CERTIFICATION OF APPROVAL

Development of an Automated Guided Vehicle (AGV)

by

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD HAFIZ B ZAINAL (892)

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Thank You.

ABSTARCT

This project is mainly design for automated guided system. This system can lead to detect any other object with the space constraint without any operation by human being. It means that this system has the brain in order to control its movement by getting signal from its sensor.

This paper describes a mechatronics project completed by undergraduate mechanical and electrical engineering students. This project had leaded an author to combine his knowledge in mechanical design, analysis, electronics, sensoring and control, and, the most important, his creativities to complete a prototype of an autonomous guided vehicle (AGV). Implementation and progress of the AGV project is then reported.

In this report, author will briefly discuss about the mechanism of the AGV. The theory part will be covered first while followed by the calculation. It is to prove the application with theoretical basis. Besides, author will also briefly touch a bit on electrical point of view. This will complete the overall development of the AGV.

In order to produce this system, problem statement need to be identified. Then, followed by preliminary studies in order to get more idea on producing the system. After the suitable design had been chosen, the detailed design need to be conducted. All the specification for this system is done in this stage. At the same time, major equipment is procured and followed by construction stage. After all component had been assembled, troubleshoot need to be carried out if there is a failure encountered.

The system use four wheels mode and driven by electric motors. It is steered by using rack gear mechanism which is guided by infra red sensors with digital encoding located in front of the base. Torsional spring is used to ensure the front shaft turn to its original position after turning.

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CHAPTER 1

INTRODUCTION

1.1 Background

Automated Guided vehicle is widely used in production, manufacturing and many other industries. It can replaced for an about half of total production workers. The AGV system mainly is controlled by microcontroller with the guidance by sensor. In this project, infra red sensor is used as a primary sensor and microchip 16F84 for the microcontroller.

Microcontroller will give a command to electric motor in order for this AGV system to make a left or right turn. In order to convert rotational motion to translational motion for the turning mode, rack gear had been used together with the dc motor. This AGV system is powered by battery. There are two types of batteries used in this project. Primary battery is used to power the electric circuit and secondary battery is used to power electric motor.

There are three major activities have been carried out throughout two semesters. Conceptual design is done at the earlier stage of this project. In this stage, problem statement needs to be identified. Then preliminary studies are conducted and information about AGV had been collected. Alternative design need to be studied in order to choose the appropriated design before entering detailed design stage. In detailed design stage, the AGV specification will be specified. This specification including the dimension of the physical base, gear set, and also material selection for each component. Procurement is done concurrently with this stage before move on to construction stage. After all components had been assembled, this AGV system is tested in order to make sure that this AGV had met the project's objective. Troubleshoot is conducted if the AGV system had encountered failure.

1.2. Problem Statement

Currently, there are a lot of automated guided vehicle in the market. Those system is vary upon of it usage. This project is designed so that it can find a suitable path to move. It can avoid any obstacle and have the intelligent in terms of choosing the path.

This project is basically to design such system that can avoid any obstacle in front. Basically, the scope of the mechanical part is to decide the type of movement, the turning concept, and the major part, of course the whole body. This is important because, the space of this model might be important so that it can go along although the path is small. For the electrical part, the major scope of study is to design the sensor system and also the microchip as this AGV's brain.

The design can be used to explore the mine before it is fully operated by human being. This is basically will minimize the risk of the workers itself. It can be modified to suit the application of the usage. But in this project, the main idea is the design can be operated by battery and can find its own path without collide to any obstacle.

1.3. Objective

- To design a system that can avoid obstacle and can move along sandy area
- To simulate the design
- To construct the design by following the required specification
- To troubleshoot the design if there is a failure

1.4. Scope of study

As mentioned earlier, this project will be carried out stage by stage. There are two major stages in order to develop this project.

1.4.2. Design

In this stage, there will be a lot of literature reading about the respective topics. The area that might be covered is the mechanism of this system, in terms of gearing device, turning shaft, and the type of movement that is suitable for the specified environment. After the basic idea on the theoretical basis had been achieved, the specification of the module will be made. This will be based on some calculation that is to prove on the theoretical side. Some of the equipment will be procured concurrently during this stage.

1.4.3. Construction & Troubleshoot

In this stage, it will more towards the modelling the system itself. This will take a lot of time because of the unpredictable result. That is why the troubleshoot stage will take into consideration at the last stage. It is to make sure that the entire objective is successfully achieved.

Besides, the scope of work will include:

1.4.4. Hands on Activities

In doing this project the author might learn some of the design software in order for drawing purposes. For an example, Computer Aided Three-dimensional Interactive Application (CATIA). This software is used by Engineering Design Department for their routine work everyday. Besides, AutoCAD also might be used to draw the module. The latest software that might be used is ADAMS. It is simulation software that can simulate a several part in thus AGV itself.

1.4.5. Research-based activity

Since the project is about the system test, it is compulsory to flow via the research stage. This research activity is done to acquire the information about the system and also to create new specification. The result of this research is used in designing stage and also in system implementation. Besides that the result is also very useful for future reference.

1.4.6. Teamwork cooperation

In engineering teamwork cooperation is the most important aspect that should be considered especially in the research and development process. Although this is small project but it may need team spirit in order to success.

CHAPTER 2

LITERATURE REVIEW

2.1. Gears and speed ratio

Gear belongs to a special class mechanism whose principal function is to transmit motion and power from one shaft to another. Specifically, gears are usually in the form of cylinders whose active surfaces are provided by teeth that interlock or "mesh" such that the rotation of one accurately controlled that of the other and the relationship between their angular speed as well as torque is remains constant. When two gears are in mesh, the smallest of the pair is generally called the *pinion*, whereas the larger is referred to as the gear. When the pinion is on the drive shaft the pair acts as a speed reducer. Conversely, when the gear drives *pinion*, the pair acts as an increaser. Gears are more frequently used as speed reducers than as speed increases.

There are many types of gears, each designed according to its special application. In this project, spur gear had been chosen. This is because of the simplest and most common form of all gear types. In this type the teethes are cut straight and parallel to the axis of the shaft, and motion is transmitted from one parallel shaft to another. Spur gears are very widely used in the machine design construction because of their simplicity and economy. However, their used is limited to low to moderate speeds because of their low contact ratios.

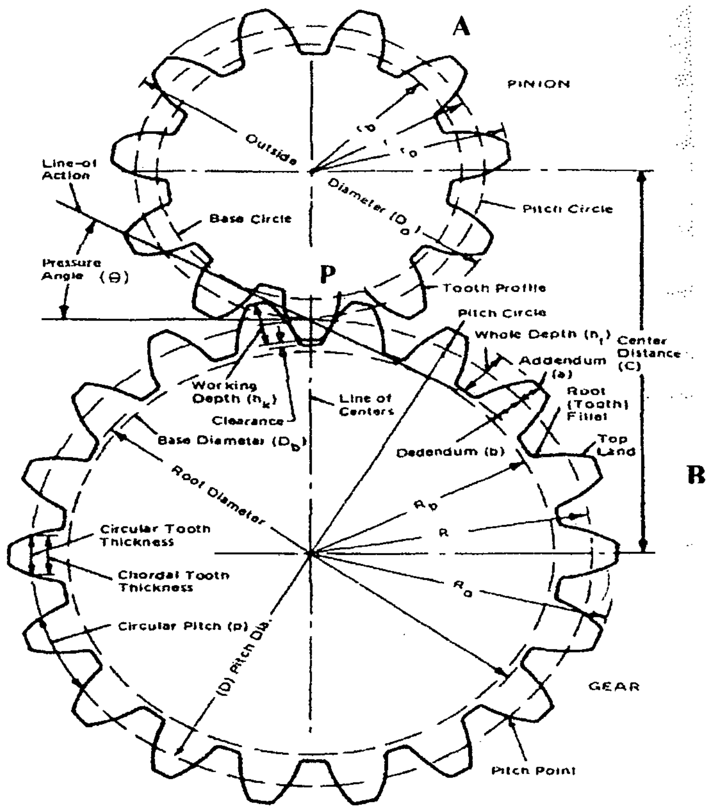


Figure 2.1: Two-meshing spur gears

The speed or velocity ratio of two meshing spur gears can be established by referring to Figure 2.1, where the pitch circles of the gears A (pinion) and B behave like two rolling cylinders in contact at point P. David H. Myszka (2002) point up that there can be no slipping for pure rolling of the linear velocity of P on gear A must be the same as the linear velocity of P on gear B (p 351).

In mathematical form,

$V^A{}_P = V^B{}_P$

Or

$R_A\omega_A = R_B\omega_B$ .... (2-1)

Therefore;

The speed ratio $= \dfrac{\omega_A}{\omega_B} = \dfrac{R_B}{R_A}$ [constant].................... ....(2-2a)

Or,

$$\frac{\omega_A}{\omega_B} = \frac{D_B}{D_A} \quad \text{.......... (2-2b)}$$

The speed ratio may also be written, $D = \dfrac{T}{P_d}$, as

$$\frac{\omega_A}{\omega_B} = \frac{T_B / P_d}{T_A / P_d}$$

thus;

$$\frac{\omega_A}{\omega_B} = \frac{T_B}{T_A}$$

The speed ratio is not only inversely proportional to the gear ratio, but also inversely proportional to the ratio of tooth numbers.

From previous explanation, we know that:

$$\frac{\omega_2}{\omega_1} = \frac{T_1}{T_2} \quad \text{.......... (2-3)}$$

According to David H. Myszka (2002)

Recall from the law of gearing that if two gears A and B are in mesh, they behave like two rolling cylinders, and their speed ratio is inversely proportional to their tooth numbers. Applying this principle to successive mating gears of the present gear train, we can write; (p. 372)

For pair A and B,

$$\frac{\omega_B}{\omega_A} = \frac{T_A}{T_B} \quad \text{.......... (2-4a)}$$

For pair B and C;

$$\frac{\omega_C}{\omega_B} = \frac{T_B}{T_C} \quad \text{.......... (2-4b)}$$

For pair C and D;

$$\frac{\omega_D}{\omega_C} = \frac{T_C}{T_D} \quad \text{.......... (2-4c)}$$

Putting together this relationship, we can calculate the overall speed ratio (SR);

Speed Ratio (SR)

$$= \frac{\omega_B x \omega_C x \omega_D}{\omega_A x \omega_B x \omega_C} = \frac{T_A xT_C xT_D}{T_B xT_C xT_D}$$

$$= \frac{\omega_D}{\omega_A} = \frac{T_A}{T_D}$$

The intermediate gears A and B do not influence the overall ratio. For this reason, these gears are called idlers. It is used when a large distance must be spanned between the input and output gears, and gears with large diameters are not permitted. They are also used to change the direction of rotation of the output gears.

The direction of rotation of the follower with respect to the driver is very important. When the driver and follower rotate in opposite directions, the speed ratio is considered as negative and given a minus sign.

David H. Myszka (2002) had points up that speed ratio can be defined as: (p. 373)

$$SR = \frac{outputspeed}{inputspeed}$$

2.2 Torsion Spring (Alignment)

According to Joseph E. Shigley (2001)

When a helical coil spring is subjected to end torsion, it is called a torsion spring. It is usually close-wound, as is a helical coil extension spring, but with negligible initial tension. There are single-bodied and double-bodies types as depicted in Figure 2.2. As shown in the figure, torsion springs have ends configured to apply torsion to the coil body in a convenient manner, with short hook, hinged straight offset, straight torsi and special ends. The ends ultimately connect a force at a distance from the coil axis to apply a torque. The most frequently encountered (and least expensive) end is the straight torsion end. If intercoil friction is to be avoided completely, the spring can be wound with a pitch that just separates the body coils. Helical coil torsion springs are usually used with a rod for reactive support when ends cannot be built in, to main alignment, and to provide buckling resistance if necessary. (p.664)

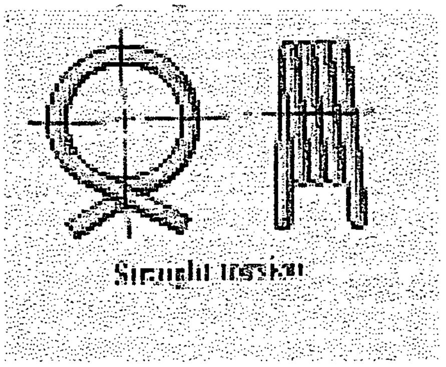


Figure 2.2: Torsion Spring

The wire in a torsion spring is in bending, in contrast to the torsion encountered helical in coil compression and extension springs. The springs are designed to wind tighter in service. As the applied torque increases, the inside diameter of the coil decreases. This is because the applied forces had shrunk the inner diameter of the coil. Care must be taken not to grab the pin, rod, or arbor. The bending mode in the coil might seem to invite square- or rectangular-cross-section wire, but cost, range of materials, and availability discourage its use. The treatment of the ends is dictated by application.

Torsion springs are familiar in clothespins, window shades, animal traps, where they may be seen around the house, and out-of-sight in counterbalance mechanisms, ratchets and a variety of other machine components. There are many stock springs that can bough off-the-shelf from a vendor. This selection can add economy of scale to small projects that can avoid the cost of custom design and small-run manufacture.

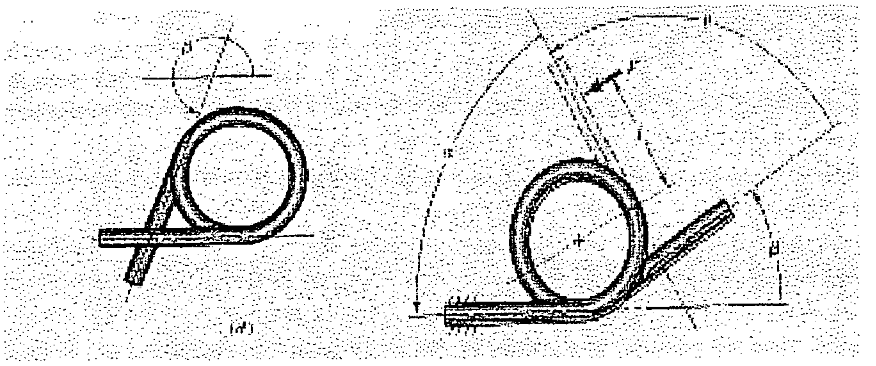


Figure 2.3: Free end location angle is β. The rotational coordinate θ is proportional to the product Fl

According to Shigley (2001)

The number of body turns N_b is the number of turns in the free spring body by count. The body count is related to the initial position angle β by:

N_b = integer + β/360 = integer + N_p , where N_p is the number of partial turns.

The angle subtended by the end deflection of a cantilever, when viewed from the built in ends, is *y/l* rad

$$\vartheta_e = \frac{y}{l} = \frac{Fl^2}{3EI} = \frac{Fl^2}{3E(\eta d^4/64)} = \frac{64Ml}{3\eta d^4 E} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2-5)}$$

For a straight torsion end spring, end spring, end corrections must be added to the body coil deflection. The strain energy in bending is,

$$U = \int \frac{M^2 dx}{2EI} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2-6)}$$

For a torsion spring M = Fl = Fr, integration must be accomplished over the length of the body coil wire. The body force will deflect through a distance r θ where θ is the angular deflection of the coil body. Applying Castigliano's theorem,

$$r\theta = \frac{\partial U}{\partial F} = \int_0^{\eta DN_b} \frac{\partial}{\partial F}\left(\frac{F^2 r^2 dx}{2EI}\right) = \int_0^{\eta DN_b} \frac{Fr^2 dx}{EI} \quad \ldots\ldots\ldots\ldots \text{(2-7)}$$

Substituting $I = \frac{\eta d^4}{64}$ for round wire and solving for θ gives

$$\theta = \frac{64FrDN_b}{d^4E} = \frac{64MDN_b}{d^4E} \quad \text{.....................................} (2\text{-}8)$$

The total angular deflection in radians is $\theta + 2\theta_e = \theta_t$ or,

$$\theta_t = \frac{64MDN_b}{d^4E} + \frac{64Ml_1}{3\eta d^4E} = \frac{64Ml_2}{3\eta d^4} = \frac{64MD}{d^4E}\left(N_b + \frac{l_1 + l_2}{3\eta D}\right) .. (2.9)$$

Defining the number of end equivalent turns as N_e, we write

$N_e = \frac{l_1 + l_2}{3\eta D}$ The equivalent number of active turns N_a is expressed as

$N_a = N_b + N_e$

The spring rate *k* in torque per radians is

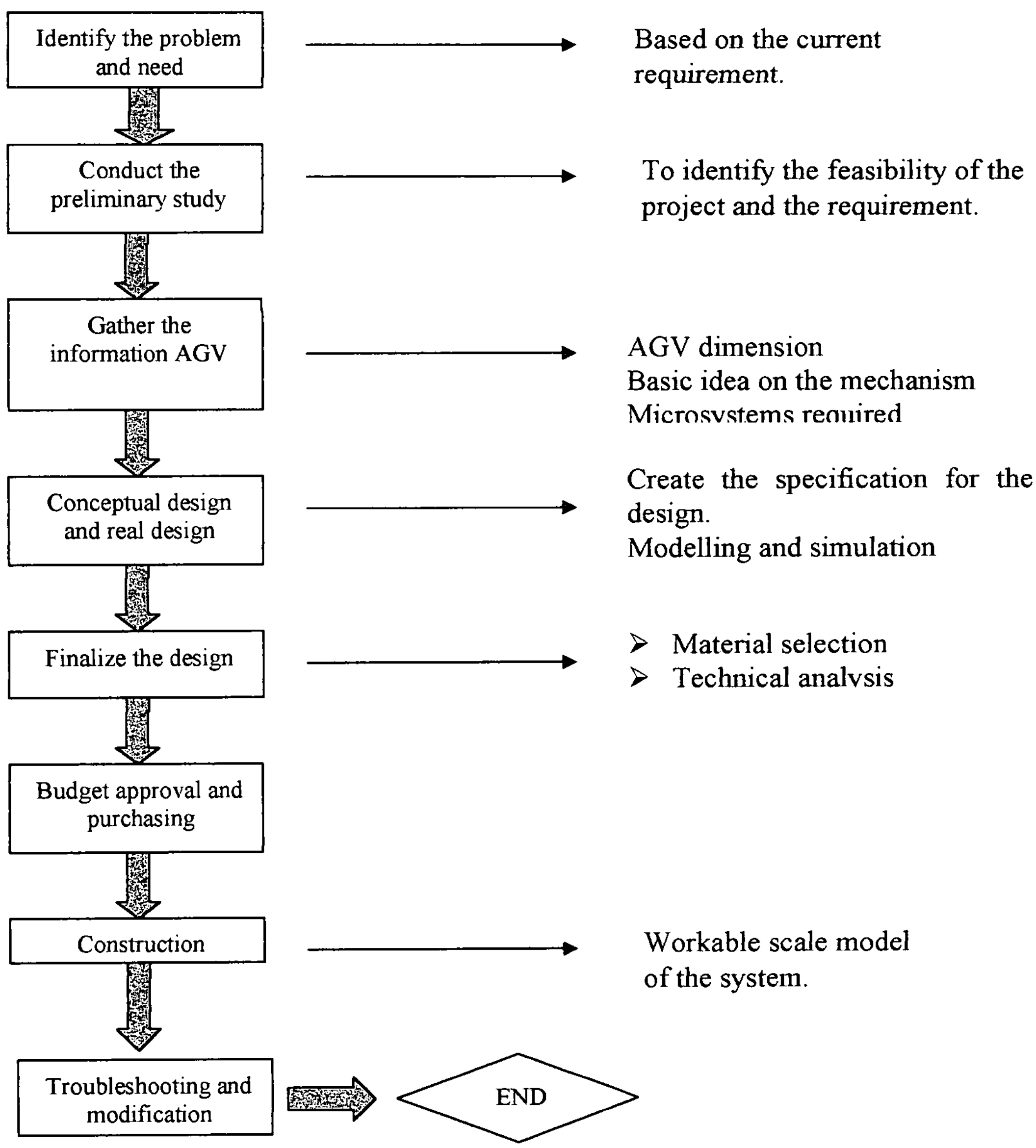
$$k = \frac{Fr}{\theta_t} = \frac{M}{\theta_t} = \frac{d^4E}{64DN_a} \quad \text{...} (2\text{-}10)$$

(p.666)

CHAPTER 3

METHODOLOGY/ PROJECT WORK

3.1 Typical Procedure Identification



3.2 Design and Prototyping an AGV

An AGV consists of hardware and software. The former includes the mechanical structure of the vehicle and the power transmission system as well as electronic hardware for sensoring and control. These two parts are integrated by the control system driven by control schemes, coded in software.

The design process includes the following steps: survey and define functional specifications, conceptual and functional design, detailed engineering design, manufacturing planning, material preparation, parts machining and components purchase, system assembly, sensing and control assembly, system integration, adjustment and refinement. The author will briefly discuss some of these steps in the following subsections.

3.3 Survey and Define Specifications

In the beginning, the author has no idea what is the mechanism used behind the AGV. As the first step in product design is to solve the problem. This is done by defining some introduction material including the function and applications of AGV's in automated systems. Some functional specifications, hardware and key characteristics are also hinted and suggested. While keep the approach "learning by doing" in mind, several literatures, references, magazines, and videos are suggested to read or watch as a survey. Some key characteristics are asked to survey including the following items:

- Structure and power system: Structure of an AGV often based on its loading, motion characteristics such as speed, as well as working environment. The structure is different for and AGV used in FMS (flexible manufacturing system) and in an office as the former must be stiff with high power in order to carry parts used in a production line while the latter is often light with silent power system as it is often used to transfer documents or stationeries among offices.
- Path planning and guidance system: This characteristic depends on the function of the AGV. While an AGV employed in a factory needs simple

path and robust guidance, an AGV used in office may be required to equip with good path planning and guidance system as its path is often complicated. Several sensing and guidance methods were surveyed in order to understand the state of the art of sensoring and positioning technologies.

- Sensing and control: This is often the weakest part for ME-majored students as I have limited knowledge on electronics and sensoring technologies. This item is close related to the guidance system as the accuracy of movement and positioning are determined mainly by the resolution and sensitivity or sensors and controller. Several different sensoring technologies and corresponding control schemes are reviewed for designing the AGV.

In addition, there are several related technologies involved in the design and fabrication of an AGV because it is an integrated system. Table 3.1 shows the survey of technologies involved in the AGV system and possible options

Table 3.1: Survey of technologies involved in the AGV system and possible options

Technology	Options
Driving System Motion Control	Three or multiple wheels Constant speed, constant torque, constant power.
Positioning Method Guidance Method	Mechanism-based or sensor-based Optical, metal band, electro-magnetic, laser-sensing, wireless
Power supply Safety mechanism	DC with automatic, spare, or fixed charge Sensor-based, (contact and non-contact) with bumper
Control scheme	Analog or digital
Control system Centered, Communication method	Centered, distributed, hybrid, PC-based Wired, wireless, networked, stand-alone

Typical specification for the AGV:

- The mechanical structure: two-floor simple and light structure such that material can be put in either floor. The driving system should be a four - wheel structure for stable motion.
- The driving system: DC-powered motor driving system so that the AGV can move as far as possible but not limited by the power line.

- Sensing and control system: Optical sensors are used for positioning and path tracking as this non-contact technology can be employed in an office environment. Only position control is considered for this first-generation AGV.

A conceptual design, based on the above specifications, with the rear wheel, driven by a DC motor, as the driving wheel and direction controlled by the front wheel steered by a stepping motor is shown in Figure 3.1. The structure is composed of one unit dc motor, front shaft (rack gear) two unit tyres and two unit of tyre-to-shaft join.

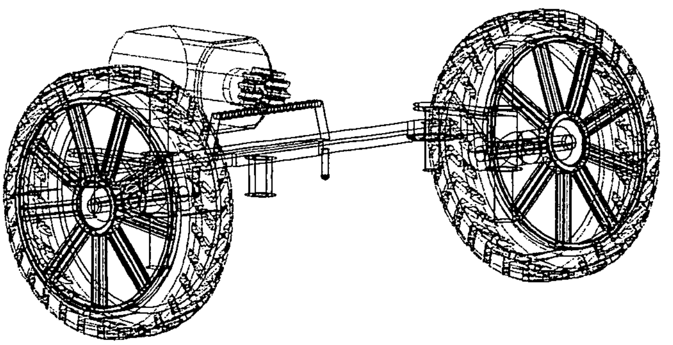


Figure 3.1: Typical Design for Turning Mode

3.4 Concept and detailed designs

Based on the functional specifications, different possible structures and mechanisms that satisfy functional requirements were studied. It was then revised based on comments and suggestions from project advisors and other lecturers. This is intended to let the author understand the design loop from functional specification to concept sketch, to functional check, and design revision. The structure of the first draft is not determined until functional specifications and some specification evaluations are checked. This stage usually requires four to six weeks as the concept is solidified during this stage.

Engineering drawings, including parts, sub-assemblies and assemblies, are then prepared using CAD system as design changes are expected in the following phases. Direction guidance is controlled by two photo-based steering sensors that detect signals from a metal band in the ground. Control scheme are developed to determine the direction of rotation of the front wheel based on simple algorithms. Signals from steering sensors are sent to microcontroller. Position is detected based on contact sensors allocated in front of the model. Signals are sent to activate the on/off switch of the DC motor that drives the driving wheel. Electronic circuits are designed and to meet the interface and I/O specifications.

3.5 Parts preparation and assembly

Detailed engineering drawings of machined parts and components from the above design are then prepared. Some commercially available components are directly purchased, often from used parts market to save money.

The AGV system is then assembled at the same time when parts and components are prepared. This is also part of the training for the author to get some feelings on the "concurrent engineering" technique.

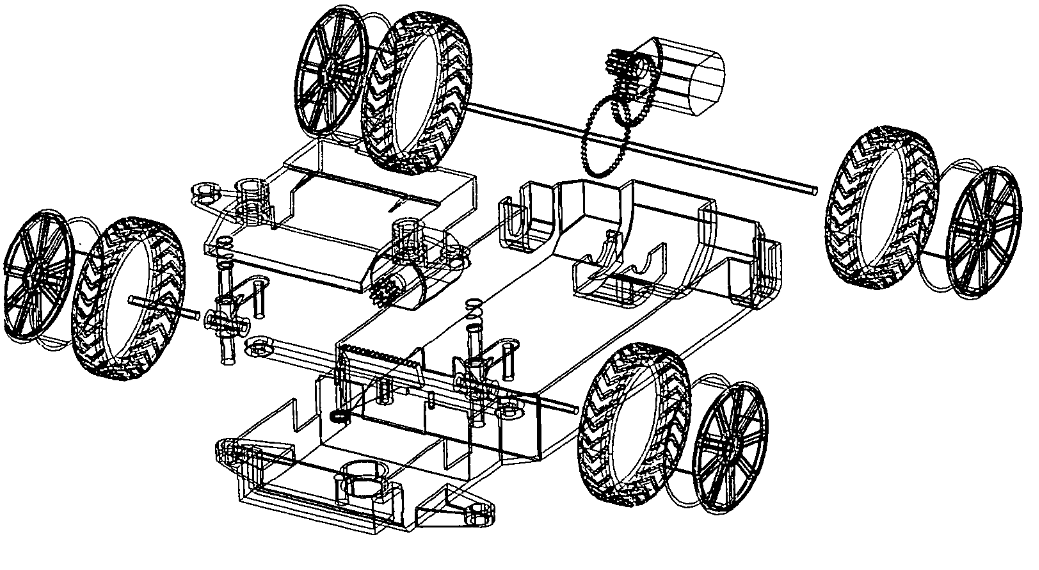


Figure 3.2: Typical assembly drawing of the AGV

3.6 System testing and refinement

The assembled system was tested against the specifications. This is often in the final stage close to the end of the one-year project-oriented and thus a little bit tight in schedule. However, this process is always required though students are sometimes kind of frustrated after the whole-year long project. This is because not all the part will be fully operated. Some may have technical problem and hence the system cannot run accordingly.

There are various software that can be used in order to test the design in terms of its kinematics and dynamics. In this project, ADAM is used to check the kinematics and dynamics of the system.

CHAPTER 4
RESULT & CALCULATION

4.1 Mechanical

4.1.1 Motor and Gear

Specification of motor used.

There are two unit of electric motor used in this project. The first unit is to control backward and forward movement. For the forward and backward movement, the specification is shown below:

- Manufacturer: Futaba Corporation.
- Dimension: (40.4 x 19.8 x 36) mm
- Weight: 70.0g q
- Torque: 3.0kg/cmq
- Operation angle: Rotary system
- Power supply: 4.8 or 6.0 volt
- Operation speed: 4.8 rad/sec.

From the specification given, the angular velocity of the motor is 4.8 rad/sec and this is equivalent to 453.39 revolution/minute (rpm).

The other unit of dc motor used is to control the turning mode of the system. This electric motor is attached together with the rack gear as shown in previous chapter.

4.1.2. Conversion between Angular and Rectilinear Motion

$s = r\theta$

if the motor is rotating at uniform velocity, ω, where the angular displacement ,

$\theta = \omega t$. The total displacement is:

$s = r[\omega t]$ ----------- (1)

Also, the motor moves at uniform speed. It's velocity v, is related to the displacement by:

$s = vt$ --------- (2)

By substituting (2) to (1);

$v = r\omega$

4.1.3. Calculation on Speed Control

No. of teethes of Gear A = 10
No. of teethes of Gear B = 38
No. of teethes of Gear C = 10
No. of teethes of Gear D = 44

$$\frac{\omega_B}{\omega_A} = \frac{T_A}{T_B}$$

$$\frac{\omega_B}{452.39} = \frac{10}{38}$$

$$\therefore \omega_B = 119.05 rev/\min$$

$$\frac{\omega_C}{\omega_B} = \frac{T_B}{T_C}$$

$$\omega_C = \omega_B x \left[\frac{T_B}{T_C}\right]$$

$$\omega_C = 119.05 x \left[\frac{38}{10}\right]$$

$$\therefore \omega_C = 452.39 rev/\min$$

$$\frac{\omega_D}{\omega_C} = \frac{T_C}{T_D}$$

$$\omega_D = 452.39 x \left[\frac{10}{44}\right]$$

$$\therefore \omega_D = 102.82 rev/\min$$

4.1.4. Calculation on Degree of Turning

$$\theta \approx \tan^{-1}\frac{1.5}{1.5}$$

$$= \tan^{-1}(1.0)$$

$$\theta = 45.0^{o}$$

From the above calculation, the maximum turning angle is 45.0°. This value tells us that the maximum angle for the tyre to turn right or left is within that angle. This angle of turning can be changed by reducing or increasing the distance of the stopper (Figure 4.1) at the turning shaft as shown in the diagram. The turning mode is controlled by the DC motor.

This motor is places at the centre of the turning shaft. The turning shaft is designed to have a teethes at the middle of it. The combination of rack gear and electric motor is used to turn the wheels. Rack gear is used to convert rotational motion from the electric motor to linear motion.

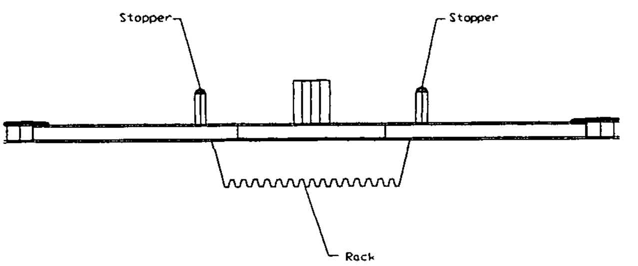


Figure 4.1: Front view of turning shaft

Rack gear is a straight gear of infinite radius, normally used with a spur gear called the pinion. It's used to convert rotary motion to translation motion or vice versa. Normally rack is used extensively in machine tools.

Electric motor is attached to the rack gear as shown in figure 4.1. This mechanism is used to navigate the AGV whether to turn right or left. The maximum deflection is

45^0. This angle can be changed by shorten or lengthen the stopper at the front shaft as shown in figure 4.1.

4.1.5. Calculation for springs constant.

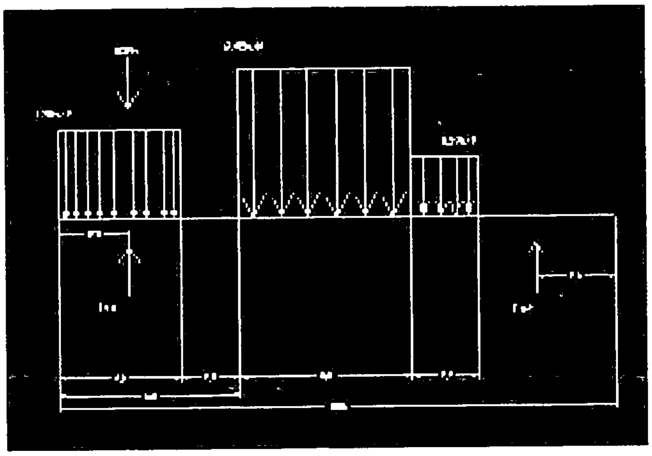


Figure 4.2: Free Body Diagram of the model (2D).

To calculate the F_wb (back) and $F_wf.$ (front)

Solution

$$\sum F_y = 0$$

$$\uparrow +ve; F_{wb} + F_{wf} - (0.047 + 0.02 + 0.1421 + 8.63x10^{-3} + 0.02) = 0$$

$$F_{wb} + F_{wf} = 0.238N \text{ ------}(1)$$

$$\sum M = 0$$
$$counterclockwise = +ve$$
$$-0.047(0.02) - 0.02(0.023) + F(0.023) - 0.142(0.089) - 8.63x10^{-3}(0.1) - 0.02(0.159) + F_2(0.159) = 0$$
$$-0.00094 - 0.00046 + 0.023F_1 - 0.0126 - 0.000863 - 0.00318 + 0.159F_2 = 0$$
$$0.159F_2 + 0.023F_1 = 0.018N ....(2)$$
$$F_1 = 0.238N - F_2 ....(3)$$
$$(3) to (2)$$
$$0.159F_2 + 0.023(0.238 - F_2) = 0.018N$$
$$0.159F_2 - 0.023F_2 = 0.018 - 0.000547$$
$$0.136F_2 = 0.0174526N$$
$$\therefore F_2 = 0.128N$$
$$F_1 = 0.238 - 0.128$$
$$\therefore F_1 = 0.11N$$

From the above calculation, the force exerted at front wheels is 0.128N and 0.11N for the backward wheels. Thus the amount of spring constant needed to overcome this force within certain amount of displacement is calculated. In this case, the maximum displacement is 0.01m. This is to maintain the height of the AGV from the working environment.

The calculation of the front wheels is shown below:
F=kx, where x is the displacement and k is spring constant. The spring constant, *k* is calculated.

By taking $F = F_{wf} = 0.128N$
Thus;
$$0.128N = 0.01m(k)$$
$$k = \frac{0.128N}{0.01m}$$
$$k = 12.8N/m$$

From the above calculation, the spring constant that should be used, as the suspension is 12.8N/m. That's mean the stiffness of the spring as shown in Figure 4.3 should be equal or greater than this value.

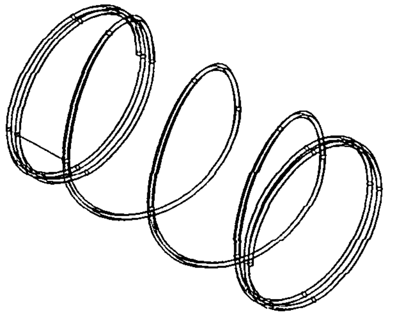


Figure 4.3: Coil spring as the suspension

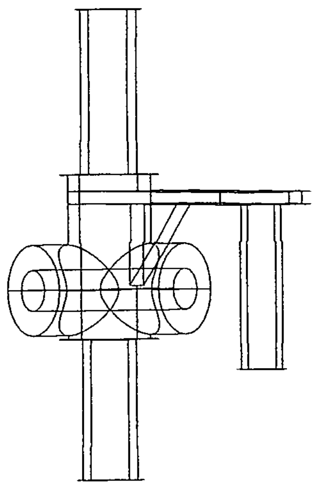


Figure 4.4: Typical Isometric drawing of tyre-to-shaft

4.1.6. Material Selection

There is a wide range of materials available for us to choose from and correspondingly wide range of properties. It is important to realize that although the material may be chosen mainly because it is able to satisfy predominant requirement for one property above all others; there must always be in addition certain back-up properties. That is. Every useful material must possess a combination of properties. Certain types of material can be broadly generalized as characteristically possessing certain combination of properties.

As always, there are exceptions to these generalizations. Plastic are indeed frequently extremely durable, but some are subjected to stress corrosion. Metals are generally tough; widely used for engineering purpose is due to largely to the fact that they are mostly able to combine strength and toughness.

At an early stage in the design process should become apparent that several different materials are capable of performing a particular function. It is then necessary to choose between them. This requires that the important properties be measured in an unambiguous, rational manner.

The achievement of satisfactory properties in choosing the materials is only part of the materials engineer's task. It is necessary also that they be achieved at acceptable cost. For this reason cost is sometimes incorporated into property parameters to facilitate comparison. The cost for is RM 45.60. This cost include all the component such as coil spring, torsional spring, four set of tyre, gearing set, and a unit of electric motor. The other unit of electric motor (servo) is bought separately which cost about USD 80. The gross cost for this development is RM 350 which include only mechanical part.

Below is the briefly description about material used in order to build our model:

Table 4.1: Description about material used

Components	**Material Used**	**Justification/Specification.**
AGV • Base • Casing	Polyvinyl Chloride (PVC)	1. Non-reactive, durable, high strength. 2. Good insulator and weather resistant. 3. Water proof. 4. Electrical resistivity: >10^4 5. Yield strength: (40.7-44.8)MPa 6. Tensile strength: (40.7-51.7)Mpa
Motion System	Standard Servo Motor. (Manufactured by FUTABA Corp.)	1. Small, may reduced space used.(40.4x19.8x36)mm 2. Light weigh : 44.8g 3. Power supply: 4.8/6.0V 4. Output torque: 3.0kg/cm 5. Operation speed: 0.22 sec/60 degree.
Tyre	Rubber	1. Chemical and biological inertness. 2. Minimize the time when it's collided. ❖ Expensive to produce.
Suspension.	Spring	1. Extremely stiff spring. 2. Minimize the impact time. 3. Minimize the momentum.
Screw	Stainless Steel	1. Cheaper and stronger. 2. High corrosion resistant. 3. Resists attack by oxidizing solutions and most organic chemicals.

4.1.7. Battery

We will use battery as power source for our mobile. It is because our mobile will move in a tunnel and it needs power source that can be brought with him. As we know we can bring a battery anywhere we want. In addition battery is compatible, cheap and easy to handle. There are two types of battery, which are primary and secondary. Primary battery is a battery that can be used once while secondary battery is a battery that can be recharged and reused. We will use both types of battery for our mobile.

4.1.7.1 Primary Battery

As we know, primary battery is a battery that can be used once. Example of this battery is Zinc/Manganese Alkaline battery, Lithium/Copper Monoflouride battery and so on. For our mobile we will use lithium battery. This battery is for powering the electronic circuit. Lithium battery has a gravity energy density up to 330 Wh/kg or three times more than ordinary primary battery such as mercury battery. It means that the battery can give enough power to our circuit for making the circuit working properly. The other advantages of lithium battery are it is long life battery, high temperature endurance has a high voltage and has a highest volumetric energy density, which is 600 Wh/dm^3. So by using this battery, our circuit in the mobile can be powered up for a long time.

The second type of battery, which is secondary battery, will be used to power a motor in our mobile. There are two motors in our mobile. One for the mobile to move front and back and the other motor for making the mobile move right and left. As we know secondary battery is a battery that can be recharged and reused. It means that the electrical current can be passed back into the battery to recharge it. So in chemistry view, we said the reaction for the battery to produce electrical energy is reversible. Examples for this type of battery are Nickel/Cadmium, Silver/Zinc and so on. For our motors in our mobile, we will use a nickel cadmium battery. This battery can be recharged repeatedly; approximately 500 cycles with 100% depth of discharge and 2000 cycles with 50% depth of discharge. So we can use the battery many times and this will save the cost for maintaining it. This battery also has lot of advantages such as it can be produced in the sealed form because they do not generate gas during discharge. Besides that it can be overcharged and has low internal resistance. All this characteristics make it appropriate to use in electronic equipment. One cell of this battery provides 1.32V. One of disadvantage of this battery is it has low energy density which is 40Wh/kg.

CONCLUSION

This paper discussed the philosophy, design, and implementation of the AGV's project. Important steps involving the design of the AGV are also briefly discussed in the paper. The project is designed to give experience in mechanical design and prototyping and system integration via mechatronics. It also gives the author more exploration to related knowledge in addition to theoretical training.

The objective of this project is to design s system that can avoid obstacle. The overall AGV system includes two major parts which is mechanical and electronic part. In this report, the author emphasizes only mechanical part. This includes the kinematics and dynamics of the system.

There are several stages involved in order to design and construct this AGV. Those stages were survey and define specification, conceptual and detailed design, parts preparation and assembly, assembly of sensing and control systems and system integration, system testing and refinement.

As the first step in product design is to form the problem, this project is started by some introduction material including the function and applications of AGVs in automated systems. Some functional specifications, hardware and key characteristics are also hinted and suggested. Based on the functional specifications, different possible structures and mechanisms that satisfy functional requirements is discussed. The structure of the AGV was first sketched It was then revised based on comments and suggestions from project advisors.

Detailed design analyses are then conducted. This included engineering drawing, including parts, sub-assemblies and assemblies are then prepared using CAD system. The detail design phase is a time-consuming process. As design is a trade-off among different aspects thus design change is common after design analyses and evaluations.

Detailed engineering drawings of machined parts and components from the above design are then prepared. The AGV system is then assembled at the same time when parts and components are prepared. The sensing and control systems are designed and assembled at after the design and assembly of the mechanical structure. As mentioned that the AGV is guided by a metal band with photo sensors to detect the path. Two photo sensors, located in the front of the AGV frame. The assembled system must be testified against the specifications.

This project also gives author more exploration to related knowledge in addition to theoretical training. This project has been proven a great success that students in Universiti Teknologi Petronas (UTP) are trained not only to complete Final Year Project (FYP with his or her own design but also to learn the methods and skill for teamwork and brainstorming.

As engineering education plays an important role in the society, curriculum and courses must be carefully designed to ensure that author are learning what required in the society. Although the author had discussed in previous section some steps involved in the design and prototyping an AGV, many considerations are put into the training including resource management, project management, as well as teamwork. Author was asked to plan working items and schedule when the first draft design is completed. This is to remind them how much work in the following process and how much resource, including budget and time.

While coming to the last word, author want to give some recommendation for the coming candidate of final year to design such thing that have interconnection between different aspect of engineering. It is because, when we come to the real life application, there is no such thing that stands only on one scope of engineering. They might be a combination of two or more engineering studies. In order to get to know into various scope of engineering, we have to do some basic application on that engineering field. This might face problem in the beginning but after some revision and literature review, those problems can be solved.

Last word, author wants to recommend to the next FYP's candidates to continue this project and upgrade this model. The usage if this model can be narrow to some specific environment and also can explore and take any data from given environment. For an example, the exploration in mines. In order to minimize the risk, we can send this model in order to take some data in that particular environment to make sure that the condition inside there is safe for human to do their work.

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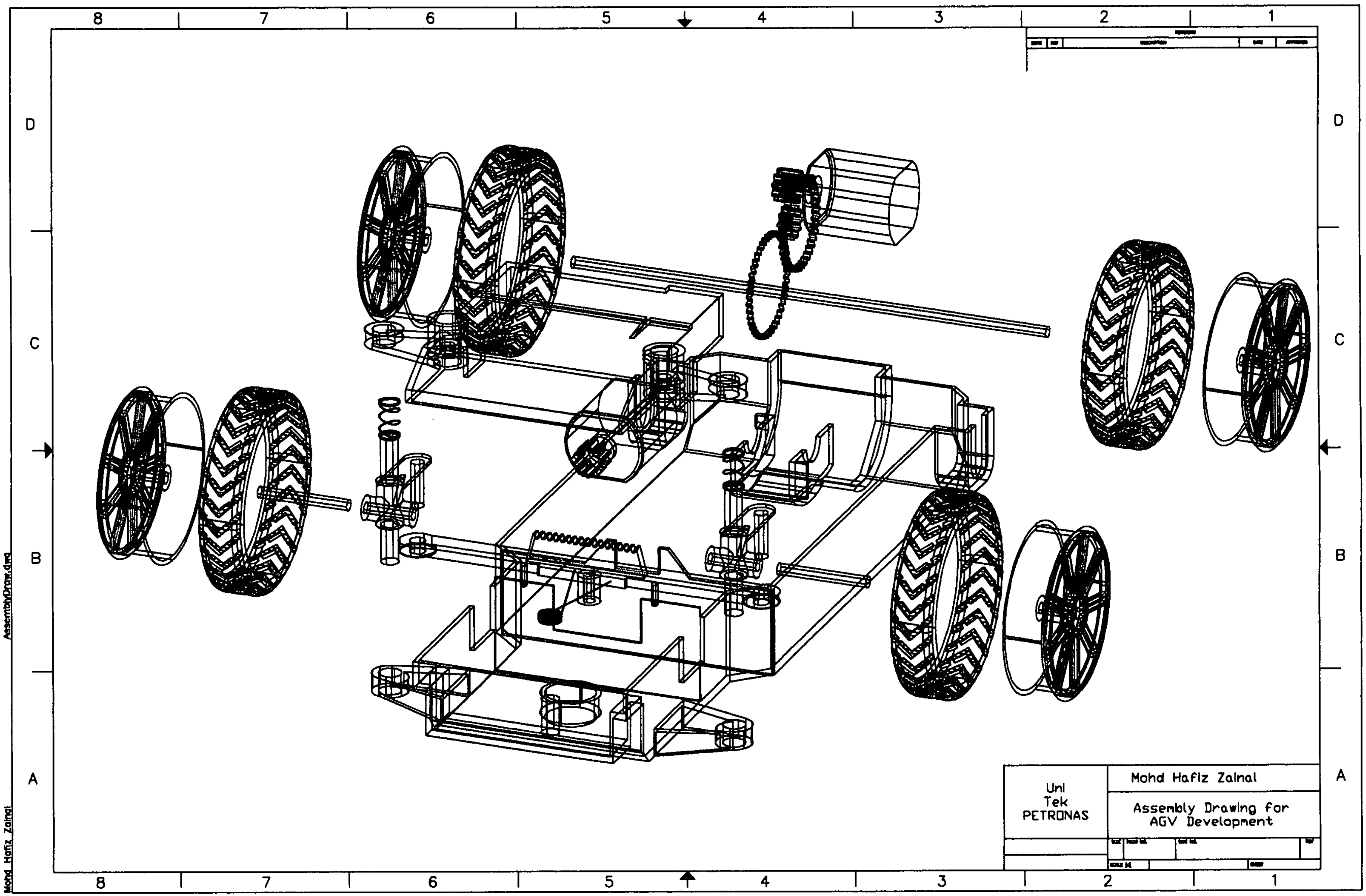
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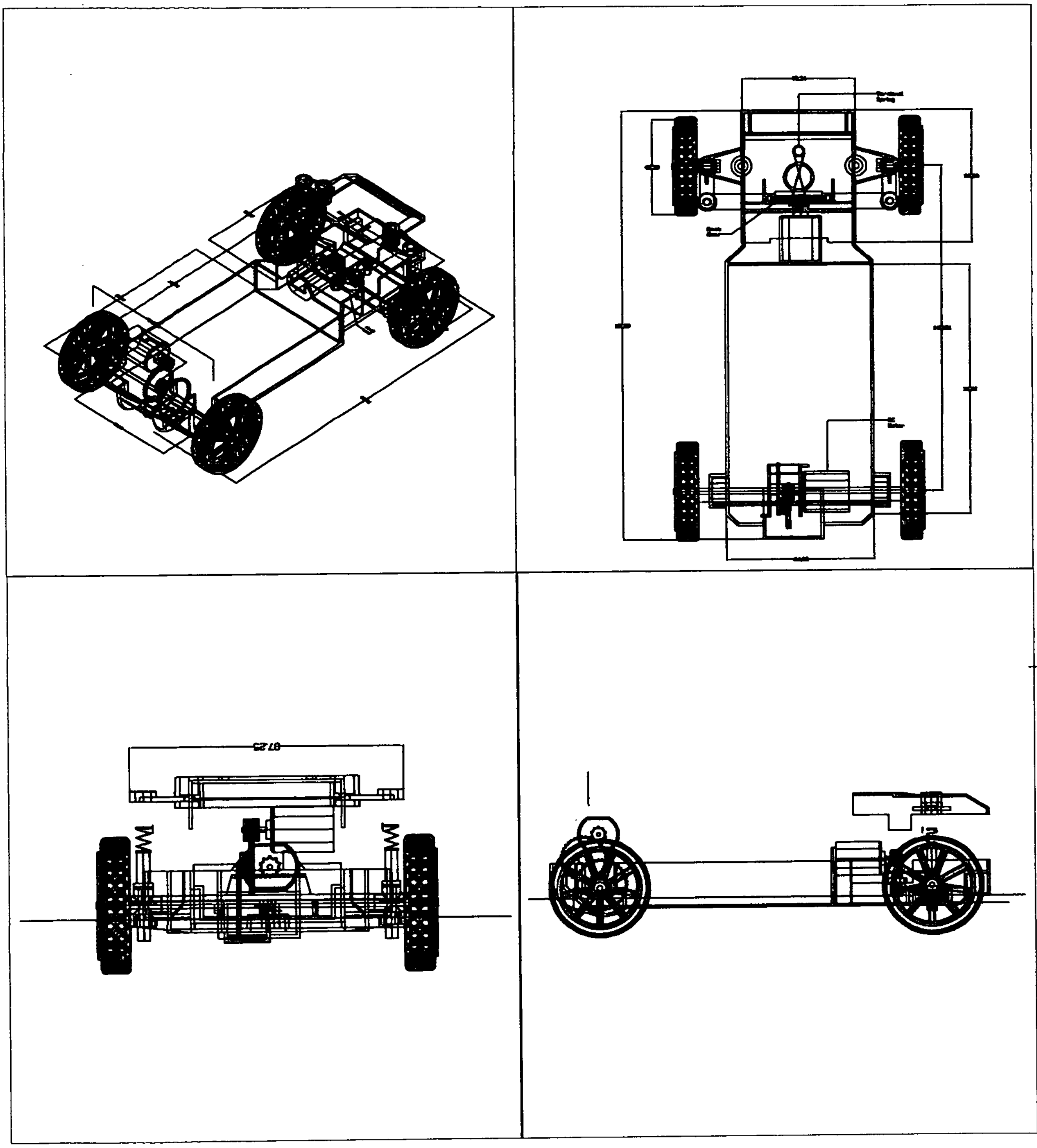

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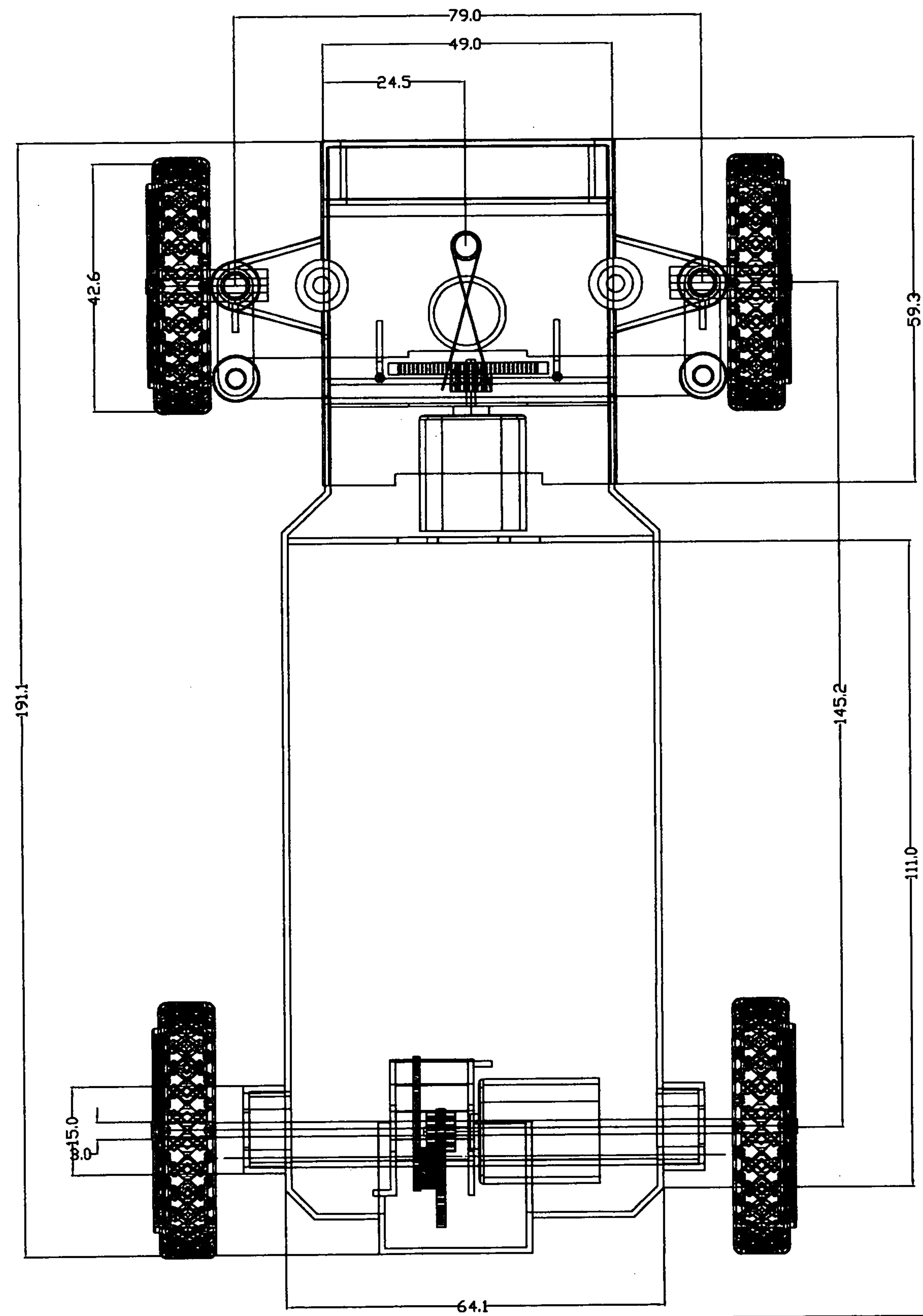

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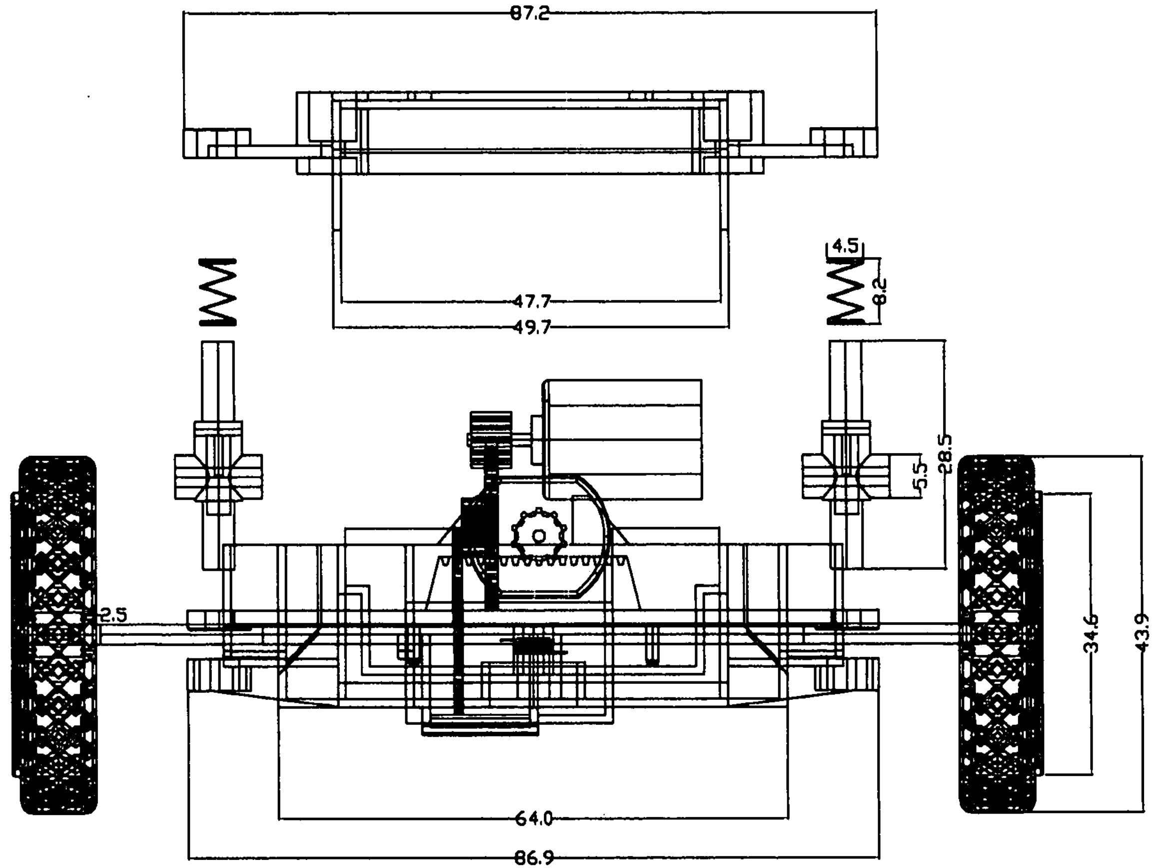

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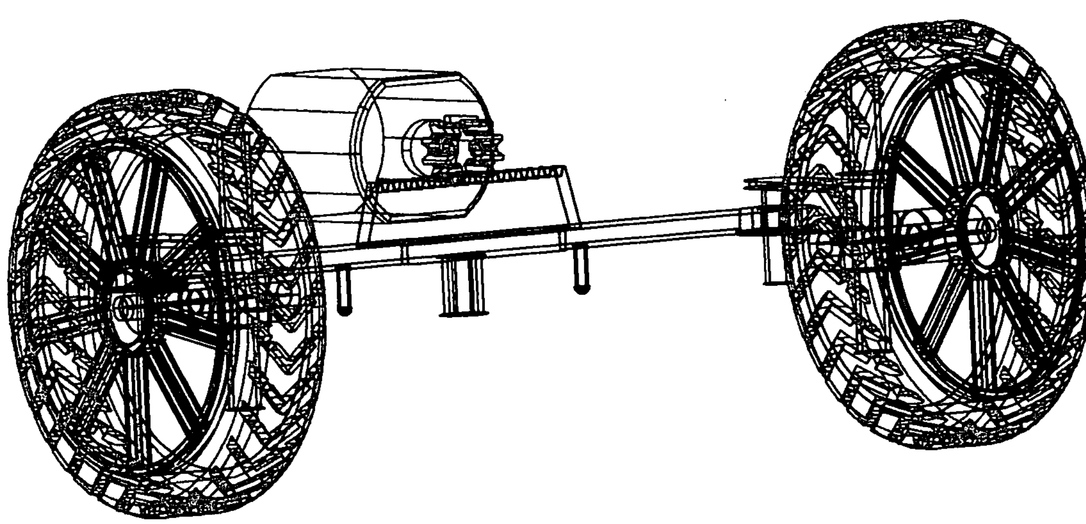

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