# Design of a Powertrain System for Simple Vehicle

by

Mohd Hazrul Azam Bin Alias

Dissertation submitted in partial fulfilment of
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Bachelor of Engineering (Hons)
(Mechanical Engineering)

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**CERTIFICATION OF APPROVAL**

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A project dissertation submitted to the
Mechanical Engineering Programme
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BACHELOR OF ENGINEERING (Hons)
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Approved by,

(Dr. Zainal Ambri Bin Abdul Karim)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2011

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work effort by 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 HAZRUL AZAM BIN ALIAS

## ABSTRACT

This report is about the study to design a suitable powertrain system for a simple vehicle. The goal for the vehicle is to achieve a good range of gear ratio base on angular speed of each sprocket in order to obtain the best powertrain design and improve the vehicle movement. For the simple vehicle, the power developed by engine is transmitted to the rear wheel by 4 sets of different sizes of sprockets. The first sprocket is at the output of the engine is 9.45mm in radius transmits the power to the second sprocket which is 69mm in radius. The power transmitted along a gear reduction to third sprocket which is 29mm in radius and lastly to the fourth sprocket/rear sprocket which has a radius of 110mm. The second sprocket is varied in radius start from 39mm, 49mm, 59mm, and 69mm. The best result from the ADAMS analysis is 39mm in radius which contribute to 7.9:1 gear ratio. Honda GX160 engine is efficient in power delivery but suffers unfortunate increase in weight compares to previous project which uses Honda GX35 engine. Based from this change, the design of the drivetrain must be simple and use the lightest material as possible with a good efficiency in order to reduce the overall weight. The objective of this project is to develop the best design selection of powertrain based on each part of powertrain including chain, clutch, sprocket, and transmission that builds to an efficient powertrain that suits perfectly with the engine and study on the other existing system of drivetrain mechanism, design, structure, and material use for the vehicle.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of study

The goal for the vehicle is to achieve a good range of gear ratio base on angular speed of each sprocket in order to determine the best powertrain design and improve the vehicle movement. Engine modification, transmission system, and most important in the design of powertrain is analyzed in order to achieve efficiency in transmitted power.

The main reason why powertrain system is important is because a good transmission system could reduce the waste of energy. Good drivetrain will contribute to the good performance of the vehicle. For one thing, the design of the drivetrain is producing the excitation. Secondly, drivetrain need to be minimized for weight and a good speed range required for fuel efficiency. To reduce and improve design of powertrain based on design selection of each part of drivetrain which are include type of chain, material of sprocket, type of clutch, and type of transmission that most efficient, reliable, flexible, size and weight, that can match perfectly with the engine.

## 1.2 Problem statement

Modern gasoline engines have an average efficiency of about 25-30% when used to power a car. It start from the engine which is Engine Honda GX35 that can produce net power 1.0 kw (1.3 HP) / 7000 rpm and max net torque is 1.6 Nm at 5500 rpm (refer Appendix 2). From previous project, the gear ratio of the engine to the rear wheel sprocket was 20:1. Currently this project uses Engine Honda GX160 and has been analyzed which is the best gear ratio. This engine is efficient in power delivery. The net horse power output is 4.8 HP at 3600 rpm and the net torque is 10.3 Nm at 2500rpm (refer Appendix 1). The advantages of using this type of engine in term of delivering sufficient power based on the high 160 capacity engine compare with the previous 35 capacity engine and consider to use the minimum power that sufficient to propel the vehicle in order to reduce fuel consumption and no need to set it to maximum power.

The drawback of this type of engine is unfortunately increment in weight compares to previous one Engine Honda GX35. Based from this change the design of the drivetrain also must be simple and use the lightest material as possible. On the other hand design of drivetrain also must efficiently match from the engine to the rear wheel sprocket.

## 1.3 Objective and scope of study

### 1.3.1. Objective

- To study and make a research about the option of drivetrain mechanism, design, structure, and material use for powertrain system.
- To develop a best design selection of powertrain base on each part of powertrain included chain, clutch, sprocket, and transmission that lead to an efficient powertrain and maximum power delivery that suits perfectly with the engine.

### 1.3.2 Scope of Study

The scope of study is separated into two parts. For the first part is about the study for improvement of the previous powertrain system by the detail calculations, analysis of the structure and materials for the drivetrain system based on a new engine in order to obtain a good and efficient powertrain system that can match perfectly from the engine to the rear wheel tire. In this case there are several factors has been considered such as the structure of the model, torque (Nm) and angular speed (Rpm) produced from the engine to the drivetrain base on calculation on a free body and kinematics diagram of the drivetrain reaction force and torque along set of sprockets. The gear ratio has been analyzed using ADAMS to see the pattern of suitable graph from each set of sprocket in order for improve the efficiency of the powertrain system. The dynamic loading, vibration and external load are neglected in this analysis due to complexity. Only the weight of the engine with the kinematics load is considered in this analysis.

The Second Part is the design selection based on the calculation and research of other team that has many experience and knowledge on making decisions about the selection of each part of the powertrain which includes chain, sprockets, clutch, and transmission. In preliminary scope, the pros and cons of each part of this powertrain system that has been use in previous vehicle is explained. The design selection of each part of powertain is based on size and weight, reliability, efficiency, flexibility, and cost. The main connected part that needs more focus and attention on selection of each part is the new engine which has different specification from the previous engine. In this case, the exact calculation needs to take in serious consideration. Finally, the objective of this project is to develop a good powertrain design that can match perfectly with the engine.

# CHAPTER 2

# LITERATURE REVIEW

The design of powertrain from the previous scholar in their car had been study to get an early idea about the common layout of the powertrain system for simple vehicle. There are several cars which has different powertrain structure and design selection for engine, transmission, clutch and sprocket.

## 2.1 Previous Powertrain Design

### 2.1.1 Powertrain design of team 16, Dalhousie University, Canada [1]

Figure 2.1: Drive mechanism by using chain drive with the centrifugal clutch [1]

This is the only university that provides much information in the design and layout of powertrain system. The drivetrain mechanism use chain drive system. The design of powertrain included centrifugal clutch that attach at output Engine Honda GX35. The advantage of this design because did not have a gear reduction part and because of that it can reduce the weight of entire part of powertrain. The disadvantage, the direct one gear ratio from the output engine to the rear wheel while using low capacity engine might contribute to the insufficient power to propel the vehicle.

### 2.1.2 Powertrain design of team 15 of Dalhousie University, Canada [2]

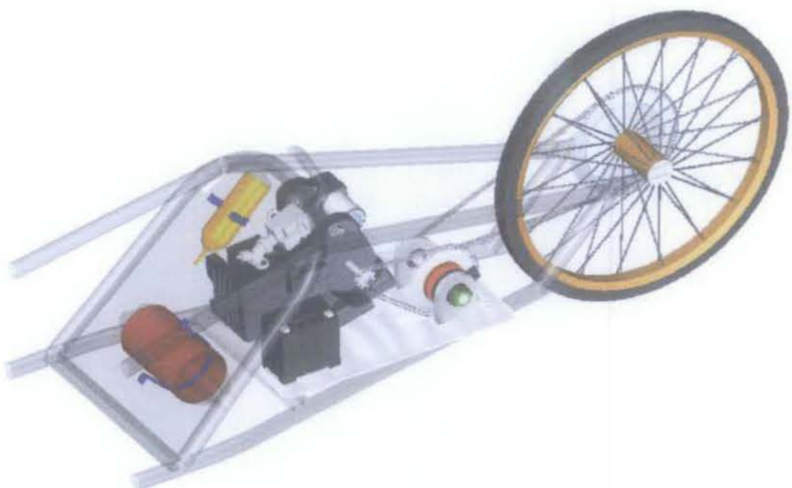

Figure 2.2: Drive mechanism by using chain drive with friction plate clutch [2]

The powertrain design is slightly different from team 16 which the design of powertrain included an external clutch which positioned besides the engine on the drivetrain system. The type of clutch is Friction Plate Clutch. The advantage is the clutch can engage and disengaged at suitable speed that control by driver and lead to prevent the loss of power. The disadvantage is the design included this type of clutch that is more complicated which requires installation of a clutch pedal that will be controlled by the driver and lead to additional parts/weight to the car.

### 2.1.3 Powertrain design of Team GMP de Toulouse, France [3]

Figure 2.3: Drive mechanism by using belt drive [3]

The powertrain of L'équipe GMP de Toulouse Nogaro, has something special about their drivetrain mechanism which by using belt drive without use of continuous variable transmission (CVT) transmission. The direct drive one gear ratio from the engine to the rear sprocket by using belt drive with set of pulley. The advantage is reduction in weight while consider pulley and belt compare to sprocket and chain. The disadvantage is uncertainty weather the design can sustain the high torque and power from the engine to the rear wheel.

## 2.2 Overview of Drive Mechanism

The drive mechanism transfers the power generated by the engine to the clutch, transmission, and finally the rear wheel to propel the vehicle. Three concepts for the drive mechanism were considered which are belt drive, gear drive, and chain drive.

### 2.2.1 Belt Drive

A belt is a loop of flexible material used to link two or more rotating shafts mechanically. Belts may be used as a source of motion, to transmit power efficiently or to track relative movement. Belt drive systems use pulleys that grip the belt on either end while they rotate, transmitting the angular rotation of the input pulley to that of the output pulley. Belts are the cheapest utility for power transmission between shafts that may not be axially aligned. There are two types of belts which are Friction belts and Notched synchronous belt. Belt drives are lightweight, low in cost, and do not require lubrication compares to other drive mechanism chain and gear mechanism. However a belt drive has major disadvantage which is the design is not as robust as a chain or gear drive because belts tend to wear and stretch with extended use. On the other hand, synchronous belts also are not compatible with belt driven transmissions (such as variable diameter sheaves); therefore a secondary drive mechanism would be required if a belt drive is used. Other disadvantages of a synchronous belt drive outweigh the benefits.

Figure 2.4: Synchronous belt drive [4]

### 2.2.2 Gear Drive

A gear is a rotating machine part having cut teeth which mesh with another toothed part in order to transmit torque. Two or more gears working in tandem are called a transmission and could produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, magnitude, and direction of a power source. An advantage of gears is that the teeth of a gear prevent slipping. The main advantage over other drive mechanism belt and chain is in precise and exact speed ratio. A gear drive is efficient and has low maintenance, but weighs significantly more than a belt drive or chain drive and is more costly. As well, a gear drive is not practical for transmitting power over distances that require idler gears to connect the driven and driving gears because of the increased weight of the additional components.

Figure 2.5: Spur gear drive [5]

### 2.2.3 Chain Drive

Chain drive is a way of transmitting mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles. It is also used in a wide variety of machines besides vehicles. Though drive chains are often simple oval loops, they can also go around corners by placing more than two gears along the chain gears that do not put power into the system or transmit it out are generally known as idler-wheels. By varying the diameter of the input and output gears with respect to each other, the gear ratio can be altered. The gear is turned, and this pulls the chain putting mechanical force into the system. The idea of a roller chain drive is much the same as a synchronous belt system in that both the drive and driven pulleys or sprockets have teeth that grip the notched roller chain as they rotate, transmitting power. Roller chains are durable and offer high transmission efficiency at a reasonable cost compared to a belt or gear drive. On the other hand it also has disadvantages which are the roller chain drive needs for lubrication and a tensioning mechanism.

Figure 2.6: Roller Chain Drive [6]

## 2.3 Overview of Clutch

A clutch is necessary to engage and disengage the engine to control movement. Three different clutch designs were considered which are centrifugal clutch, cone clutch, and plate clutch.

### 2.3.1 Centrifugal clutch

A centrifugal clutch uses the angular velocity of the engine's driveshaft to extend a rotating mass, creating pressure between two friction surfaces to transmit power to an output shaft. At low engine speed, the clutch is disengaged because the centrifugal force is not large enough to cause the rotating mass to move the friction plate outward and lock onto the output mechanism. However, as the engine speed increases the centrifugal force generated by the rotating mass pushes the friction plate to the outer drum, allowing power to be transmitted. Centrifugal clutches allow the motor to develop high torque before engaging and operate at high efficiency once engaged.

Figure 2.7: Centrifugal Clutch [7]

### 2.3.2 Cone Clutch

Friction cone clutch offer superior transmission of high torque because the design provides a wedging action that helps the frictional surfaces to bond together. As a result of the wedging action, more force is required to disengage the clutch compared to a friction plate clutch. The disadvantage of this clutch is additional size, weight, and design complexity compares to others type of clutches.

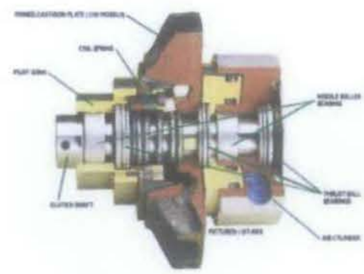

Figure 2.8: Cone Clutch [8]

### 2.3.3 Friction Plate Clutch

Friction plate clutch operate using a frictional material and plate placed between the driving shaft and the driven shaft. When the two surfaces are pressed together the result is a driving friction that enables the driven shaft to rotate with the driving shaft. Friction plate clutch are simple to build, inexpensive, and light in weight. The plate clutch can also be engaged and disengaged at any speed, requiring little input force.

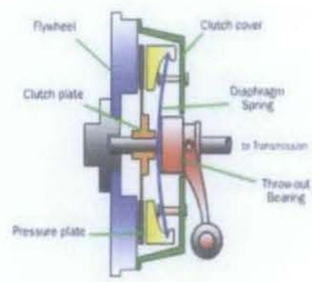


Figure 2.9: Friction Plate Clutch [9]

## 2.4 Overview of Transmission

A transmission is required to provide a variety of gear ratios to optimize fuel efficiency throughout the range of operating speeds. Three transmission designs were considered which are continuously variable, planetary hub, and sprocket and derailleur transmission.

### 2.4.1 Continuously Variable Transmission (CVT)

A CVT transmission uses a mechanism to open and close both the input and output pulleys, changing the input to output gear ratio. A CVT transmission offers a large range of gear ratios and smooth shifting between gears. As well, a CVT can be designed to disengage at low speed, eliminating the need for a separate clutch mechanism. The major drawback of a CVT is inherently lower efficiency due to belt slippage and the weight of all the required components (sheaves, clutch arms and weights, springs).

Figure 2.10: CVT [10]

### 2.4.2 Planetary Hub Transmission

A planetary hub transmission uses a series of planetary gear sets enclosed in a bicycle wheel hub to offer a range of gear ratios. This design is compact and requires low maintenance. The drawbacks of a planetary hub transmission are its higher cost and weight compared to a simple chain derailleur system, as well as its lack of availability at power ratings required for the engine. Planetary hub transmissions are typically designed for bicyclists and are not able to take the higher torque and speed of a gasoline engine.

Figure 2.11: Planetary Hub Transmission [11]

### 2.4.3 Sprocket and Derailleur Transmission

A sprocket and derailleur transmission would use a derailleur similar to that of a bicycle to move a roller chain from a large sprocket to a smaller sprocket effectively increasing the output-to-input gear ratio of the transmission. The larger gear would be used to provide the high torque needed to accelerate the vehicle from the starting line, while a smaller gear would be used to provide acceleration to top speed. Advantages of a sprocket and derailleur transmission are its light weight, high efficiency, and low cost. A disadvantage of the sprocket and derailleur transmission is its limited gear ratios compared to a CVT or planetary hub.

Figure 2.12: Two Speed Sprocket [12]

Figure 2.13: Sprocket and Derailleur Transmission [13]

## 2.5 Type of Material Consideration of Drive Mechanism

Selecting the right material for a drive hardware application involves many factors, including the cost effectiveness of the number of parts needed, as well as the material performance required. Sheaves, sprockets, bushings and related components are considered using variety of material to meet the needs of each application. Most of the components are made out of gray and ductile iron or sintered steel. Sprockets and sheaves are made with different body styles, such as arm, web or block. For any application requiring rim speeds above 6,500 feet per minute (fpm), that sprockets or sheaves need special ordered to fabricate with appropriate materials and are dynamically balanced to ensure safe drive operation.

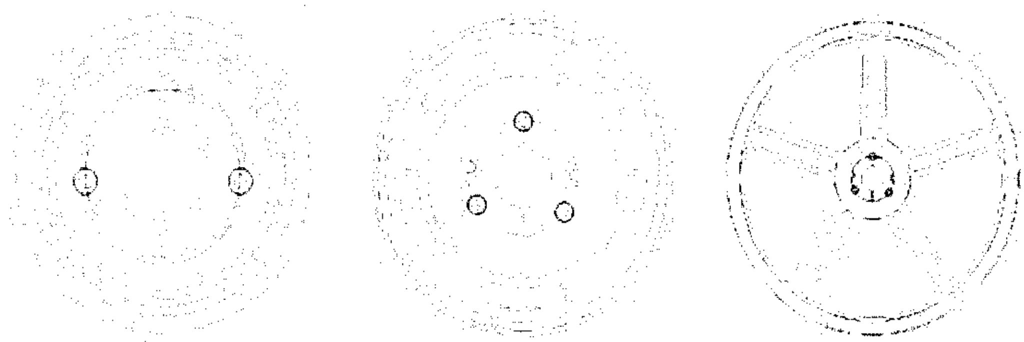

Figure 2.14: Common Styles of Sprockets and Sheaves. From left : Block style , Web style , Arm Style [14]

### 2.5.1 Gray Iron

Properties of common varieties of gray iron are described in Table 2.1 Gray iron's widespread use is due to the following characteristics such as machinability, wear resistance, dampening capacity, heat dissipation, low modulus of elasticity, and casts into most shapes.

Table 2.1: Available grades and maximum allowable speed for Gray Iron [14]

| **Available Grades and Maximum Allowable sprocket speeds** | | |
|---|---|---|
| Gray Iron | Yield Tensile Strength (psi) | Max Allowable Sprocket Speed (fpm) |
| Class 30 B,<br>ASTMA A-48 | 30,000 | 6,500 |
| Class 40 B,<br>ASTMA A-48 | 40,000 | 7,500 |

### 2.5.2 Ductile Iron

Ductile iron contains graphite modules, which improve strength and ductility over gray iron of comparable composition. Ductile iron is sometimes referred to as nodular iron because the graphite is in the shape of spheres or nodules. Properties of common varieties of ductile iron are listed in Table 2.2. Ductile Iron has the following desirable characteristics such as high tensile strength and toughness, good machinability (equal to gray iron of the same hardness), high modulus of elasticity which good shock resistance, wear resistance, excellent ductility, and casts into most shapes.

Table 2.2: Available grades and maximum allowable speed for Ductile Iron [14]

| **Available Grades and Maximum Allowable sprocket speeds** | | |
|---|---|---|
| Ductile Iron | Yield Tensile Strength (psi) | Max Allowable Sprocket Speed (fpm) |
| 65-45-12,<br>ASTMA A-536 | 45,000 | 8,000 |
| 80-55-06,<br>ASTMA A-536 | 55,000 | 9,000 |

### 2.5.3 Steel

Steels are alloys of iron and carbon, with the exception of stainless steels, which are alloys of iron, chromium and nickel. Steel is classified by its composition. The American Iron and Steel Institute (AISI) and the Society of Automotive Engineers (SAE) assign alloy designations. Most "general use" steels fall into three categories:

1. Carbon steels

2. Alloy steels

3. Stainless steels

Carbon steel contains small but specific amounts of manganese and silicon and is generally classified based on carbon content. Three broad classifications are referred to as low, medium and high carbon steels. Alloy steels are carbon steels with other elements added to increase hardness. These elements make alloy steels easier to heat treat for greater strength. Most commonly added alloys are nickel, chromium and molybdenum. Steels with certain amounts of manganese are also considered alloys. Several common steels used today are listed in Table 2.3 with their associated rim speed capabilities for sheave or sprocket.

Table 2.3: Available grades and maximum allowable speed for Steel [14]

| **Available Grades and Maximum Allowable sprocket speeds** | | |
|---|---|---|
| Steel | Yield Tensile Strength (psi) | Max. Allowable Sprocket Speed (fpm) |
| 1018 Steel | 53,700 | 9,000 |
| 1144 Steel | 89,900 | 12,000 |
| 304L Stainless Steel | 30,500 | 7,000 |
| 416 Stainless Steel | 84,800 | 11,000 |

### 2.5.4 Sintered Steel

Sintered steel can be used effectively in applications that have traditionally used other fabrication methods such as steel stampings, cast (gray or ductile) iron, die casting and screw machining. Sintering may be selected for the following reasons such as reduced secondary operations/scrap, ability to maintain close tolerances, good surface finish, complex shapes, low cost for moderate to high production quantities, wide range of mechanical properties and parts are recyclable. Sintered parts are used in power tools, appliances, firearm components, automotive components, office equipment, computers, and lawn and garden equipment. Generally, the higher the sintered steel tensile strength grades, the higher the cost. Material properties for sintered steel are listed in Table 2.4.

Table 2.4: Available grades and maximum allowable speed for Sintered Steel [14]

| **Available Grades and Maximum Allowable sprocket speeds** | | |
|---|---|---|
| Sintered Steel | Yield Tensile Strength (psi) | Max Allowable Sprocket Speed (fpm) |
| FC-0208-50 | 55,000 | 9,000 |
| F-0008-30 | 35,000 | 7,000 |

### 2.5.5 Aluminium

Aluminum offers many advantages over other materials. Some of these include light weight (~2/3 the weight of steel), machinability, high strength-to-weight ratio, non-oxidizing when exposed to air, excellent heat dissipation, high electrical conductivity, can be cast by all common casting methods, heat treatable for higher strength and hardness. Aluminum is often selected because of its light weight. If applications are lightly loaded or see limited or seasonal use, aluminum may be ideally suited for power transmission components. Many different grades and types of aluminum are available for power transmission components. Table 2.5 outlines three grades of aluminum along with their associated maximum sprocket speeds.

Table 2.5: Available grades and maximum allowable speed for Aluminium [14]

| **Available Grades and Maximum Allowable sprocket speeds** | | |
|---|---|---|
| Aluminium | Yield Tensile Strength (psi) | Max Allowable Sprocket Speed (fpm) |
| 2024-T3 | 50,000 | 12,000 |
| 6061-T6 | 40,000 | 11,000 |
| 7075-T6 | 73,000 | 15,00 |

# CHAPTER 3

# METHODOLOGY

## 3.1 The main target for this project

- There are 2 more drive mechanism options left which are belt drive and gear drive. Research about all three main mechanisms and considerations, there are advantages and disadvantages respected to the main objective. The best structure was focused in design consideration of maximizing efficiency of drivetrain in order to transmit power smoothly and reduce the load of the parts.

- Design selection of the transmission and clutch. Both are the main factor that leads to the efficiency of the powertrain. Based on research from the other team and calculation, it has been determined the best clutch and transmission that is suitable with the new engine.

- The size of the 4 set of sprockets in powertrain layout can be improved in size by analyzing using ADAMS which give result of the angular velocity and calculating the reaction force, torque of each part of the sprocket. All set of sprocket has been considered in materials that are to be used because each part will receive high torsion force.

## 3.2 Methodology

- **Powertrain design selection for each part**

  Determination of powertrain design selection for each part included drive mechanism, clutch, and transmission.

- **Calculation**

  Develop the reaction force and torque analysis on the Drivetrain system using the free body and kinematic diagram. Two critical conditions which is when the engine starts to move (Max torque to propel the vehicle, note: just consider sufficient torque which below the net torque of the engine 10.3 Nm at 2500 rpm) and when the engine at cruising (Low torque, consider rolling resistance 1.567Nm).

- **Model Creation with proper tool**

  The modeling of each part of drivetrain by using CATIA.

- **Simulation (Drivetrain Test)**

  This is to simulate the angular velocity for each set of sprockets. The pattern of the graph from the software will be analyzed to determine the best design structure and gear ratio. ADAMS will be use to this simulation process.

- **Improvement and modification**

  If does not meet the expectation the design will be improvise.

### 3.3 Methodology (Graphically)

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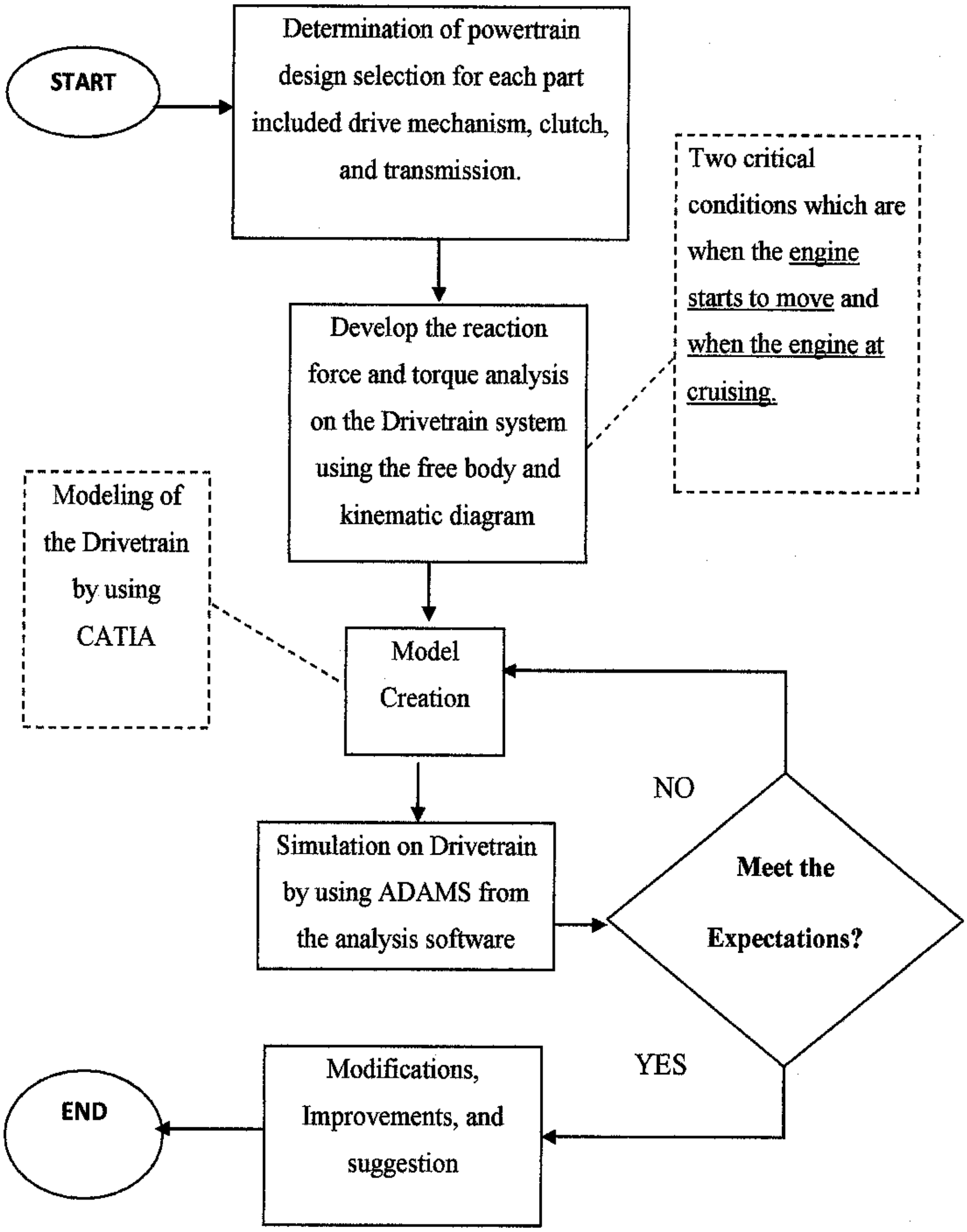



Figure 3.1: Flow chart of overall methodology

### 3.4 Layout of the Vehicle

Figure 3.2 shows the design chassis of the car with the powertrain area is at the back of the car. Focus at the powertrain area, based on kinematic diagram in Figure 3.3, power from the engine transmitted to the engine output sprocket which 9.45mm in radius transmit the power to second sprocket which is 69mm in radius. The power transmitted along gear reduction to third sprocket which is 29mm in radius and lastly to the fourth sprocket/rear sprocket which is 110mm. The proper tool is graphically shown by (CATIA) in Figure 3.4.

The car moves with the engine rotates output sprocket and provides the high torsion force or pulling power and horsepower or speed power to a large sprocket in size to provide high torque needed to accelerate and propel the vehicle from the starting line and move the gear reduction to the small size sprocket that would be use to provide acceleration to top speed. The working principle can be summarized as from the output sprocket of the engine will rotate the second sprocket then rotates the entire shaft as well as the third sprocket. The third sprocket will then rotate the rear sprocket/ fourth sprocket thus rotates the wheel of the car.

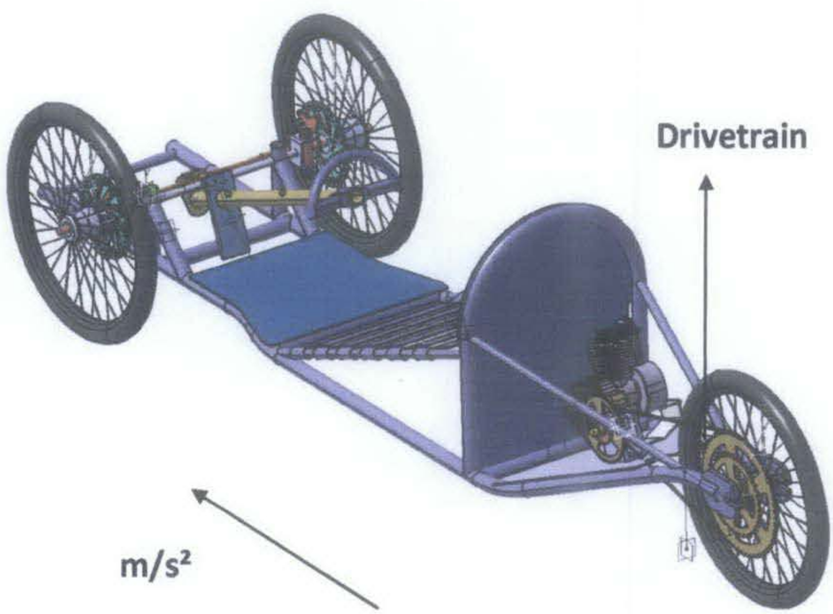



Figure 3.2: Design chassis of a simple vehicle [15]

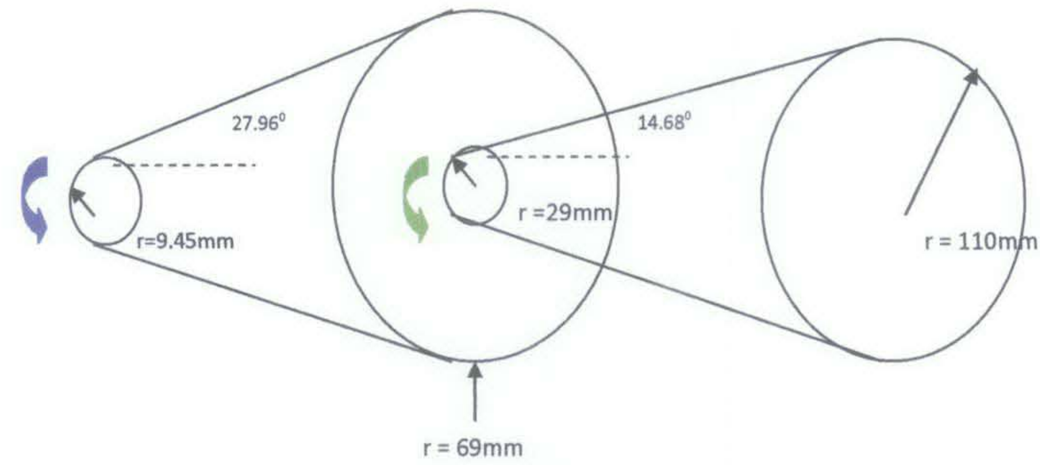



**Figure 3.3: Kinematic Diagram**

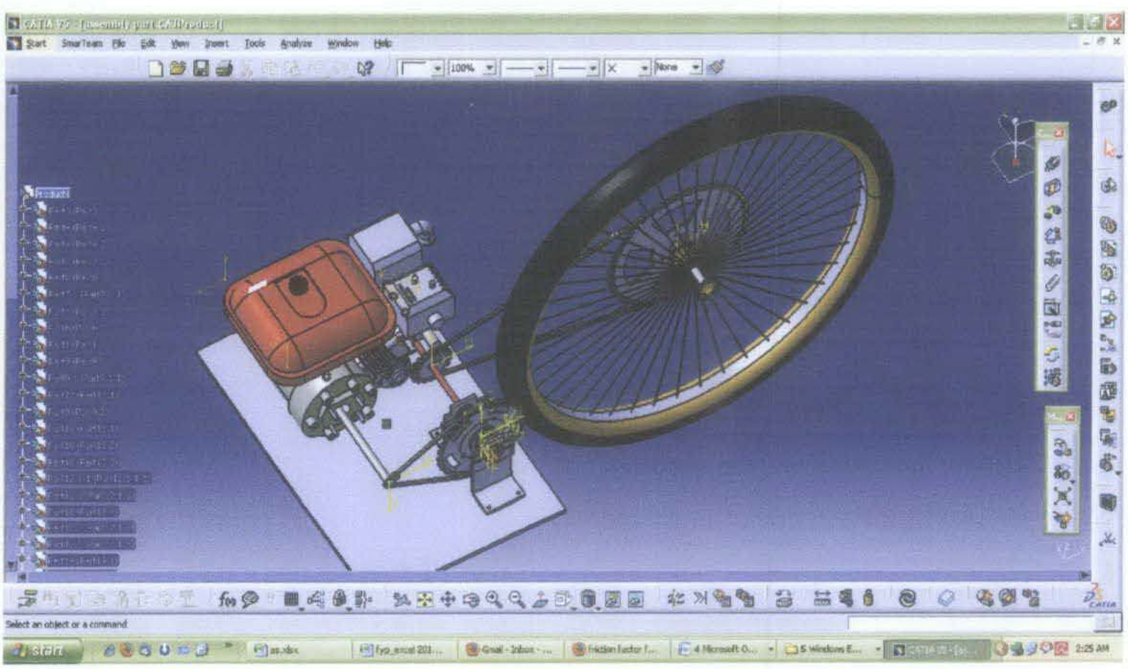


Figure 3.4: Layout of powertrain for simple vehicle in proper tool (CATIA)

### 3.5 Simulation and Analysis using ADAMS Tool

Once the reaction forces and torque which exert by the drivetrain on each sprocket has been calculated, the drivetrain is designed in more accurate drawing tool which is CATIA software and the size and design drawing of 4 sprocket and layout of drivetrain system will be used for simulation. The software tool for analysis and simulation that were used for entire project is the ADAMS VIEW. The model design was imported into ADAMS VIEW software and the data of type of element, material, and boundary condition has been defined in order to simulate the effect of each size of sprocket angular velocity and pattern of the graph obtained to improve and attain the best powertrain design. The work and steps are as shown below.

#### 3.5.1 Steps involved in the procedure

1. Computer modeling
2. Definition of material and mass

3. Assemble and connect each part with coupler
4. Boundary conditions

5. Solution using the required solver and display results/data/graph

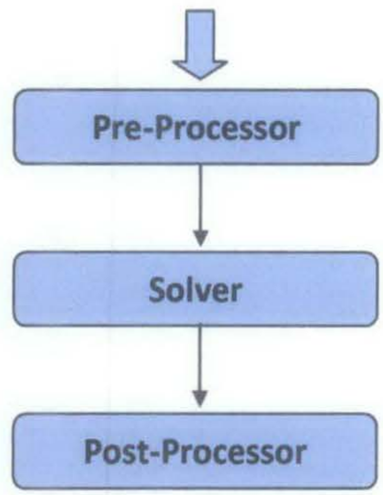



Figure 3.5 (a): Steps involved in the ADAMS simulation procedure

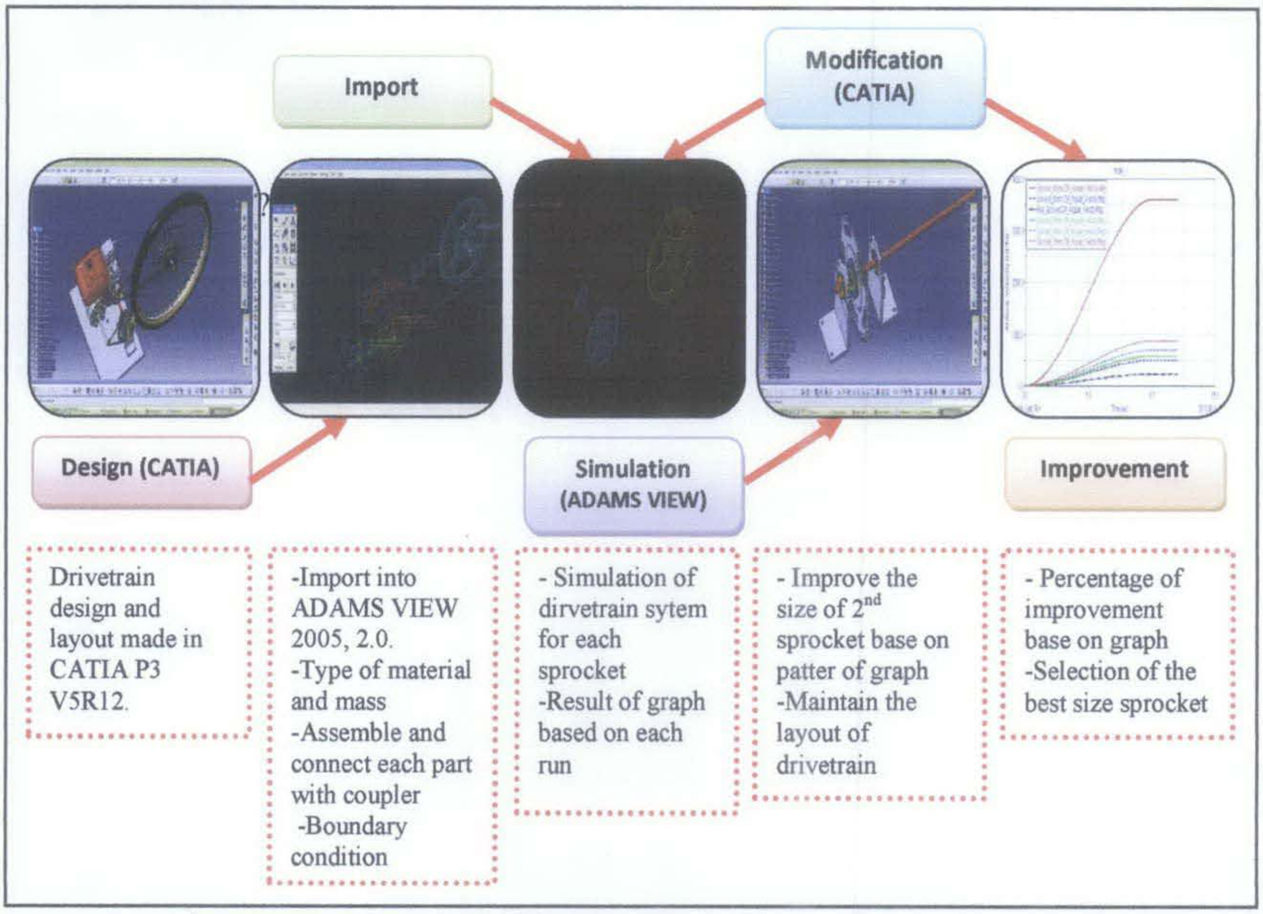



Figure 3.5 (b): Flow chart of the steps involved in ADAMS procedures

The Figure 3.5 (b) above shows the flow of the process for entire project. The design drawing is first developed from CATIA software base on the size and design of each part that had been decided earlier. From CATIA, only set sprocket part will be exported into ADAMS VIEW software. The next step is the most crucial step whereby the definition of material and mass of element. It continues to assemble and connect each part with coupler. Then the boundary conditions have been defined before running the simulation. Finally the model was simulated and the results/graph from the simulation were analyzed and brainstormed in order to come out with possible improvements to the model. If the results/graph pattern is fulfill the requirement then it will be decided as the final design size of sprocket but if the results/graph doesn't fulfill the requirement, the modification of sprocket size will be run back in CATIA. Finally the percentage of the improvements will be determined and compared.

The primary objective of this ADAMS software is to analyze the angular velocity based on each set of sprocket in order to obtain the result/graph pattern that can conclude either the design of powertrain by each sprocket is acceptable or not. For this case, we have set the preferences of this analysis to be structural.

### 3.5.2 CATIA into ADAMS

The design overall part of the powertrain system was successfully designed in CATIA software. The design which is in CATIA format were exported into ADAMS VIEW software. The unnecessary parts (i.e. engine, shaft, tire, chain, bearings, clutch, and mounting) have not been exported into ADAMS VIEW software since the only part we are interested is the set of sprockets. In ADAMS VIEW, the simulation requires a mass and definition of material steel is decided for all sprockets. Before simulation run, each part of sprocket is assembled and connected with the coupler in order to let the simulation run in entire sprocket. Boundary condition need to be justified before the simulation starts and has been decided the engine running from 0-3600rpm in 12 seconds. The result/graph of angular velocity VS each size of sprockets will be obtained after simulation. Figure 3.6 to 3.9 below show the steps of how the design being exported into ADAMS VIEW software.

Figure 3.6 : Simple vehicle drivetrain assembly (CATIA) overall part.

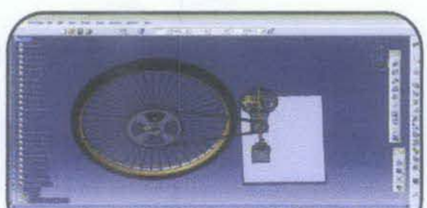


Figure 3.7 : CATIA set of sprockets part only ( Steel material)

Figure 3.8 : CATIA set of sprockets part being imported into ADAMS VIEW, boundary conditon- engine running from 0-3600rpm in 12 seconds, masterial and mass- steel material

Figure 3.9: ADAMS VIEW simulation based on boundary condition

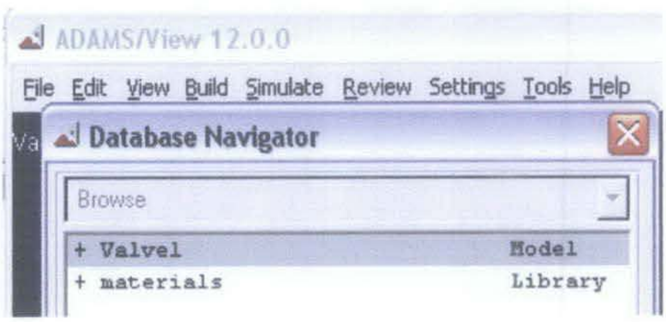
### 3.5.3 Type of Material (Steel) [16]

For this design, steel has been chosen because it is strong and design is flexible. Steel offers architectural and design flexibility due to its inherent strength. This allows large span distances and curves to be easily incorporated into designs. The other advantage is steel is durable and safe. Steel frames won't ignite, burn, rust or get eaten by pests therefore making them highly desirable in extreme environmental conditions. Steel also doesn't need to be treated with pesticides, preservatives or glues making it safer for handling and living or working around. Steel also is a fire resistant material. Severe bush fire test at over 1000 deg C endorses steel framed housing. The tensile strength of pure steel is also high. Furthermore, steel can be easily fabricated allowing low-cost to build and also a good heat conductor.

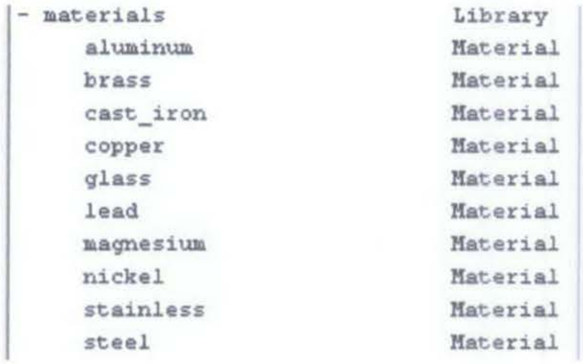
This type of material was defined in material properties for applying a mass to the sprockets. Figure 3.9 (b) shows the step of material and mass determination in ADAMS VIEW. Table 3.1 show material properties of Steel

BUILD->MATERIALS->**Modify**

DATABASE NAVIGATOR->**materials**

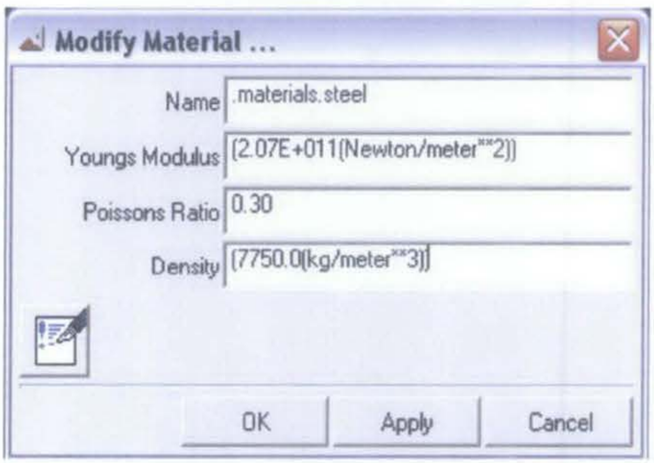


MATERIALS->**steel**




MODIFY MATERIAL->**Poisson's Ratio**=*0.30*

MODIFY MATERIAL->**Density**= *(7750.0(kg/meter**3)*




MODIFY MATERIAL->**OK**

Figure 3.9 (b): Step of material and mass determination in ADAMS VIEW.

Table 3.1: Material properties of Steel

| Properties | Units |
|---|---|
| Young's Modulus (Newton/meter**2) | 2.07E+11 |
| Poisson Ratio | 0.30 |
| Density ( Kg/meter**3) | 7750.0 |
| Tensile Strength (MPa) | 500 |
| Modulus of Elasticity (GPa) | 200 |

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Powertrain system design selection of each component

Work progress is based on scope of study and methodology and design selection. Selection of each powertrain component included:

4.1.1 Drive Mechanism
4.1.2 Clutch
4.1.3 Transmission

### 4.1.1 Drive Mechanism

The drive mechanism, both roller chains and sprockets has been used to transmit power from the engine through gear reduction shaft and finally to the transmission at the rear wheel. Both the primary and secondary drives use motorcycle chain and sprockets. A gear reduction calculation has been analyzed in ADAMS and gives the 7.30:1 ratio from 9.45mm in radius sprocket at engine output to the second sprocket which 69mm in radius for the primary drive. Leaving the remaining 3.79:1 reduction for the transmission on the secondary drive which is the second chain started from third sprocket which 29mm in radius at the end of gear reduction shaft to the final rear sprocket which 110mm in radius. Dimensions and ratings of ANSI chain sizes are shown in Table 4.1.

**Table 4.1: ANSI Chain Specifications [17]**

| Chain Number | Pitch (cm) | Working Load (kg) |
|---|---|---|
| 25 | 0.635 | 63.50 |
| 35 | 0.953 | 217.72 |
| 40 | 1.27 | 367.41 |

The maximum chain pull in the drivetrain occurs where torque is also at a maximum. In this vehicle, the maximum torque occurs at the rear wheel, when the lowest gear is engaged. The maximum chain pull occurring at the rear wheel also acts on the sprocket at the clutch shaft. Torque acting on the clutch shaft does not depend on the gear selected and therefore simplifies calculation of chain pull. The design torque of the clutch shaft is calculated from the peak engine torque and primary drive ratio as shown below:

T max: 294.86Nm ← Max Torque T2 when consider Net Torque: 10.3 Nm (7.6 Lbs Ft) at 2500rpm.

The Maximum chain pull can be calculated:

$$P\ max : \frac{2Tmax}{dp}$$

dp: pitch diameter where the maximum torque = 0.34m
P max: 2(294.86Nm) / 0.34m = 1734.5 N
1734.5 N / 9.81 = 176.8 Kg Working Load

So referring to the Table 4.1, 176.8 kg load can be sustained by chain number #35. #35 chain was commonly used on many mini bikes in the 60's and 70's. For simplicity, it was decided to use the same chain size for both the primary and secondary drives, even though the chain pull in the primary drive is significantly lower in order to prevent the chain will be accidentally damaged due to the higher rpm and torque delivered along the chain. Below is the example Figure 4.1 shows graphically using accurate tool CATIA design drawing on top view in order to show the primary and secondary chain. The distance between the engine output sprocket/1$^{st}$ sprocket which 9.45mm in radius to the first sprocket along the gear reduction shaft/2$^{nd}$ sprocket which 69mm in radius is 130mm. The distance between the second sprocket along gear reduction shaft/3$^{rd}$ sprocket which is 29mm in radius to the rear sprocket/4$^{th}$ sprocket which is 110mm in radius is 420mm.

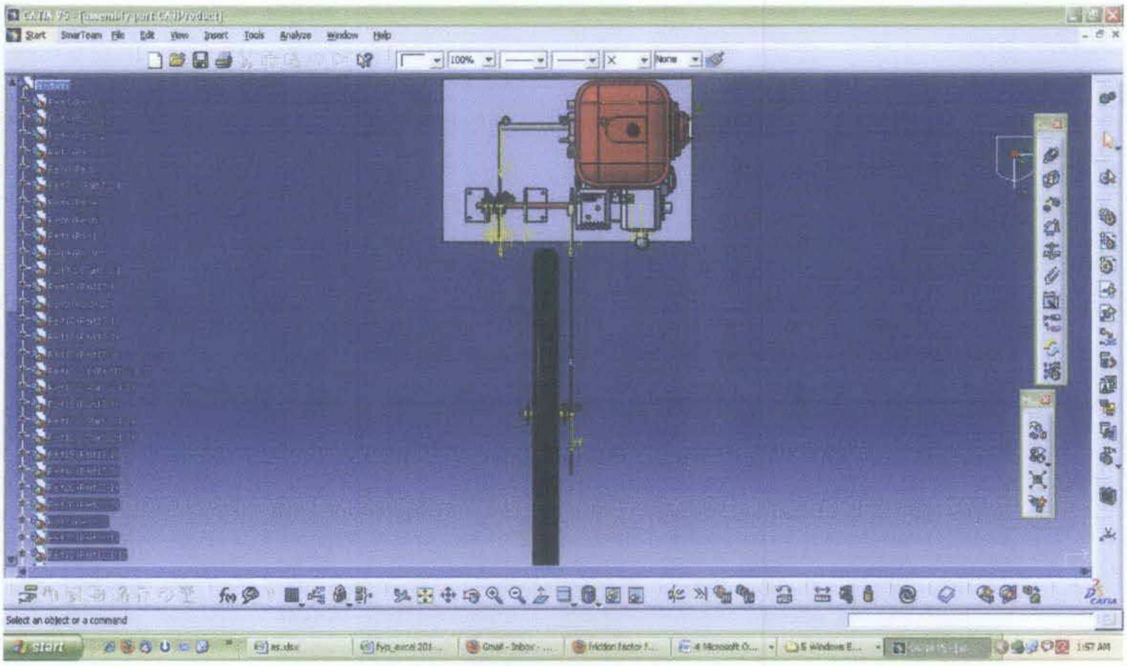


Figure 4.1: Model of Drive Mechanism and Powertrain assembly (top view)

### 4.1.2 Clutch

A Centrifugal clutch has been selected in this drivetrain. Centrifugal clutch use the angular velocity of the engine driveshaft to extend a rotating mass, creating pressure between two friction surfaces to transmit power to an output shaft. At low engine speed, the clutch is disengaged because the centrifugal force is not large enough to cause the rotating mass to move friction plate to the outer drum, allowing power to be transmitted. It allows the motor to develop high torque before engaging and operate at high efficiencies once engaged. In this simple vehicle using GX160 Honda Engine, the centrifugal clutch is engaged at 1700rpm. It wasted of energy to engage the clutch for rotate the engine shaft to the output sprocket 9.45mm in radius. The conventional way is adjusting the spring inside the centrifugal clutch base on its stiffness. There are three springs and each spring has been tested their own stiffness in order to let the clutch engaged more quickly which below 1700rpm in order to prevent the inherent loss of the power.

### 4.1.3 Transmission

The transmission that been decided in this drivetrain is sprocket hub features one large sprocket mounted to the rear wheel. The chain tensioner need to be used while using chain drive in order to remove excess slack in the chain when the chain is running on the smaller sprocket. The mounting location of these components will be determined during assembly to ensure the best performance.

The important issue that needs to be highlight in design selection of transmission of sprocket hub is the material selection. Based on research there a several class of material has been used to create a sprocket hub such as Gray iron, ductile iron, Steel, Sintered steel, and Aluminum. In this design selection, based from experience while performing the testing even though Aluminum offers many advantages over other materials mostly about the weight which is very light but it significantly not strong enough to sustain the #35 chain which transfer high rpm and torque from the GX160 engine to the set of sprockets. An event occurred when the sprocket has been extremely bent and damaged in shape because it can't sustain the #35 chain while rotating across the sprocket. The solution that comes out is to use steel material sprocket and it proves that this material can sustain more force than aluminium. Figure 4.2 graphically show the accurate model CATIA drawing of rear wheel match with sprocket hub transmission design that has been selected as the transmission in the powertrain assembly. In Figure 4.2, it shows three different size of sprocket design. Two sprockets mounted at the gear reduction shaft which the 2$^{nd}$ sprocket which 69mm in radius along the shaft to the 3$^{rd}$ sprocket which 29m in radius and finally to rear sprocket 110mm in radius. Steel material has been decided to be used for all sprockets. This is the critical area which is high torque and rpm from the chain will be received by the sprocket hub and based from that carbon steel is an accurate design selection of material need to be use as a sprocket hub transmission.

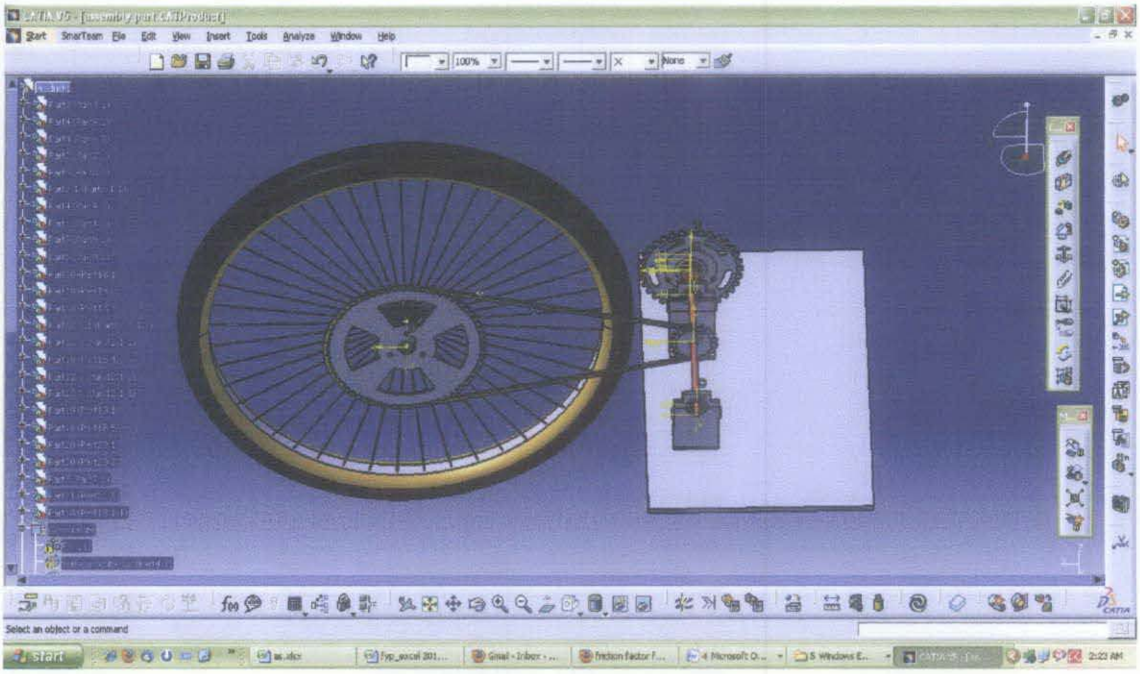


Figure 4.2: Model of Rear Wheel and Sprocket Hub Transmission

### 4.2 Kinematic Diagram of the Drivetrain Reaction Force and Torque

The force acting on the shaft has been considered as the drivetrain reaction force. The action force F1 and F2, N1 and N2. The drivetrain torque for each sprocket T0, T1, and T2 of the drivetrain system will be calculated by using kinematic diagram.

<u>Kinematic Diagram of a reaction force and torque</u>

4.2.1) Reaction force and torque of the drivetrain along sprockets calculation by using Kinematic Diagram

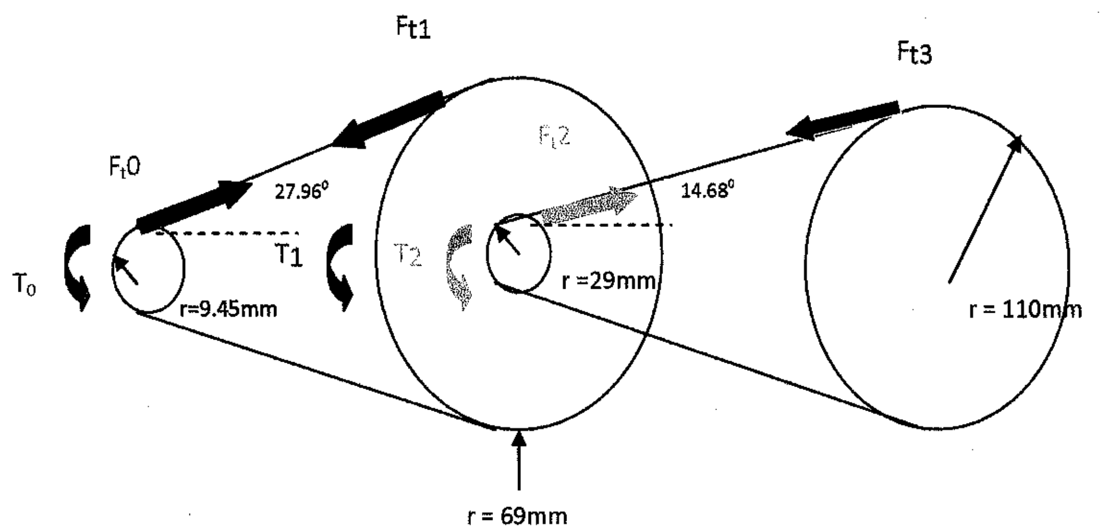



**Figure 4.3: Reaction force and Torque of the drivetrain along sprockets calculation by using Kinematic Diagram**

**Calculation for finding all reaction force and torque on drivetrain between two critical conditions:**

- The torque produced by the engine will give a force to all the sprockets set.
- The force will be transmitted via chain will and resolved into tensile force that reacts to the shaft.
- The rear wheel load will also affect the overall force for each case.

Two Critical conditions:

1) Condition of the drivetrain when the engine starts to run and move.
2) Condition of the drivetrain when the engine car is already on cruising.

**1) Condition of the drivetrain system when the engine starts to move:**

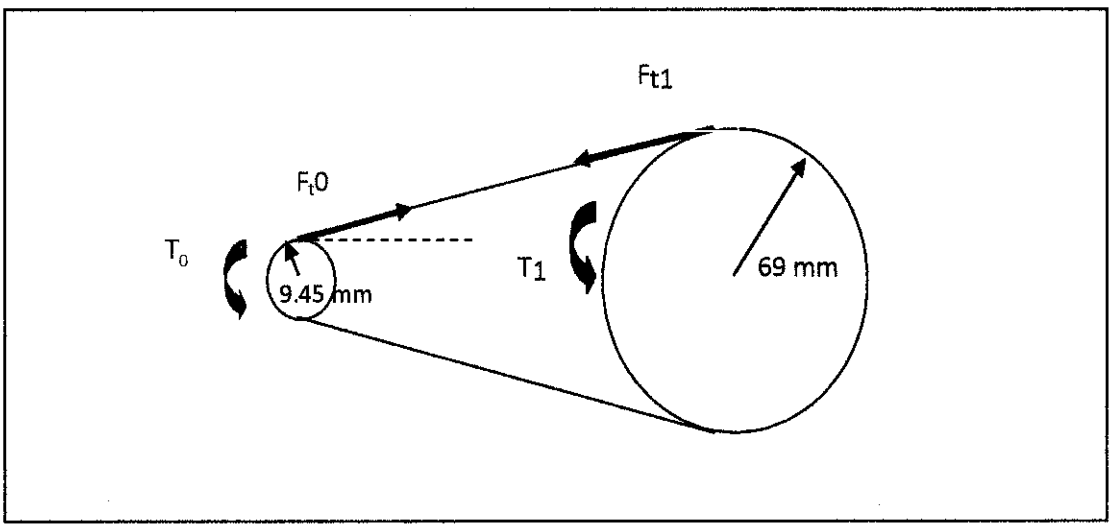
Assumption and calculation:

- Clutch is engaged at speed 1700 rpm
- Engine Net Torque : 10.3 Nm (7.6 Lbs Ft) at 2500rpm
- Engine Net Horse Power Output : 3.6 Kw (4.8 HP) at 3600 rpm

Consider the net torque in this calculation below is 10.3 Nm. In real case, the net torque propel the vehicle is far below 10.3 Nm and the power estimation for this is approximately less than 4.8 HP. The advantage of using this engine is it provides more than the power needed. The strategy is to adjust the choke until it reaches sufficient torque in order to propel the vehicle forward with less torque compares to the net torque provide by the engine. Therefore, it can successfully save fuel consumption with the strong power.

The torque from the sprocket has been transferred to another sprocket at the same shaft. In this case when the car starts to move, the max torque to propel the vehicle is T0.

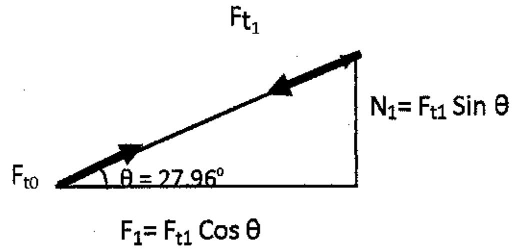
T0 = we consider the engine torque sufficient to propel the car is = 2.36 Nm




$$F_t0 = F_t1 = \frac{T_0\,(Nm)}{R(T_0)(m)} = \frac{2.357\ Nm}{0.00945m} = \mathbf{249.42\ N}$$

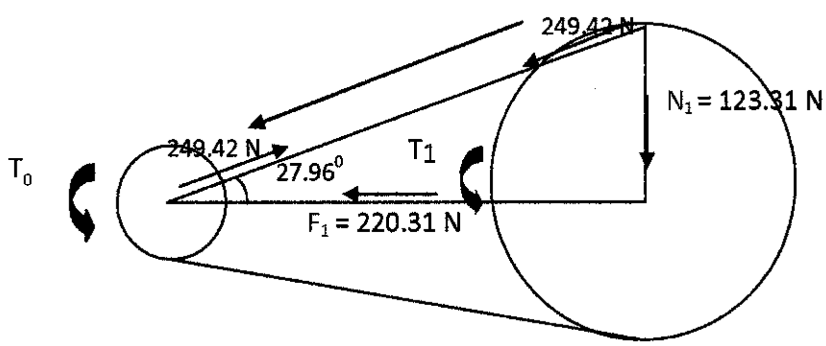
Torque

$$T_1 = F\ (r1) = 249.42\ N \times 0.069m = \mathbf{17.21\ Nm}$$




- $F_1 = 249.42\ (\text{Cos } 27.96^0) = \mathbf{220.31\ N}$

$N_1 = 249.42\ (\text{Sin } 29.63^0) = \mathbf{123.31\ N}$



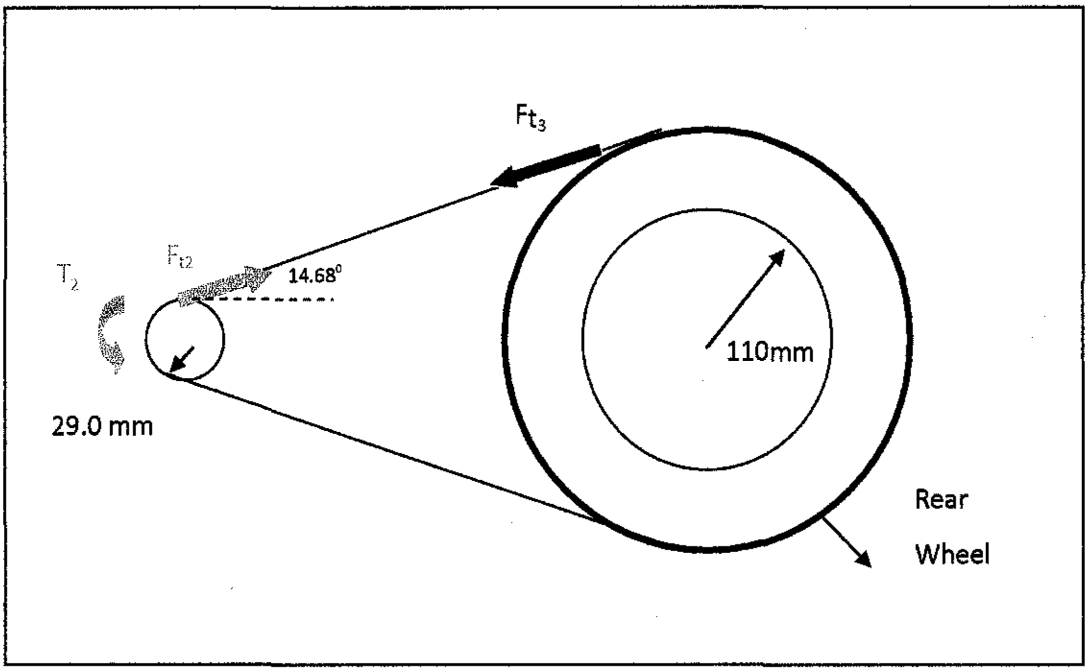

The torque from the sprocket assume to be transferred to another sprocket along same shaft,

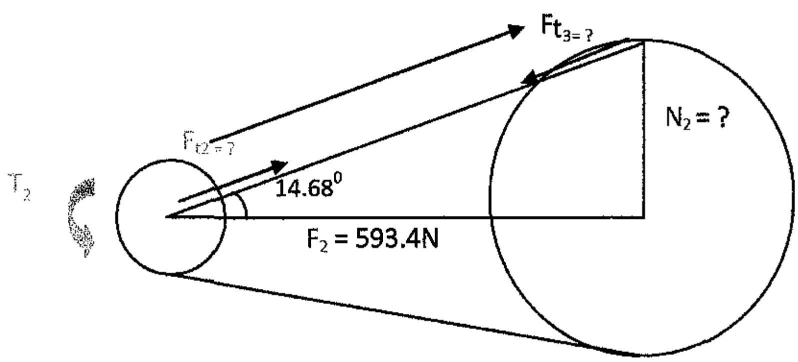
Torque transfers from :

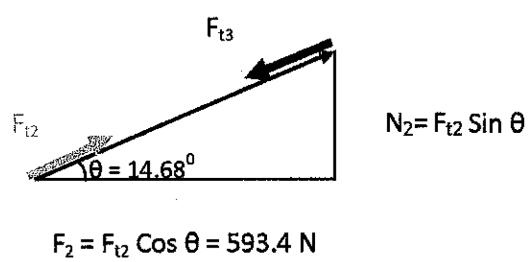
$T_1 = 17.21$ Nm → $T_2 = ?$ Nm

$T_2 = F_2 \times R_2$

$$F_2 = \frac{T_2}{R_2} = \frac{17.21\text{Nm}}{0.029\text{m}} = \mathbf{593.4\ N}$$




$F_2 = 593.4N = F_{t2} \,Cos\,( 14.68\,^0)$

$\text{Cos } 14.68^0 = 0.967$

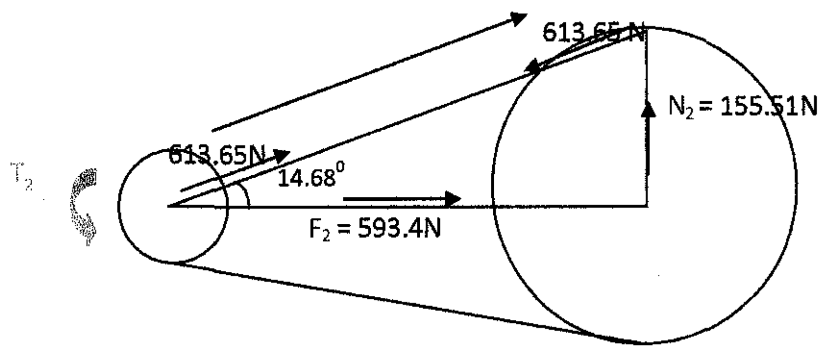
$Ft_2 (0.967) = 593.4N$

$Ft_2 = 613.65 \text{ N}$

$N_2 = Ft_2 \text{ Sin } ( 14.68^0) = 613.65 \text{ Sin } (14.68) = \mathbf{155.51N}$

<u>Torque at rear wheel</u>

$T_2 = F (r3) = 613.65N \times 0.11m = \mathbf{67.50 \ Nm}$



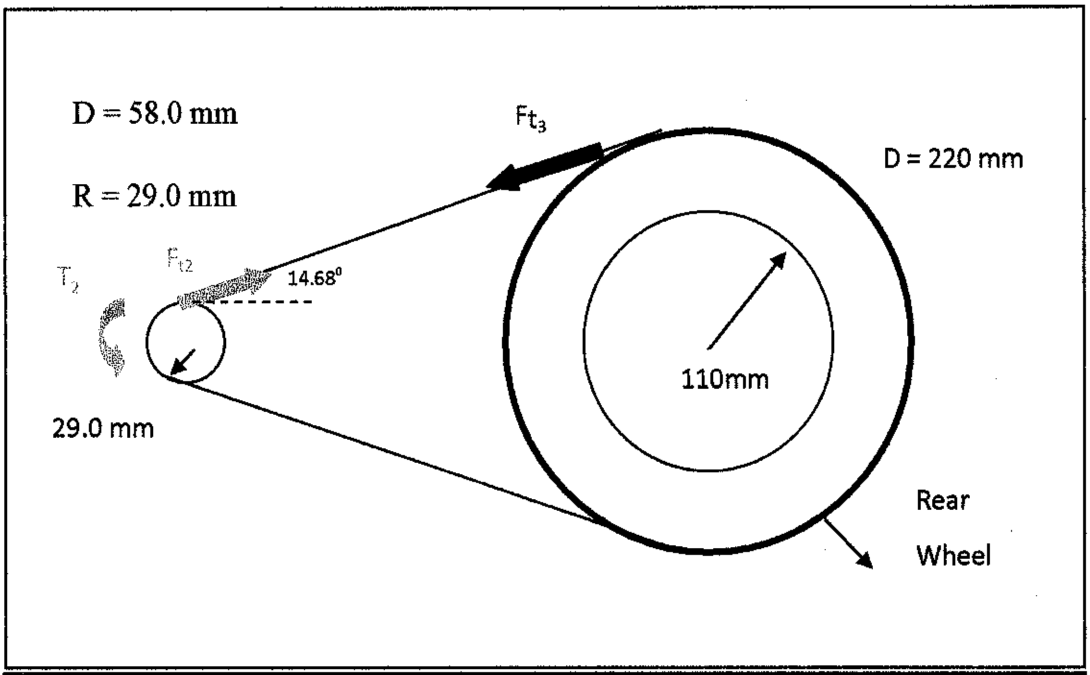

**2) Condition of the drivetrain when the engine car is already on cruising**

<u>Assumption and calculation :</u>

- Clutch start engage at speed 1700 rpm
- Rolling resistance : 1.567 Nm (from previous UTP SEM car information)

  - The force resisting the motion when a body rolls on a surface is called the rolling resistance or rolling friction.

- Force : $\frac{1.567 \text{ Nm}}{0.11}$ = 14.25 N (at rear sprocket)

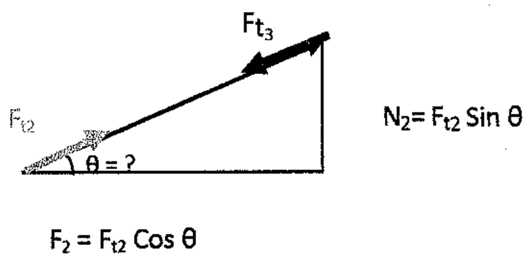



$F_{t2} = F_{t3}$ = Force at rear wheel sprocket

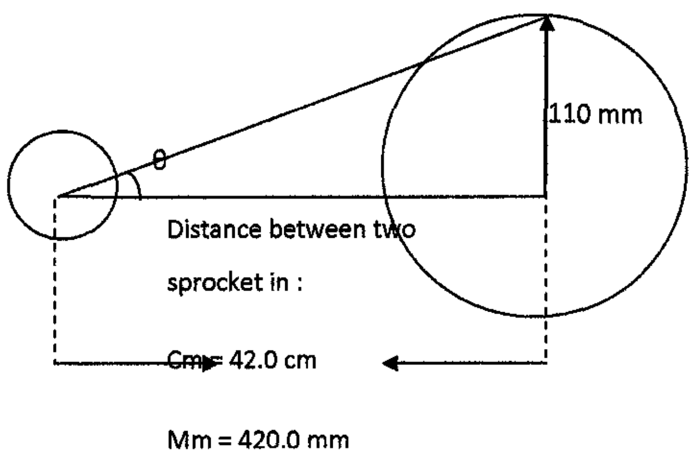
$$\text{Force} = \frac{\text{rolling resistance}}{\text{Radius of rear wheel sprocket}}$$

$$F = \frac{1.567 \text{ Nm}}{0.11 \text{ m}} = 14.25 \text{ N}$$

$F_{t2} = F_{t3} =$ **14.25N**




θ = obtain when measuring distance of 29.0 mm sprocket at gear reduction area and 110 mm rear wheel sprocket.

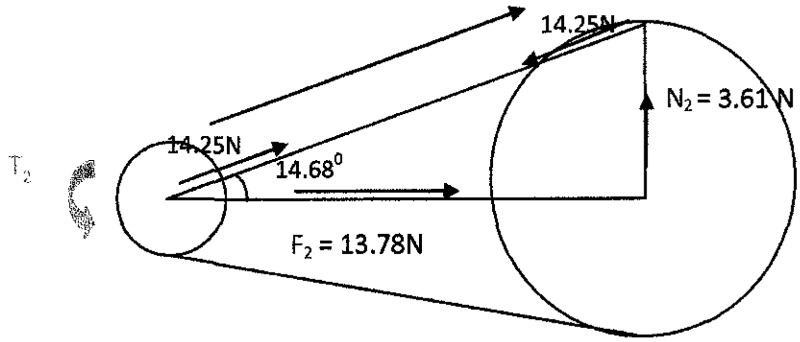



$$\tan \theta = \frac{110 \text{ mm}}{420.0 \text{ mm}}$$

$$\boldsymbol{\theta} = 14.68^{\circ}$$

- $F_2 = 14.25 \cos(14.68^0) = \mathbf{13.78\ N}$

$N_2 = 14.25 \sin(14.68^0) = \mathbf{3.611\ N}$



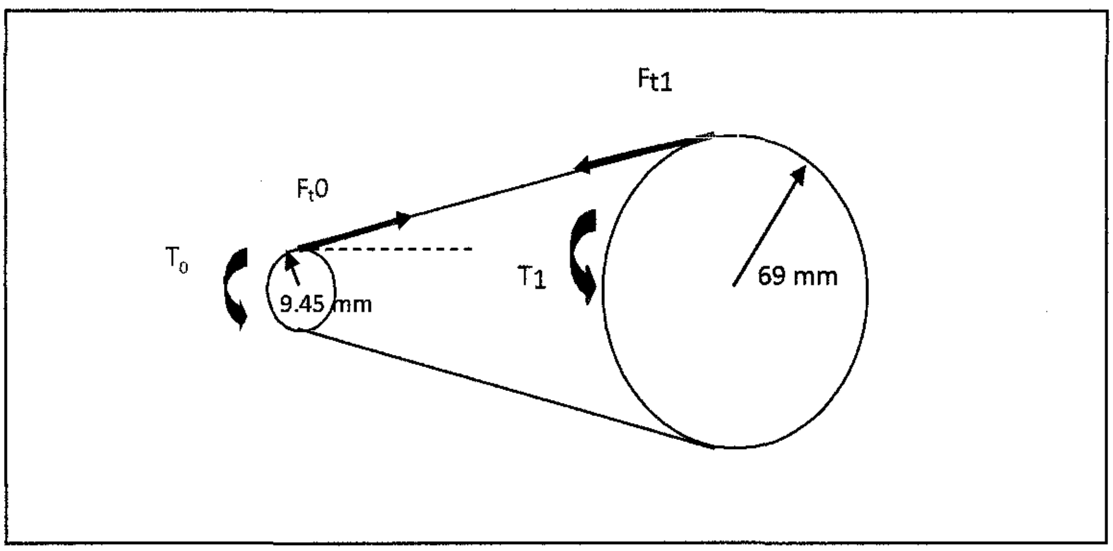

Torque :

$$T_2 = F\,(r_2) = 14.25\text{N} \times 0.029\text{m} = \mathbf{0.413Nm}$$

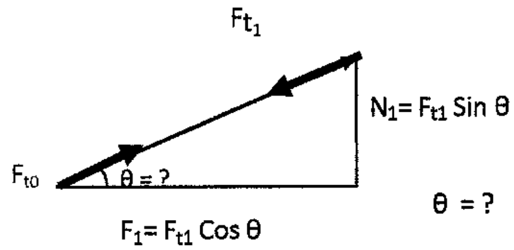
The torque from the sprocket has been transferred to another sprocket at the same shaft,

$T_2 = T1$

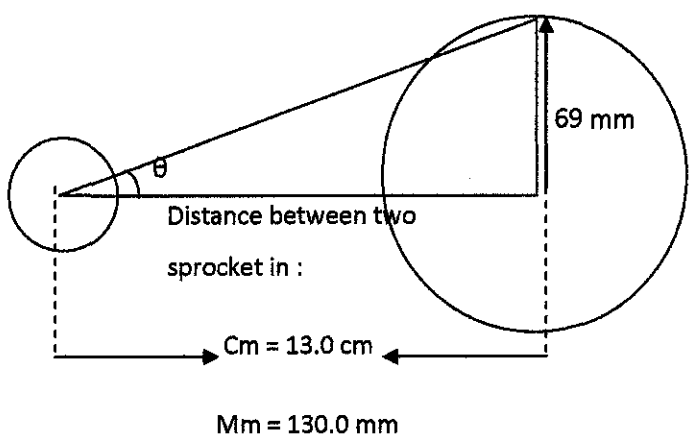
$T_2 = T_1 = \mathbf{0.413\ Nm}$



$$F_t0 = F_t1 = \frac{T_1\ (Nm)}{R\ (T_1)\ (m)} = \frac{0.413\ Nm}{0.069m} = \mathbf{5.99\ N}$$




θ = obtain when measuring distance of 9.45 mm sprocket from output engine and 69mm sprocket at gear reduction area.

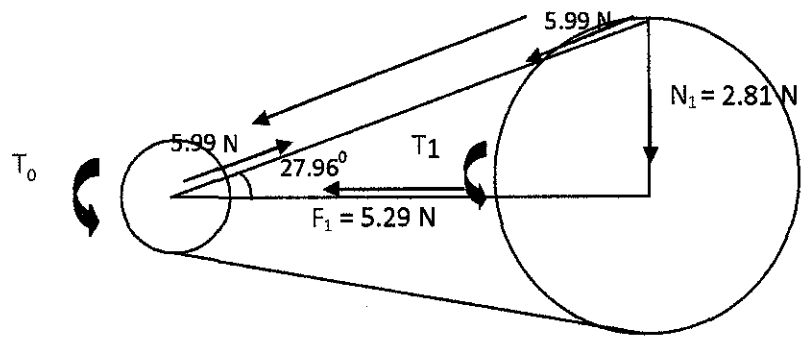



$$\tan\theta = \frac{69\ mm}{130.0\ mm}$$

$$\boldsymbol{\theta} \quad = \mathbf{27.960}$$

$F_1 = 5.99\ Cos\ (27.96^0) = \mathbf{5.29\ N}$

$N_1 = 5.99\ Sin\ (27.96^0) = \mathbf{2.81\ N}$




Torque

$T_0 = F\ (r_0) = 5.99\text{N} \times 0.00945\text{m} = \mathbf{0.06\ Nm} \approx \mathbf{0.1\ Nm}$

## 4.3 Kinematic Diagram Reaction Force and Torque of the Drivetrain along Sprockets Result and Data Gathering

### 4.3.1 Kinematic Diagram reaction force of the drivetrain along sprockets

Table 4.2: Reaction Force of the drivetrain along sprockets

| Reaction Force along sprockets | Condition Engine start to move (N) | Condition Engine while Cruising (N) |
|---|---|---|
| $F_t0 = F_t1$ | 249.42 | 5.99 |
| $F_1$ | 220.31 | 5.29 |
| $N_1$ | 123.31 | 2.81 |
| $F_t2 = Ft3$ | 613.65 | 14.25 |
| $F_2$ | 593.4 | 13.78 |
| $N_2$ | 155.51 | 3.611 |

### 4.3.2 Kinematic Diagram reaction torque of the drivetrain along sprockets

Table 4.3: Reaction Torque of the drivetrain along sprockets

| Reaction Torque along sprockets | Condition Engine start to move ( Nm ) | Condition Engine while cruising ( Nm ) |
|---|---|---|
| $T_2$ | 67.50 | 0.413 |
| $T_1$ | 17.21 | 0.413 |
| $T_0$ | 2.36 | $0.06 \approx 0.1$ |

The action force F1 and F2, N1 and N2, the drivetrain torque for each sprocket T0, T1, and T2 of the drivetrain system were calculated by using kinematic diagram. So for this kinematic diagram calculation there are two separate tables which are table 4.2 which table of reaction force of the drivetrain along sprockets to determine F1, F2, N1, and N2 and table 4.3 which table of reaction torque of the drivetrain along sprockets to determine T0, T1, and T2.

Consider two critical conditions which is condition of the drivetrain when the engine starts to run and condition of the drivetrain when the engine car is already on cruising. As can be seen on Table 4.2, the result show when the car start to move all the reaction force are higher than the result when the car in cruising. The highest reaction Force is during Engine starts to move which is 613.65N. Reaction force already lowered when the engine is at cruising state which just 14.25N. The reason why is because the engine rpm is higher when the car starts to move and the engine max torque required to propel the vehicle is larger compare to the torque required during the cruising. When the car is in cruising the torque and rpm is already lower and focus on the driving style strategy, all the prototype vehicle while cruising at 35-40 km/h , their team strategy is just gliding or to move in a smooth, effortless manner. Based on this driving strategy the reaction force of the drivetrain along sprocket will approximately higher at condition starts to move or climbing the slope and lower when it start to cruising in freeway. The fuel consumption will be improved from this driving strategy.

On Table 4.3, it still has been calculated using kinematic diagram and obtains reaction torque of the drivetrain along sprockets. There was three main parts considered that received torque which is T0 at the engine output sprocket, T1 were transferred to first sprocket 69mm in radius and transfer the torque T2 to the smaller sprocket in 29mm in radius and finally transfer the reaction torque to the rear wheel sprocket 110mm in radius. From the table 4.3, the highest reaction torque occurred at the condition engine start to move which at T2 = 67.50Nm. Reaction torque already lowered at condition engine while at cruising T2 = 0.413Nm.The larger torque is required to propel the vehicle which considers the weight of component and the driver itself. During the car in cruising at freeway, the torque is already lowered. Based from the new engine, it provided more than the power needed: net torque: 10.3 Nm at 2500rpm. Therefore the problem such as not enough or sufficient power to propel the vehicle can already be solved.

**4.4 Simulation of Powertrain Design using ADAMS**

ADAMS VIEW 2005.2.0 as in Figure 4.4 has been selected as software to simulate the powertrain design in order to determine the angular velocity for each powertrain and determine the most efficient gear ratio using the new engine Honda GX160 based on the result of the graph. The pattern of the graph that has been analyzed will give the result of the best structure/layout based on the different size of sprocket at the gear reduction.

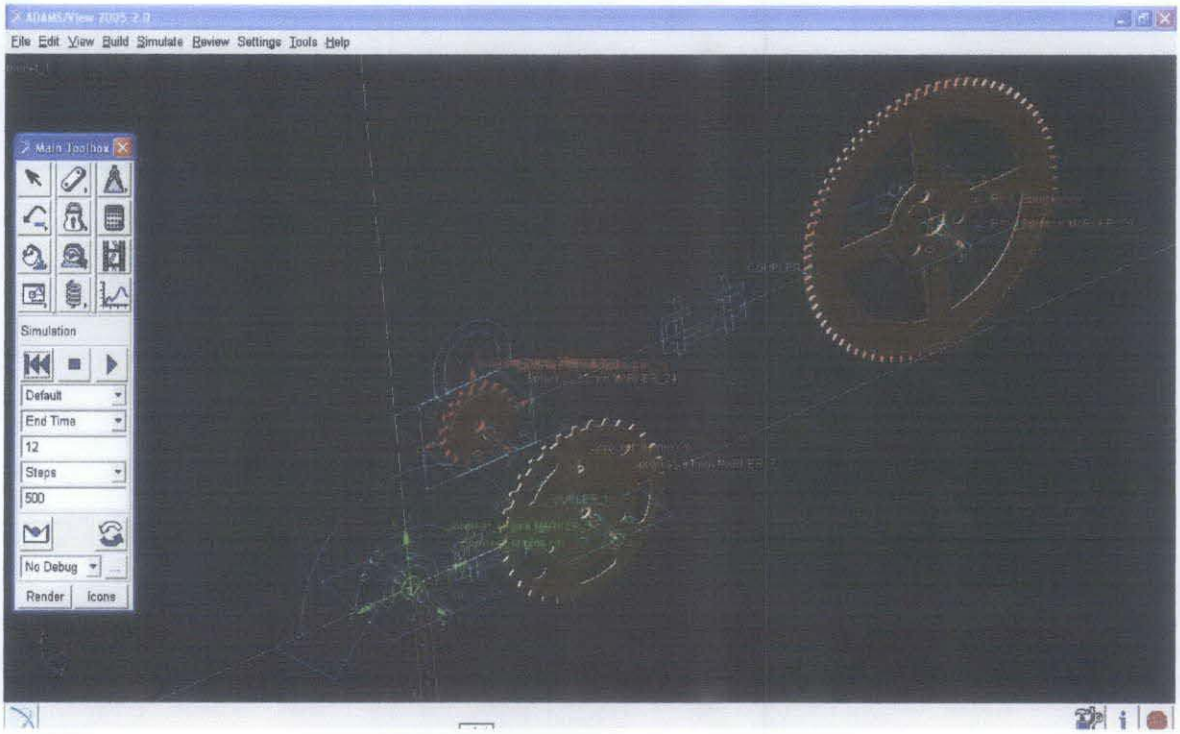



Figure 4.4: ADAMS VIEW layout – Simulation of powertrain system

<u>Simulation Criteria</u>:

1) Engine running from (0-3600rpm) in 12 seconds.
2) The simulation required a Mass and considers steel material for all four sprockets.
3) The simulation is couple like a pulley system.

### 4.5 Analysis

Working Principle of powertrain system of simple vehicle is from the engine output sprocket which determined as 1$^{st}$ sprocket transmit power to the first sprocket along gear reduction which determined as 2$^{nd}$ sprocket transmit power at the same shaft to the second sprocket along gear reduction which determined as 3$^{rd}$ sprocket and transmit power to final sprocket/ rear wheel sprocket which determined as 4$^{th}$ sprocket.

### 4.5.1 First run of simulation

First run had been simulated using the 4 set of sprocket size:

1st sprocket = 9.45mm in radius

2nd sprocket = 69mm in radius

3rd sprocket = 29mm in radius

4th sprocket = 110mm in radius

**The result of the angular velocity for each sprocket shown in the graph below:**

Figure 4.5: Result of angular velocity based on each sprocket

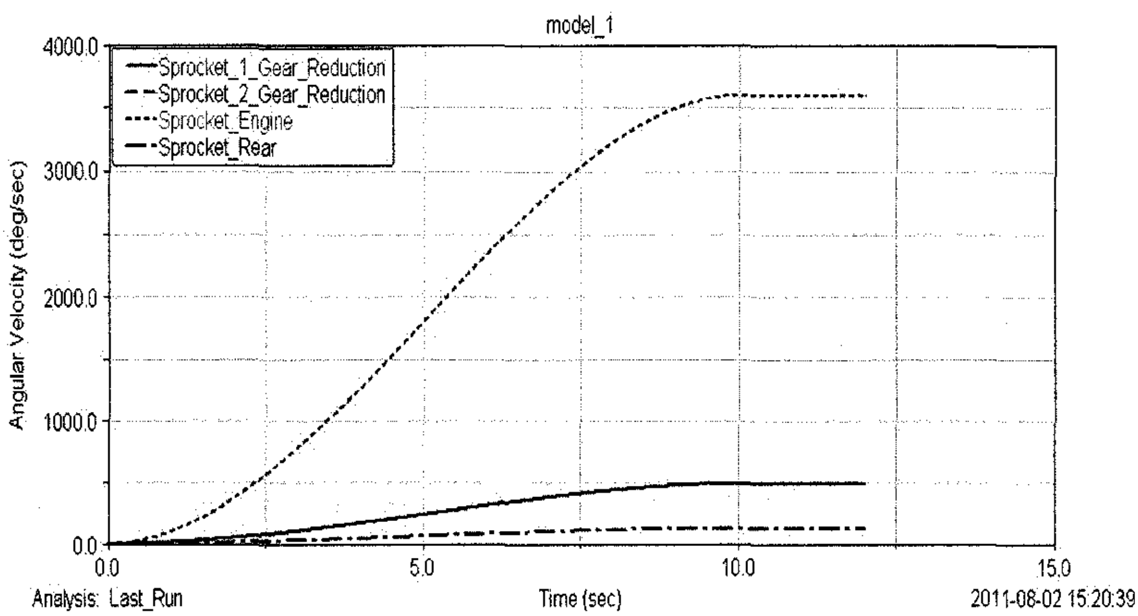



Table 4.4: Final angular velocity for each sprockets

| Sprocket number | Final Angular velocity (RPM) |
|---|---|
| 1st | 3600 |
| 2nd | 500 |

| | |
|---|---|
| 3rd | 500 |
| 4th | 220 |

The 2nd and 3rd sprocket final angular velocity is same because it rotates along the same shaft which at gear reduction area. Based on the graph, there had a large gap between 1st and 2nd sprocket and small gap between 3rd and 4th sprocket like 90%-10%. This graph pattern is made because of sprocket 9.45mm in radius straight away to 69mm in radius. It prove that 69mm in radius sprocket which 2nd sprocket is not suitable and efficient and need to reduce in size in order to get the 70%-30% or 75%-25% gap based on the graph. The design of preliminary of the 2nd sprocket needs to be modified and improvement. The limitation of the rear sprocket/4th sprocket fabrication like in cost and availability lead to just focus in make a another set 2nd sprocket in different size.

### 4.5.2 Gear Ratio

Gear Ratio Formula :

***Output sprocket radius/input sprocket radius***

For the first run the 69mm/9.45mm to get of 7.30:1 gear ratio at the primary drive and 110mm/29mm to get 3.79:1 gear ratio at the secondary drive. Total gear ratio is 11:1. We can see the result of different angular velocity of rear sprocket/4th sprocket at different gear ratio. We set the gear ratio vary from 14:1 , 13:1 , 12:1 , 11: 1. The result is shown in Figure 4.6.

Figure 4.6: Result of angular velocity of rear sprocket/4th sprocket at the different gear ratio.

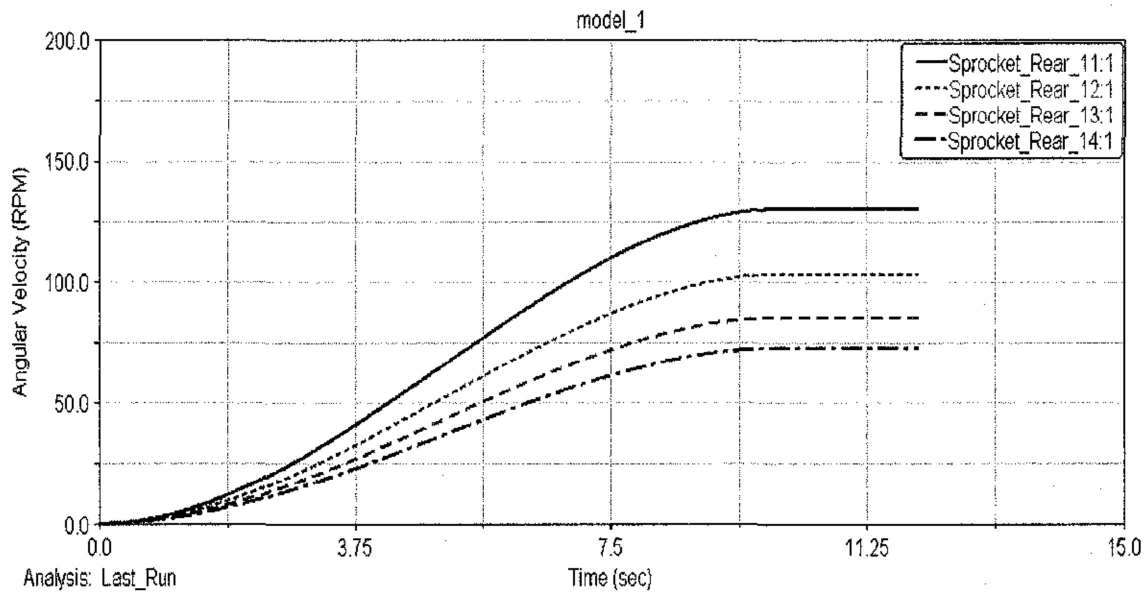



Table 4.5 : Angular velocity at rear sprocket/4th sprocet based on different gear ratio

| Gear ratio ( had been set) | Angular velocity (RPM) |
|---|---|
| 11:1 | 130 |
| 12:1 | 115 |
| 13:1 | 85 |
| 14:1 | 75 |

The graph shows that when the gear ration increased from 11:1 to 14:1 the angular velocity of the rear is reduced. Based on the simulation of different gear ratio, only rear sprocket/4th sprocket has a different graph of angular velocity, 1st sprocket is maintained at 3600rpm in all graph while 2nd and 3rd sprocket has intercepted each other and reduced while varying the gear ratio from 11:1 to 14:1.

### 4.6 Modification

Modification process has been done at the 2nd sprocket. Previously 2nd sprocket is 69mm in radius. There were three other size will be considered and analyzed using ADAMS VIEW in order to obtain the efficient powertrain movement along sprocket which is perceived by the graph. Base on the graph, now the target is to reduce the gap percentage of the 1st and 2nd sprocket from 90% to 75% or 70% gap and 3rd and 4th sprocket from 10% to 25% or 30% gap. The reason why must reduce the percentage gap of the graph is because in reality if the gear reduction is too large, problem such as the chain might be broken might occur because of the inefficiency in transmitted power across each sprocket that leads to inefficient overall design of the powertrain for this simple vehicle.

#### 4.6.1 Second run of simulation

Three different size of 2nd sprocket that had been considered to involve in second run of the simulation are:

1st Sprocket – 9.45mm in radius (maintain from the first run)

2nd Sprocket – 59mm, 49mm, 39mm in radius (new size for second run)

3rd sprocket – 29mm in radius (maintain from the first run)

4th sprocket – 110mm in radius (maintain from the first run)

**The result of the angular velocity for the new size of 2nd sprocket shown in the graph below:**

Figure 4.7: Result of angular velocity base on different size of 2nd Sprocket

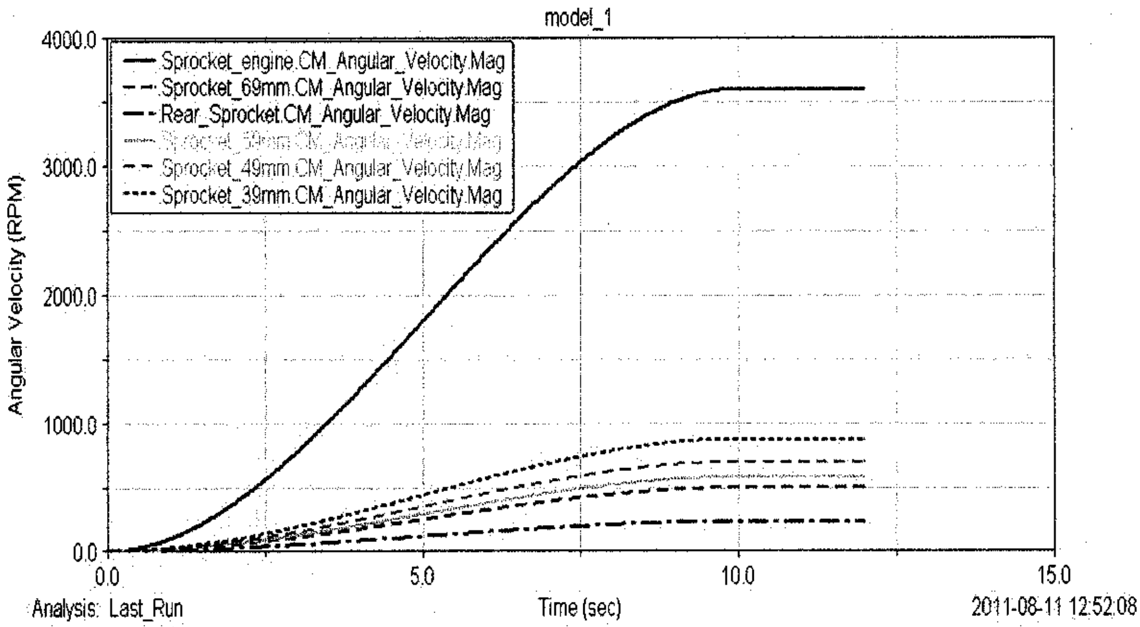



Table 4.6: Angular velocity of the 2nd Sprocket with different size in radius (mm)

| Size of 2nd Sprocket (mm) | Angular velocity (RPM) |
|---|---|
| 69 | 500 |
| 59 | 650 |
| 49 | 800 |
| 39 | 950 |

Based on the graph, it can tell that the gap percentage of the 1st and 2nd sprocket from 90% gap using 69mm in radius of 2nd sprocket has been reduced slightly to 75% gap using the best new size 39mm in radius of 2nd sprocket. The gap percentage of 3rd and 4th sprocket also improved from 10% to 25% gap. It sufficient gap percentage of 75%-25% in order to reduce the probability of the chain being broken and reduce the power loss from the previous size of 2nd sprocket.

### 4.6.2 Gear ratio

The new gear ratio has been calculated while consider different size of 2nd sprocket:

<u>First size (Actual)</u>

**69mm**/9.45mm = 7.30:1, 110mm/29mm = 3.79:1

Total gear ratio = 7.30 + 3.79 = 11.09:1

<u>Second size (Modify)</u>

**59mm**/9.45mm = 6.24:1, 110mm/29mm = 3.79:1

Total gear ratio = 6.24 + 3.79 = 10.03:1

<u>Third size (Modify)</u>

**49mm**/9.45mm = 5.19:1, 110mm/29mm = 3.79:1

Total gear ratio = 5.19 + 3.79 = 8.98:1

<u>Fourth size (Modify)</u>

**39mm**/9.45mm = 4.13:1, 110mm/29mm = 3.79:1

Total gear ratio = 4.13 + 3.79 = 7.92:1

**Based on the calculation, the new sprocket based on modification of 2nd sprocket is 39mm in radius which give the 7.9:1 as a new efficient gear ratio.**

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

According to results and discussion above, it can be concluded that the best design structure for design of powertrain system for simple vehicle is based on the selection of the drive mechanism, clutch, and transmission with proper and detail analysis and calculation. Table 5.1 below is the summarization of the design selection of each part:

Table 5.1: Final Design Selection of Powertrain assembly

| Item | Type |
|---|---|
| Drive Mechanism | Chain drive ( Secondary and Primary chain) – both chain number #35 |
| Clutch | Centrifugal clutch |
| Transmission | Sprocket Hub ( steel material) |

The kinematic diagram of drivetrain gives the estimated value of force and torque along each set of sprocket which consider two critical conditions. The first condition is condition engine start to move and the second condition is condition engine while cruising. The highest reaction force is during engine starts to move which is 613.65N. Reaction force already lowered when the engine is at cruising state which just 14.25N. Based on this reaction force calculation, it requires the design of the structure must be good in strength of the mounting, sprocket, and chain to sustain the high reaction force.

Reaction torque is a measure of the turning force of the set of sprockets. The highest reaction torque occur at the condition engine start to move which at T2 = 67.50Nm. Reaction torque already lower at condition engine while at cruising T2 =

0.413Nm. Based on this reaction torque, it needs serious consideration of material use of the sprockets and that the reason alumunium had been eliminated and all 4 set of sprocket use steel material. On the other hand mounting and chain also must be strong enough to sustain the high torsion force from the engine.

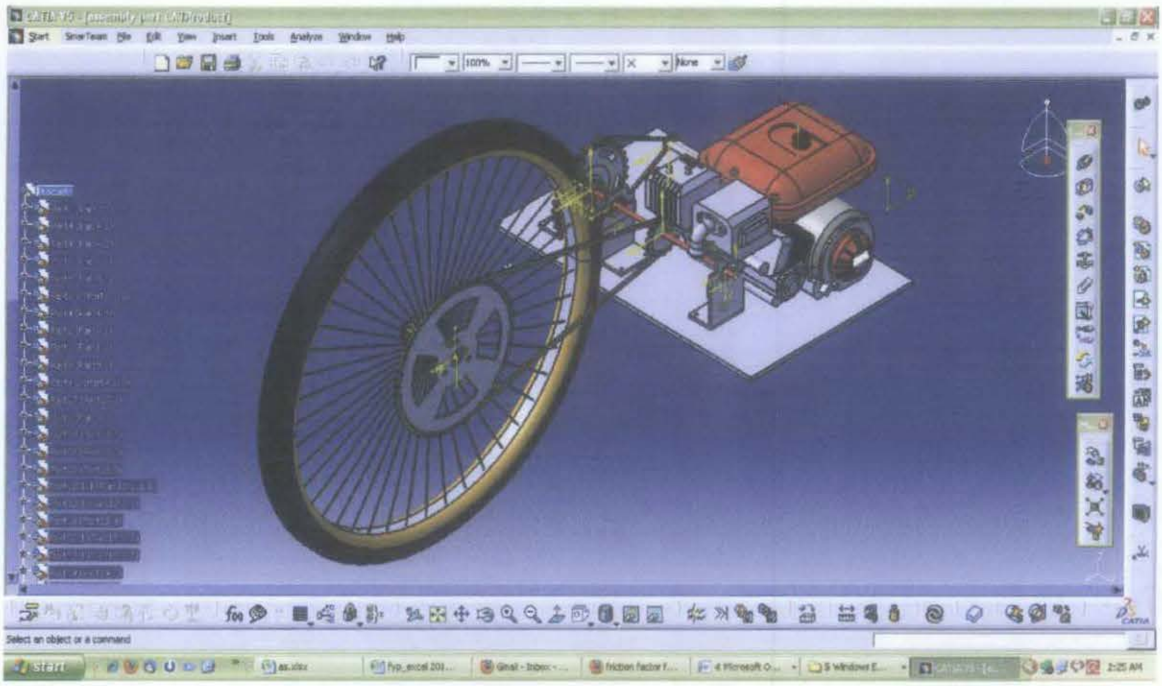
The ADAMS VIEW simulation test gives the results of the powertrain design analysis based on each size of the sprockets angular velocity. The pattern of the graph gives results and ideas to determine the best design selection of sprockets size. First test run, it starts with engine output sprockets/ 1$^{st}$ sprocket which 9.45mm in radius transmitted power from the engine to the first sprocket/2$^{nd}$ sprocket along the gear reduction which 69mm in radius, transmitted power into shaft to the second sprocket/3$^{rd}$ sprocket along the gear reduction which 29mm in radius, transmit power to final rear sprocket/4$^{th}$ sprocket which 110mm in radius. The result pattern of the angular velocity graph of 1$^{st}$ and 2$^{nd}$ sprocket is 90% gap and 3$^{rd}$ and 4$^{th}$ sprocket from 10% gap. It shows the design size of sprockets is not efficient to transmit power because the gap of reduction is too large and may lead to failure in transmitted power efficiently and may also lead to damage of each part like sprockets or chain.

The modifications done in second test when consideration to vary the 2$^{nd}$ sprocket which the first sprocket along gear reduction. Preliminary, the radius is 69mm; need to consider 4 more size which is 59mm, 49mm, 39mm in radius in order to get the best pattern of the graph. The result for 39mm is the best size of the 2$^{nd}$ sprocket which gives the result pattern of the angular velocity graph of 1$^{st}$ and 2$^{nd}$ sprocket is 75% gap and 3$^{rd}$ and 4$^{th}$ sprocket from 25% gap. Based on the gap of reduction is acceptable and prove the efficiency of the powertrain improve and much stronger to sustain the high working load. As a conclusion, the objective of this project has been achieved after detail calculation, analysis, and simulation. The best design sprocket is:

1$^{st}$ Sprocket (Engine output sprocket) = 9.45mm in radius
2$^{nd}$ Sprocket (First sprocket along gear reduction) = 39mm in radius
3$^{rd}$ Sprocket (Second sprocket along gear reduction) = 29mm in radius
4$^{th}$ Sprocket (Rear sprocket) = 110mm in radius

Based on this each size of the sprocket show above, the result of the most efficient gear ratio is 7.9:1 from the 1st sprocket to the 4th sprocket.

The final drawing (Isometric view) using accurate tool (CATIA) has graphically represented in Figure 5.1, final design assembly of powertrain system for a simple vehicle. The video of simulation each sprocket using ADAMS VIEW has been attached in (Appendix 3).



. Figure 5.1: Model of powertrain final design assembly for a simple vehicle (Isometric view)

### 5.2 Recommendations

The improvement will be minor modification of overcoming the limitation of cost, time, knowledge, and availability to fabricate the larger in size of rear sprocket (4th sprocket) using accurate tool in machining it. It may results in different pattern of the graph and improving the efficiency of the powertrain while transmitting power from the engine to each set of sprockets. On the other hand, the material and design of mounting can also further be studied to improve the strength of the structure.

In order to come out with reliable and durable powertrain layout, the safety factor of the design should be greater than 2 since the dynamic load; vibration and external loading produced by the system are not included for this analysis. This external loading might increase the stress to the powertain thus, will increase the possibility of the powertrain fail to run efficiently.

The results obtained from this simulation might be different from the actual condition. Simulation tool is just to provide an initial study for designers to investigate and analyze the effect of movement of the powertrain system. Material testing should be performed in order to validate the result obtained from the simulation. The results from the actual testing must be compared to the simulation in order to come out with proper documentation.

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**MILESTONES FOR FYP I**

| No | Details work | 1 | 2 | 3 | 4 | 5 | 6 | | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Selection of Project Topic** | | | | | | | | | | | | | | | |
| | a) Literature review on a design of a powertrain system for simple vehicle from previous vehicle and scholar | | | | | | | | | | | | | | | |
| 2 | **Preliminary Research Work** | | | | | | | | | | | | | | | |
| | a) Problem definition about changing of an engine based on previous powertrain system | | | | | | | | | | | | | | | |
| | b) Identify option of each part of drivetrain system | | | | | | | | | | | | | | | |
| | c) Devide scope of work and draw methodology for this project | | | | | | | | | | | | | | | |
| 3 | **Submission of Preliminary Report** | | | | | | | | | | | | | | | |
| 4 | **Project Work** | | | | | | | | | | | | | | | |
| | a) Calculation on gear ratio | | | | | | | | | | | | | | | |
| | b) Consideration about type of material in drivetrain system | | | | | | | | | | | | | | | |
| 5 | **Submission of Progress Report** | | | | | | | | | | | | | | | |
| 6 | **Seminar (compulsory)** | | | | | | | | | | | | | | | |
| 7 | **Project Work Continues** | | | | | | | | | | | | | | | |
| | a) Identify and make design selection of each part of drivetrain system based on analysis and calculation | | | | | | | | | | | | | | | |
| | b) Identify the preliminary size of each sprockets | | | | | | | | | | | | | | | |
| | c) Calculation on reaction force and torque analysis on drivetrain system | | | | | | | | | | | | | | | |
| | d) Finalize the design/layout of powertrain system. | | | | | | | | | | | | | | | |
| 8 | **Submission of Interim Report (Final Draft)** | | | | | | | | | | | | | | | |
| 9 | **Oral Presentation** | | | | | | | | During study week | | | | | | | |

## MILESTONES FOR FYP II

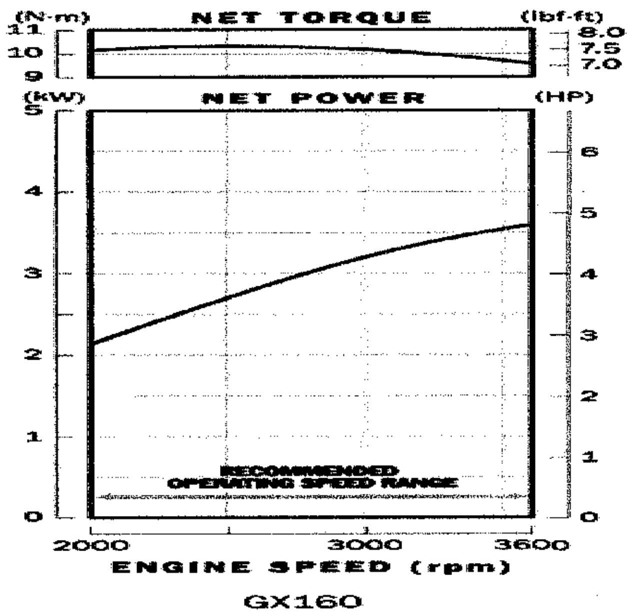
| No | Details work | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Project Work Continues** | | | | | | | | | | | | | | | | |
| | a) Continuity from FYP 1 (Design of a Powertrain for Simple Vehicle) | | | | | | | | | | | | | | | | |
| | b) Make correction on reaction force and torque analysis on the Drivetrain system. | | | | | | | | | | | | | | | | |
| | c) Modeling of the Drivetrain by using CATIA | | | | | | | | | | | | | | | | |
| 2 | **Submission of Progress Report** | | | | | | | | | ● | | | | | | | |
| 3 | **Project Work Continues** | | | | | | | | | | | | | | | | |
| | a) Export drivetrain sprockets part from CATIA into ADAMS | | | | | | | | | | | | | | | | |
| | b) Simulation on Drivetrain by using ADAMS | | | | | | | | | | | | | | | | |
| 4 | **Pre-EDX** | | | | | | | | | | | | ● | | | | |
| | a) Poster exhibition | | | | | | | | | | | | | | | | |
| 5 | **Submission of Draft Report** | | | | | | | | | | | | | ● | | | |
| | a) Modifications and improvement on Drivetrain based on ADAMS analysis | | | | | | | | | | | | | | | | |
| | b) Make correction on gear ratio calculation based on ADAMS analysis | | | | | | | | | | | | | | | | |
| 6 | **Submission of Dissertation (soft bound)** | | | | | | | | | | | | | | ● | | |
| | a) Improvement in report, methodology had been repair and further explain in hardware/tools use | | | | | | | | | | | | | | | | |
| 7 | **Submission of Technical Paper** | | | | | | | | | | | | | | ● | | |
| 8 | **Oral Presentation** | | | | | | | | | | | | | | | ● | |
| 9 | **Submission of Project Dissertation (hard bound)** | | | | | | | | | | | | | | | | ● |

# APPENDICES

## Appendix 1 : Engine GX160

Specification:

| | |
|---|---|
| Engine type | Air-cooled 4-stroke OHV |
| Bore X Stroke: | 68 X 45 mm |
| Displacement: | 163 $cm^3$ |
| Compression Ratio: | 8.5:1 |
| Lamp/Charge Coil Options | 25W, 50W / 1A, 3A, 7A |
| Net Horse Power Output: | 3.6 Kw (4.8 HP) at 3600 rpm |
| Net Torque: | 10.3 Nm (7.6 Lbs Ft) at 2500rpm |
| PTO Shaft Rotation | Counterclockwise (from PTO shaft side) |
| Ignition System: | Transistorized Magneto Ignition |
| Starting System: | Recoil Starter |
| Carburetor: | Float Type |
| Lubrication System: | Splash |
| Governor System | Centrifugal Mechanical |
| Cooling System: | Forced Air |
| Air Cleaner: | Dual element, Oil Bath, Semi-Dry Type |
| Oil Capacity: | 0.6 L |
| Fuel Tank Capacity | 3.1 |
| Dimensions (L X W X H) | 305mm X 341mm X 318mm |
| Dry Weight: | 13~18 Kg |



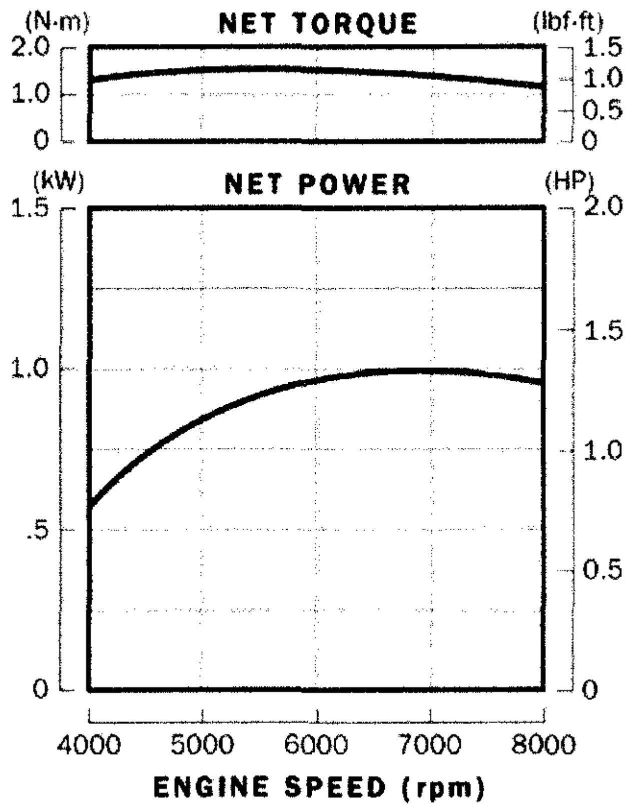

**Engine torque and power for Honda GX160**

**Appendix 2 : Engine GX 35**

Specification:

| Honda GX 35 | |
|---|---|
| Engine type | Air cooled 4-stroke single-cylinder<br>OHC petrol engine |
| Bore x stroke | 39 x 30 mm |
| Displacement | 35.8 cm3 |
| Compression ratio | 8.0 : 1 |
| Net power | 1.0 kW (1.3 HP) / 7 000 rpm |
| Max. net torque | 1.6 Nm / 0.16 kgfm / 5 500 rpm |
| Ignition system | Transistorised |
| Starting system | Recoil |
| Fuel tank capacity | 0.63 l |
| Fuel cons. at rated power | 0.71 L/hr - 7 000 rpm |

| | |
|---|---|
| Lubrication | 0.71 L/hr - 7 000 rpm |
| Engine oil capacity | 0.1 l |
| Dimensions (L x W x H) | 198 x 234 x 240 mm |
| Dry weight | 3.33 kg* *w/o clutch |




GX35

**Appendix 3 : The video of simulation each sprocket using ADAMS VIEW (screen capture images of video simulation)**

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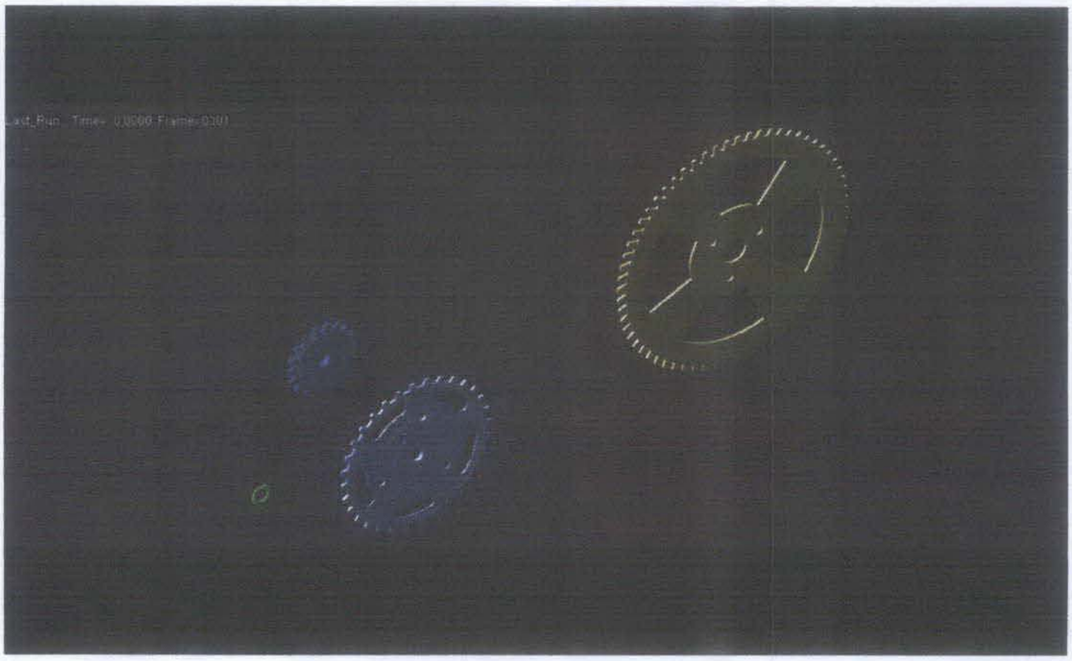

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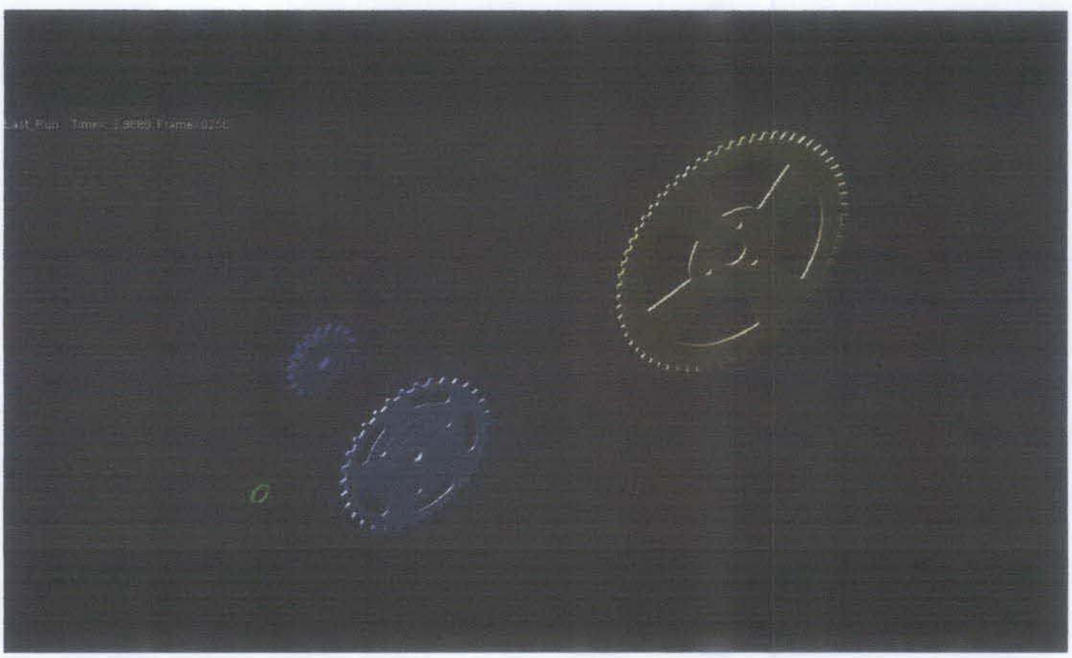

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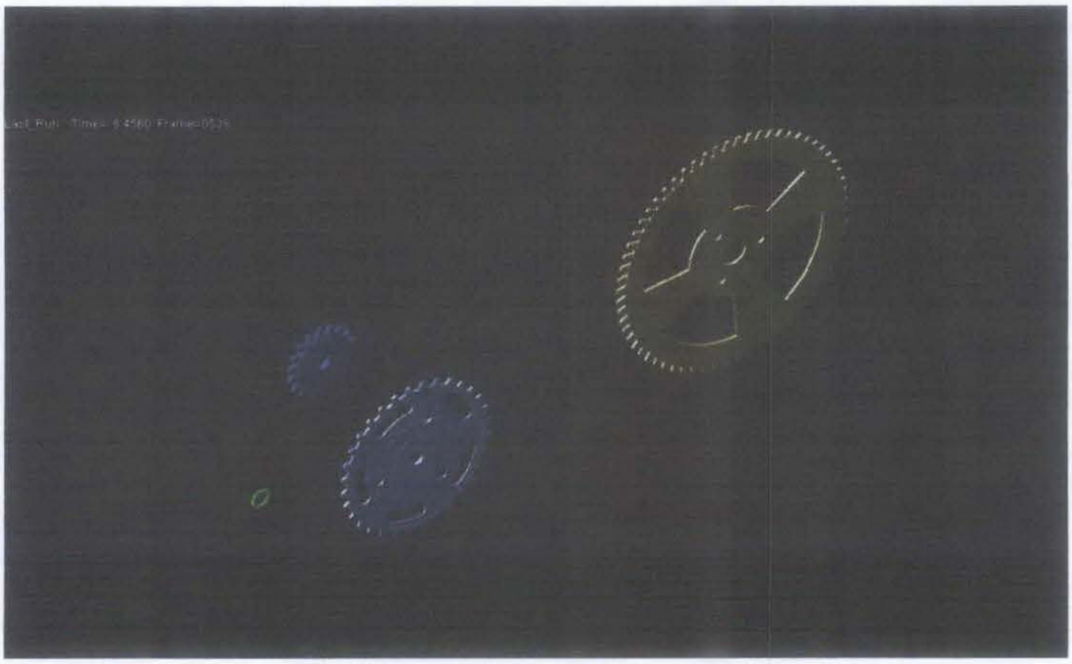

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