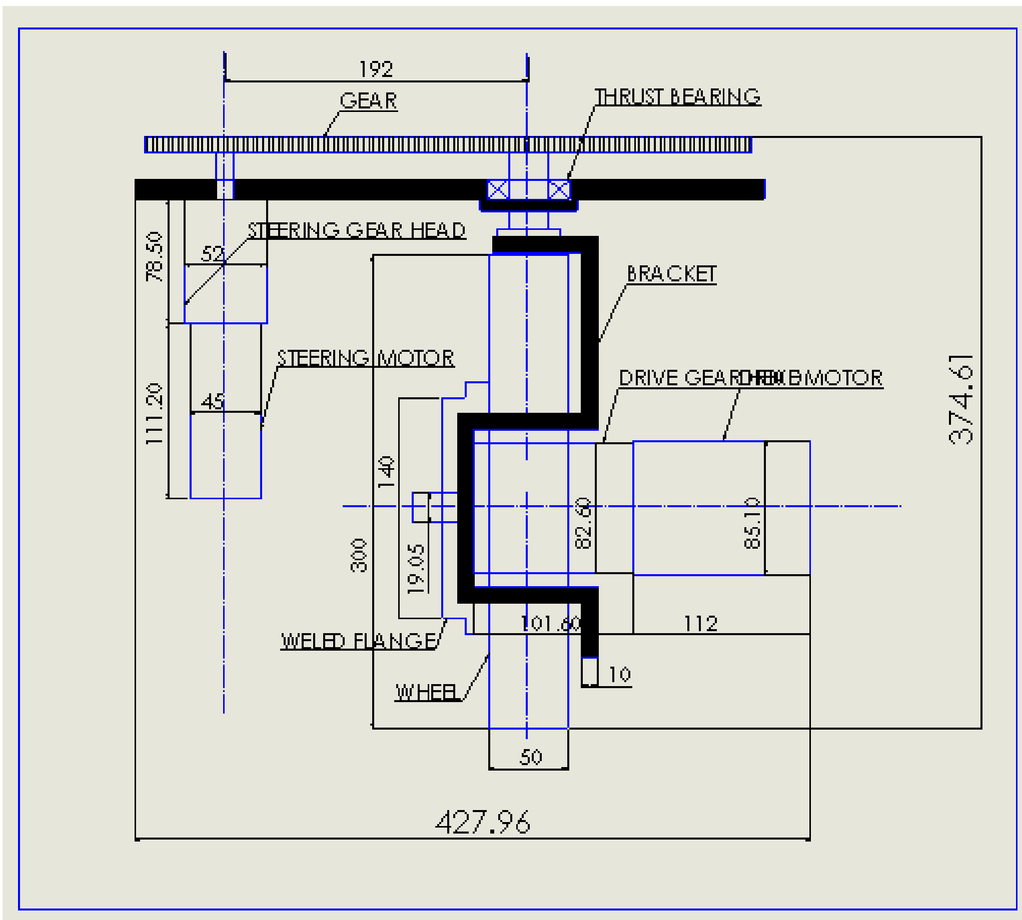


Fig 5.4 type-2 2-d drawing

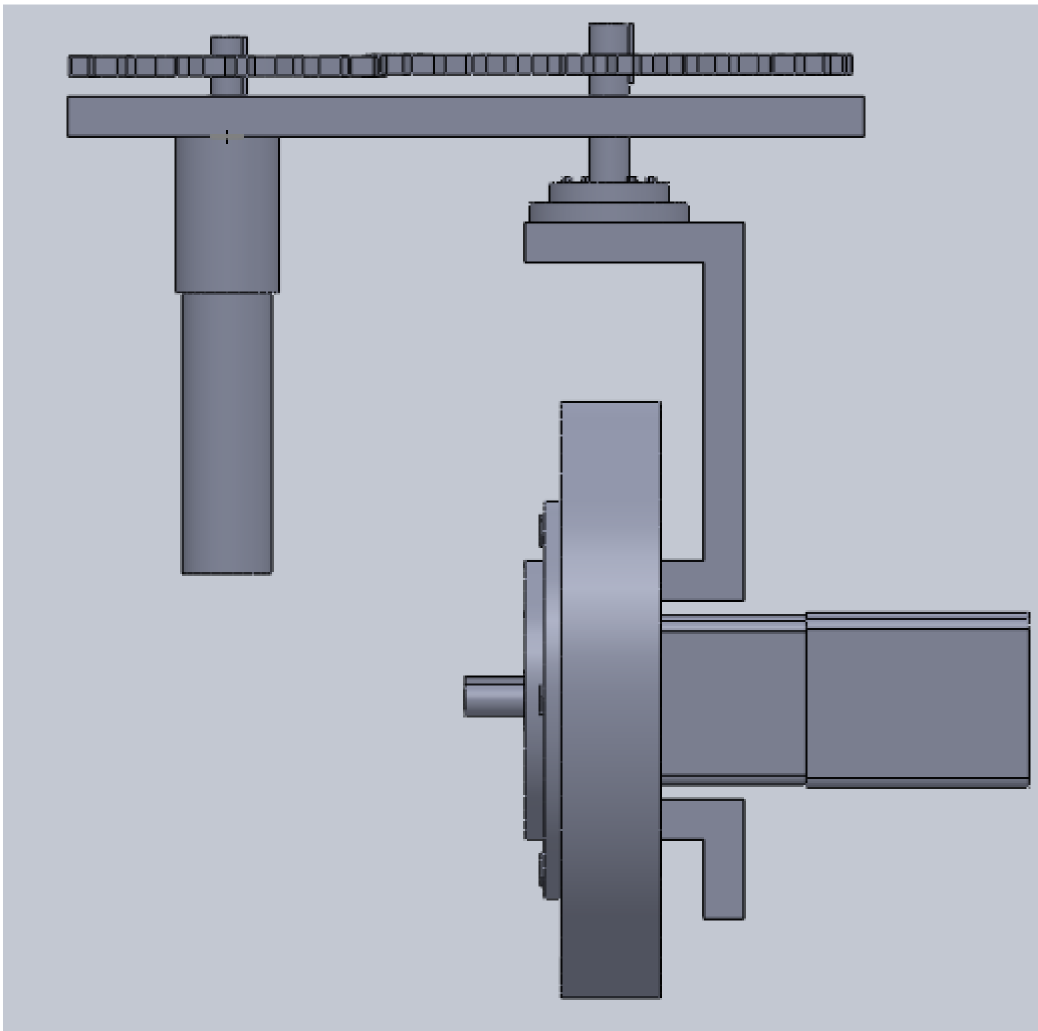


Fig 5.5 type-2 solid works 3-d model

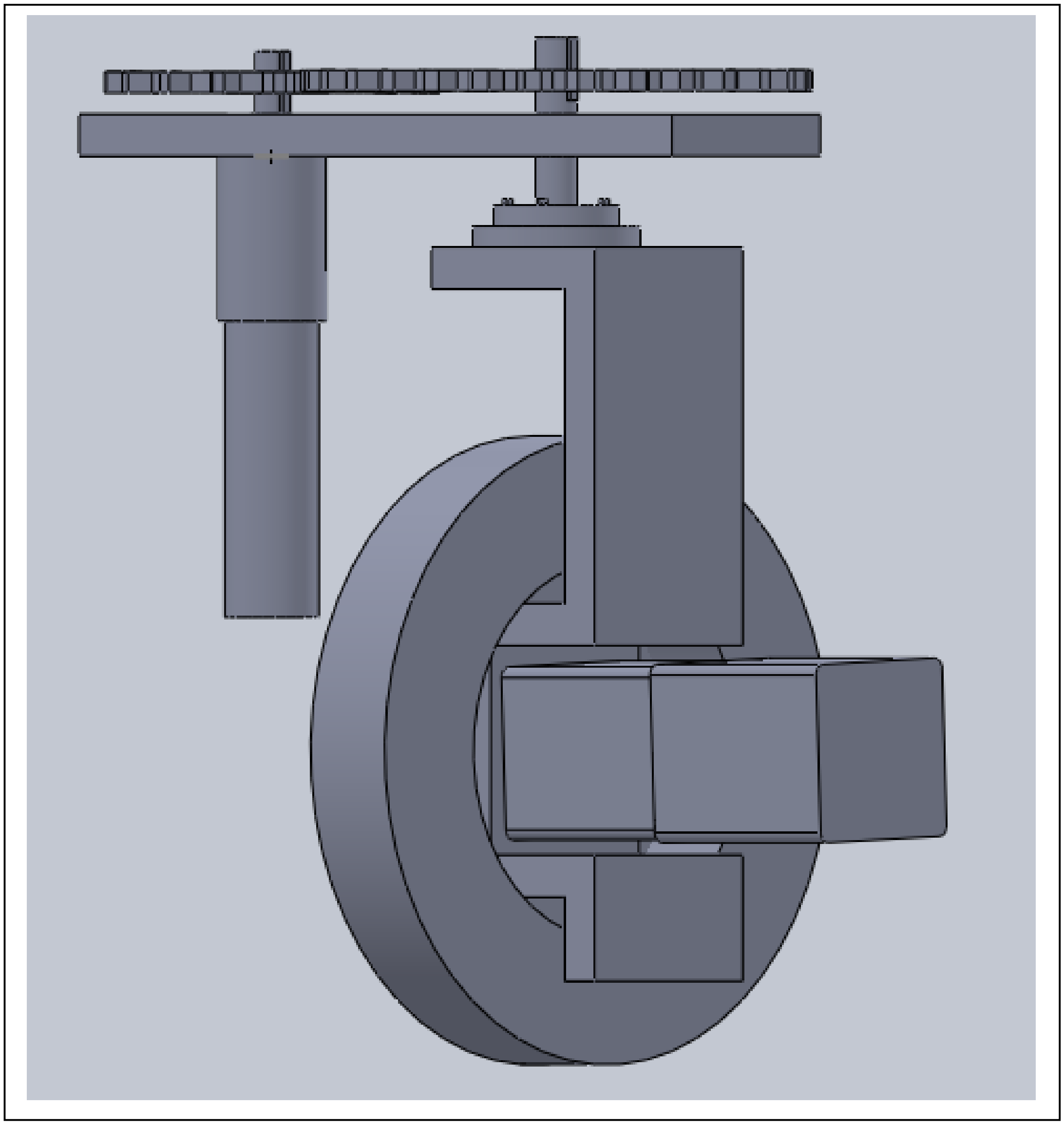


Fig 5.6 type-2 solid works model

4.3.3 Drive and steering system- Type III

Introduction of harmonic drive:

Harmonic drive is a strain wave drive that can improve certain characteristics compared to traditional gearing system. High gearing ratio is possible (a ratio of **30:1 to 320:1** is possible in same space **planetary** gears produces only **10:1**ratio)

Component of harmonic drive

- Wave generator (ellipse-shaped)
- Circular spline
- Flexi spline

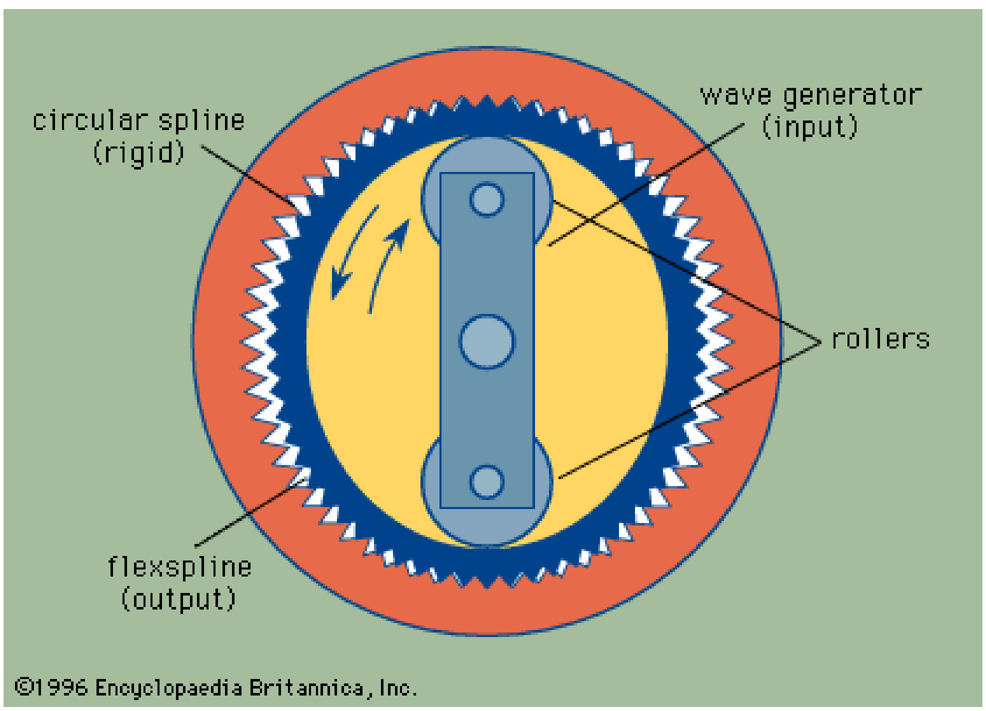


Fig5.7 harmonic drive

Reduction ration is given by equation

GR=$\frac{FS}{CS-FS}$

Where GR= Gear ratio

FS= no. of teeth on the Flexi spline

CS=no. of teeth on the circular spline

Advantage:

1. High performance.
2. There is no backlash in harmonic drive.
3. Input and output shafts have same center line.
4. Ability to produce high reduction ratio in single pass with high torque capacity.

Selecting harmonic drive

After finding varies harmonic drive (considering parameter like radial load, torque and speed) we had concluded to use the CHA-20A as harmonic drive for drive and steering system.

Technical data:

Table 4.9 Harmonic drive for drive system:

Make and Model no.	Harmonic drive(CHA-20A)
Maximum o/p torque (Nm)	56
Maximum o/p speed (rpm)	120
Hallow shaft diameter(mm)	18
Length (without brake) in mm	118
Weight (kg)	3.2

Table 4.10 Harmonic drive for steering system:

Make and Model no.	Harmonic drive(CHA-20A)
Maximum o/p torque (Nm)	92
Maximum o/p speed (rpm)	38
Hallow shaft diameter(mm)	18
Length in mm	118
Weight (kg)	3.2

Drive and steering system type-3:

This is type-3 drive and steering system.

Total horizontal length of system=320.37mm

Total vertical length of system=476.11mm

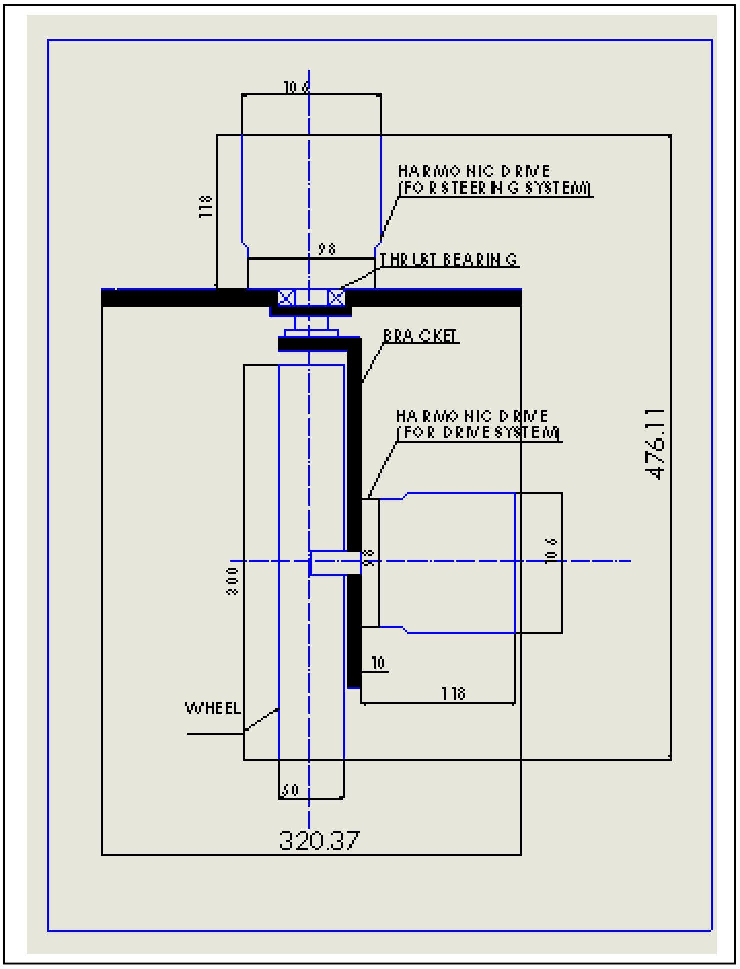


Fig 5.8 Type-32-d drawing

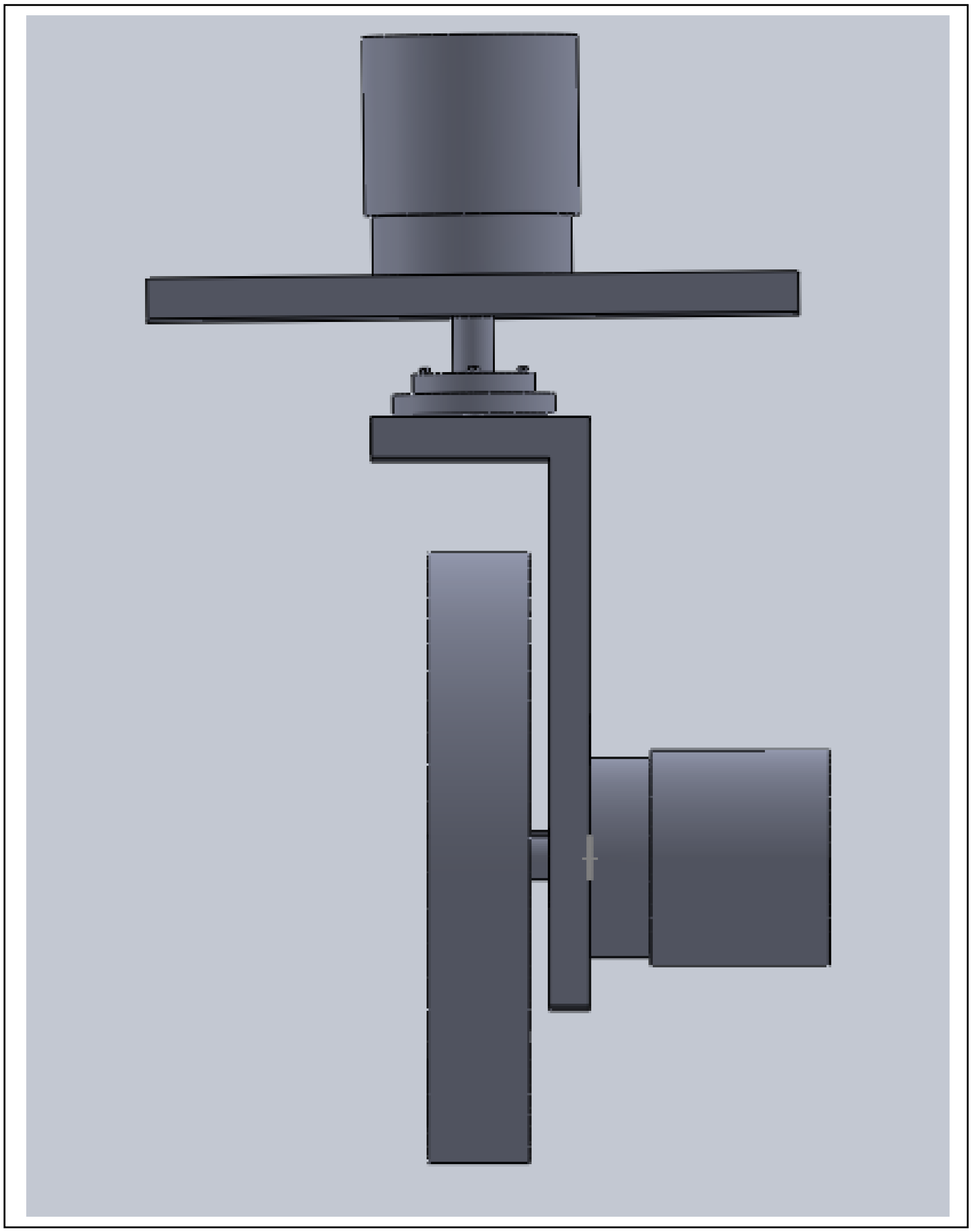


Fig5.9 type-3 solid works 3-d model

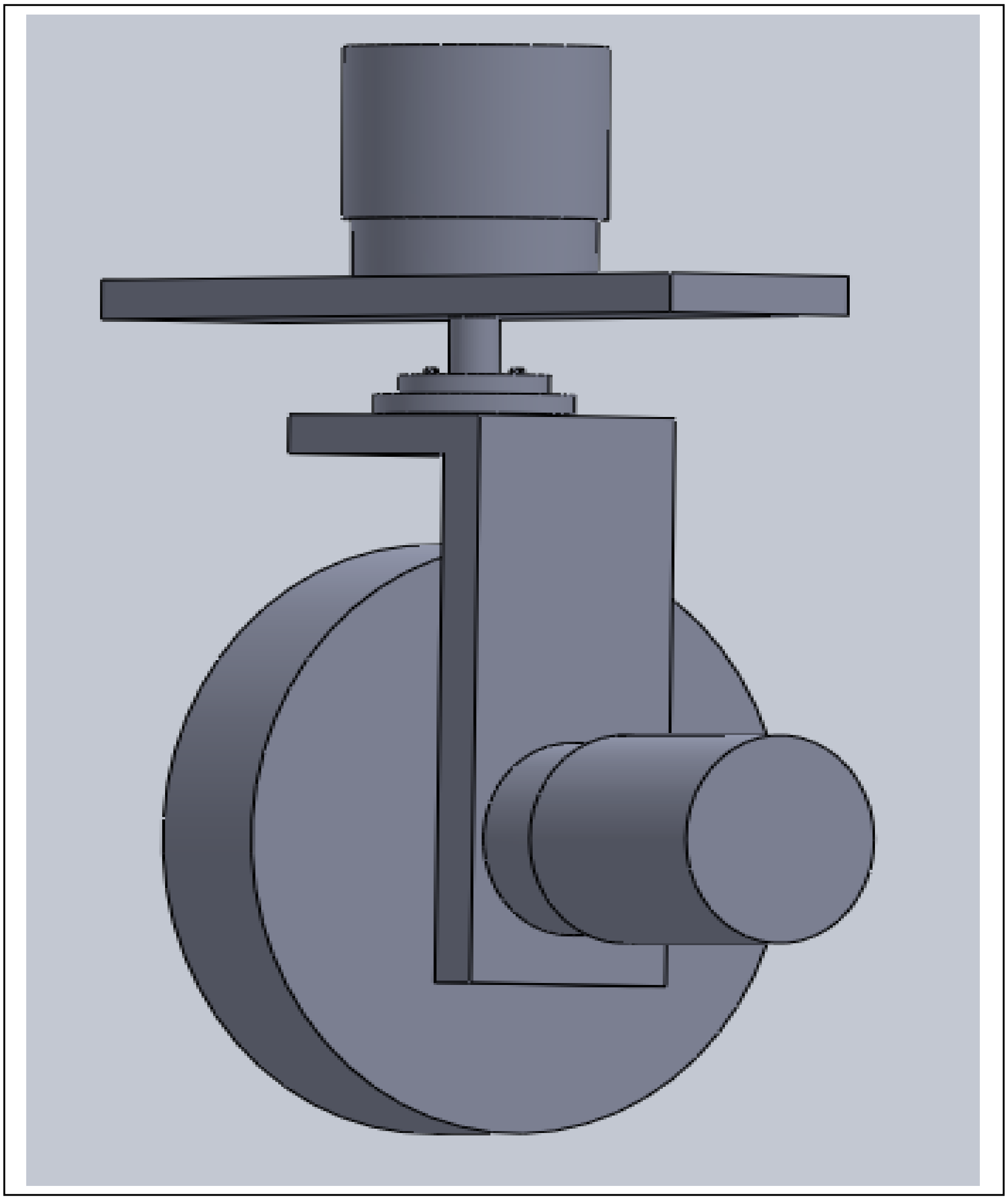


Fig 5.10 type-3 solid works 3-d model

Chapter no 5-Result

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TABLE 5.1 COMPARISON OF ABOVE THREE ARRANGEMENTS 47

Results:

We select appropriate motors , gearboxes and bearing for the driving and steering arrangements by considering required power , speed and torque.

Then we arrange them in such a way that overall size of assembly reduces.

We got following results from our study:

Table 5.1 Comparison of above three arrangements:

Types	**Total horizontal length of system(mm)**	**Total vertical length of system (mm)**
Type-1	**593.24**	**377.61**
Type-2	**427.96**	**374.61**
Type-3(harmonic drive)	**320.37**	**476.11**

CHAPTER 6 - Conclusion

Conclusion

From above comparison, it is clear that total size of arrangement of **type I 593mm** (horizontal) assembly which is largest.

So, we try to reduce it by modifying bracket over which driving gear head is mounted. By doing so we have manages to reduce the horizontal length of assembly by 165 mm.

Thought it is not by much amount but anything which is compact is good.

So**, type-3 Harmonic drive** is the best solutions as it have motor and gearbox mounted in a single unit. In this total overall horizontal length get compacted to **320 mm** (i.e. reduced by 272mm)

So the overall length of the assembly reduces and makes it more compact which our desired requirement.

References

Books:

[1] Modern electric-hybrid electric and fuel cell vehicle by Merdad Ansari, pp.82-93

[2] Automated guided vehicle, Ing Thomas Muller. pp25-30,40-45.

[3] Theory of machines by R.S Khurmi.

Catalogues:

[1] Parker motors and gearbox catalogue.

[2] Maxon motor and gearbox catalogue.

[3] CFR catalogue