UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS ◆

JUDUL: **PRELIMINARY DESIGN OF DOUBLE RUBBER BELT CONTINUOUSLY VARIABLE TRANSMISSION (CVT)**

SESI PENGAJIAN: 2009/2010

Saya, **MOHD FADZLI BIN MANSOR (850225-03-5425)**
(HURUF BESAR)

mengaku membenarkan tesis (Sarjana Muda / ~~Sarjana / Doktor Falsafah~~)* ini disimpan di perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis ini adalah hakmilik Universiti Malaysia Pahang (UMP).
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐	**SULIT**	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD**	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi / badan di mana penyelidikan dijalankan)
√	**TIDAK TERHAD**	

(TANDATANGAN PENULIS)

Alamat Tetap:

KAMPUNG BUKIT TIU,
18500 MACHANG,
KELANTAN.

Tarikh: **24 NOVEMBER 2009**

Disahkan oleh:

(TANDATANGAN PENYELIA)

DR. SUGENG ARIYONO
(Nama Penyelia)

Tarikh: **24 NOVEMBER 2009**

CATATAN: * Potong yang tidak berkenaan.

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

◆ Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled *"Preliminary Design Of Double Rubber Belt Continuosly Variable Transmission (CVT)"* is written by *Mohd Fadzli bin Mansor*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering.

NIK MOHD IZUAL NIK IBRAHIM

(Name of panel member)

Examiner

Signature

PERPUSTAKAAN UMP
0000044233

PI ,E RUBBER BELT CONTINUOSLY VARIABLE TRANSMISSION (CVT)

MOHD FADZLI BIN MANSOR

Report submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

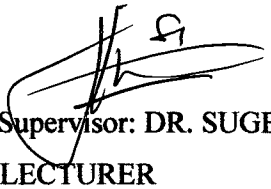
Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2009

PERPUSTAKAAN
UNIVERSITI MALAYSIA PAHANG
No. Perolehan 044233
Tarikh 05 MAR 2010
No. Panggilan TJ 1100 .F33 2009 rs Bc.

SUPERVISOR'S DECLARATION

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

Signature 
Name of Supervisor: DR. SUGENG ARIYONO
Position: LECTURER
Date: 24 NOVEMBER 2009

STUDENT'S DECLARATION

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

Signature

Name: MOHD FADZLI BIN MANSOR

ID Number: MH 06009

Date: 24 NOVEMBER 2009

To my beloved father and mother

Mr. Mansor Bin Mohd Noor

Mrs. Hasmah Binti Yaacob

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Dr. Sugeng Ariyono for germinal ideas, invaluable guidance, continuous encouragement and constant support in making this research possible. He has always impressed me with his outstanding professional conduct, his strong conviction for science, and his belief that a Degree program is only a start of a life-long learning experience. I am truly grateful for his progressive vision about my training in science, his tolerance of my naïve mistakes, and his commitment to my future career. I also would like to express very special thanks for their suggestions and co-operation throughout the study. I also sincerely thanks for the time spent proofreading and correcting my many mistakes.

My sincere thanks go to all my course mates for their excellent co-operation, inspirations and supports during this study and staffs of the Mechanical Engineering Department, UMP, whom helped me in many ways and made my stay at UMP pleasant and unforgettable.

I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. Special thanks should be given to my committee members. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.

ABSTRACT

A vehicle that is powered by an internal combustion engine (ICE) needs a transmission system to change the transmission ratio between the engine and the drive wheel for smooth and comfortable drive. Rubber belt continuous variable transmission (CVT) is commonly used in scooter with small engine. The engine with capacity above 200 cc need more torque to deliver its power; hence it needs modification at its CVT to overcome this problem. Research and development in continuous variable transmission (CVT) for scooter show variety of possibility. One of them is by modifying single rubber belt CVT into double rubber belt. The objective of this work is to study the preliminary requirement for designing double rubber belt CVT. This paper introduces an alternative way of changing CVT ratio for double rubber belt system using mechanical system. This new system introduces a T-shape housing for the ball roller as a mechanism of shifting the pulley ratio. The ball roller regulated the axial movement of two movable pulley sheave to shift the two rubber belt place between the sheaves, and change the belt-pulley contact radius. Changing this contact radius means changing the CVT ratio. To support the design requirement some calculation was made and CAE software was used to analyze force distribution on input shaft. From the analysis, it shows that the shaft still can support with two rubber belt system to generate the power in high revolution. The result shows that the new system using two rubber belt system and application of the ball rollers in T-shape housing gives more torque to deliver of power machine and this system approach that can be used as the new technology for automotives industry.

ABSTRAK

Sebuah kenderaan yang dijanakan oleh enjin pembakaran dalaman (ICE) memerlukan sistem transmisi untuk menukar nisbah penghantaran antara enjin dan roda penggerak untuk memastikan kelancaran dan keselesaan memandu. Tali sawat getah penghantaran pembolehubah berterusan (CVT) secara amnya digunakan pada skuter yang menggunakan. Mesin dengan kapasiti di atas 200 cc memerlukan lebih banyak daya kilas untuk memberikan kuasanya, maka pengubahsuaian perlu dilakukan pada bahagian CVT untuk mengatasi masalah ini. Penyelidikan dan pembangunan pada transmisi pembolehubah berterusan (CVT) untuk skuter menunjukkan pelbagai kemungkinan. Salah satunya adalah dengan mengubahsuai CVT yang menggunakan satu tali sawat getah kepada system yang menggunakan dua tali sawat getah. Objektif kajian ini adalah mengkaji keperluan awal dalam mereka bentuk dua tali sawat getah untuk dimasukkan ke dalam system CVT. Kajian ini adalah memperkenalkan salah satu alternatif untuk menukar nisbah CVT dalam dua tali sawat getah takal yang menggunakan system mekanikal. Sistem baru ini memperkenalkan perumah bentuk-T bagi bebola sebagai mekanisma pertukaran nisbah takal. Bebola melaraskan pergerakan axial dua takal bergerak untuk menukar diameter dua tali sawat getah yang ditempatkan antara takal, dan menukar radius takal yang bersentuhan dengan tali sawat.dengan mengubah jejari sentuh ini, bererti menukar nisbah CVT. Untuk menyokong keperluan reka bentuk, beberapa pengiraan perlu dibuat dan perisian CAE digunakan untuk menganalisis pengagihan daya pada batang paksi. Daripada analisis, itu menunjukkan bahawa paksi masih boleh menyokong dengan dua sistem tali sawat getah untuk menghasilkan kekuatan dalam putaran yang tinggi. Ini membuktikan bahawa sistem baru menggunakan dua sistem tali sawat getah dan aplikasi bebola pada perumah bentuk-T memberi lebih banyak daya kilas untuk memberikan kekuatan mesin dan sistem ini pendekatan yang boleh digunakan sebagai teknologi baru untuk industri Automotif.

TABLE OF CONTENTS

		Page
SUPERVISOR'S DECLARATION		ii
STUDENT'S DECLARATION		iii
ACKNOWLEDGEMENTS		v
ABSTRACT		vi
ABSTRAK		vii
TABLE OF CONTENTS		viii
LIST OF TABLES		xii
LIST OF FIGURES		xiii
LIST OF SYMBOLS		xv
LIST OF ABBREVIATIONS		xvi
CHAPTER 1	**INTRODUCTION**	
1.1	Background of Project Title	1
1.2	Problem statement	2
1.3	Objective of the Research	2
1.4	Scope of Project	3
1.5	Methodology	3
1.6	Project Flow Chart	4
CHAPTER 2	**LITERATURE REVIEW**	
2.1	Introduction	5
2.2	Background of Continuously Variable Transmission (CVT)	5
2.3	History of Continuously Variable Transmission	6
2.4	Components in CVT	6
	2.4.1 Variator	7
	2.4.2 Roller Weights	8
	2.4.3 Clutch	8

	2.4.4	How clutch springs work	9
	2.4.5	Clutch Bell	10
	2.4.6	V belt	10
	2.4.7	Pulley	11
2.5	Comparison of V Belt and Other form of Power Transmissions		12
2.6	Mechanism of CVT		13
2.7	Operation of CVT for Scooter		13
2.8	Principle of Improvement in Fuel Economy and Performance with CVT		15
	2.8.1	Principle of Improvement in Fuel Economy	15
	2.8.2	Principle of Improvement in Power Performance	16
2.9	Advantages and Disadvantages		17
	2.9.2	Advantages of CVT	17
	2.9.2	Disadvantages of CVT	18
	2.9.3	Perceptual Disadvantages	18
2.10	Type of CVT		19
	2.10.1	Variable-Diameter pulley (VDP) or Reeves Drive	19
	2.10.2	Toroidal or roller-based CVT	19
	2.10.3	Infinitely Variable Transmission (IVT)	20
	2.10.4	Ratcheting CVT	20
	2.10.5	Hydrostatic CVTs	21
	2.10.6	Variable Toothed Wheel Transmission	22
	2.10.7	Cone CVTs	22
	2.10.8	Radial Roller CVT	22
	2.10.9	Electronically-Controlled CVT	23
2.11	Summary		24

CHAPTER 3 METHODOLOGY

3.1	Introduction	25
3.2	Design Criteria	25
3.3	Conceptual Design	25
3.4	Sketching Model	26

3.5	Engineering Software using Solidwork		26
	3.3.1	Solidwork Software	27
	3.3.2	Computer Aided Engineering (CAE) Software	27
3.6	Engineering drawing by Solidworks Software		27
	3.6.1	Training of Advance Skill in Engineering Drawing	28
	3.6.2	Engineering Drawing Block	28
	3.6.3	Complete Engineering Block	28
3.7	Description of the Design		29
	3.7.1	Design 1	29
	3.7.2	Design 2	30
	3.7.3	Design 3	32
3.8	Comparison between Three Designs		33
	3.8.1	Comparison of Three Designs	33
	3.8.2	Selection Based on Design Requirement	34
3.9	Analysis of Pulley Movement and Force Analysis		34
	3.9.1	Displacement of the Moveable Pulley	34
	3.9.2	Torque Measure on Shaft	36
	3.9.3	V Belt Drive Equation	37
	3.9.4	The contributors to the stress in the belt	40
	3.9.5	Center Distance	40
3.10	V belt Sheaves		41
3.11	Situation in CVT System		43
3.12	CAE Analysis		48
	3.12.1	Meshing Setting	49
	3.12.2	Boundary Condition Setting	50
	3.12.3	Materials Selection for Analysis	52
	3.12.4	Analysis Process	53
3.13	Summary		54

CHAPTER 4 RESULT AND DISCUSSION

4.1	Introduction	55
4.2	Selected Design	55
4.3	Modification	58
	4.3.1 Modified Component	58
4.4	Detail Sketching and Function	61
4.5	Structure Analysis	67
	4.5.1 Main Structure Analysis	67
4.6	Summary	69

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1	Conclusion	70
5.2	Recommendation	71

REFERENCES		72
APPENDICES		73
A	Project Gantt Chart	73
B1	Drawing Block (fully Assembly)	74
B2	Drawing Block (Component)	75

LIST OF TABLES

Table No.	Title	Page
2.1	Advantages of Continuous variable transmission	17
3.1	Comparison Between Three Concept Designs	33
3.2	Design Requirement Selection	34
3.3	Parameter of Pulley	39
3.4	Parameter of Three Situations	47
3.5	Value for Three Situations	47
4.1	Parts of Sketching by Solidworks Software	61
4.2	Result of Stress on Shaft	68

LIST OF FIGURES

Figure No.	Title	Page
1.1	Project Flow Chart	4
2.1	CVT System	6
2.2	Ramp Plate	7
2.3	systemClutch	9
2.4	Compression Spring	10
2.5	V Belt with Pulley	11
2.6	Pulley	12
2.7	Front Set Driver Pulley	13
2.8	Rear Set Driven Pulley	14
2.9	Engine Load Vs Engine Speed	15
2.10	Driving Force Vs Vehicle Speed	16
2.11	Nissan Extroid toraidal CVT	19
2.12	System Of Hydrostatic CVTs	21
3.1	Complete Conceptual for Design 1	29
3.2	Exploded Drawing of Design 1	30
3.3	Complete Conceptual for Design 2	30
3.4	Design Concept Control By Linear Actuator	31
3.5	Conceptual for Design 3	32
3.6	Angle between Two Sheaves	35
3.7	Belt Geometry	35
3.8	Definition of Force Applied	36
3.9	Basic Belt Drive Geometry	38

3.10	Graph Diameter Vs Velocity Ratio	39
3.11	Forces on Belts or Pulley	41
3.12	Main Structure Analysis Applying Force and Fixed Part	48
3.13	Design Scenario Menu	49
3.14	Model Mesh Setting	49
3.15	Meshing Type	50
3.16	Meshing in Progress	50
3.17	Menu for Boundary Condition Setting	51
3.18	Nodal Force Setting	51
3.19	Material Selection from ALGOR Library	52
3.20	Analysis Perform Icon	53
3.21	Analysis in Process	53
4.1	Complete Figure for Design 3	55
4.2	Explode View for Detail System Design 3	56
4.3	Explode View of Front System of Double Rubber Belt System	56
4.4	Placement of housing to the shaft(a) and the position of ball roller in the housing	57
4.5	Explode View of Rear System of Double Rubber Belt System	57
4.6	Comparison of Housing of Roller before and After Whole Modification	58
4.7	Comparison of Roller before and after Modification	59
4.8	Comparison of Shaft Before and After Modification	59
4.9	Comparison of Sheaves Pulley before and After Modification	60
4.10	Comparison of Fix Pulley before and After Modification	60
4.1	Von Mises Result of Stress analysis on Shaft Structure	68

LIST OF SYMBOLS

α	Angle
R	Radius
F	Force
r	Distance
P	Power
D	Diameter
V	Velocity
S	Span
C	Center
N	Newton
τ	Torque
ω	Angular Velocity
θ	Angel
$^\circ$	Degree

LIST OF ABBREVIATIONS

CVT	Continuously Vehicle Transmission
3D	Three Dimensions
CAE	Computer Aided Engineering
IVT	Invinite Variable Transmission
HP	Horse Power
CAD	Computer Added Design

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF PROJECT TITLE

Many small tractors for home and garden use have simple hydrostatic or rubber belt CVTs. For example, the John Deere Gator lines of small utility vehicles use a belt with a conical pulley system. They can deliver a lot of power and can reach speeds of 10-15 MPH, all without need for a clutch or shift gears. Many new snowmobiles and motor scooters use CVTs. Virtually all snowmobile and motor scooter CVTs are rubber belt/variable pulley CVTs. Additionally, newer hybrids, such as the Toyota Prius or Camry, use CVT to maximize fuel efficiency.

Lately, continuously variable transmissions (CVT) have aroused a great deal of interest in the automotive sector due to the potential of lower emissions and better performance. A CVT is an emerging automotive transmission technology that offers a continuum of gear ratios between high and low extremes with fewer moving parts. This consequently enhances the fuel economy and acceleration performance of a vehicle by allowing better matching of the engine operating conditions to the variable driving scenarios. *(Nilabh Srivastava and Imtiaz Haque, 2008)*

CVTs have been used in aircraft electrical power generating systems since the 1950s and in SCCA Formula 500 race cars since the early 1970s. More recently, CVT systems have been developed for go-karts and have proven to increase performance and engine life expectancy. The Tomcar range of off-road vehicles also utilizes the CVT system.

1.2 PROBLEM STATEMENT

Continuous Variable Transmission (CVT) is one of the well-received transmissions around the world nowadays. In the production of a simple series of scooter, many manufacturers companies compete to produce their own product. However, scooter is rarely used for long distance travel. They are afraid to move for example in driving distance of 500 km and above. Most of them still doubted the system that uses CVT belting. They think that belting made from rubber is not long-lasting than chains which made from iron. According to the CVT forum in the internet, most of them still doubt about the strength of the belting. They also doubted the system used in the CVT system. This might be they are not well exposed with this system compared to manual transmission of four strokes engine for instance Honda Ex-5 and Yamaha Lagenda which have been used widely. The flexibility of a CVT allows the driving shaft to maintain a constant angular velocity over a range of output velocities. Rubber belt CVT is now widely used in the motorcycle with most of them using single rubber belt. The engine with the capacity above 200cc needs more torque to deliver its power; hence it needs modification to overcome this problem.

1.3 **OBJECTIVE OF THE RESEARCH**

The aim of this project is to study the preliminary design for double rubber belt continuous vehicle transmission (CVT) used in medium size engine.

\

1.4 SCOPE OF PROJECT

The approach in designing double rubber belt continuous vehicle transmission (CVT) will be as follows:

i. Literature review/study based on 250 cc CVT engine
ii. Design the conceptual of controller the movement of two sheave pulley
iii. Re-design / engineering drawing of concept CVT system by solid work
iv. CAE analysis by ALGOR
v. Design and performance comparison. Documentation - Preparing a report for the project.

1.5 METHODOLOGY

i. Literature study
   - Make review on other model and focusing on how to make it simple and relevance to the project title
ii. Conceptual design
   - Sketching several type of design based on concept that being choose.
   - State the dimension for all part.
iii. Re-design / engineering drawing by solid work
   - Design the several model using SOLIDWORKS software.
iv. Design Solution
   - Make a selection design using theoretical analysis (calculation)
v. Computer Aided Engineering (CAE) analysis
   - Analysis the design for strain stress structure by using ALGOR.
   - Define critical point.
vi. Blue print
   - Come out detailed plan in drawing block.
vii. Documentation
   - Preparing a report for the project.

1.6 PROJECT FLOW CHART

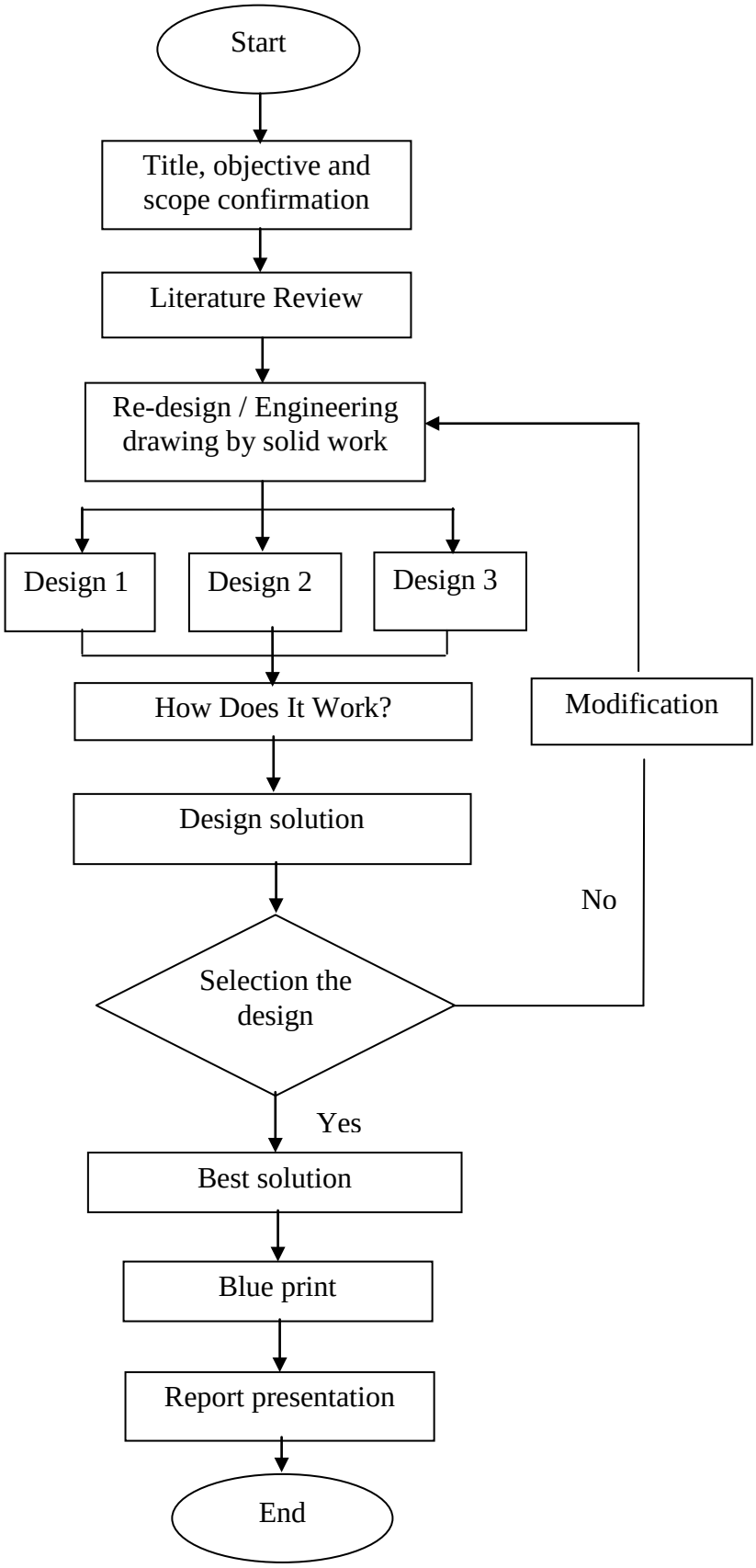


Figure 1.1: Project Flow Chart

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The aim of this chapter is to give some overview information about the continuously variable transmission (CVT). In this chapter, the explanations and details of type of continuously variable transmission (CVT), the previous research and findings, the theories are included. It also will describe the basic design, analysis from using software to simulate the continuously variable transmission (CVT) system.

2.2 BACKGROUND OF CONTINUOUS VARIABLE TRANSMISSION (CVT)

A continuously variable transmission (**CVT**) is a transmission which can change sleeplessly through an infinite number of effective gear ratios between maximum and minimum values. This contrasts with other mechanical transmissions that only allow a few different distinct gear ratios to be selected. The flexibility of a CVT allows the driving shaft to maintain a constant angular velocity over a range of output velocities. This can provide better fuel economy than other transmissions by enabling the engine to run at its most efficient revolutions per minute (RPM) for a range of vehicle speeds. *.(Nilabh Srivastava and Imtiaz Haque, 2008)*

Unlike traditional automatic transmissions, continuously variable transmissions don't have a gearbox with a set number of gears, which means they don't have interlocking toothed wheels. The most common type of CVT operates on an ingenious pulley system that allows an infinite variability between highest and lowest gears with

no discrete steps or shifts. Although CVTs change this ratio without using a set of planetary gears, they are still described as having low and high "gears" for the sake of convention.

2.3 HISTORY OF CONTINUOUS VARIABLE TRANSMISSION

Leonardo DaVinci sketched the first CVT in 1490. Dutch automaker DAF first started using CVTs in their cars in the late 1950s, but technology limitations made CVTs unsuitable for engines with more than around 100 horsepower. In the late 80s and early 90s, Subaru offered a CVT in their Justy mini-car, while Honda used one in the high-mileage Honda Civic HX of the late 90s. Improved CVTs capable of handling more powerful engines were developed in the late 90s and 2000s, and CVTs can now be found in cars from Nissan, Audi, Honda, Ford, GM, and other automakers.

2.4 COMPONENT IN CVT

The Continuously Variable Transmission (CVT) system consists of two parts: the variator (drive pulley), and the clutch (driven pulley). These are connected by the CVT belt.

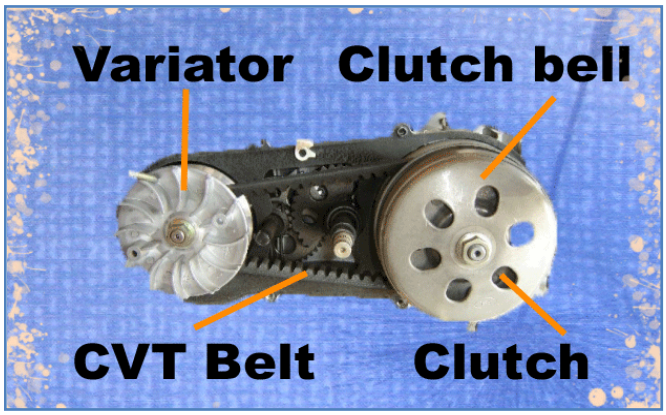


Figure 2.1: CVT System

Source: Buggypartsnw

The CVT system works through the changing of the distance between the plates on the two pulleys. The clutch pulley plate width increases, and vice versa. This creates an infinite number of possible gear ratios, as the transmission is altering itself on the fly to adapt to the current driving condition.

2.4.1 Variator

The variator is driven directly by the engine. Inside the variator are 6 rollers that are positioned in individual slots with ramps that they will move along outward when centrifugal force is applied. As the rollers move outward, they press against the ramp plate which causes the pulley plates of the variator to move toward one another, compressing the belt. This "V" shape created by the pulley plates pushes the belt outward, which draws the belt inward on the driven (clutch) side, increasing the gear ratio.

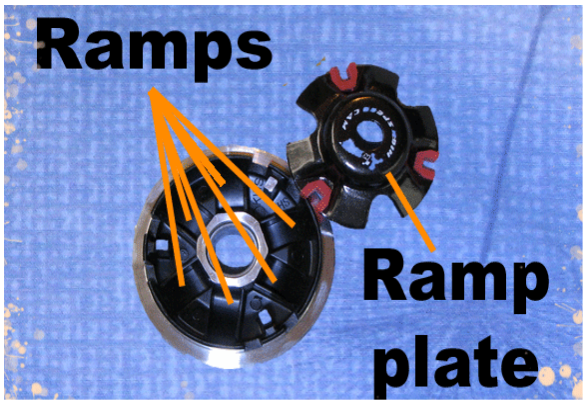


Figure 2.2: Ramp Plate

Source: Buggypartsnw

At idle, the rollers are at their innermost position, the variator pulley plates are at their farthest apart, and the CVT belt is low on the variator side and high on the clutch side. With increasing RPMs, the rollers move outward along their ramps applying pressure to the ramp plate, which compresses the variator pulley plates and squeezes the CVT belt outwards.

In the CVT transmission system, the rollers are actually working against the spring tension of the main torque spring on the clutch side. This is discussed in detail later in this report in the Clutch section.

Performance and racing aviators have specially engineered "ramps" for the rollers. Many have Teflon ramps and ramp cover plates for reduced roller friction. This means smoother transition between "gears".

2.4.2 Roller Weights

Rollers come in many different sizes and weights, depending on application. Roller weights that are at the lowest recommended end of the scale are often too light to fully push the aviator plate far enough out to achieve maximum speed. Similarly, the heavier weights quickly move you into a higher gear ratio at the expense of low end power. Please keep this in mind when choosing the right weights for your style of riding.

Rollers and sliders should be inspected annually (at minimum) for wear. Rollers are especially prone to developing flat spots that inhibit their ability to move smoothly. If this occurs, they should be replaced. This is one advantage of sliders, as they already have flat sides and are not affected by this wear as quickly as rollers.

2.4.3 Clutch

The clutch in a CVT system engages when the centrifugal forces of the spinning clutch overcomes the tension of the clutch arm springs and allow the clutch pads to engage with the clutch bell, creating movement.

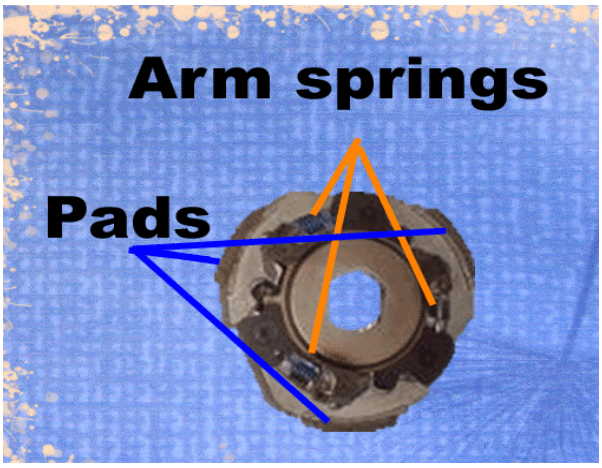


Figure 2.3: System Clutch

Source: Buggypartsnw

Racing and performance clutches are made of higher quality materials, such as metal composite or Kevlar clutch pads to reduce wear and heat damage. These clutches often have much larger clutch pads for better engagement with the clutch bell. Clutches can be altered with different rated arm springs to change their engagement RPMs.

The main clutch torque spring compresses the clutch pulley plates together, forcing the belt outward and acting against the variator. As the rollers compress the variator side pulley plates when RPMs increase, the belt is forced outward on the variator. Since the belt is a constant length, this causes the belt to be pulled inward on the clutch, overcoming the tension of the torque spring.

2.4.4 How clutch springs work

The main torque spring makes it harder for the aviator to draw the belt inward on the clutch. This keeps the scooter in a lower gear ratio longer, and "downshifts" faster when decelerating so have more power when hit the gas again. This is especially helpful when climbing or coming out of a corner. A higher tension main torque spring downshifts more quickly than a lower tension spring, but be aware that high spring tensions can prevent very light roller weights from ever reaching the maximum position inside the aviator, sacrificing top speed.Clutch arm springs control when the clutch arms and pads engage with the clutch bell. These springs are rated at 1000, 1500, and

2000 RPMs. This means that the clutch has to be spinning at this RPM speed before the centrifugal force will overcome the spring tension and allow the clutch pads to engage. This is not the same as engine RPMs, as the engine will be idling at some rate and the engagement RPM is on top of this.

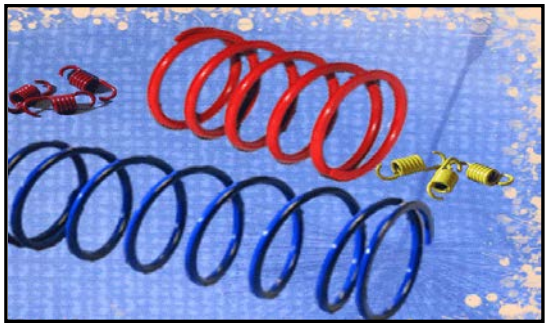


Figure 2.4: Compression Spring

Source: Buggypartsnw

2.4.5 Clutch Bell

The clutch bell is something that you should inspect annually at minimum and more often if you find that you are bogging down when climbing with the engine revving high and the wheels won't spin. This can be indicative of a "glazed" or smoothed clutch bell and/or clutch pads. An amount of frictional heat is created when pushing the climbing limits of your scooter, and this eventually leads to smoothing of the inside edge of the clutch bell. The heat (and smoke) can turn the bell a purplish color and result in a very smooth, glazed appearance. When this happens, it's time to replace the clutch bell.

2.4.6 V belt

The function of a V belt drive is to transmit rotational motion and torque from one pulley to another, smoothly, quietly and inexpensively. Belt provides overall combination of design flexibility, low cost low maintenance, ease of assembly and space savings. A V belt is made of fabric and cord, usually cotton, rayon, or nylon, and impregnated with rubber. In contrast with flat belts, v belt are used with similar

sheaves and at shorter center distances. V belt are slightly less efficient than flat belts, but a number of them can be used on a single sheave, thus making a multiple drive. V belt are made only in certain lengths and have no joint.

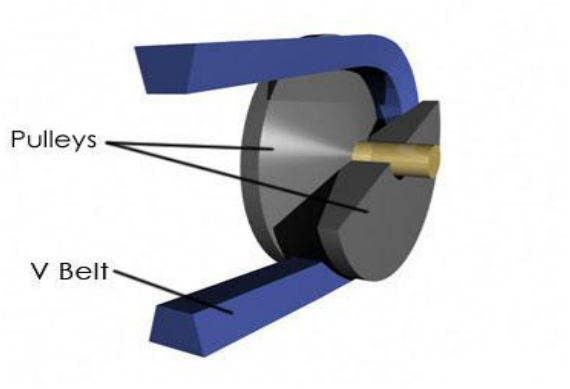


Figure 2.5: V Belt with Pulley

Source: Howstuffwork

2.4.7 Pulley

Pulleys, also referred to as sheaves, are the wheels that are connected to the shaft. The pulley has a groove around the outside, with a shape to match that of the belt. Scooter sheaves are machined from steel or cast iron, depending on diameter. Sheaves are classified with a pitch diameter, which is the diameter slightly smaller than the outside of the groove, corresponding to the location of the center of the belt. In CVT system that utilizes a belt drive need some feature that can compensate for the belt stretch, such as idler pulley. An idler pulley is used to maintain constant tension on the belt. It is usually place on the slack side of the belt and is preloaded, usually with springs, to keep the belt tight.

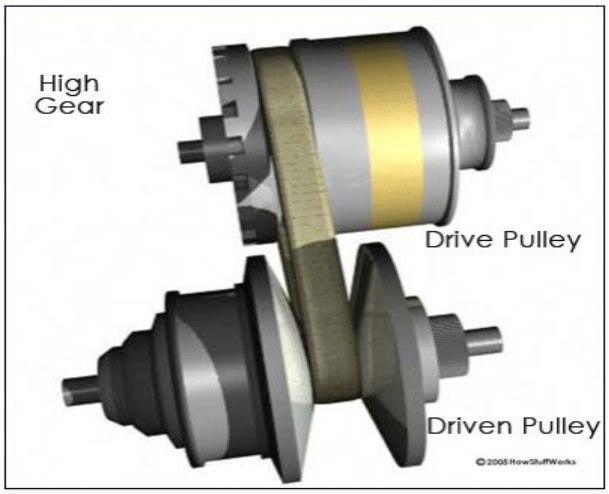


Figure 2.6: Pulley

Source: CVT gallery

2.5 COMPARISON OF V BELT AND OTHER FORMS OF POWER TRANSMISSION

Compared to other forms of power transmission, belt drives have these advantages:

i. They are less expensive than gear or chain drives.
ii. They have flexible shaft center distances, where gear drives are restricted.
iii. They operate smoothly and with less noise at high speed.
iv. They can design to slip when an overload occurs in the machine.
v. They required no lubrication, as do chains and gears.
vi. They can be used in more than one plane.
vii. They are easy to assemble and install and have flexible tolerance.
viii. They required little maintenance.
ix. They do well in absorbing shock loading.

2.6 MECHANISM OF CVT

In system of CVT, when the engine is rotating, some roller in driving pulley is create the displacement of the drive pulley and change the CVT ratio by centrifugal force depend on how much speed from crankshaft. That roller will push the drive pulley to increase their diameter.

The distance between the centers of the pulleys to where the belt makes contact in the groove is known as the pitch radius. When the pulleys are far apart, the belt rides lower and the pitch radius decreases. When the pulleys are closes together, the belt rides higher and the pitch radius increases. The ratio of the pitch radius on the driving pulley to the pitch radius on the driven pulley determines the gear.

V belt is connected between drive pulleys to driven pulley to transmit the energy from the engine. In the driven pulley have weight set clutch to control the rotating of the rear tire. When engine on idle, the clutch set is not functioned till the rotation is increase. Clutch set is function to grab the cover clutch when reach a certain speed. In cover clutch consist a special spring to control the ratio of diameter.

2.7 OPERATION OF CVT FOR SCOOTER

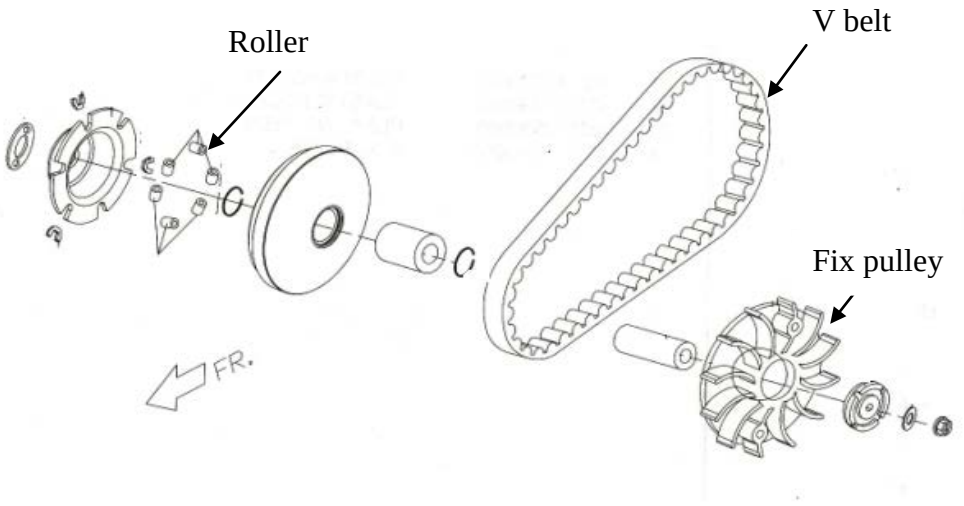


Figure 2.7: Front Set Driver Pulley

Source: Modenas User Manual

The variable-diameter pulleys are the heart of a CVT. Each pulley is made of two 20-degree cones facing each other. A belt rides in the groove between the two cones. Variable-diameter pulleys must always come in pairs. One of the pulleys, known as the drive pulley (or driving pulley), is connected to the crankshaft of the engine. The driving pulley is also called the input pulley because it's where the energy from the engine enters the transmission.

When the two cones of the pulley are far apart (when the diameter increases), the belt rides lower in the groove, and the radius of the belt loop going around the pulley gets smaller. When the cones are close together (when the diameter decreases), the belt rides higher in the groove, and the radius of the belt loop going around the pulley gets larger. For the front set driver pulley, roller is the main part to control the movement of pulley in X-direction to adjust the diameter depends on centrifugal force

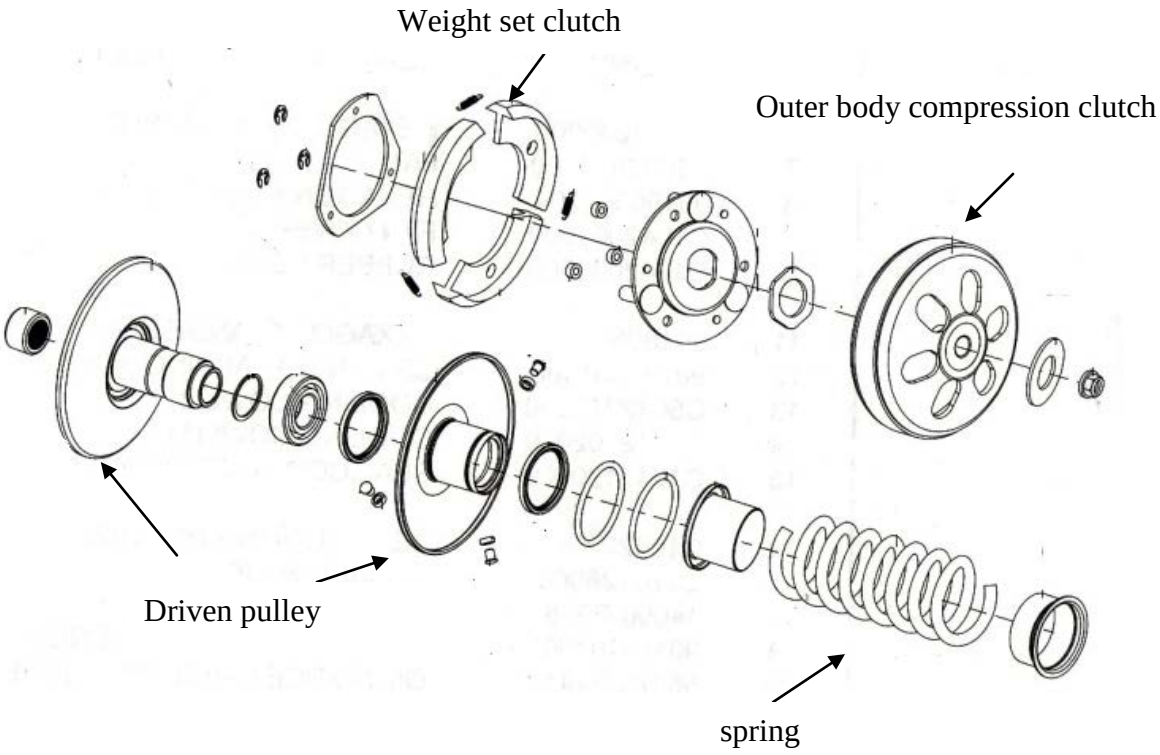


Figure 2.8: Rear Set Driven Pulley

Source: Modenas User Manual

The second pulley is called the driven pulley because the first pulley is turning it. When one pulley increases its radius, the other decreases its radius to keep the belt tight. As the two pulleys change their radii relative to one another, they create an infinite number of gear ratios, from low to high and everything in between. For the rear set driven pulley have a spring to create the force necessary to control the pulley halve. Spring also is the part which is to make sure the belt always tension. Thus, in theory, a CVT has an infinite number of "gears" that it can run through at any time, at any engine or vehicle speed.

2.8 PRINCIPLE OF IMPROVEMENTS IN FUEL ECONOMY AND PERFORMANCE WITH CVT

2.8.1 Principle of Improvement in Fuel Economy

The general concept of CVT is described as follows

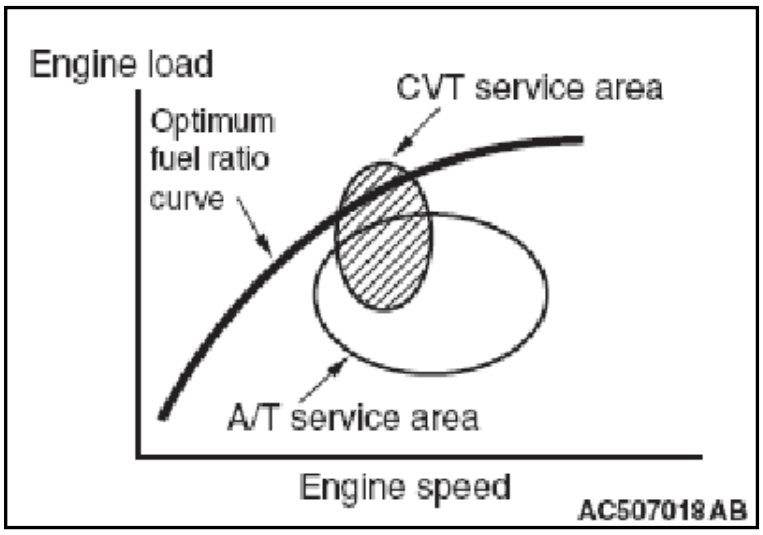


Figure 2.9: Engine Load Vs Engine Speed

Source: Buggypartsnw

CVT can continuously vary the pulley ratio, so the vehicle can be driven in the high engine fuel efficiency range all the time, resulting in excellent fuel economy. It means CVTs can compensate for changing vehicle speeds, allowing the engine speed to remain at its level of peak efficiency. For automatic transmission the change speed is

depend on torque converter. Torque converter will change the gear ratio when enough the torque. For CVT system, the velocity of scooter depends on engine speed. That why the service operation for both transmission is different and from that can show the better fuel economy.

2.8.2 Principle of Improvement in Power Performance

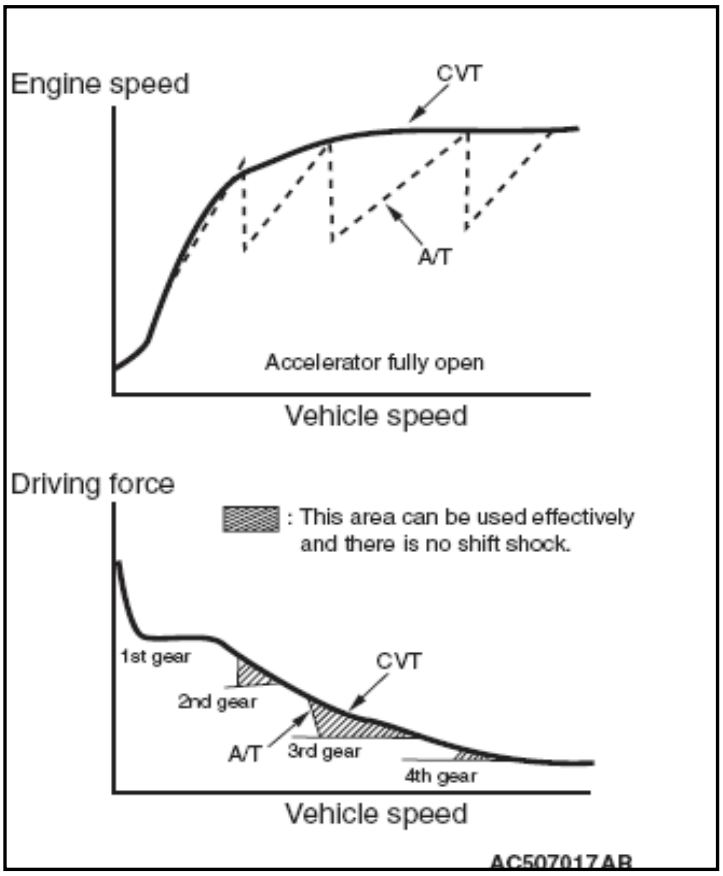


Figure 2.10: Driving Force Vs Vehicle Speed

Source: Buggypartsnw

The figure shows the maximum driving force diagram representing the power performance. The comparison with A/T shows that when the throttle is fully open, A/T causes a step change in driving force due to a step shift, but CVT changes driving force smoothly because it can accelerate with the engine kept in the high output range. Therefore, CVT provides more smooth and shockless driving without driving loss as much as the shaded area in the figure shown **(Figure2.10)**

2.9 ADVANTAGES AND DISADVANTAGES

2.9.1 Advantages of CVT

Continuously variable transmissions are becoming more popular for good reason. They boast several advantages that make them appealing both to drivers and to environmentalists. The table below describes some of the key features and benefits of CVTs.

Table 2.1: Advantages of Continuous Variable Transmission

Advantages of CVTS	
Feature	Benefit
Constant, step less acceleration from a complete stop to cruising speed	Eliminates "shift shock" makes for a smoother ride
Works to keep the vehicle in its optimum power range regardless of how fast its traveling	Improved fuel efficiency
Responds better to changing conditions, Car such as changes in throttle and speed	Eliminates gear hunting as a decelerates, especially going up a hill.
Less power loss in a CVT than a typical automatic transmission	Better acceleration
Better control of a gasoline engine's speed range	Better control over emissions
Can incorporate automated versions of mechanical clutches	Replace inefficient fluid torque converters

2.9.2 Disadvantages of CVT

i. CVT torque-handling capability is limited by the strength of their transmission medium (usually a belt or chain), and by their ability to withstand friction wear between torque source and transmission medium (in friction-driven CVTs). CVTs in production prior to 2005 are predominantly belt- or chain-driven and therefore typically limited to low-powered cars and other light-duty applications. Units using advanced lubricants, however, have been proven to support a range of torques in production vehicles, including that used for buses, heavy trucks, and earth-moving equipment.

ii. Some CVTs in production vehicles have seen premature failures.

iii. Some CVTs transmit torque in only one direction, rendering them useless for regenerative or engine-assisted vehicle braking; all braking would need to be provided by disc brakes, or similar dissipative systems.

2.9.3 Perceptual Disadvantages

i. CVTs operate smoothly and efficiently, without jerk, unlike a conventional gear transmission does while shifting. This can give a perception of low power, because many motorists expect a jerk when the vehicle begins to move and during acceleration. However, the jerk can be emulated by CVT control software, thus eliminating this marketing problem.

ii. Since the CVT keeps the engine turning at a constant rate over a wide range of vehicle speeds, pressing on the accelerator pedal will make the car move faster, but does not change the sound coming from the engine as much as a conventional automatic transmission gear-shift. This can be considered a disadvantage if the driver desires to hear the engine change tone.

2.10 TYPE OF CVT

2.10.1 Variable-Diameter pulley (VDP) or Reeves drive

In this most common CVT system, there are two V-belt pulleys that are split perpendicular to their axes of rotation, with a V-belt running between them. The gear ratio is changed by moving the two sections of one pulley closer together and the two sections of the other pulley farther apart. Due to the V-shaped cross section of the belt, this causes the belt to ride higher on one pulley and lower on the other. Doing these changes the effective diameters of the pulleys, this changes the overall gear ratio. The distance between the pulleys does not change, and neither does the length of the belt, so changing the gear ratio means both pulleys must be adjusted (one bigger, the other smaller) simultaneously to maintain the proper amount of tension on the belt.

2.10.2 Toroidal or roller-based CVT

Toroidal CVTs (Figure 2.12) are made up of discs and rollers that transmit power between the discs. The discs can be pictured as two almost conical parts, point to point, with the sides dished such that the two parts could fill the central hole of a torus. One disc is the input, and the other is the output (they do not quite touch). Power is transferred from one side to the other by rollers.

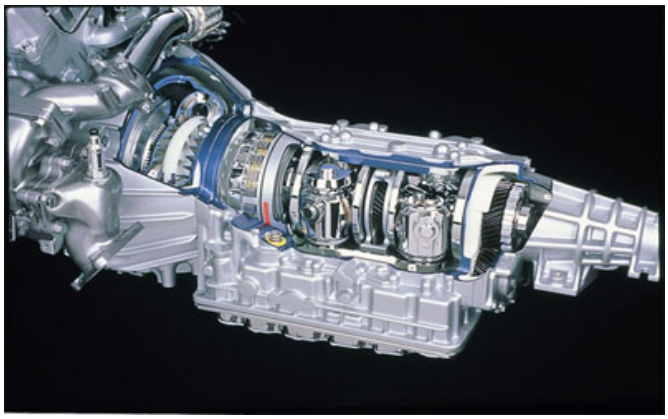


Figure 2.11: Nissan Extroid Toroidal CVT

Source: Buggypartsnw

When the roller's axis is perpendicular to the axis of the near-conical parts, it contacts the near-conical parts at same-diameter locations and thus gives a 1:1 gear ratio. The roller can be moved along the axis of the near-conical parts, changing angle as needed to maintain contact. This will cause the roller to contact the near-conical parts at varying and distinct diameters, giving a gear ratio of something other than 1:1. Systems may be partial or full toroidal. Full toroidal systems are the most efficient design while partial toroidals may still require a torque converter, and hence lose efficiency.

2.10.3 Infinitely Variable Transmission (IVT)

A specific type of CVT is the infinitely variable transmission (IVT), in which the range of ratios of output shaft speed to input shaft speed includes a zero ratio that can be continuously approached from a defined "higher" ratio. A zero output speed (low gear) with a finite input speed implies an infinite input-to-output speed ratio, which can be continuously approached from a given finite input value with an IVT. *Low* gears are a reference to low ratios of output speed to input speed. This low ratio is taken to the extreme with IVTs, resulting in a "neutral", or non-driving "low" gear limit, in which the output speed is zero. Unlike neutral in a normal automotive transmission, IVT output rotation may be prevented because the backdriving (reverse IVT operation) ratio may be infinite, resulting in impossibly high backdriving torque; ratcheting IVT output may freely rotate forward, though.

2.10.4 Ratcheting CVT

The ratcheting CVT is a Transmission that relies on static friction and is based on a set of elements that successively become engaged and then disengaged between the driving system and the driven system, often using oscillating or indexing motion in conjunction with one-way clutches or ratchets that rectify and sum only "forward" motion. The transmission ratio is adjusted by changing linkage geometry within the oscillating elements, so that the summed maximum linkage speed is adjusted, even when the average linkage speed remains constant. Power is transferred from input to output only when the clutch or ratchet is engaged, and therefore when it is locked into a static friction mode where the driving & driven rotating surfaces momentarily rotate

together without slippage. Ratcheting CVTs are distinguished from VDPs and roller-based CVTs by being static friction-based devices, as opposed to being dynamic friction-based devices that waste significant energy through slippage of twisting surfaces.

2.10.5 Hydrostatic CVTs

Hydrostatic transmissions use a variable displacement pump and a hydraulic motor (Figure 2.13). All power is transmitted by hydraulic fluid. These types can generally transmit more torque, but can be sensitive to contamination. Some designs are also very expensive. However, they have the advantage that the hydraulic motor can be mounted directly to the wheel hub, allowing a more flexible suspension system and eliminating efficiency losses from friction in the drive shaft and differential components. This type of transmission is relatively easy to use because all forward and reverse speeds can be accessed using a single lever.

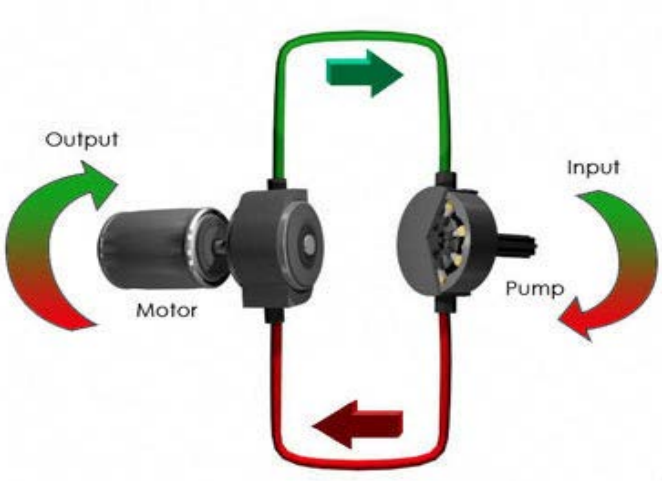


Figure 2.12: System of Hydrostatic CVTs

Source: Buggypartsnw

2.10.6 Variable Toothed Wheel Transmission

A variable toothed wheel transmission is not a true CVT that can alter its ratio in infinite increments but rather approaches CVT capability by having a large number of ratios, typically 49. This transmission relies on a toothed wheel positively engaged with a chain where the toothed wheel has the ability to add or subtract a tooth at a time in order to alter its ratio with relation to the chain it is driving. The "toothed wheel" can take on many configurations including ladder chains, drive bars and sprocket teeth. The huge advantage of this type of CVT is that it is a positive mechanical drive and thus does not have the frictional losses and limitations of the Roller based or VDP CVT's. The challenge in this type of CVT is to add or subtract a tooth from the toothed wheel in a very precise and controlled way in order to maintain synchronized engagement with the chain.

2.10.7 Cone CVTs

This category comprises all CVTs made up of one or more conical bodies that function together along their respective generatrices in order to achieve the variation. In the single-cone type, there is a revolving body (a wheel) that moves on the generatrix of the cone, thereby creating the variation between the inferior and the superior diameter of the cone. In a CVT with oscillating cones, the torque is transmitted via friction from a variable number of cones (according to the torque to be transmitted) to a central, barrel-shaped hub. The side surface of the hub is convex with a specified radius of curvature, smaller than the concavity radius of the cones. In this way, there will be only one (theoretical) contact point between each cone and the hub.

2.10.8 Radial Roller CVT

The working principle of this CVT is similar to that of conventional oil compression engines, but, instead of compressing oil, common steel rollers are compressed. The motion transmission between rollers and rotors is assisted by an adapted traction fluid, which ensures the proper friction between the surfaces and slows down wearing thereof. Unlike other systems, the radial rollers do not show a tangential

speed variation (delta) along the contact lines on the rotors. From this, a greater mechanical efficiency and working life are obtained. The main advantages of this CVT are the manufacturing inexpensiveness and the high power efficiency.

2.10.9 Electronically-Controlled CVT

This system is not a true CVT, having a fixed gear ratio, but behaves very similar to a true CVT. In this system, the transmission is an integral part of the hybrid power train and is actually a torque combiner. The gear train is a permanently-engaged, fixed-ratio, 3-way planetary gear. The engine is attached to one input, the driveshaft and the main electric motor to another, and then a smaller motor-generator controls the differential's third input to create a continuously-variable ratio between engine speed and wheel speed, with the variation taken by the electric motor and generator. At the extremes, the vehicle can move under electric power without the engine turning, or it can run the engine while stationary during engine warm-up or if needed to prevent discharge of the batteries.

The advantage of the system is its mechanical simplicity - no clutches, torque converters or shifting gears. A disadvantage is that continuous electrical power transmission between the two motor-generators is needed even during cruise, with resulting conversion losses, but the total effect is to increase the net efficiency through four methods:

i. The internal combustion engine may be completely shut down, rather than idle.
ii. The electric motor operates during high torque demands required to put the vehicle in motion.
iii. The internal combustion engine operates mostly at higher power demands, where it is more efficient.
iv. Energy may be recovered through the generation function when the vehicle is slowing or coasting downhill, with the energy (stored in the battery) applied to the initial acceleration of the vehicle and when high power demands require a that both the internal combustion engine and the electric motor operate.

2.11 SUMMARY

This project is begun by doing some research and survey on internet, journal, books and idea for design consideration to make decision the suitable concept and component to development in final project. Rubber belt CVT is now widely used in the motorcycle with most of them using single rubber belt system. Single rubber belt system is not suitable applied to engine with 200cc and above because need more torque to transmit high power from the engine. So, the engine with capacity more than 200 cc using CVT system must need modification at their transmission system. To overcome this problem, alternative way is proposed by design double rubber belt system to replace the current system. Further information, concept and the analysis of this system is show in the next chapter.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Based on literature review, planning to modeling the double rubber belt CVT then will be proceed with the way how to design it. The project begins with some conceptual design with free sketches in plain paper before transfer into 3D software with dimension. By comparing the all conceptual design, the best design is selected to do more analysis in this chapter.

3.2 DESIGN CRITERIA

i.	Transmission	:	continuously Variable (CVT)
ii.	Compression ratio	:	10:1
iii.	Rates output	:	11kW (15HP) @ 7000rpm
iv.	Max speed	:	120km/h (75mph) verified accurate +/- 5 mph
v.	Max torque	:	17.6NM @ 5500RPM (12.98 lb/ft)
vi.	Final drive	:	828 mm belt

3.3 CONCEPTUAL DESIGN

The major conceptual design is describe :

Driver pulley	: have two pulley and control by roller
Driven pulley	: have two pulley and control by spring
Connection	: belting (rubber belt)

Based on 250cc engine concept, free sketches make to see how the model will be creates and comes out. Three (3) designs are sketches in plain paper to make more choice to make a best decision. Overall dimensions and parameter also be determined here.

After free sketches on paper, the design is drawn into solid model using CAD software. In this project, Solidworks is used to model the design. The model is drawn according to actual dimension. In this stage, the design is redesign to simplification. It is important to ensure the design can easily to assemble.

The model will be creates part by part and then the part will be assembling together to see how the shape will come out. This 3D software can show how the model will be expected look in real view.

3.4 SKETCHING MODEL

After getting conceptual design, model from free sketching is drawn in paper. Free sketching is more important thing in design for any system in mechanical part. From sketching, we can decide the dimension of part and the model. From sketching also we can see the real concept is what to do.

To draw the real concept in solidworks software, the detail sketching must be completed. This sketch is very important as reference to make the model in solidworks software.

3.5 ENGINEERING SOFTWARE

In this design and development of double rubber belt for CVT system, two engineering software are used to model the design and to analyze one of component structure. Solidworks 2007 is used to model the design while software is use to do analysis on structure.

3.5.1 Solidworks Software

Solidworks is a parasolid-based solid modeler, and utilizes a parametric feature based approach to create models and assemblies. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, and so on. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent.

Building a model in Solidworks usually starts with a 2D sketch. Features refer to the building blocks of the part. They are the shapes and operations that construct the part. Shape-based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, and other. This shape is then extruded or cut to add or remove material from the part. Operation-based features are not sketch-based, and include features such fillets, chamfers, shells, applying draft to the faces of a part, and extras.

3.5.2 Computer Aided Engineering (CAE) Software

To do the analysis on the model, ALGOR Fempro V16 is use. This software can show the value of strain stress, mechanical contact, thermal conductivity, fluid dynamic and couple and uncouple metaphysics. Usually color contour will show the comparison of part to be broken and which part will receive high force. This software provides cost-effective solutions for design, analysis and simulation and enables engineers to virtually test and predict real-world behavior of new and existing product designs.

3.6 ENGINEERING DRAWING BY SOLIDWORKS SOFTWARE

After the design phase and materials selection, this information then transform into engineering language- Technical Drawing. It is use to store the design information into hardcopy and this is the easier way to communicate with manufacturer.

3.6.1 Training of Advance Skill in Engineering Drawing

Engineering drawing is very important aspect in engineering. Without good engineering drawing, failure could happen during fabrication process and more worst than that is when the system is failure during operation cause in reading error in reading engineering drawing. Week engineering drawing also can cause losses to an organization because it can crate large error in manufacturing process.

Thus to avoid this from occur, a training in advance engineering drawing is held before real engineering drawing is drawn. It have several phase such as making good drawing blocks, drawn simple but compact, standardize font, arrows, and features in drawing.

3.6.2 Engineering Drawing Block

Function of this engineering block is for verify the drafter, the material, tolerance, scale and many more tat state the initial configuration of the drawing. All this detail must be state on a simple block. The most important factors about creating a good engineering block is to verify the drawing as an intellectual properties and to make sure initial configuration of the drawing is completely receive if the drawing hand to others. The detail engineering drawing block of this project is in Appendix B.

3.6.3 Complete Engineering Block

After training engineering drawing block, next process is completing all parts engineering drawing. In this process, the simplest part is drawn first and then followed by complex geometry parts..The drawing is use third angle view. It is consist front, side and top view, the drawing also include isometric view of the parts. All the part is carefully dimensional to make sure the drawing easy to read and all the info to fabricate the parts is stated. After done all part created, it will be assemble together. This will show how the model will come out. If there is any miss matching and poor looks, refinement on the model and part will be done.

3.7 DESCRIPTION OF THE DESIGN

3.7.1 Design 1

First concept as show in figure 3.1 can be exposed as follow:

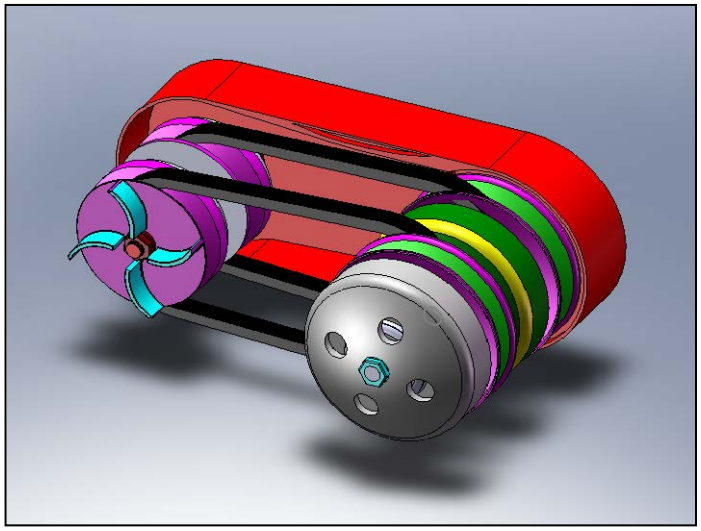


Figure 3.1: Complete Conceptual for Design 1

The system is similar the current system CVT which used in single rubber belt system. The different of design 1 is used the current system and modified to be a double rubber belt. The movement of pulley is caused by centrifugal force by mean of 6 rollers (figure 3.2)which push the pulley sheaves.

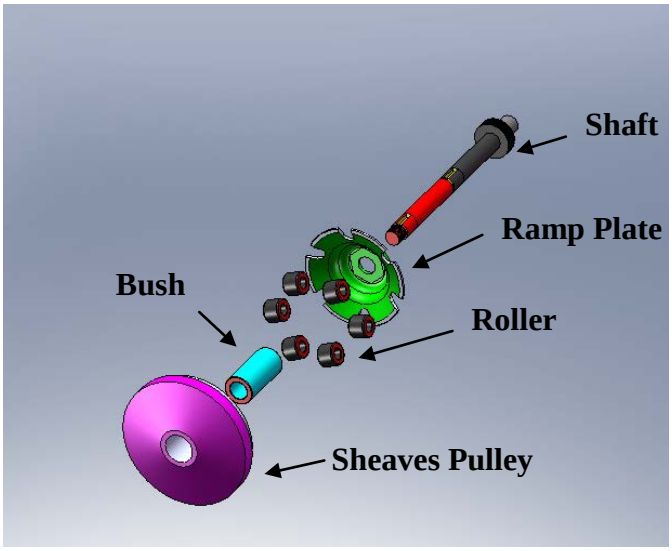


Figure 3.2: Exploded drawing of Design 1

Ram plate also important in this in this design which is to support roller and as a house of the roller. When the shaft rotates faster, the centrifugal force is increase so that the roller will push of the ram plate and the pulley sheave to move toward the belt and the result is increasing its diameter.

3.7.2 Design 2

Second concept is show in Figure 3.3 where the control movement of sheaves pulley is control by hydraulic system.

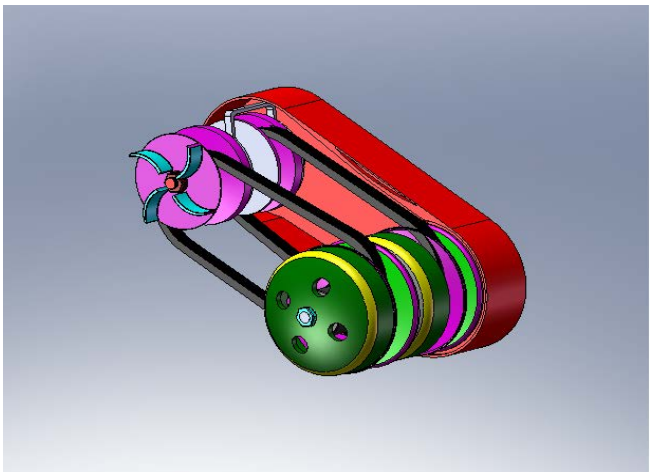
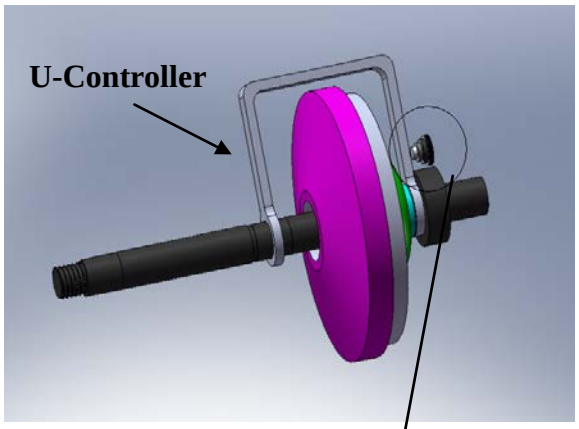
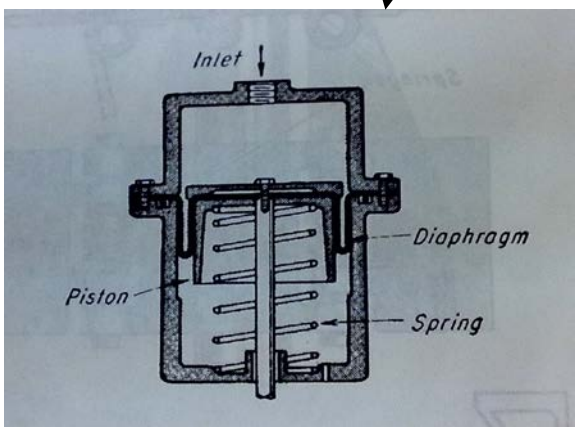


Figure 3.3: Complete Conceptual for Design 2

In design 2, this concept is a manual transmission where its control by hydraulic system. Hydraulic system is function when push the switch level which it's have 4 level means level 1 is gear 1 and same like the another level. This design is modified to make it similar function with manual transmission. System hydraulic is the main function to control the amount of fluid inlet into the linear actuator (Figure 3.4) then converts fluid pressure into a linear stroke to push the U-Controller where the sheaves pulley also connects to them. This mechanism is a concept to control the gear ratio of this CVT system.



3.4 (a)



3.4 (b)

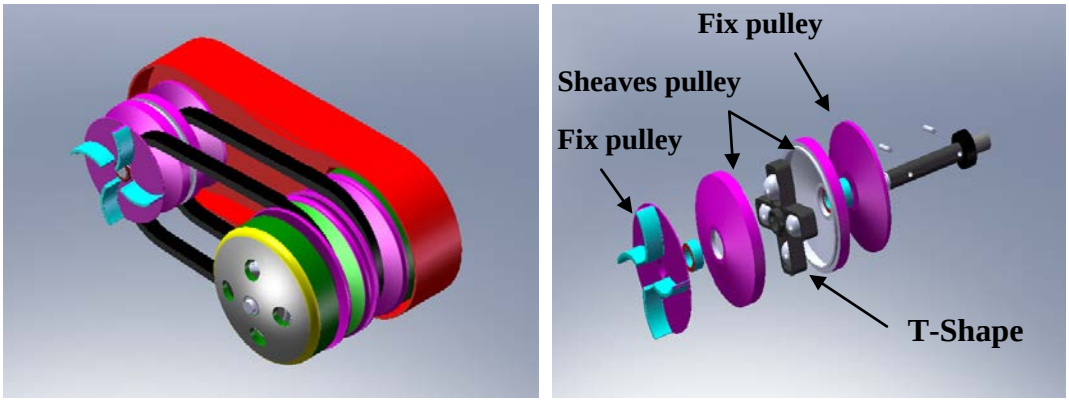
Figure3.4: Design Concept Control by Linear Actuator

From Figure 3.4 (a) U-Controller is sliding during the shaft is rotating. This component located at the groove inside of the top cover to prevent from rotating when

engine is running. Actuator pushes the U-controller to actuate the 2 sheave pulley move to increase the radius of belt.

3.7.3 Design 3

The third concept design is show in figure 3.5 where its controller mounted at the middle of the system (Figure 3.5a).



3.5 (a) 3.5 (b)

Figure 3.5: Conceptual for Design 3

For the design 3, the controller of the gear ratio is control by round ball is located in T-Shape. The ball roller is move up and down caused by centrifugal force by mean of 4 ball roller which pushes the pulley sheave to change the ratio. This concept is same like pulley is control by roller. This concept is similar to the first design where pulley is controlled by roller but the first design must have the ramp plate to locate of the roller then the design three controls by ball roller which located in T-shape.

3.8 COMPARISON BETWEEN THREE DESIGNS

3.8.1 Comparison of Three Designs

Table 3.1: Comparison between Three Concept Designs

Conceptual design	Description	Advantages	Disadvantages
Design 1	- Normal movement. - Control by 12 roller	- Easy to make - That function is same like 1 belt system - Cost more cheapest	- Not exactly efficient control by roller - Complicated design
Design 2	- Pulley control by actuator. - Actuator control by fluid - Manual usage - Have a key to select gear level	- Good feeling handling. - Simple design than design 1	- Looks complicated at their controller - Difficult to put actuator to the CVT
Design 3	- Control by 8 ball roller - Have a housing (T-Shape) for ball roller	- Strong structure due to it controller movement - Lighter than other - Reduce space - less material use - easy to fabricate .	- same like current CVT transmission system

3.8.2 Selection Based on Design Requirement

Table 3.2: Design Requirement Selection

Conceptual Design	Properties				
	Fabrication WF=25	**Costing** WF=30	**Maintenance** WF=25	**reliability** WF=20	**Total Score**
Design 1	15	15	20	15	65
Design 2	10	10	5	10	35
Design 3	20	25	20	15	80

* WF=Weight Factor

Table 3.1 show the different between the three proposed concept design before select the best design and Table 3.2 show the different of design requirement before make a best selection design. From the table 3.1 and 3.2 the third design show much better compare to other. Costing, maintenance fabrication and reliability is the main factor on the selection design. Costing related to manufacturer to make a mass production and maintenance is related to user choose the best motorcycle.

3.9 ANALYSIS OF PULLEY MOVEMENT AND FORCE ANALYSIS

3.9.1 Displacement of the Moveable Pulley

The minumum drive pulley diameter is 35mm and this value increase until 95mm during the CVT working. So the movement pulley have to move between two position. This distance is function of the belt angle α. The following skecthes show the belt and the two pulley sheaves, and we have to find a relation between the mobile sheave displacement and the belt displacement

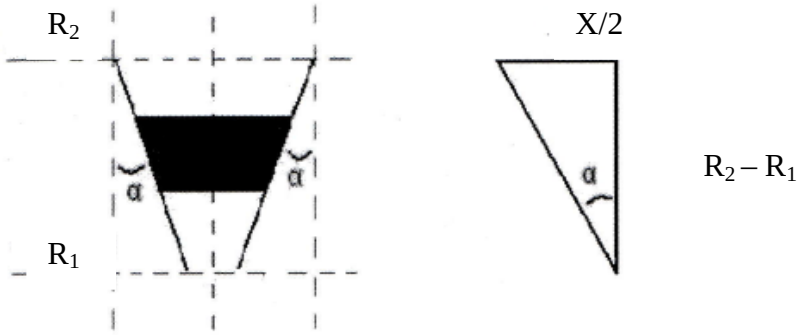


Figure 3.6: Angle between Two Sheaves

R_1: represents the minimal radius of the pulley

R_2: represent the maximal radius

X : the value of the axial displacement between the two sheaves.

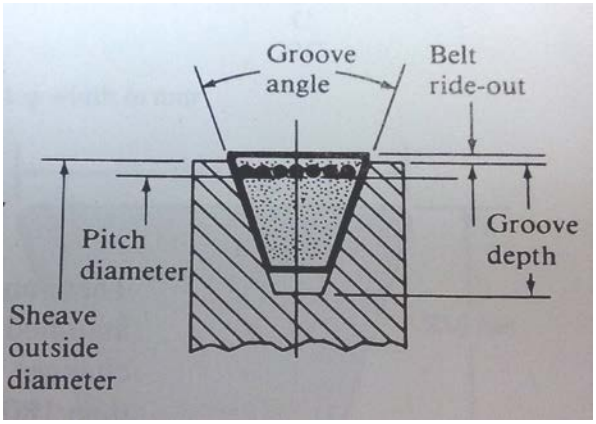


Figure 3.7: Belt geometry

Source: Robert L. Mott

We study just one side of the belt (figure 3.7) because the system is symmetrical and so we use a value of X/2 for the displacement between the two sheaves. Hence, we can write:

$$Tan\ \alpha = \frac{\frac{x}{2}}{R2-R1} = \frac{x}{2\,x\,(R2-R1)} \qquad (3.0)$$

So,

$$x = 2\ x\ (R_2 - R_1)\ x\ tan\alpha \qquad (3.1)$$

displacement of pulley in underdrive to overdrive :

$$x = 2 \text{ x } (42.5 - 17.5) \text{ x } tan14^0 = 14.9\text{mm}$$

From the equation 3.1 the value of maximum displacement of pulley is 12.8mm in situation underdrive to overdrive.

3.9.2 Torque Measure on Shaft

Torque is a measure of how much force acting on a shaft when its rotating. The shaft rotates about an axis, which we will call the pivot point, and will label 'O'. We will call the force 'F'. The distance from the pivot point to the point where the force acts is called the moment arm, and is denoted by 'r'. Note that this distance, 'r', is also a vector, and points from the axis of rotation to the point where the force acts.

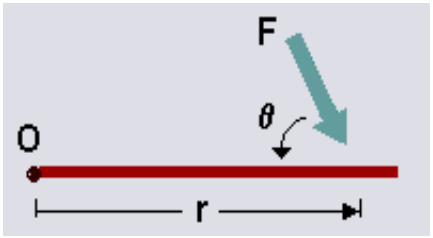


Figure 3.8: Definition of Force Applied
Source: David H. Myszka

Torque is defined as

$$\tau = \mathbf{r} \text{ x } \mathbf{F} = \mathbf{r\ F\ sin(\theta)}. \qquad (3.2)$$

When, r=22mm and F = 477N (from equation 3.2 so, τ)

τ = 22mm *x* 477N sin 90
= 10.5Nm

Another equation to calculate the amount of torque in shafts. Calculate by using power and revolution per unit (RPM):

Power = P = 11kw

Angular velocity = ω = 43982rad/sec

$$\tau = P/\omega \quad (3.3)$$

$$= 11000/43982$$

$$= 25Nm$$

3.9.3 V Belt Drive Equation

The pulley, with a circumferential groove carrying the belt, is called a sheave. The size of a sheave is indicated by its pitch diameter, slightly smaller than the outside diameter of the sheave. The speed ratio between the driving and the driven sheaves is inversely proportional to the ratio of the sheave pitch diameters. Thus the linear speed of the pitch line of both sheaves is the same and equal to the belt speed, vb. Then,

$$v_b = R_1\omega_1 = R_2\omega_2 \quad (3.4)$$

But R1 = D1 / 2 and R2 = D2/2.

Then,

$$v_b = D_2\omega_1/2 = D_2\omega_2/2 \quad (3.5)$$

The angular velocity ratio is

$$\frac{\omega 1}{\omega 2} = \frac{D2}{D2} \quad (3.6)$$

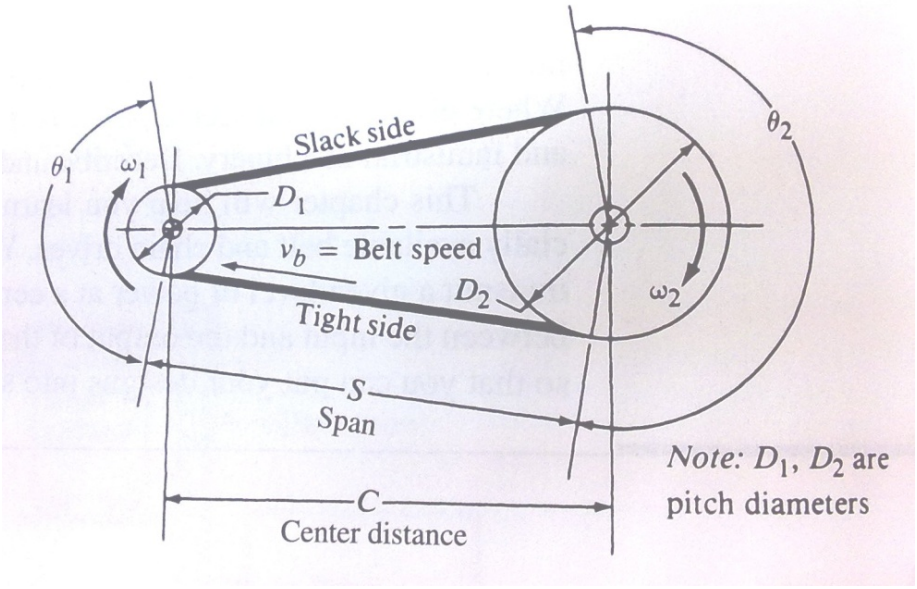


Figure 3.9: Basic Belt Drive Geometry

Source: Machine Element in Mechanical Design

The relationships between pitch length, L, center distance, C, and the sheave diameter are

$$L = 2C + 1.57(D_2 + D_1) + \frac{(D_2 + D_1)^2}{4C} \qquad (3.7)$$

By using equation (3.7), the variable diameter of D_2 was found as shown in Table (3.3). From the table show that the changing of ratio diameter pulley where the value of C = center is used in constant 230mm. Other constant variable value of L = 760mm length. The value of D1 is shown that the diameter of front pulley in different value. Conclusion from the table, the figure 3.10 is shown that the diameter of D_2 is proportional with D_1. The line D1 is beginning with low diameter and increasing to 110mm of diameter with difference ratio. The line D2 is increasing the diameter vs. ratio from 60 mm to 136mm. When the D1 is increase, it given the effect of value at D2. When value of D_1 is higher, the D_2 is decreasing. At the velocity ratio is 1, means that the diameter of front and rear pulley is similar approximately 85.43mm where the under drive situation is low than 1 of velocity ratio.

Table 3.3: Parameter of Pulley

D_1 (mm) front pulley	D2(mm) Rear pulley	C(mm) Center	L (mm) Length	Ratio D_2/D_1
35	135.9	230	760	3.9
40	130.6	230	760	3.3
45	125.9	230	760	2.8
50	120.9	230	760	2.4
65	115.7	230	760	1.8
70	110.7	230	760	1.6
75	105.9	230	760	1.4
85	85.51	230	760	1.1
90	80.9	230	760	0.9
95	75.9	230	760	0.8

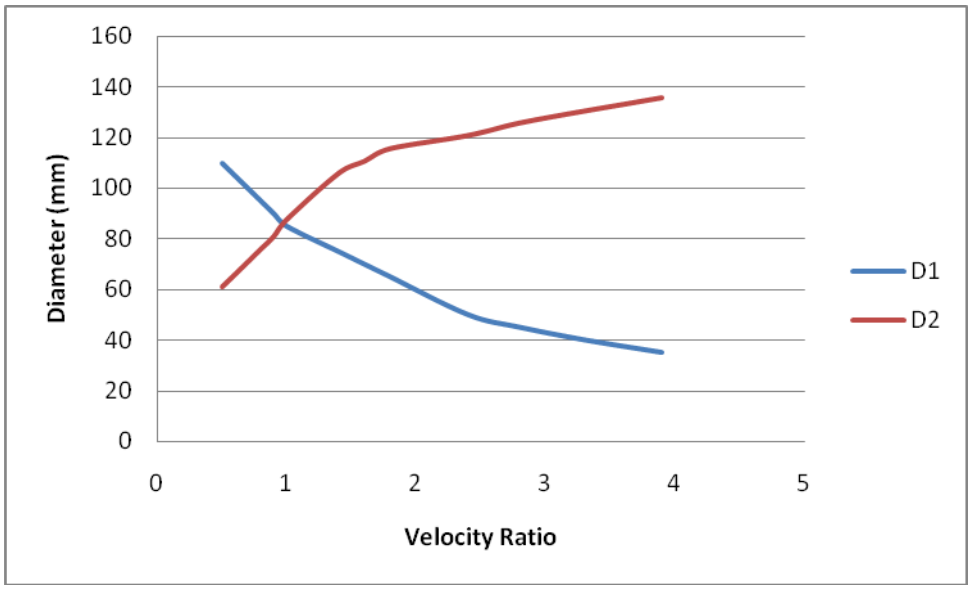


Figure 3.10: Graph Diameter Vs Velocity Ratio

3.9.4 The contributors to the stress in the belt are:

i. The tensile force in the belt, maximum on the tight side of the belt.
ii. The bending of the belt around the sheaves, maximum as the tight side of the belt bends around the smaller sheave
iii. Centrifugal forces created as the belt moves around the sheaves.\The maximum total stress occurs where the belt enters the smaller sheave and the bending stress is a major part. Thus there are recommended minimum sheave diameters for standard belts. Using smaller sheaves drastically reduces belt life.The design value of the ratio of the tight side tension to the slack side tension is 5.0 for V-belt drives. The actual value may range as high as 10.0.

3.9.5 Center Distance

The distance from the center that the v-belt contacts the pulley is determined by the distance between them, the further apart they are, the lower the belt rides and the smaller the pitch radius. In CVT system, center distance is fixing with variable ratio of pulley. Provision for increasing the center distance must be made to permit the initial tensioning of the drive and to take up for belt stretch. The nominal range of the center distances should be

$$D_2 < C < 3(D_2 + D_1) \tag{3.8}$$

Hence, can write:

$$142<C < 3(142 + 106)$$

$$\mathbf{142<C< 248}$$

So, the center distance of 230mm is use in table 3.3 is locate in a range between 142-248 and this center is reasonable to propose in this project.

3.10 V BELT SHEAVES

The general appearance of the V-belt drive system looks similar to the chain drive system. But there is one important difference: Both sides of the V-belt are in tension, as indicated in figure below.

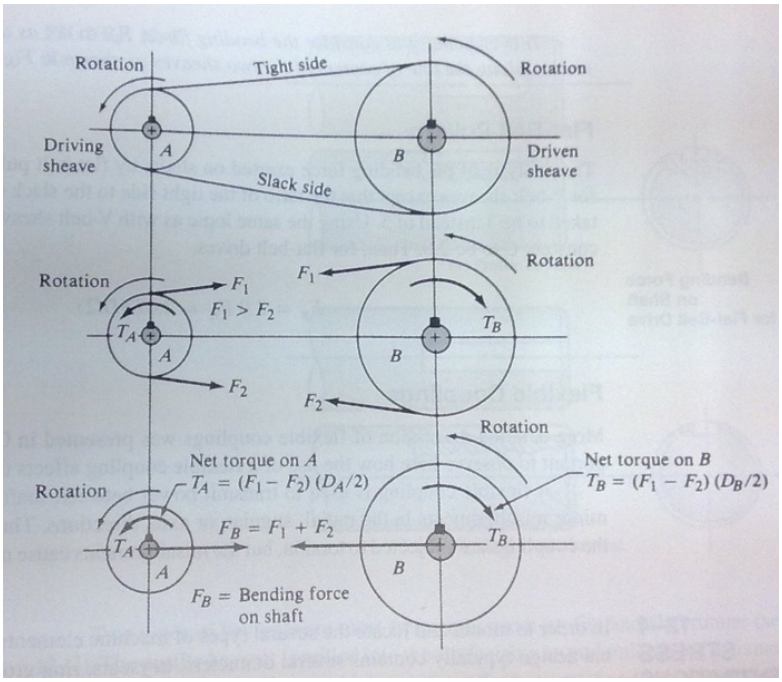


Figure 3.11: Forces on Belts or Pulley

Source: Machine Element in Mechanical Design, Robert L. Mott

The tight side tension, F_1, is greater than the "slack side" tension, F_2, and thus there is a net driving force on the sheaves equal to

$$F_N = F_1 - F_2 \tag{3.9}$$

The magnitude of the net driving force can be computed from the torque transmitted:

$$F_N = T/(D/2) \tag{3.10}$$

The bending force on the shaft carrying the sheave is dependent on the sum, F1 + F2 = FB. To be more precise, the component of F1 and F2 parallel to the line of centers of

the two sprockets should be used. But unless the two sprockets are radically different in diameter, little error will result from

$$F_B = F_1 + F_2 \tag{3.11}$$

To determine the bending force, F_B, an equation involving the two forces F_1 and F_2 is needed. This is provided by assuming a ratio of the tight side tension to the slack side tension. For V-belt drives, the ratio is normally taken to be

$$F_1/F_2 = 5 \tag{3.12}$$

It is convenient to derive a relationship between FN and FB of the form

$$F_B = CF_N \tag{3.13}$$

Where C = constant to be determined

$$C = \frac{F_B}{F_N} = \frac{F_1 + F_2}{F_1 - F_2} \tag{3.14}$$

From ratio equation 3.17, $F_1 = 5F_2$, then

$$C = \frac{F_1 + F_2}{F_1 - F_2} = \frac{5F_2 + F_2}{5F_2 - F_2} = \frac{6F_2}{4F_2} = 1.5$$

Bending force on shaft for V-belt drive

$$F_B = 1.5\ F_N = 1.5T/\ (D/2)$$

So, the bending force of on the shaft is

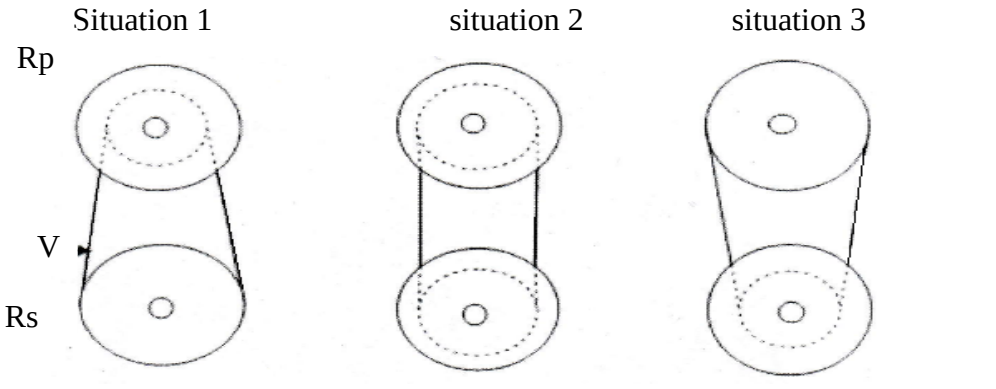
$$F_B = 1.5\ (\ 17.5N) / (110mm/2)$$

$$= \mathbf{477N}$$

From the derivation of equation3.15 and equation 3.16; can get the value of F_1=397.5 N

3.11 SITUATION IN CVT SYSTEM

$$\text{Transmission ratio, } = \frac{Rp}{Rs} \tag{3.15}$$



G < 1, under drive G = 1, 1;1 ratio G >1, overdrive

Situation 1:

Diameter 1 = 1.496in

Diameter 2 = 4.33in

Output rate = 7000rpm/15hp

From equation, the velocity ratio is determined by

$$VR = \frac{D2}{D1} \tag{3.16}$$

$$= \frac{4.33}{1.496}$$

$$= 2.89$$

The speed of the driven pulley can be determined from:

$$\omega_2 = \frac{D1\omega1}{D2} \tag{3.17}$$

$$= \frac{(1.496in)(7000rpm)}{4.33in}$$

$$= 2418.47rpm$$

Unit of the motor shaft speed are converted to radian per unit time

$$\omega_{1 = 7000rpm} \left(\frac{2\Pi rad}{1rev} \right) \quad (3.18)$$

$$= 43982.3 \text{ rad/min}$$

So we can find the belt speed for this situation

$$Vb = \left(\frac{D1}{2} \right) \omega_1 \quad (3.19)$$

$$= \frac{1.496in}{2} (43982.3rad/min)$$

$$= 32898.8 \text{ in/min}$$

Hence, the bending force for situation 1 determine by

$$F_B = 1.5 (17.6N) / (38mm/2)$$

$$= \mathbf{1390N}$$

Situation 2:

Diameter 1 = 3.36in

Diameter 2 = 3.36in

Output rate = 7000rpm/15hp

From equation, the velocity ratio is determined by

$$VR = \frac{D2}{D1}$$

$$= \frac{3.36}{3.36}$$

$$= 1.00$$

The speed of the driven pulley can be determined from:

$$\omega_2 = \frac{D1\omega1}{D2}$$

$$= \frac{(3.36in)(7000rpm)}{3.36}$$

$$= 7000.00 \text{ rpm}$$

Unit of the motor shaft speed are converted to radian per unit time

$$\omega_{1 = 7000\text{rpm}} \left(\frac{2\Pi rad}{1rev} \right)$$

$$=43982.3 \text{ rad/min}$$

So we can find the belt speed for this situation

$$Vb = \left(\frac{D1}{2}\right) \omega_1$$

$$= \frac{(3.36in)}{2} (43982.3\text{rad/min})$$

$$= 73890.3 \text{ in/min}$$

Hence, the bending force for situation 2 determine by

$$F_B = 1.5\ (\ 17.6N) / (85mm/2)$$

$$= \mathbf{620N}$$

Situation 3:

Diameter 1 = 3.74in

Diameter 2 = 2.99in

Output rate = 7000rpm/15hp

From equation, the velocity ratio is determined by

$$VR = \frac{D2}{D1}$$

$$= \frac{2.99}{3.74}$$

$$= 0.79$$

The speed of the driven pulley can be determined from:

$$\omega_2 = \frac{D1\omega1}{D2}$$

$$= \frac{(3.74in)(7000rpm)}{2.99}$$

$$= 8755.85rpm$$

Unit of the motor shaft speed are converted to radian per unit time

$$\omega_{1 = 7000rpm} \left(\frac{2\Pi rad}{1rev} \right)$$

$$=43982.3 \text{ rad/min}$$

So we can find the belt speed for this situation

$$Vb = (\frac{D1}{2})\ \omega_1$$

$$= \frac{3.74}{2}(43982.3\text{rad/min})$$

$$= 82246.901\text{in/min}$$

Simplified Tabular Form for 3 Situations in CVT System

Hence, the bending force for situation 2 determine by

$$F_B = 1.5\ (\ 17.6\text{N}) / (95\text{mm}/2)$$

$$= \mathbf{555N}$$

Table3.4: Parameter of Three Situations

parameter	Situation 1 (G < 1)	Situation 2 (G = 1)	Situation 3 (G > 1)
Rotation per minute	7000	7000	7000
Diameter 1(in)	1.496	3.36	3.15
Diameter 2(in)	4.33	3.36	1.97

Table 3.5: Value for Three Situations

Type	Situation 1 (G < 1)	Situation 2 (G = 1)	Situation 3 (G > 1)
Velocity ratio	2.89	1	0.625
Speed ω_2 (rpm)	2418.7	7000	8756
Belt speed (in/min)	32898.8	73890.3	82247
Bending force(N)	1390	620	555

3.12 CAE ANALYSIS

In this analysis, software of ALGOR Version 16 is use to predict how strong material chosen and how tough the model can be loaded. Stress Analysis with Linear Material Models is test here to improved contact along edges and improved calculation of out-of-plane shear effects for thick composite elements.

Main part like input shaft will be analysis. Data show the maximum force that structure can hold before it collapses and break. The force will attach on the shaft with first load is 1390N. At front, which is inner shaft joint to engine source will be fixed. Maximum bending force (F_B) due to belt tension based on table 3.3 is 1390N. Therefore for FEA analysis the load is assumed to be greater than 1390N as a safety factor.

Although this software cannot show how it broke, but it still can be determine by compare maximum stress and strain with tensile of materials used. This software will show the effect occur while receive more force by contrast of color. Figure 3.10 shows two forces applied at input shaft structure which is part of two system rubber belt function.

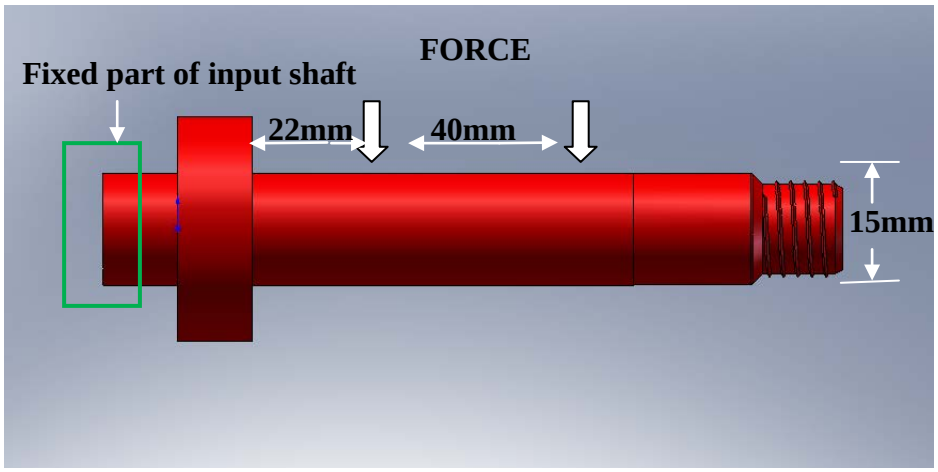


Figure 3.12: Main Structure Analysis Applying Force and Fixed Part

3.12.1 Meshing Setting

From the 3D drawing, file saves into IGES format. This format is use when analysis using ALGOR. For the design scenario, single analysis and static stress with linear materials model is choose. Figure 3.13 shows design scenario menu.

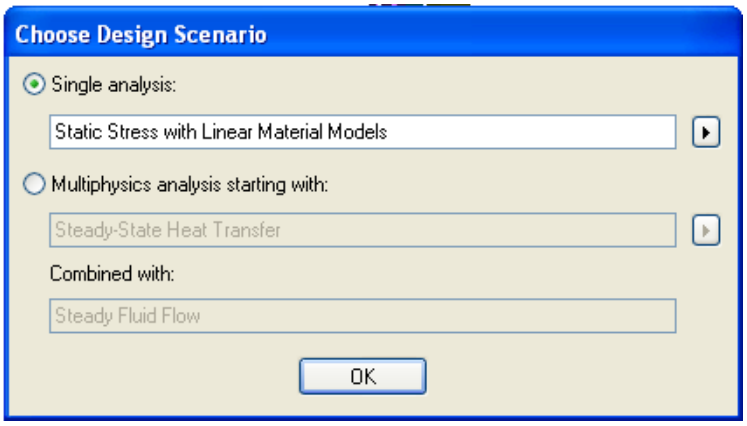


Figure 3.13: Design Scenario Menu

Figure 3.14 **is** model mesh setting. Analysis will do on surface structure and meshing size is 100%. Meshing type is solid and meshing size is middle between course and fine. Meshing level is important because it will influence the final result. Figure 3.15 shows meshing type. Figure 3.16 show meshing in progress.

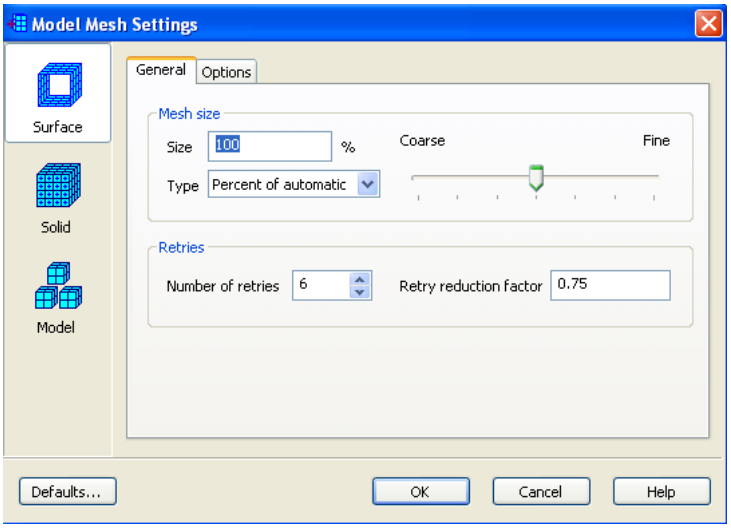


Figure 3.14: Model Mesh Setting

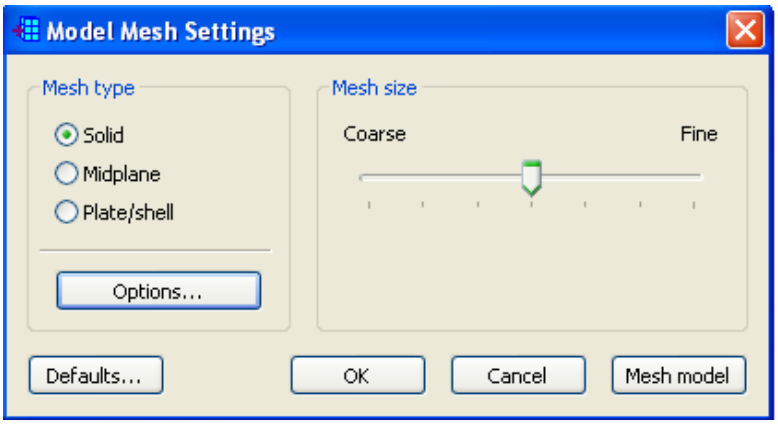


Figure 3.15: Meshing Type

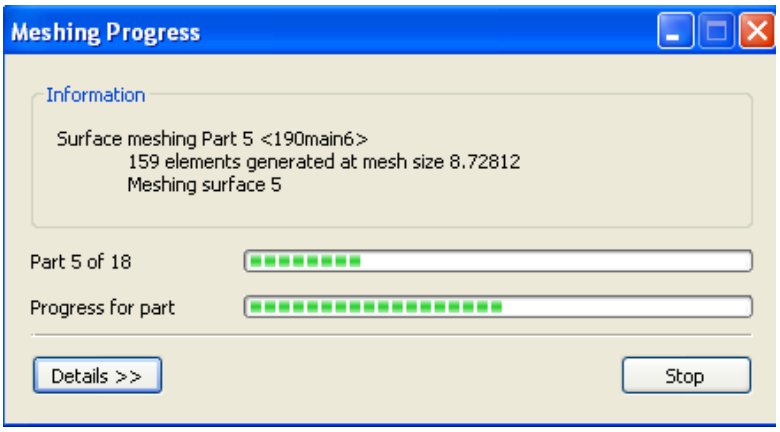


Figure 3.16: Meshing in Progress

After mashing process, this analysis will move to FEA editor. Here unit for analysis will be determined to standard imperials (SI) unit and change at length to be millimeter unit. In this FEA editor, material for analysis is steel AISI 4130, element type is brick and boundary condition setting will be set before proceed with analysis.

3.12.2 Boundary Condition Setting

Figure 3.17 show menu for boundary condition setting. Inner shaft part located is defined to be fixed from all direction force. Due to static part, no load applied, the inner area is assumed free from any force.

Figure 3.16 is nodal force setting. This is the part where load attach.. By selecting middle surface area of shaft, setting to the force applied with come from calculation of tension belt.

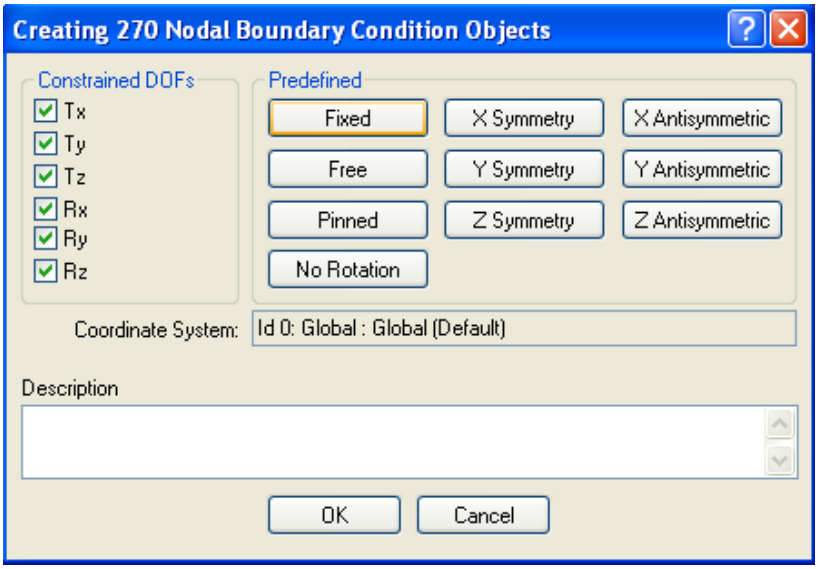


Figure 3.17: Menu for Boundary Condition Setting

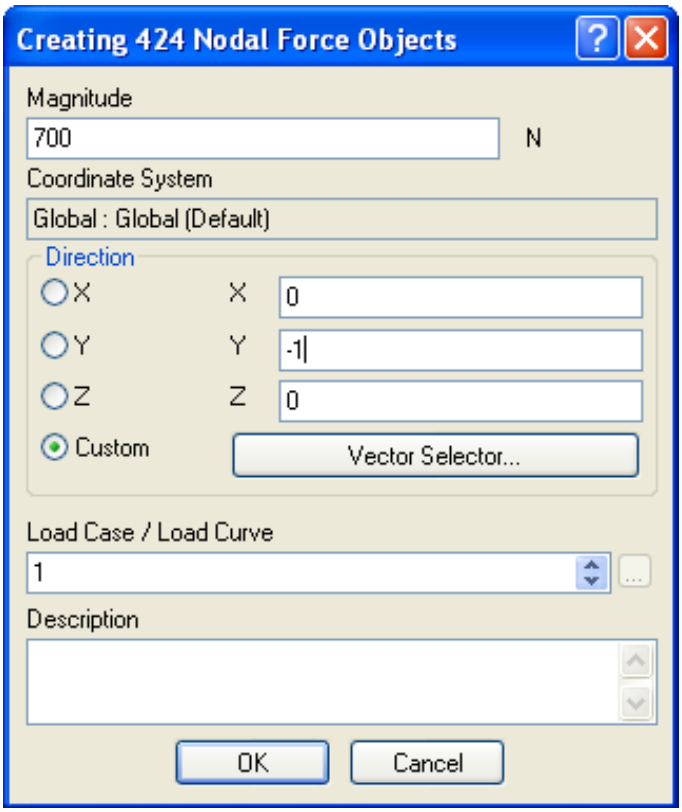


Figure 3.18: Nodal Force Setting

3.12.3 Materials Selection for Analysis

Materials to be used for analysis are takes from ALGOR library which is the main parameter should be considered to do analysis. Figure 3.19 shows the element types that already have in ALGOR library. For the shaft structure, steel AISI 4130 is chosen to do this analysis.

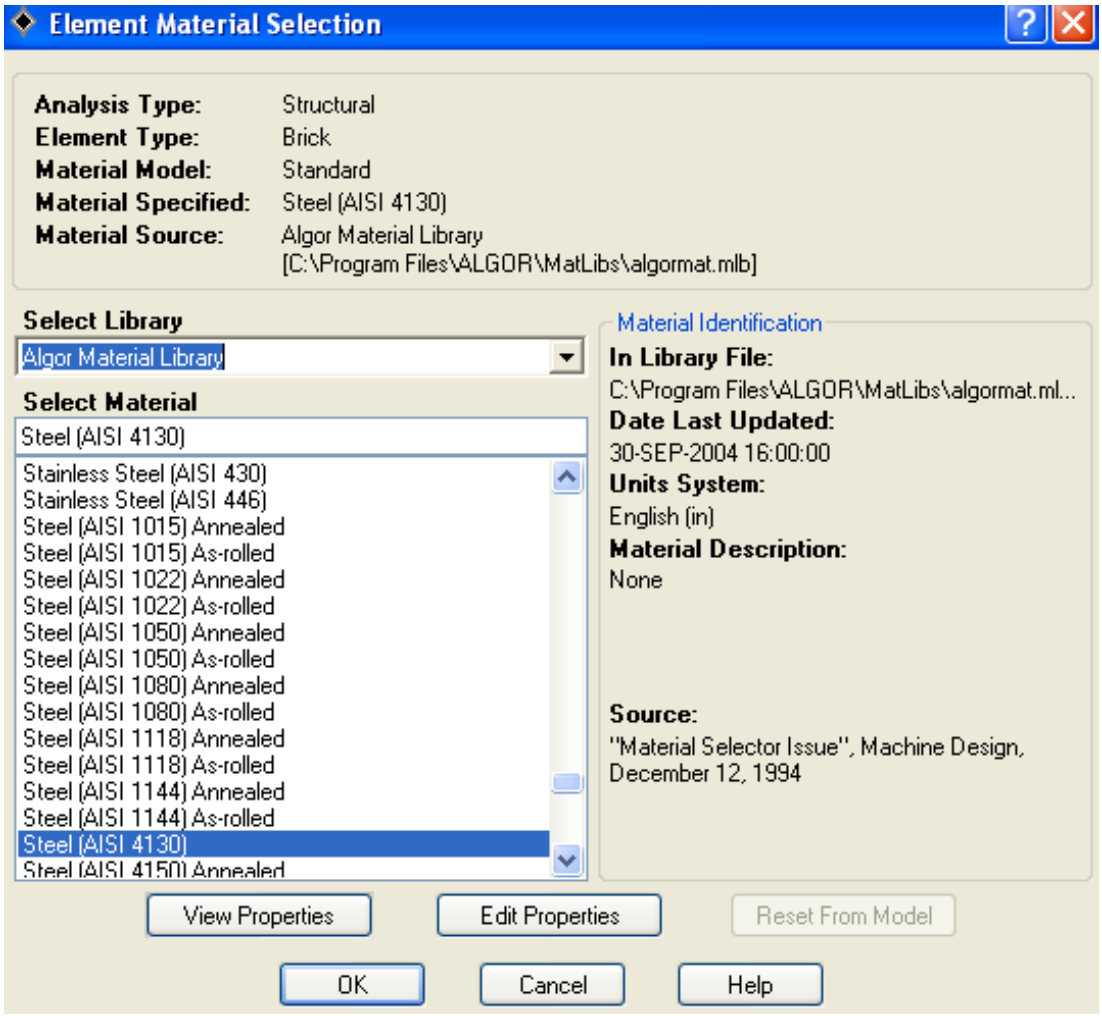


Figure 3.19: Material Selection from ALGOR Library

Source: *ALGOR selection materials librarY*

3.12.4 Analysis Process

After all parameter is set, analysis will perform to see how structure will looked after receive load. A Figure 3.20 shows the analysis perform icon and Figure 3.21 is analysis in process.

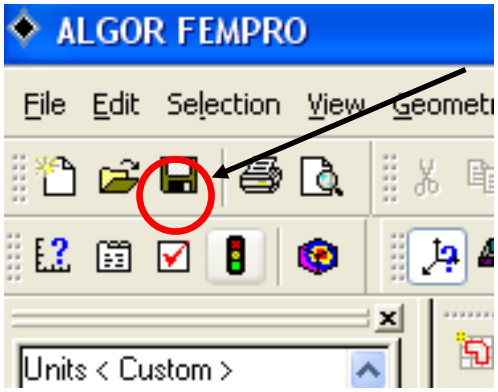


Figure 3.20: Analysis Perform Icon

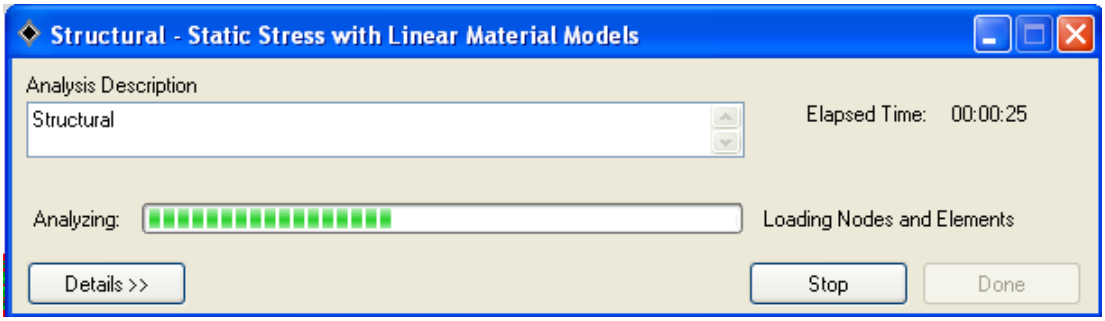


Figure 3.21: Analysis in Process

By using this CAE software, result of the analysis will show in contour of color. The dark color (blue) shows that the structure is safe, while the bright color (red) shows that the point will receive high force. Some modification should be done to reduce brightness color. In the result of Stress Analysis with Linear Material Models, it will show the value of minimum and maximum stress strain, displacement of structure and also deformation shape.

From the data tested, comparison to the real modulus elasticity characteristic of materials should be done. This is to compare maximum load structure can support before it break.

3.13 SUMMARY

These methodology are very important to follow one by one in time that planed. This is because to make sure that the project will be settled in time. If any problems appear at certain steps involved, the suitable solution must be taken quickly in case to prevent the other problems. Te good results will be have if all the methods completed by using true actions. From this methodology, will be presente detail information of concept design in the next chapter.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter covers in detail the selected conceptual design and the results that achieved by the analysis process that have been done. After doing a research about the existing system CVT and through the development process, the expected double rubber system now successful had been produced. The detail drawing and how the design does is work shown in this chapter.

4.2 SELECTED DESIGN

Figure 4.1 show the complete system of two rubber belt where is applied to CVT system of scooter with capacity engine above 200cc. The design is made by considering a couple of design consideration such as how to fabricated, costing to produce and reliability of the conceptual design. The figure 4.2 show the explode figure to show the all part is assemble in CVT system.

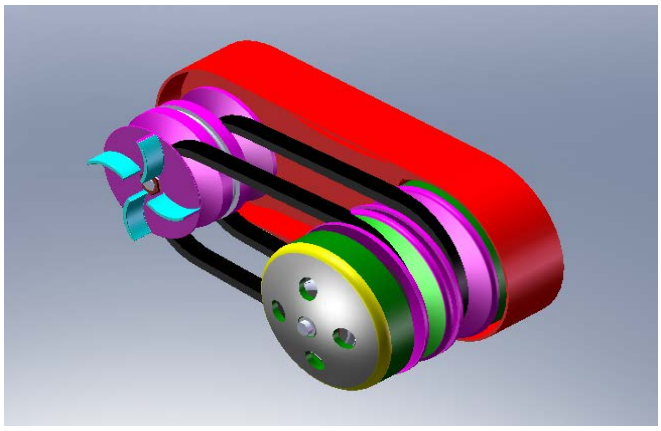


Figure 4.1: Complete Figure for Design 3

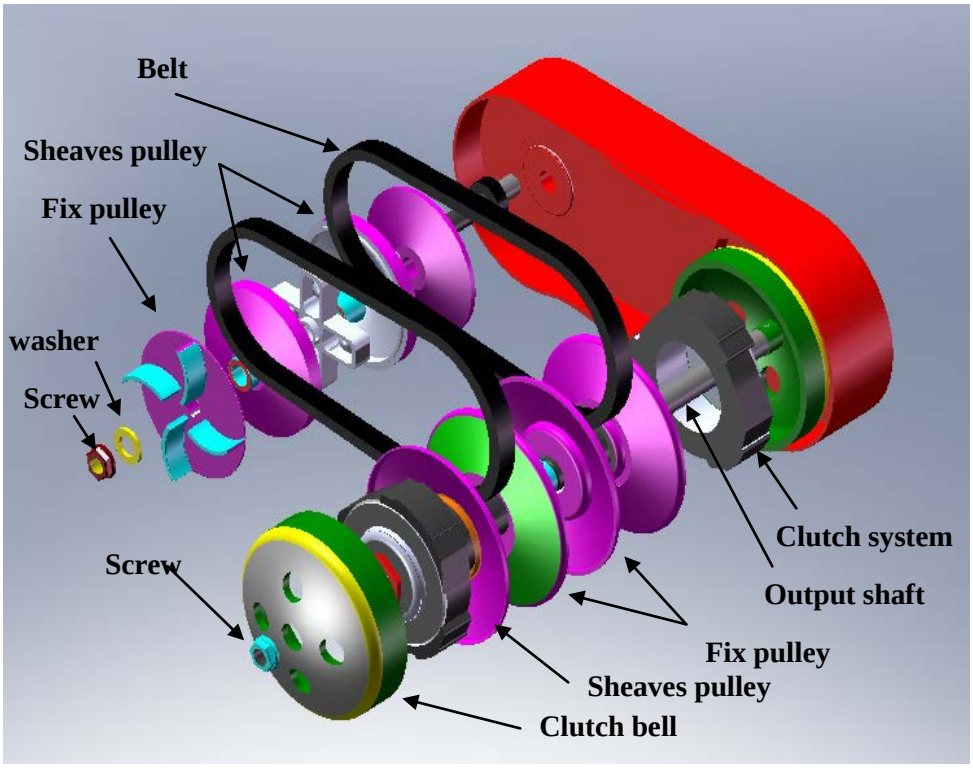


Figure 4.2: Explode View for Detail System Design 3

Source: Sketching from solidworks software

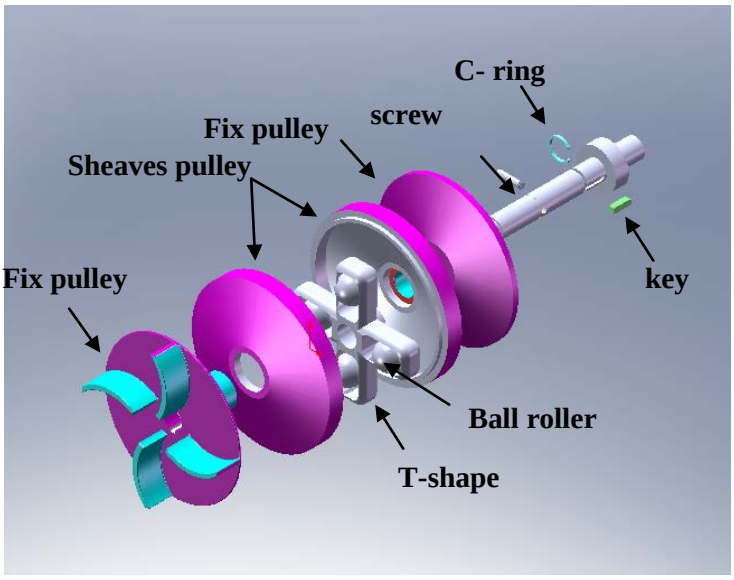


Figure 4.3: Explode View of Front System of Double Rubber Belt System

The front system of two rubber belt is used ball roller to change the gear ratio. The ball roller placed in a housing (T-shape) where it's rotated together with input shaft. The fix pulley (Figure 4.3) is place at both of outer shaft and the sheaves pulley is the located in middle.

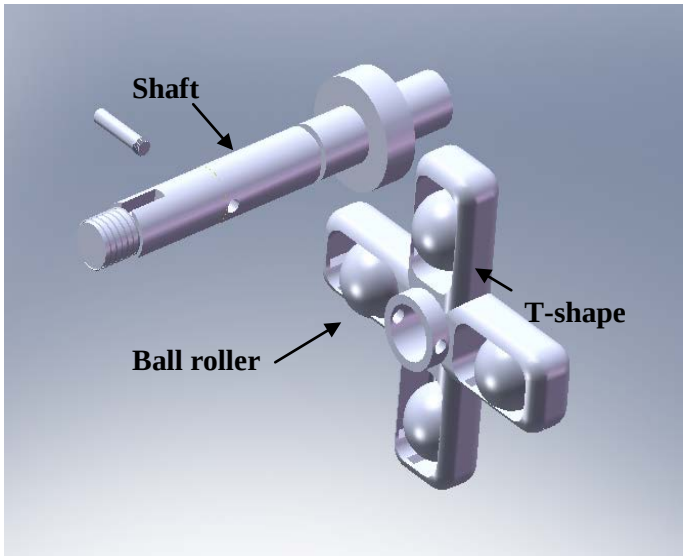


Figure 4 4: Placement of housing (T-shape) to the shaft and the position of ball roller in the housing.

The housing and the ball roller (Figure 4.4) is fixed in the middle of system and that tighten by screw. Ball roller is use to reduce the friction when contact with movement pulley.

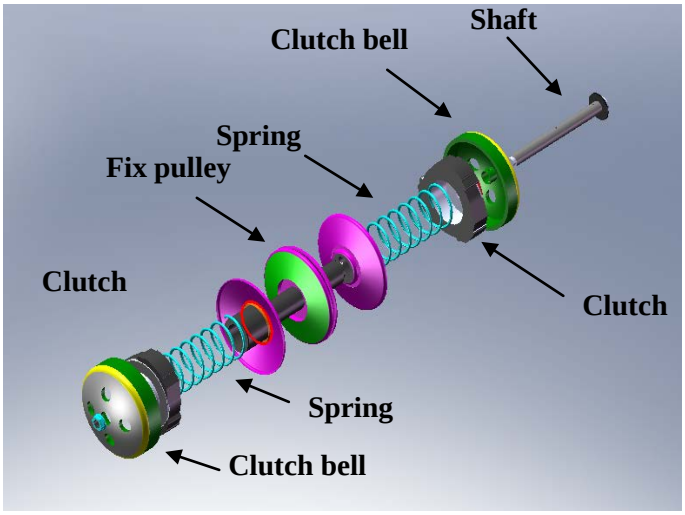


Figure 4.5: Explode View of Rear System of Double Rubber Belt System

The rear system (figure 4.5) is not to modified and only use the normal system by using the spring to maintain the belt tension and to create the force necessary to control the pulley halves. Thus, a CVT has an infinite number of gears that it can run through at any time, at any engine or vehicle speed.

4.3 MODIFICATION

In this project SolidWorks is used to model the design. The model is drawn according to actual dimension. In this stage the selected design is redesign to simplification. Some of the part is modified to make sure it's easy and time constraint to fabricate, assemble and reassemble. The dimension of the design is also conversion to metric SI from imperial value consider tolerance, clearance, and fit component and material selection.

4.3.1 Modified Components

`

The first stage, the housing of the roller is totally modified round shape to rectangle (figure 4.6**)**. This housing is fixing to the shaft with screw. For the original system is use 6 rollers and the new design is use 4 ball roller (figure 4.7) to changing the gear ratio. This housing is fixing to the shaft with screw. By using the ball roller, it can reduce the friction of contact with housing because ball roller is round shape compare to normal scooter is use 6 roller.

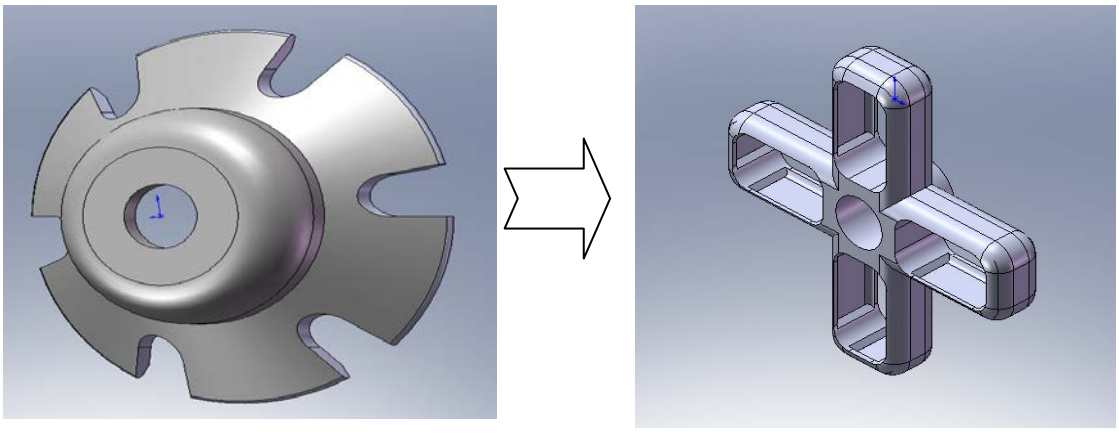


Figure 4.6: Comparison of Housing of Roller before and After Whole Modification

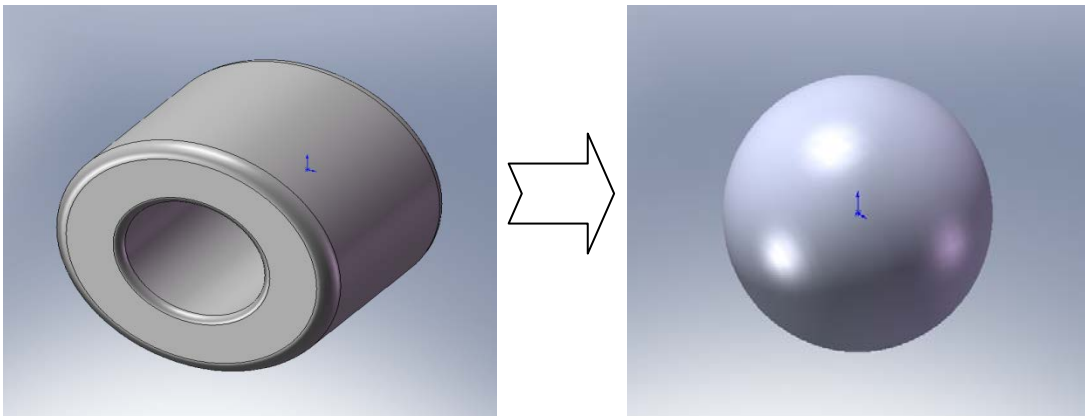


Figure 4.7: Comparison of Roller before and after Modification

Second stage, modification continues with shaft component. **Figure 4.8** shows the minimum modification but maximum of function. The hole of screw and the groove of pin is otter on the shaft to fix the pulley and T-shape in other that not slide when shaft is rotating. These parts modification essential to easy modification but functioned.

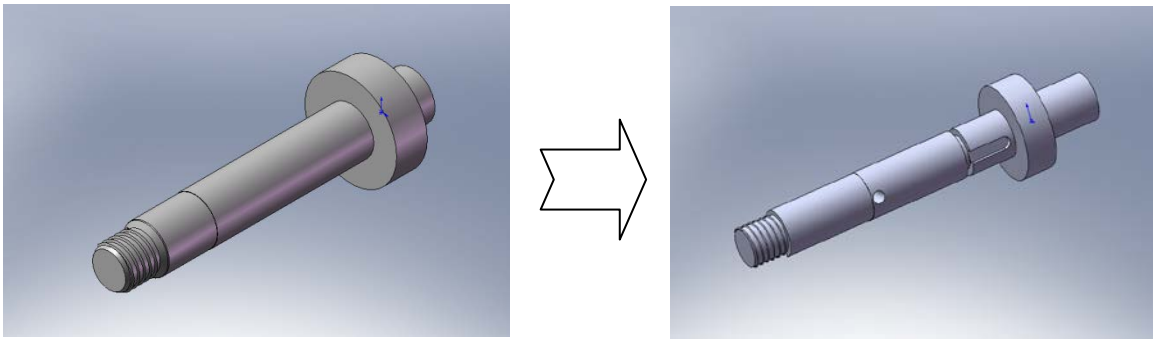


Figure 4.8: Comparison of Shaft Before and After Modification

For the movement pulley **(figure 4.9),** some modification will change. In the inside of the pulley, all the shape is trim. The normal system is use a roller and that roller must have a supported housing to make sure it not drop on it place. When the housing of the roller is modified, the shape of inside the pulley is not use. The ball roller only move up and down to changing the ratio only in housing (T-shape).

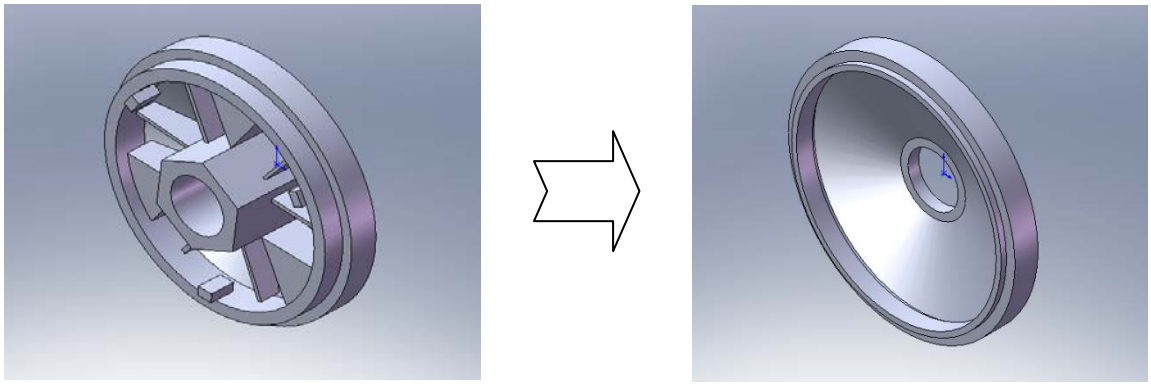


Figure 4.9: Comparison of Sheaves Pulley before and After Modification

The next modification is to design the fix pulley. It because, the normal fix pulley hard to assemble at the inside of system because have a more fin and this situation is not use in inside. To outcome this problem, fin is cut (Figure 4.10) and the pulley have a hole to fix from sliding. From this modification, the space of two rubber belt system is decrease

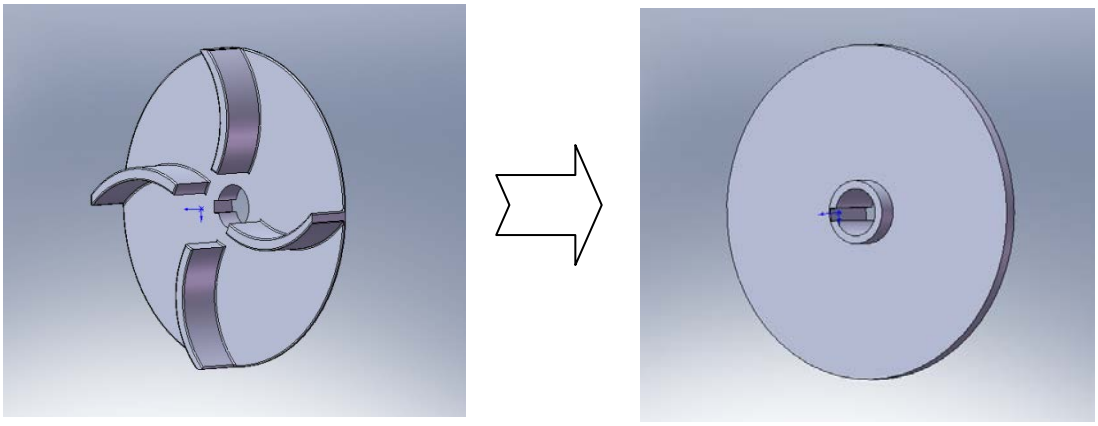


Figure 4.10: Comparison of Fix Pulley before and After Modification

4.4 DETAIL SKECHING AND FUNCTION

After get conceptual of design that wants to be creates, model from free sketching is drawn in engineering drawing and then transfer to 3D software, which is the model is come out like real model. Table 4.1 shows the result of sketching in Solidworks software.

Table 4.1: Parts of Sketching by Solidworks Software

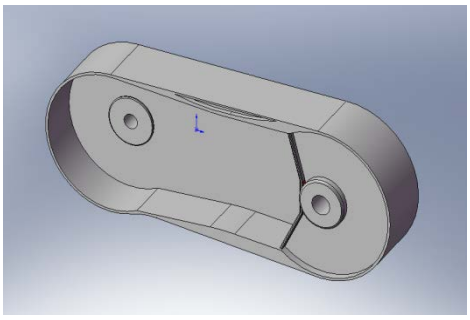
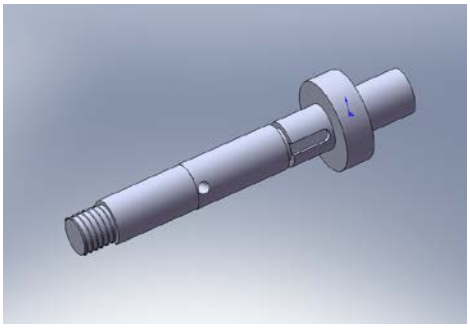
Part	Descriptions
1. Cover 	Place of CVT system running. Very hard to support the 2 rubber belt system. Made from Cast Iron
2. Input shaft 	Have an otter at the surface to fix the pulley and controller. Material used is steel.

Table 4.1: Continue

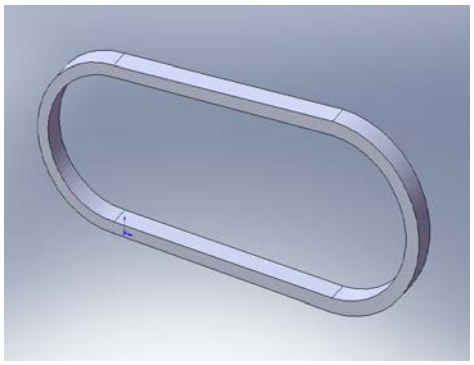
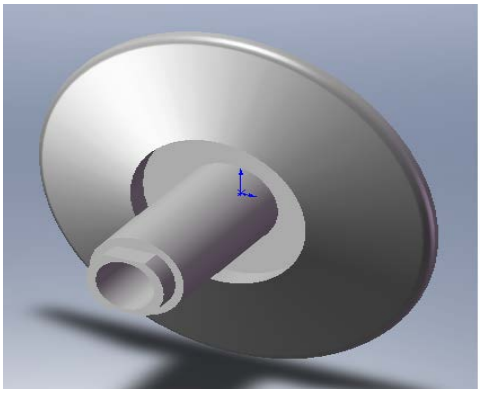
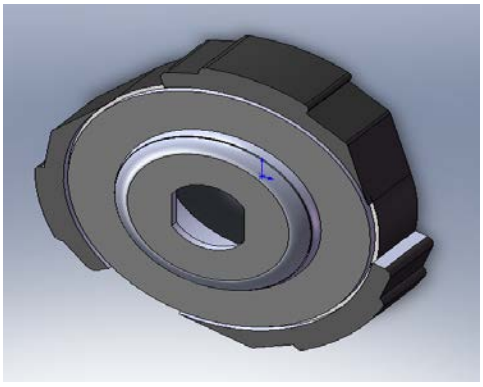
Part	Descriptions
3 belt	
	This V-belt drive is to transmit rotational motion and torque from pulley to another. Made of fabric and cord, usually cotton, rayon, or nylon, and impregnated with rubber.
4. Fix pulley	
	This part is rear fix pulley that support for the movement pulley. Made from standard material alloy.
5. Clutch	
	This part is the clutch in the rear pulley system. It can expand the diameter when get enough rotary motion.

Table 4.1: Continue

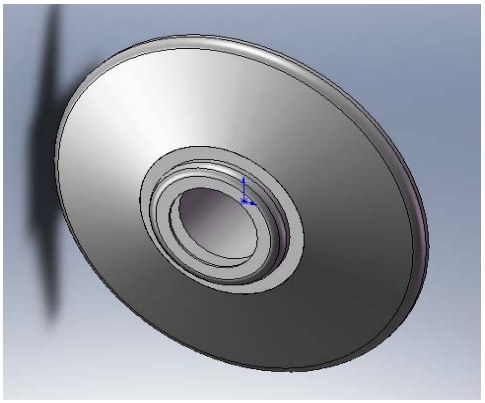
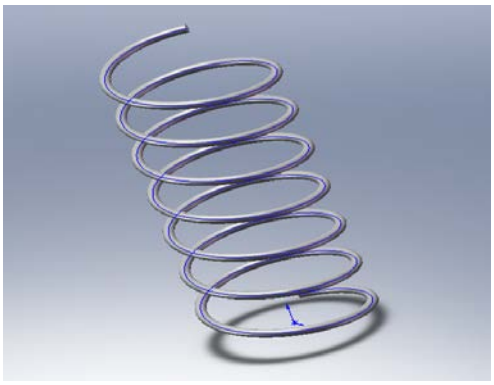
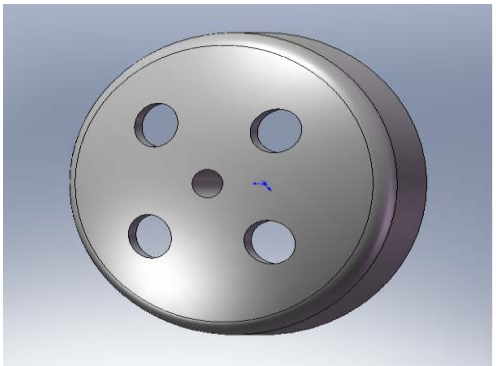
6. Pulley (move)	
	This part is front movement pulley controled by roller of their diameter. it important on control speed of scooter. Made from alloy.
7. Spring	
	This spring is controlling the movement of pulley for X-axis. This part also to maintain the belt is always tight.
8. Clutch bell	
	This function is to joint with clutch to rotate the tyre. This part is direct joint with shaft of tyre.

Table 4.1: Continue

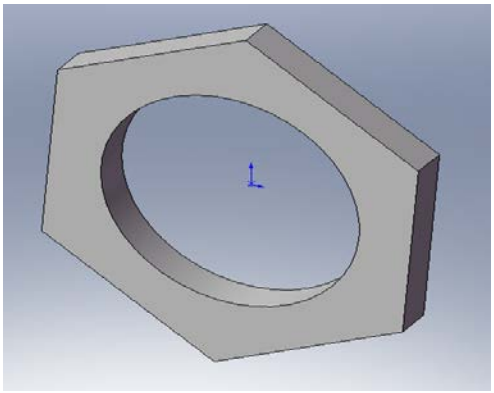
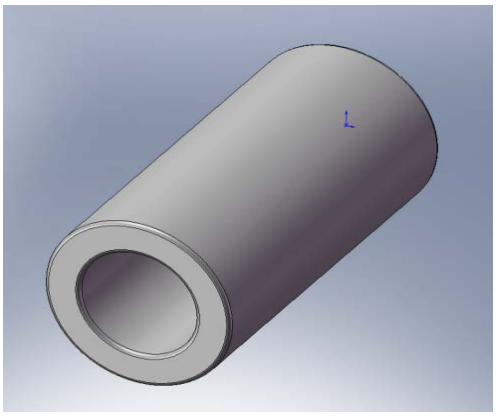
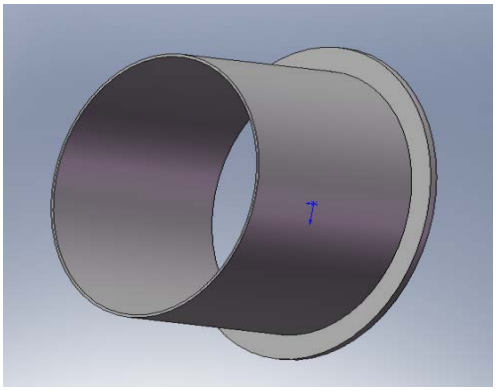
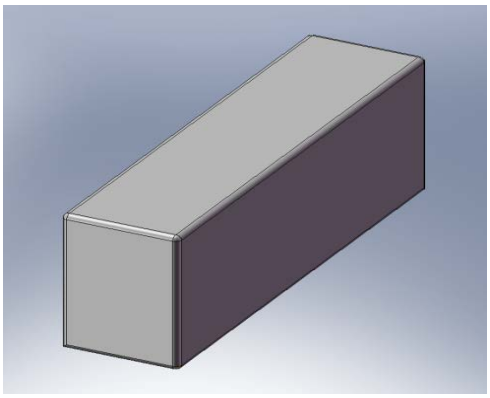
9. Big nut	
	This nut is to tighten the system clutch to shaft. Made from steel
10. bush	
	This bush is support the pulley to move on shaft. Made from brass.
11. Spring Holder	
	This part is to make sure spring is place correctly.

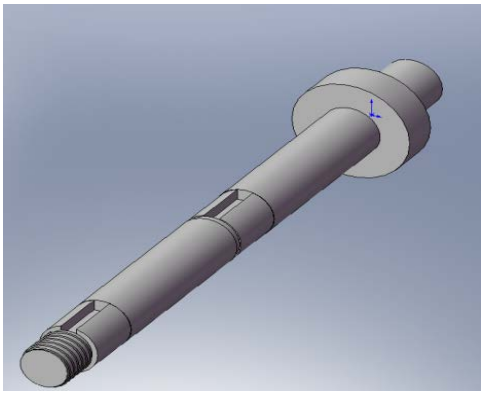
Table 4.1: Continue

12. Key



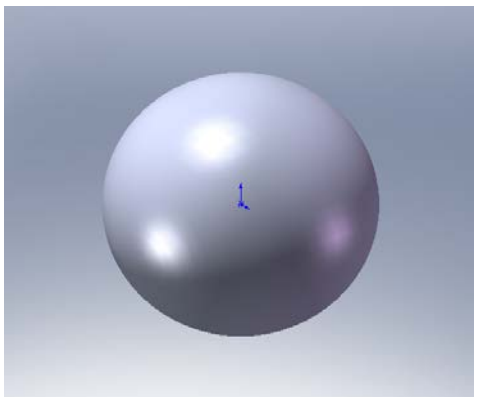
This key is to fix for rear pulley to the output shaft. This part is change of thread on the shaft.

13. Shaft



This rear shaft is support of two pairs of pulley system.
Material used from steel.

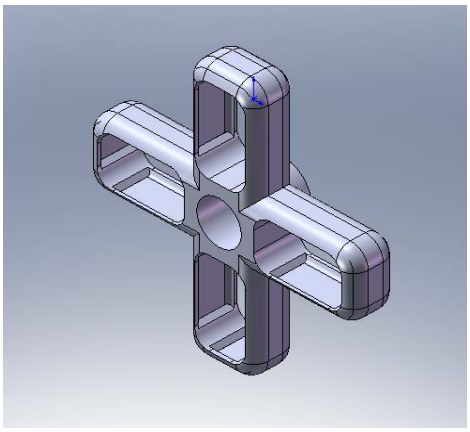
14. Roller



To control the front pulley to close and open by centrifugal force.
Made from cast alloy steel.
Weight of one = 30.58g
4 x 30.58 = 122.32g

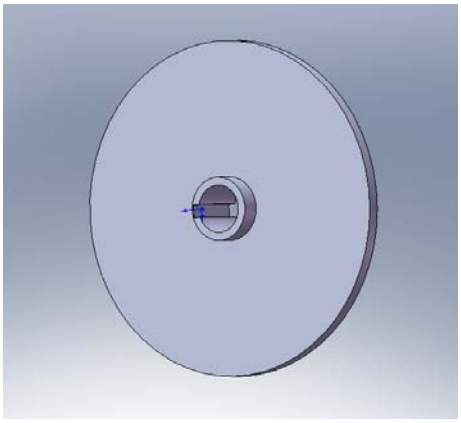
Table 4.1: Continue

15. T-shape (housing)



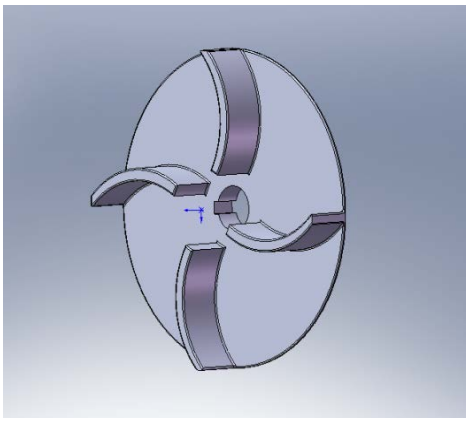
This part is the housing for the ball roller to control pulley movement.
Made from steel.

16. Fix pulley



This part is fix pulley is located at inner of the system.
Made from alloy.

17. Fix pulley



Front fix pulley but have a fin to reduce temperature in casing.
Made from alloy.

4.5 STRUCTURE ANALYSIS

From the part sketches in 3D software, analysis can be done by using CAE software. In this project, software that use to analysis structure is ALGOR version 16. This CAE analysis will focus on the shaft which is to support two pulley systems on that.

In design criteria, analysis is very important process that must be done before create something. It is one way to measure how strong enough model can be create and what is the best material should be use to make the design that can achieve the objective. Nowadays, there are many software can be used to do the test and analysis on model that want fabricate. It will reduce manufacturing cost, can define materials should use and save time.

4.5.1 Main Structure Analysis

By using this CAE software, result of the analysis will show in contour of color. The dark color (blue) shows that the structure is safe, while the bright color (red) shows that the point will receive high stress and first part to be break. Some modification should be done to reduce brightness color. In the result of Stress Analysis with Linear Material Models, it will show the value of minimum and maximum stress strain, displacement of structure and also deformation shape. Figure 4.11 show the result of stress after the analysis.

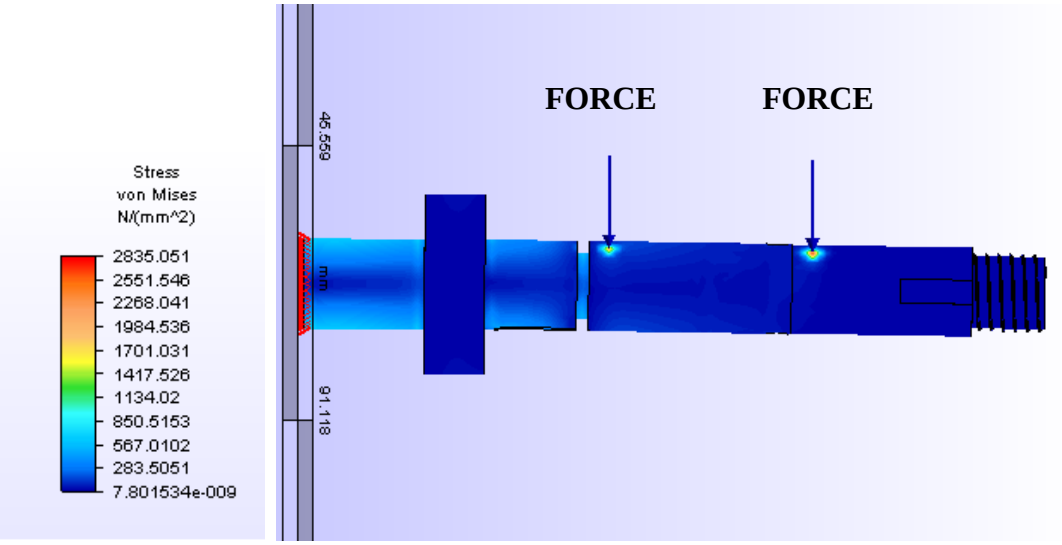


Figure 4.11: Von Mises Result of Stress analysis on Shaft Structure

Source: ALGOR software

From the analysis, can been see that part of shaft to connect to the engine base will receive high stress and strain. This point is first location of creaking or failure will occur. Failure at that point occurs because of design structure. Different of color more occur at force applied to shaft. This high value occurs because that point is the force is applied when the system is running. Dark (blue) color shows that the structure is strong and this usually occur at force given and receive minimize stress. Table 4.2 shows the displacement and testing force is applied.

Table 4.2: Result of Stress on Shaft

Load (N)	**Stress N/(mm^2)**	
	min	**max**
1300	5.60189e-009	2195.69
1400	5.90365e-009	2354.86
1500	6.58788e-009	2576.98
1600	6.92312e-009	2709.08
1700	7.80153e-009	2835.05

4.6 SUMMARY

To preliminary design and development of double rubber belt system, many aspects must be considered. For instant, the mechanism use, the result of calculation, material selection, pulley design, shaft design and others. All these criteria and aspects influent the data and the result in the research and development for this project. In other to come out with an effective mechanism in double rubber belt CVT, a research done to collect as much information about the existing implementation of CVT and the analysis have been done to make a suitable mechanism and also to improve the disadvantages of existing of CVT.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Based on the preliminary design and calculation, the double rubber belt system can deliver more torque compared to conventional system used. Research done indicate that the design is indeed plausible and can be applied in modern scooter 200cc engine and above after more extensive research.

The study on design, design requirement and selection of materials where by considering weight, strength and low cost, the third proposed design was selected. The shaft is proposed to be manufactured by steel and it has been analyzed using Algor. The result shows satisfy to support load 1300N due to belt tension.

A working prototype can be derived from the technical drawing available. The design can be use by the manufactured in the fabrication process. Some refinement and modification were done on the design to ensure all the components can be assembled correctly. As an overall conclusion, the objective designing the suitable double rubber belt CVT to apply to the scooter has been achieved.

5.2 RECOMMENDATION

This development still has to carry forward to improve accuracy of the result before continuing to the next phase. The selected design of the double rubber belt system can still be refined and there are spaces to improve it. Further work that are strongly recommended:

i. Optimized pulley ratios and belt dimension to overcome higher class engine. The various diameter and weight of the ball roller need to be tested to analyze it effect on displacement.
ii. Analytical of other component is also further study for improvement of selected design. The inclination of the pulley needs more analytical research to get the optimum result.
iii. To optimize engine load performance due to ratio change the pulley sheave movement can be controlled electronically or using advance controller.
iv. The centrifugal force which is currently used, can be improve using manual clutch or electronically clutch which is expansion of the clutch can be control according to the user need.

REFERENCES

[1] Fundamental of vehicle dynamics, Thomas D Gillespie, Society of Automotive Engineers. Inc,Third Edition,2005

[2] Shingle's Mechanical engineering design, Richard G.Budynas, Rochester Institute Of technology,Eight Edition,2008.

[3] Machine Element In mechanical design, Robert L. Mott, University Of Dayton,Fourth Edition,2004.

[4] **Kobayashi, D., Mabuchi, Y. and Katoh, Y**, "*A Study on the Torque Capacity of a Metal Pushing V-belt for CVTs*", SAE Paper 980822, 1998.

[5] **Fewkes, R., Gunsing, J., Sumiejski, J.L.**,"*Lubricant as a Construction Element in VDT Push-Belt CVT System*", SAE Paper 932848,1993.

[6] **Morgan, C., Fewkes, R., Marty, S.D.**,"*Development of a belt CVT fluid test procedure using the VT20/25E belt box for the DEX-CVT specification*", SAE Technical Paper Series 2002-01-2819, 2002.

[7] **Brandsma, A., van Lith, J., Hendriks, E.**, "*Push belt CVT developments for high power applications*",Proc. of CVT99, Eindhoven University ofTechnology 1999.

[8] **Nilabh Srivastava,Imtiaz Haque,** *A review on belt and chain continuously variable transmissions (CVT): Dynamics and control* [a]Department of Mechanical Engineering and Engineering Science, University of North Carolina at Charlotte

[9] **Gregor Čepon[a] and Miha Boltežar,** *Dynamics of a belt-drive system using a linear complementarity problem for the belt–pulley contact description,*

[a]University of Ljubljana, Faculty of Mechanical Engineering, Aškerčeva 6, 1000 Ljubljana, SI, Slovenia

[10] **M. Bullinger, F. Pfeiffer and H. Ulbrich**, "*Elastic modelling of bodies and contacts in continuous variable transmissions*", Multibody System Dynamics (2005)

[11] Ide, **T. and Tanaka, H.**, *Contact Force Distribution Between Pulley Sheave and Metal Pushing V-Belt*, Proceedings of CVT 2002 Congress, VDI-Bericht 1790, VDI-Verlag, Duesseldorf, 2002.

[12] **J. Kim, F.C. Park, Y. Park and M. Shizuo**, *"Design and analysis of a spherical continuously variable transmission"*, *ASME Journal of Mechanical Design* **124** (1) (2002)

[13] **R. Fuchs, Y. Hasuda and I. James**, "*Modeling simulation and validation for the control development of a full-toroidal IVT*", *Proceedings of CVT 2002 Congress* **vol. 1709**, VDI Berichte (2002)

[14] **P. Kanphet, P. Jirawattana and B. Direcksataporn**, *Optimal operation and control of a hydrostatic CVT powertrain*, SAE Transactions Journal of Passenger Cars: Mechanical Systems.

APPENDIX A

GANTT CHART

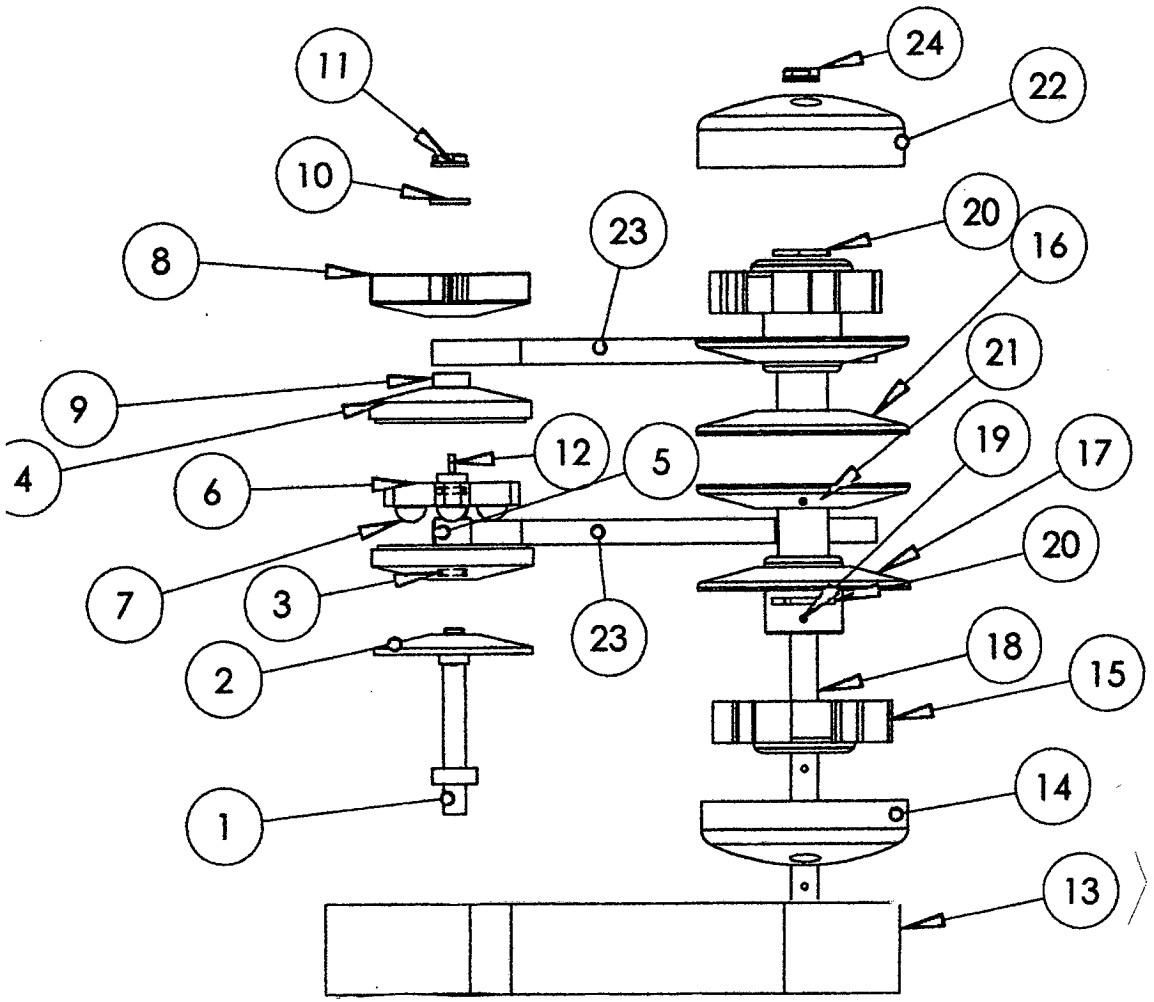
Gantt Chart

	Task No.	Event	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9	Wk 10	Wk 11	Wk 12	Wk 13	Wk 14	Wk 15	Wk 16
PSM 1	1	**LITERATURE REVIEW** - Introduction - Background - CVT at scooter - Type of CVT - Operation of CVT	4 WEEKS															
	2	**REVERSE ENGINEERING** - Solid Modeling - Modification - Technical Drawing					6 WEEKS											
	3	**DRAFT PROPORSAL PREPARATION**									6 WEEKS							
PSM 2	5	**DEFINE THE REAL GEOMETRY OF PULLY AND V BELT**	4 WEEKS															
	6	**DESIGN THE BEST SOLUTION**					4 WEEKS											
	7	**ANALYSIS THE COMPONENT USING FEA**									3 WEEKS							
	6	**DISCUSS** - **Discuss result**												3 WEEKS				
	8	**FINAL THESIS WRITING** - Documentation - Thesis Draft - Presentation preparation	16 WEEKS															

APPENDIX B1

DRAWING BLOCK

(FULLY ASSEMBLY)



ITEM NO	PART NAME	DRAWING NO.	QTY
1	INPUT SHAFT	S-10001	1
2	FIX PULLEY	F-10002	1
3	KEY FIX PULLEY	K-10003	1
4	MOVEMENT PULLEY	M-10004	2
5	BUSHING	B-10005	2
6	T-SHAPE	T-10006	1
7	BALL-ROLLER	R-10007	4
8	FIX PULLEY	F-10008	1
9	BUSHING	B-10009	1
10	WASHER	W-10010	1
11	NUT	N-10011	1
12	PIN	P-10012	1
13	BASE	B-10013	1
14	INNER CLUTCH BELL	C-10014	1
15	CLUTCH	C-10015	2
16	FIX PULLEY	F-10016	2
17	MOVEMENT PULLEY	M-10017	2
18	OUTPUT SHAFT	S-10018	1
19	KEY SHAFT	K-10019	3
20	CLUTCH NUT	N-10020	1
21	BUSH	B-10021	1
22	CLUTCH BELL	C-10022	1
23	BELT	B-10023	2
24	NUT	N-10024	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Fadzli		
CHK'D	Dr.Sugeng		
APPV'D			
MFG			
Q.A			

MATERIAL:

TITLE:

FULLY ASSEMBLY PULLEY

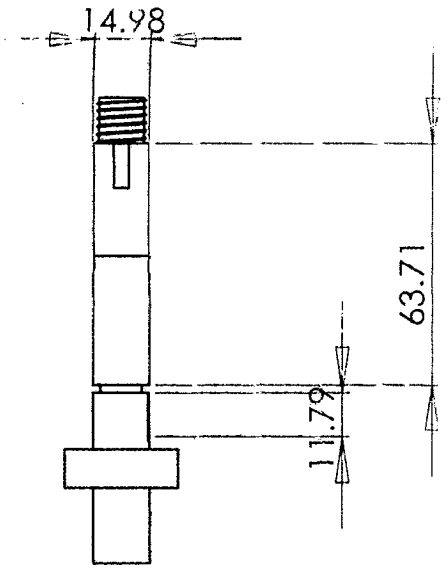
DWG NO. F-131006A

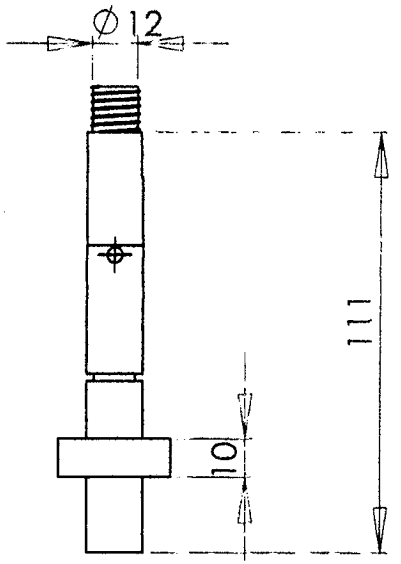
A4

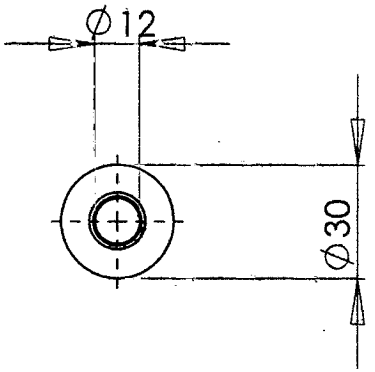
APPENDIX B2

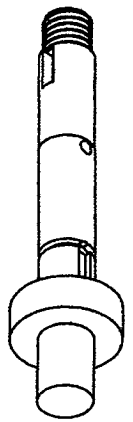
DRAWING BLOCK

(COMPONENT)









UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	fadzli		
CHK'D	Dr.Sugeng		
APPV'D			
MFG			
Q.A			

MATERIAL:

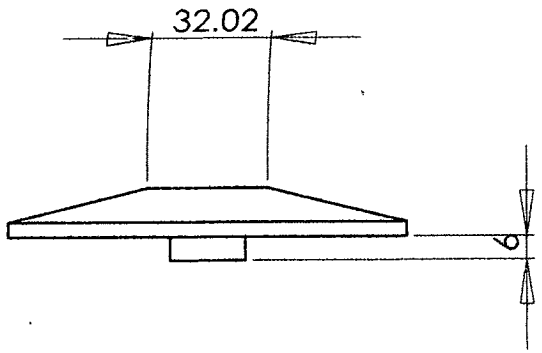
TITLE:

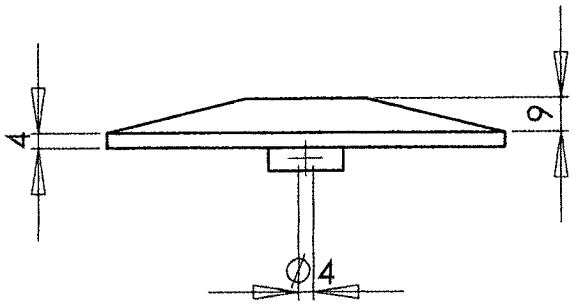
INPUT SHAFT

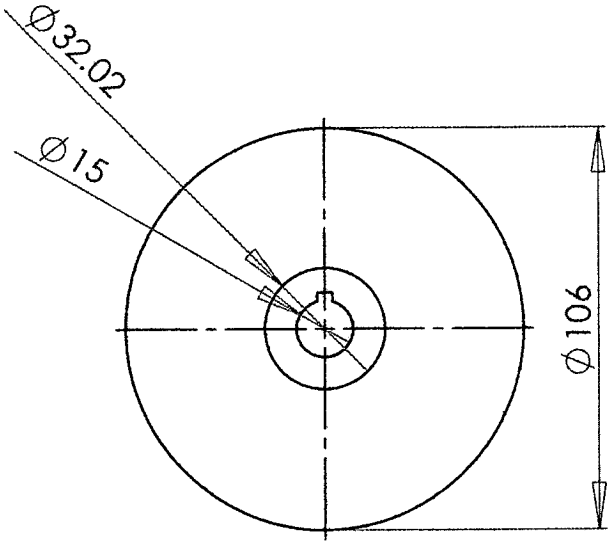
DWG NO.

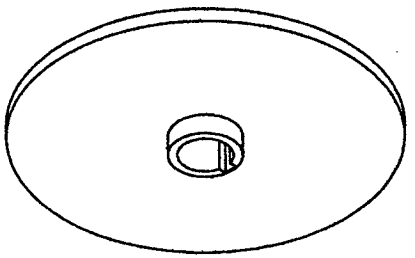
S-10001

A

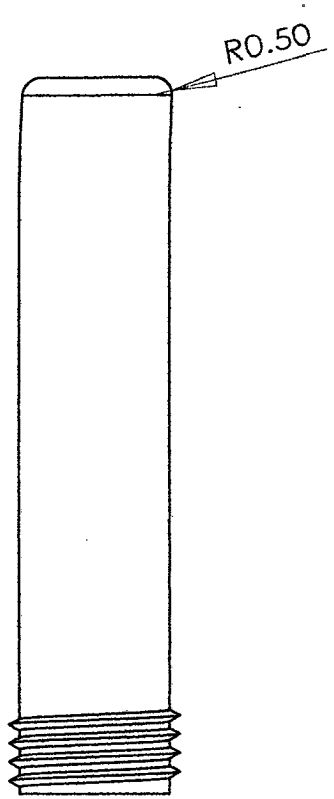


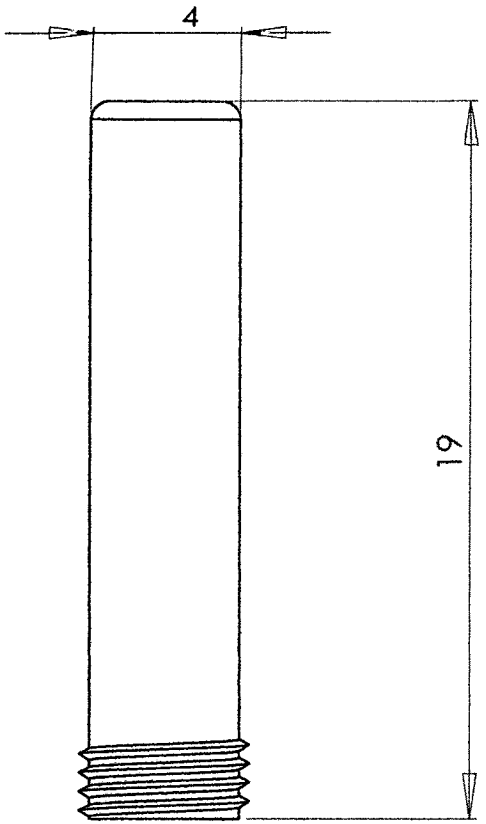


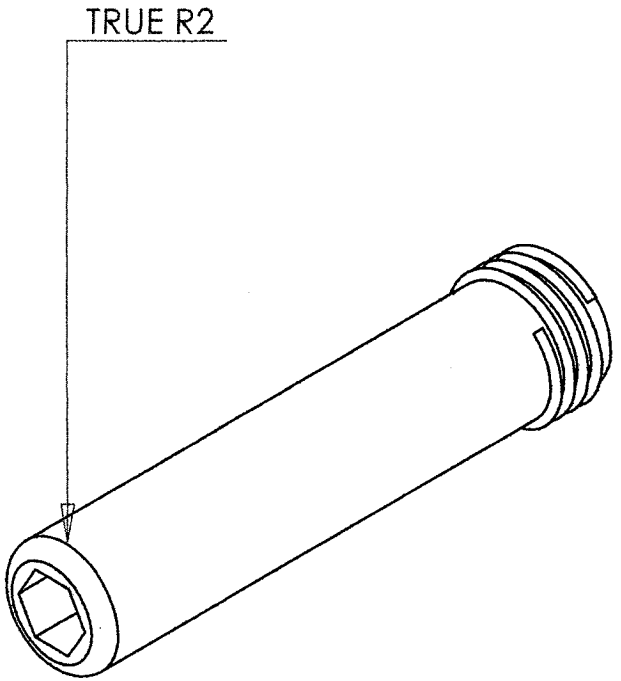


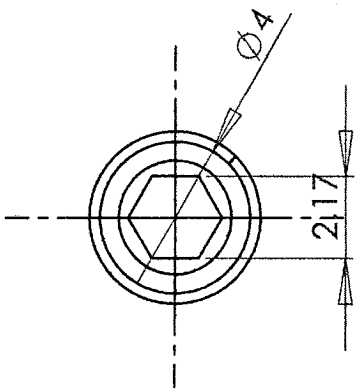


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN	Fadzli					FIX PULLEY	
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO. F-10002	A4

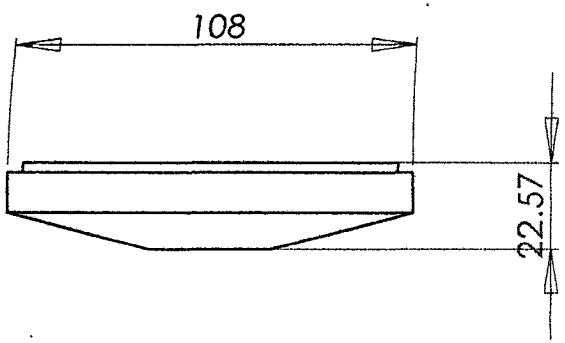


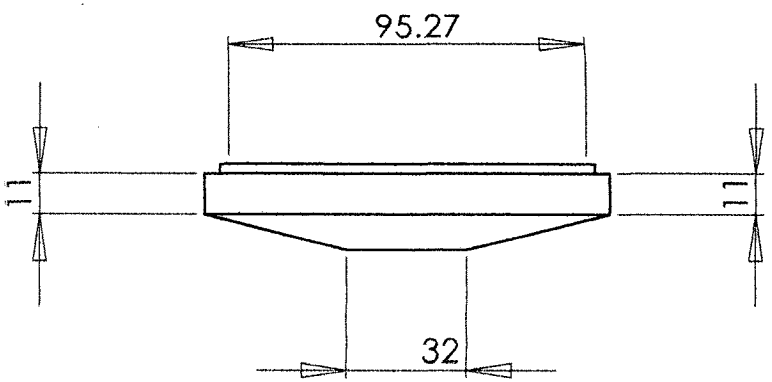


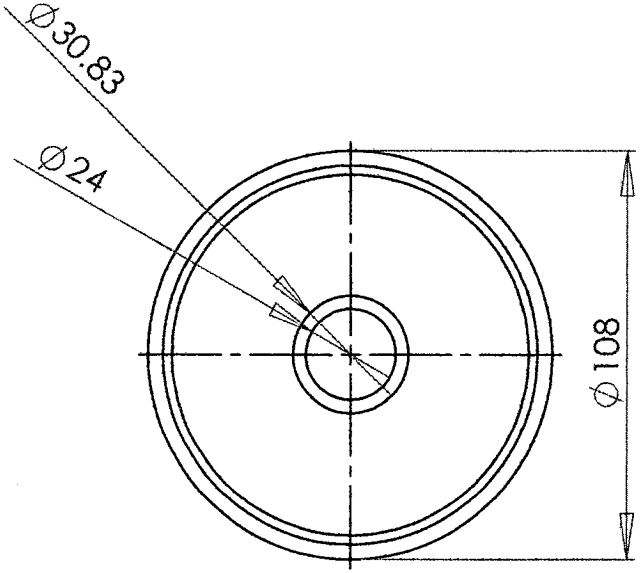


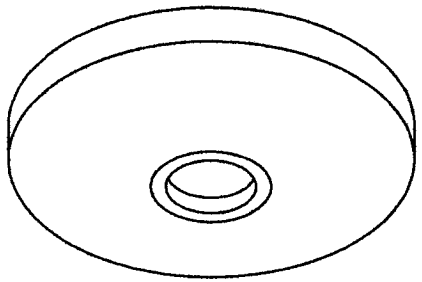


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: KEY FIX PULLEY
DRAWN	fadzli						
CHK'D	Dr.sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. K-10003 / A

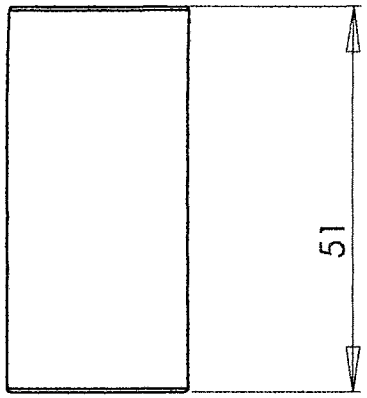


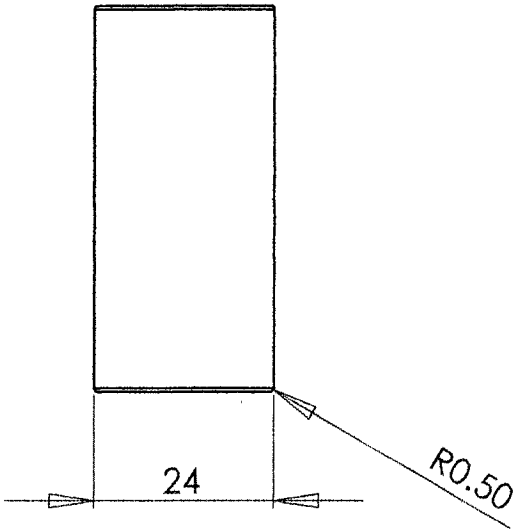


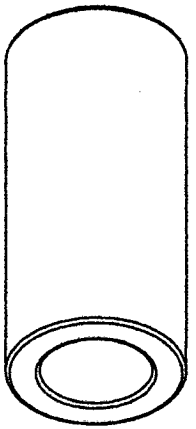


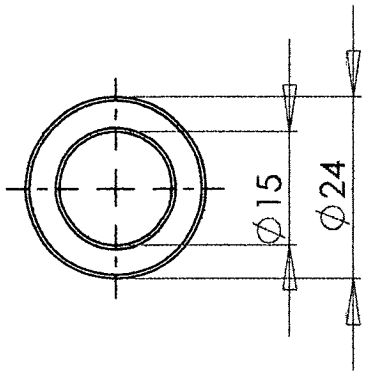


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE:
DRAWN	fadzli						MOVEMENT PULLEY
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. M-10004 / A4

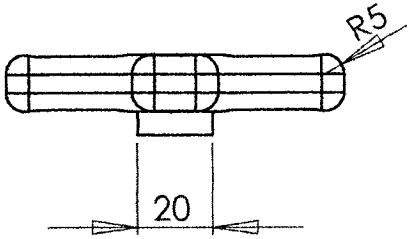


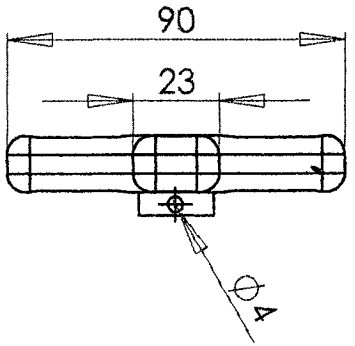


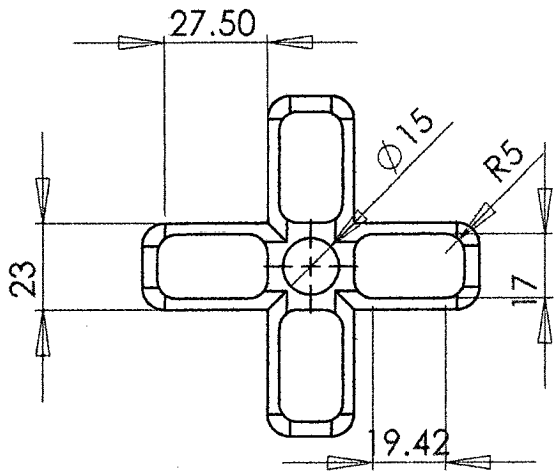


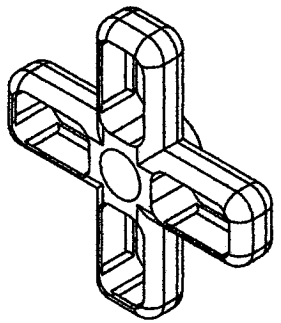


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: BUSHING
DRAWN	Fadzli						
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. B-10005 / A4

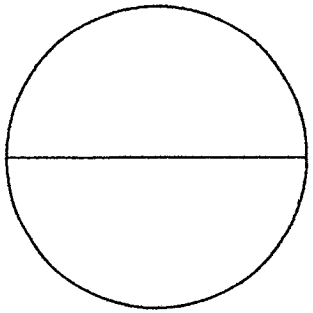


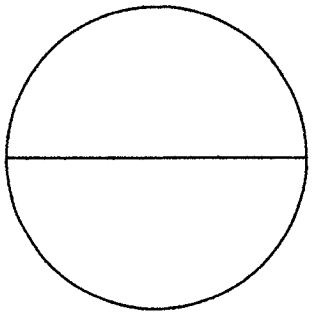


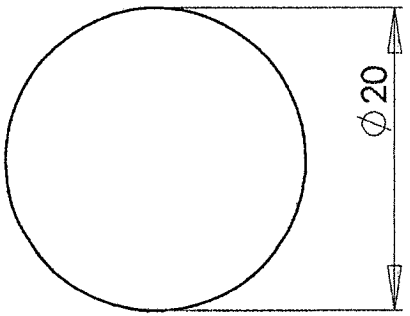




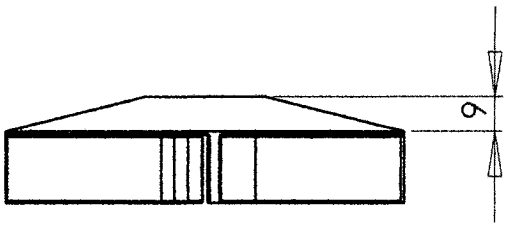
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: T-SHAPE
DRAWN	fadzli						
CHK'D	Dr. Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. T-10006 / A4

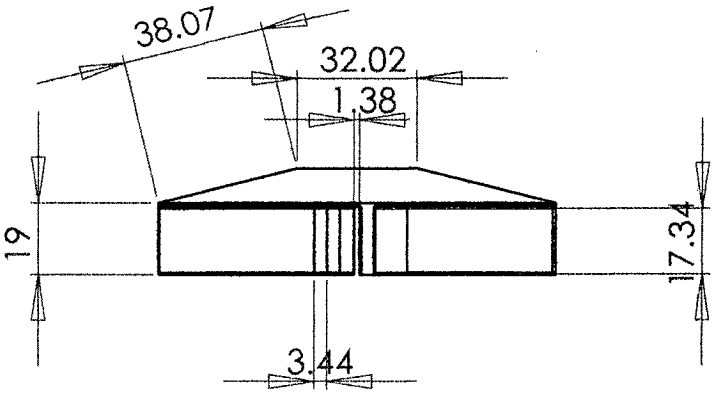


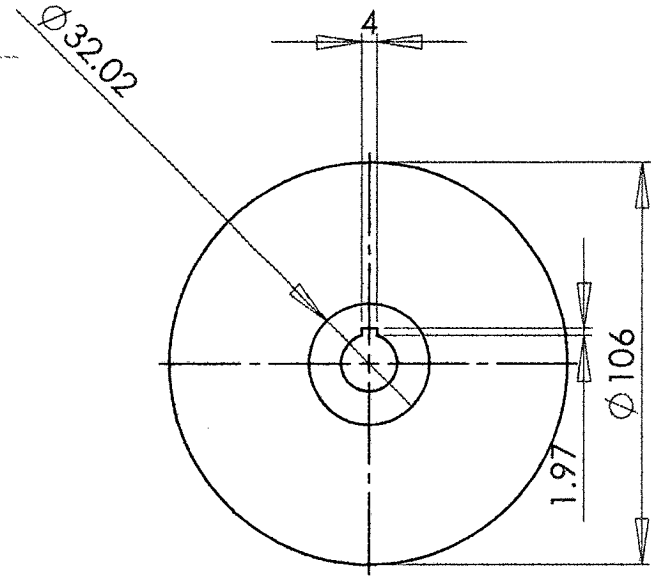


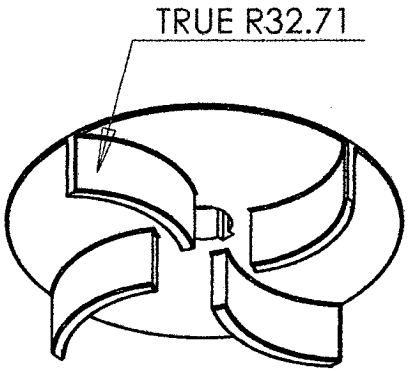


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: BALL ROLLER
DRAWN	fadzli						
CHK'D	Dr. Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. R-10007 / A

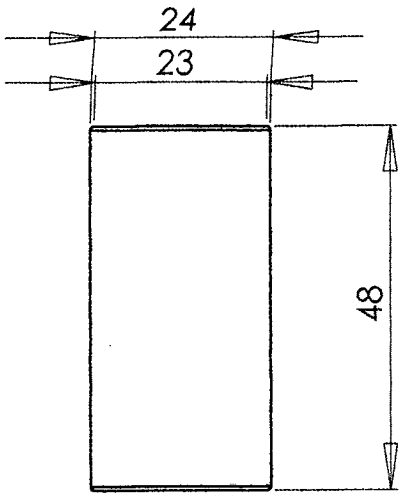


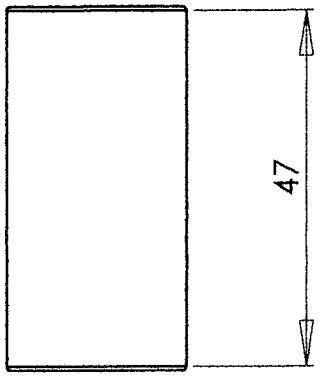


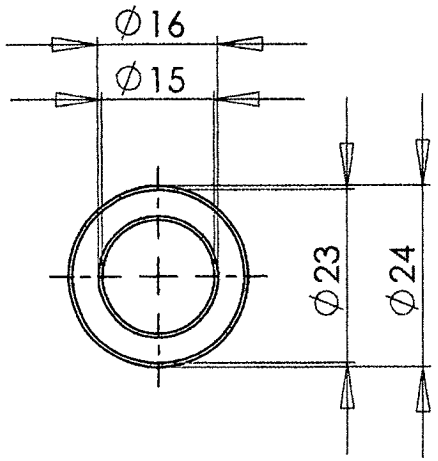


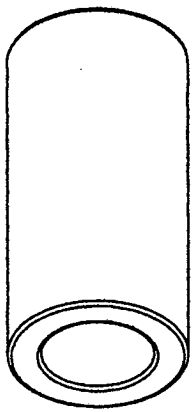


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: FIX PULLEY
DRAWN	Fadzli						
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. F-10008 / A

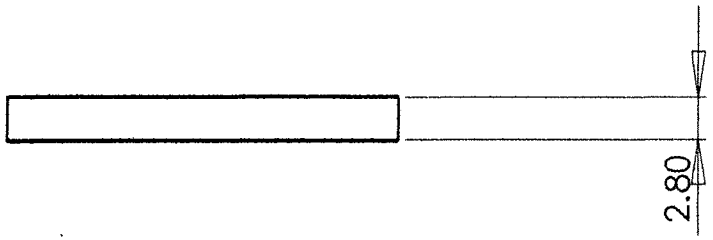


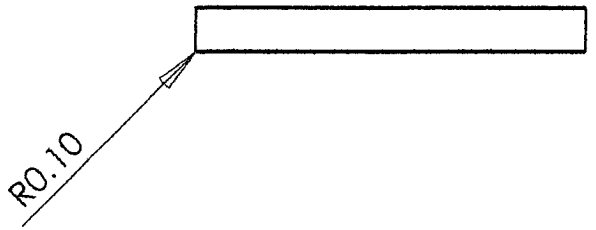


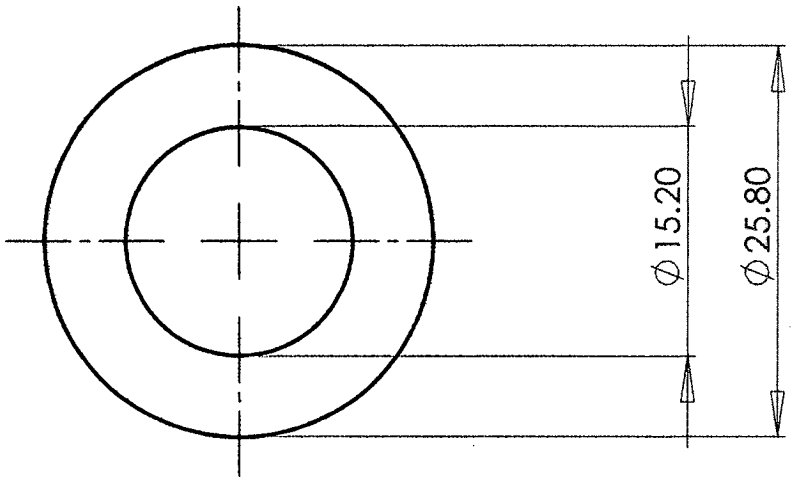


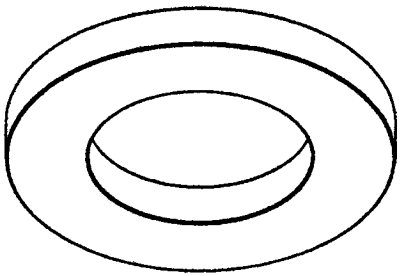


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN						BUSHING	
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A4
						B-10009	

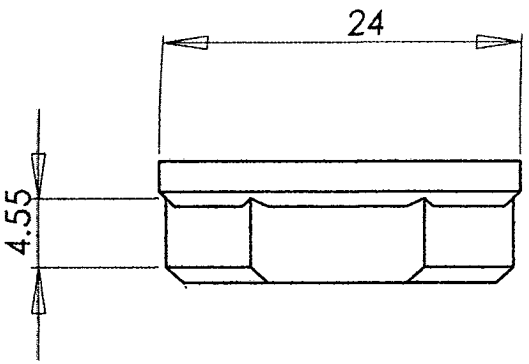


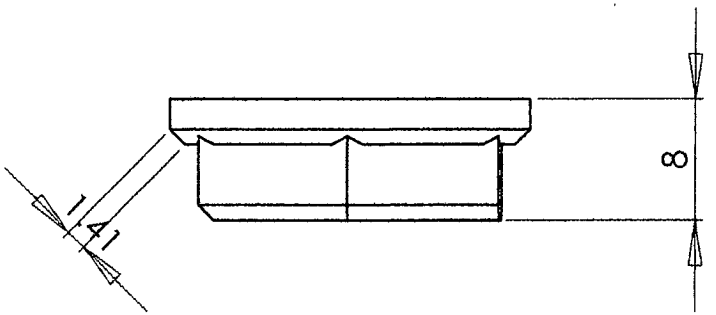


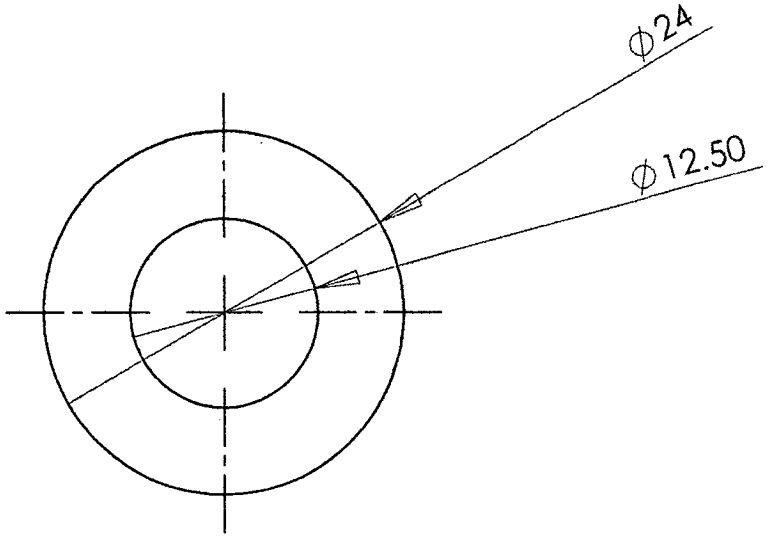


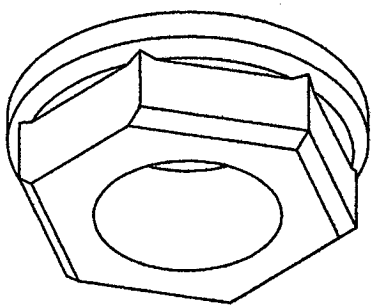


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: WASHER
DRAWN	Fadzli						
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. W-10010 / A4

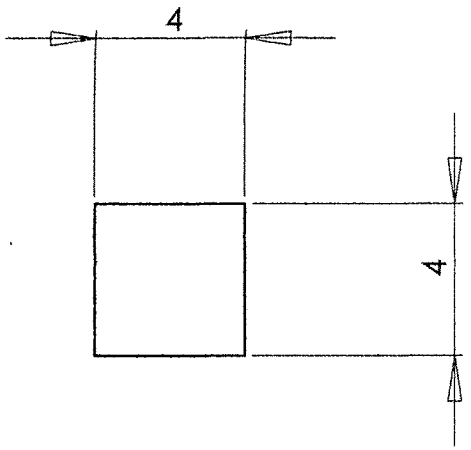


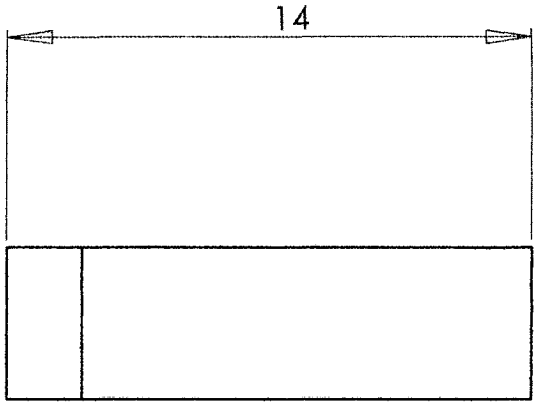


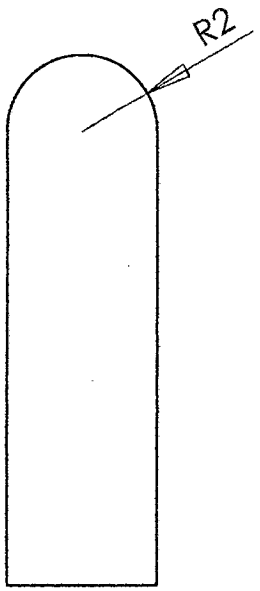




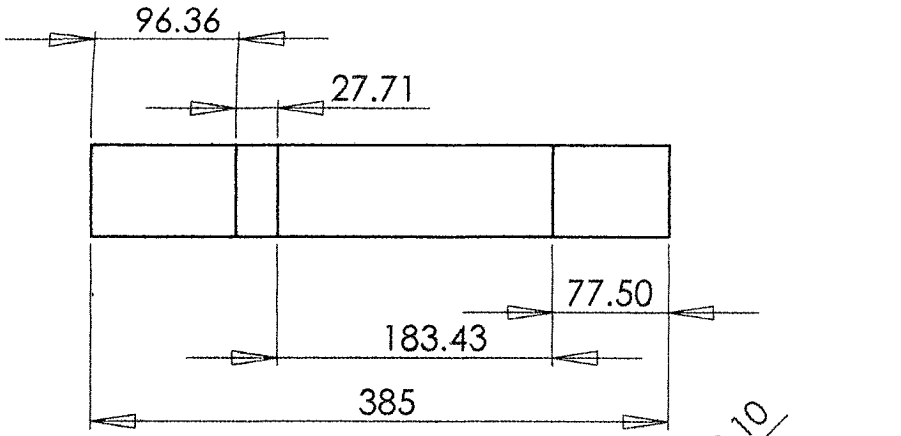
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: NUT
DRAWN	Fadzli						
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. N-10011 / A4

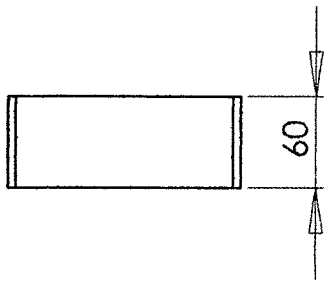


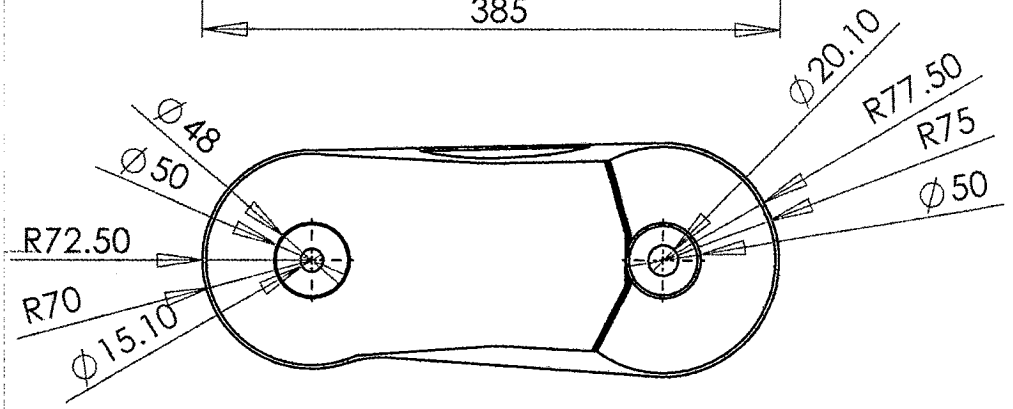


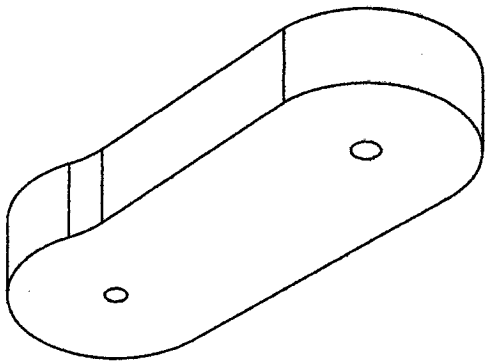


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: PIN
DRAWN	fadzli						
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. K-10012 / A

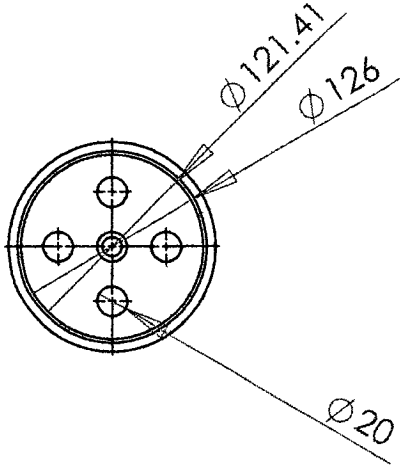


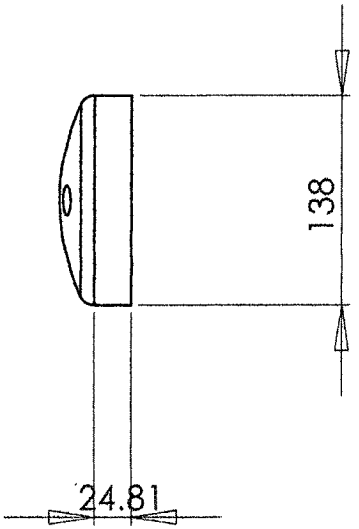


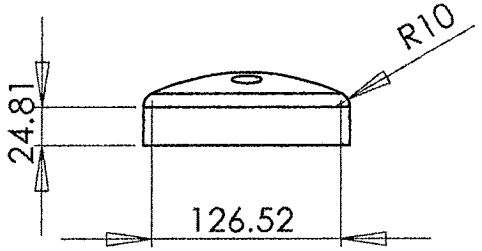


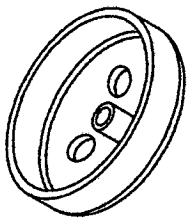


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: BASE
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. B-10013 / A4

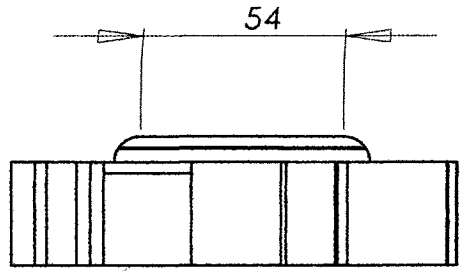


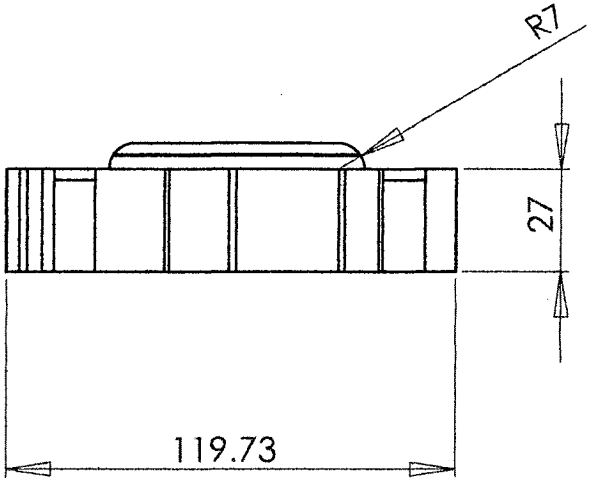


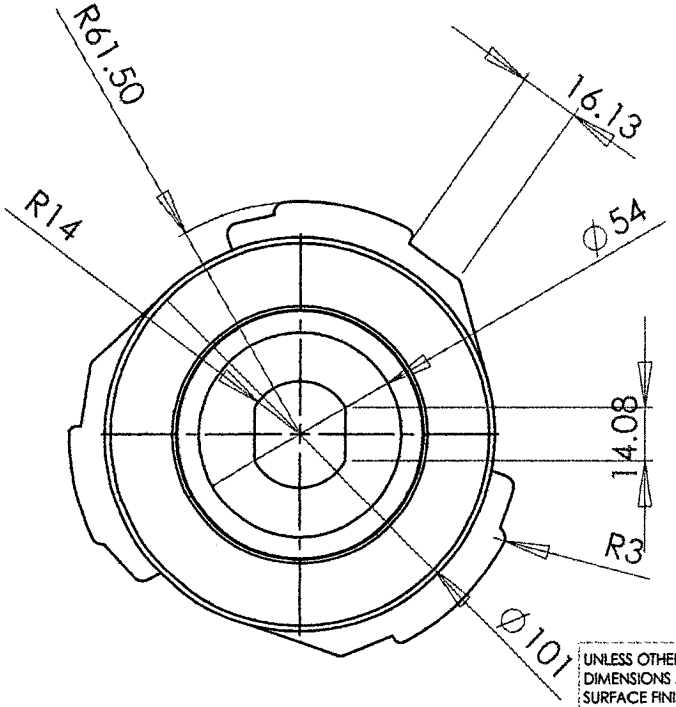


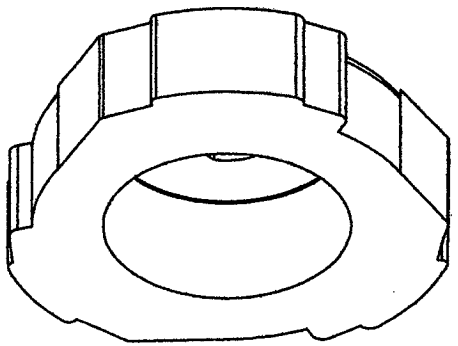


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: INNER CLUTCH BELL
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. C-10014 / A

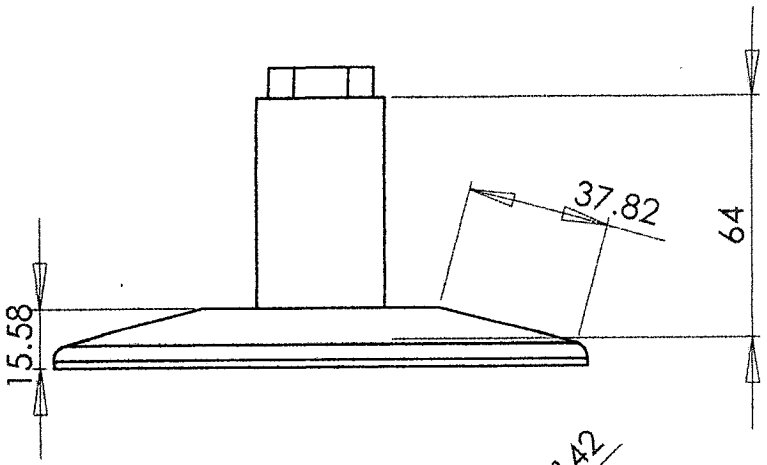


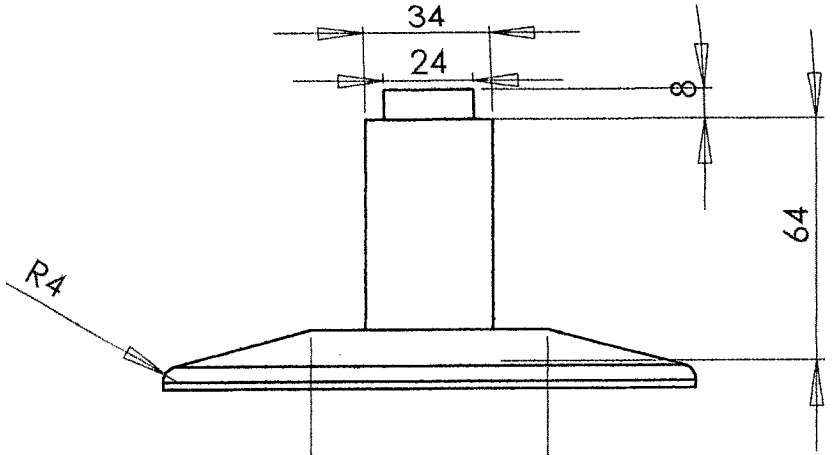


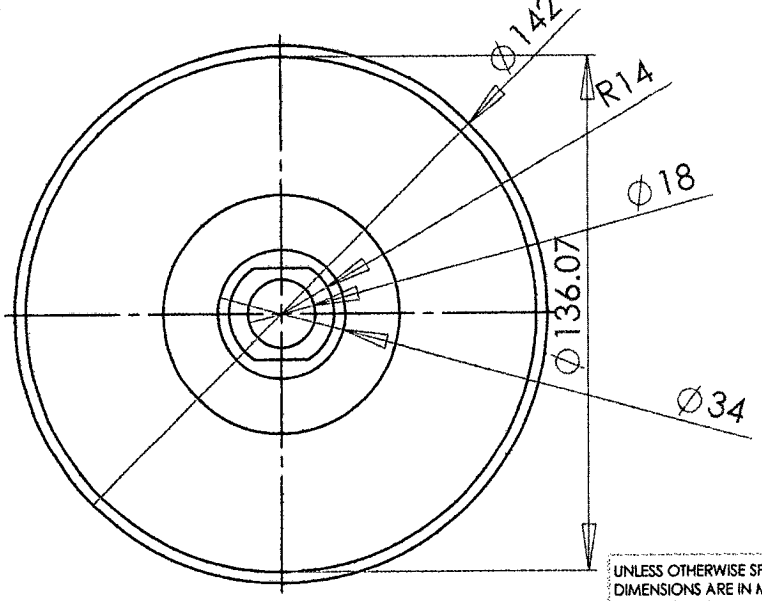


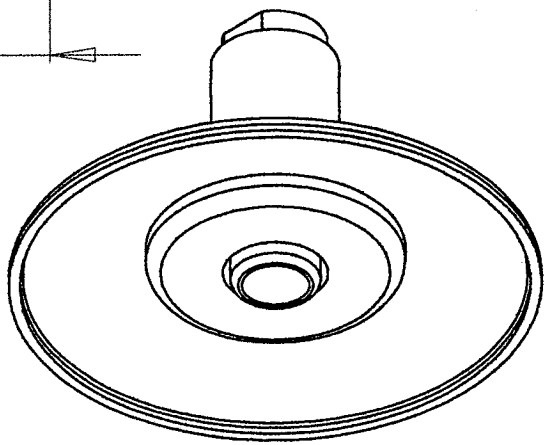


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE:
DRAWN	Fadzli						CLUTCH
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. C-10015 / A









UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:
DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING
REVISION	

	NAME	SIGNATURE	DATE
DRAWN	Fadzli		
CHK'D	Dr.sugeng		
APPV'D			
MFG			
Q.A			

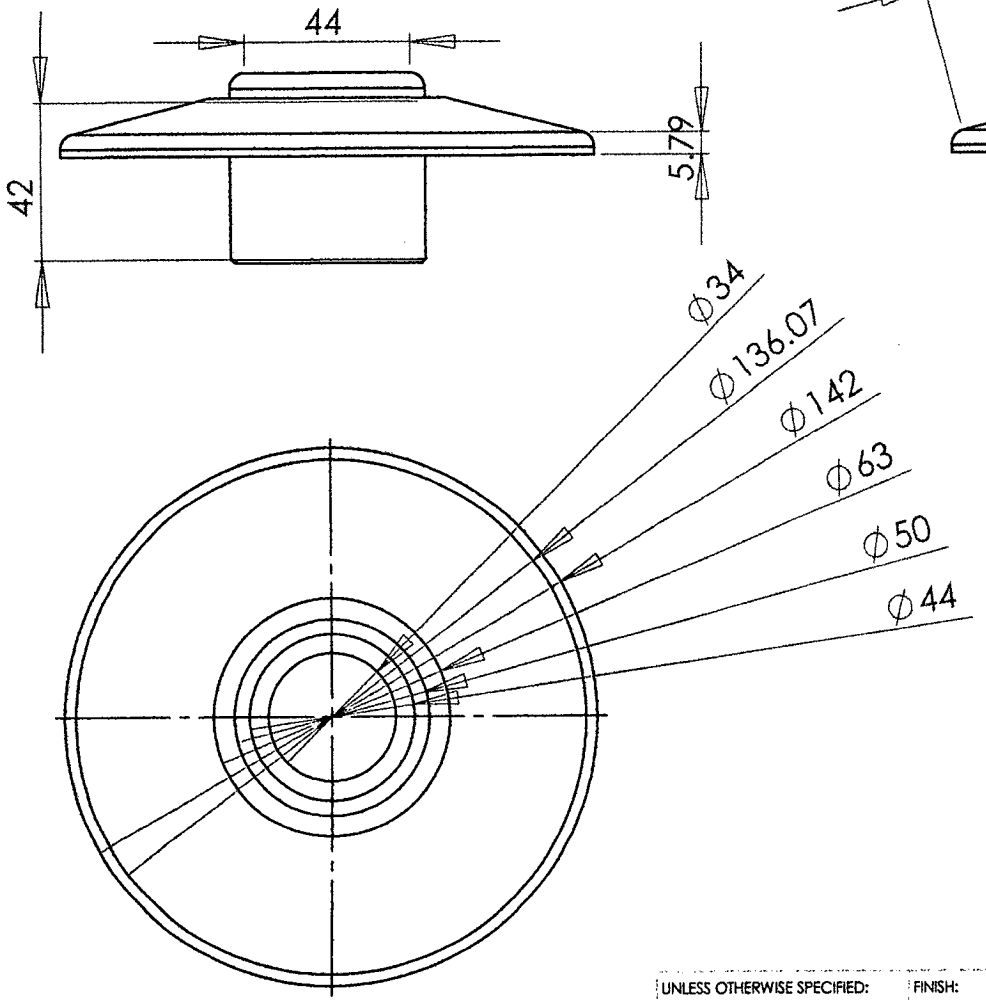
MATERIAL:

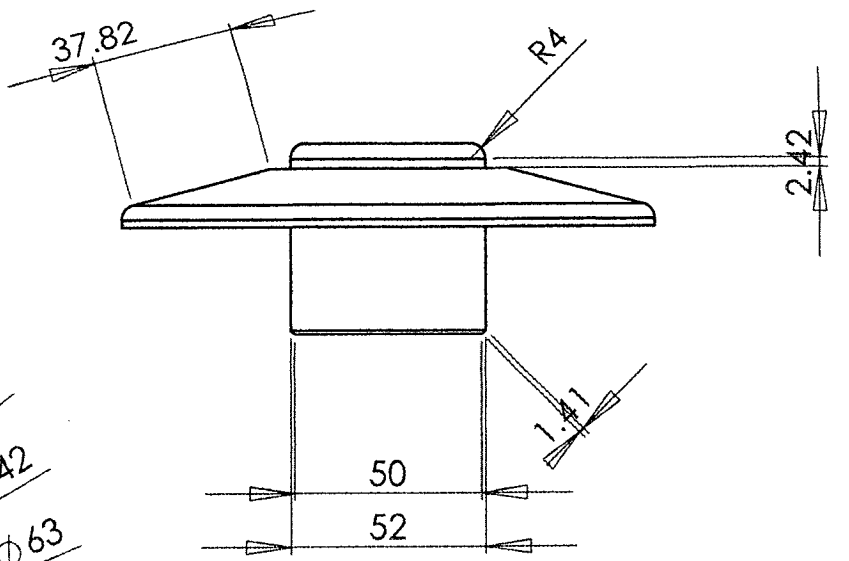
TITLE:

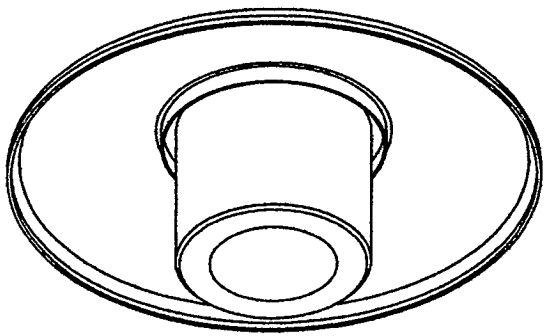
FIX PULLEY

DWG NO. F-10016

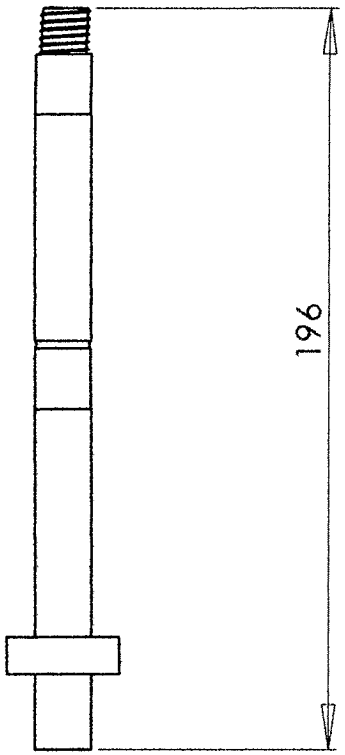
A4

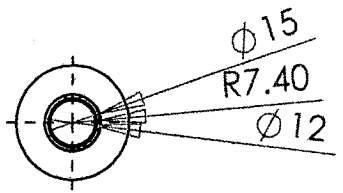


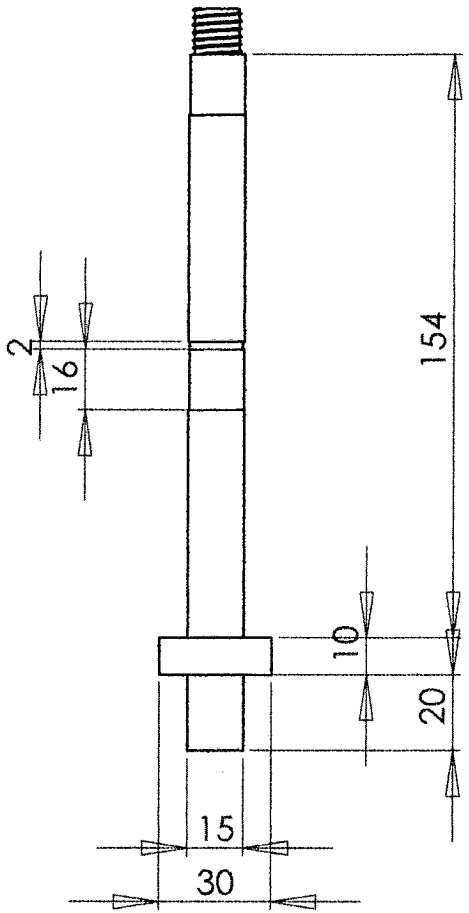




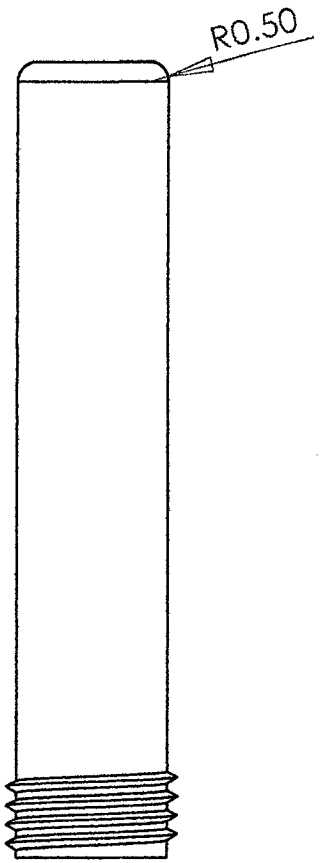
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE		TITLE: MOVEMENT PULLEY
DRAWN	Fadzli				
CHK'D	Dr.Sugeng				
APPV'D					
MFG					
Q.A				MATERIAL:	DWG NO. M-10017 / A

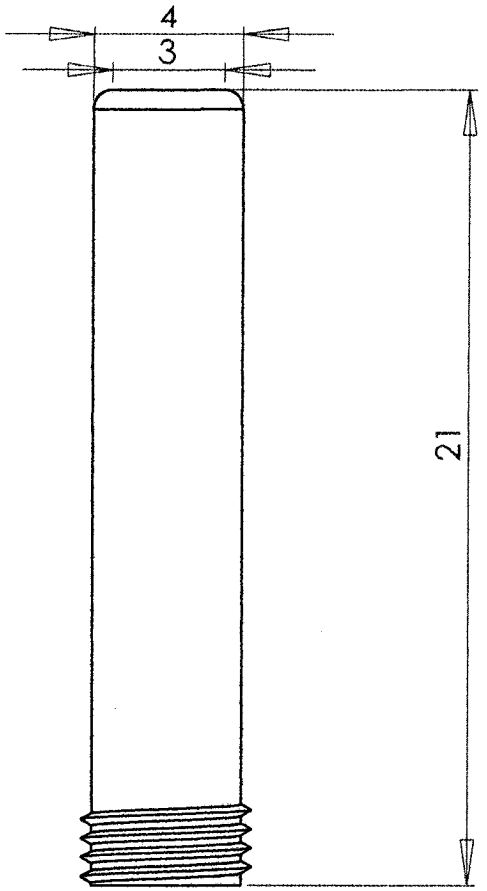


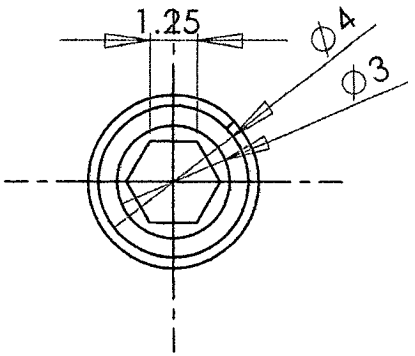




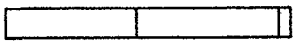
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN						OUTPUT SHAFT	
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO. S-10018	A4

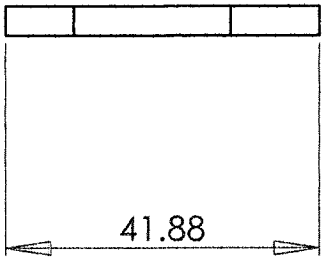


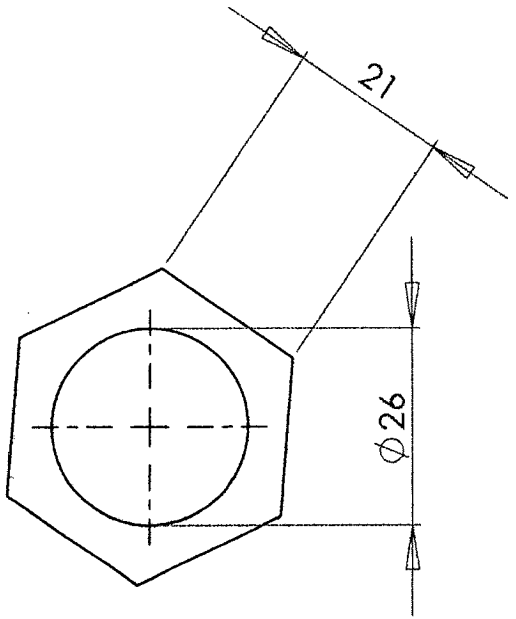


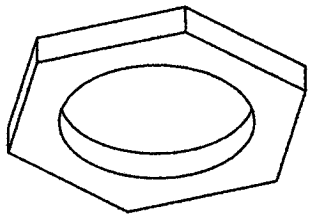


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE			TITLE: KEY SHAFT
DRAWN						
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL:		DWG NO. K-10019 / A4

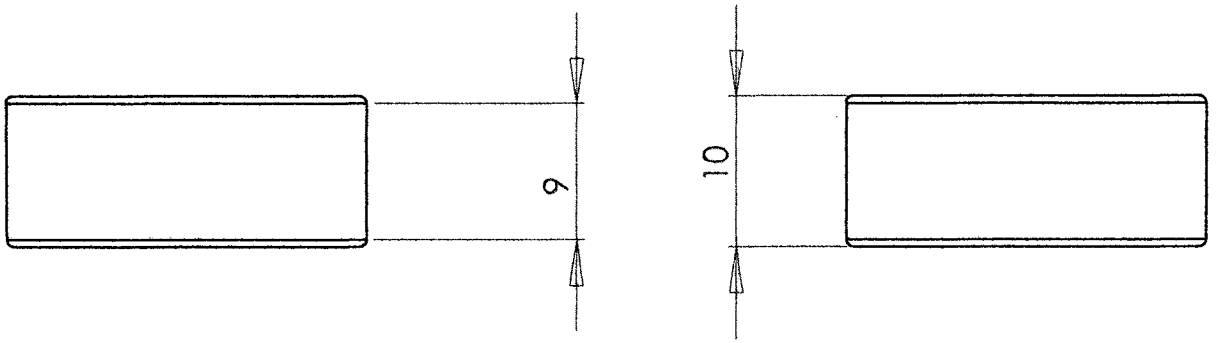


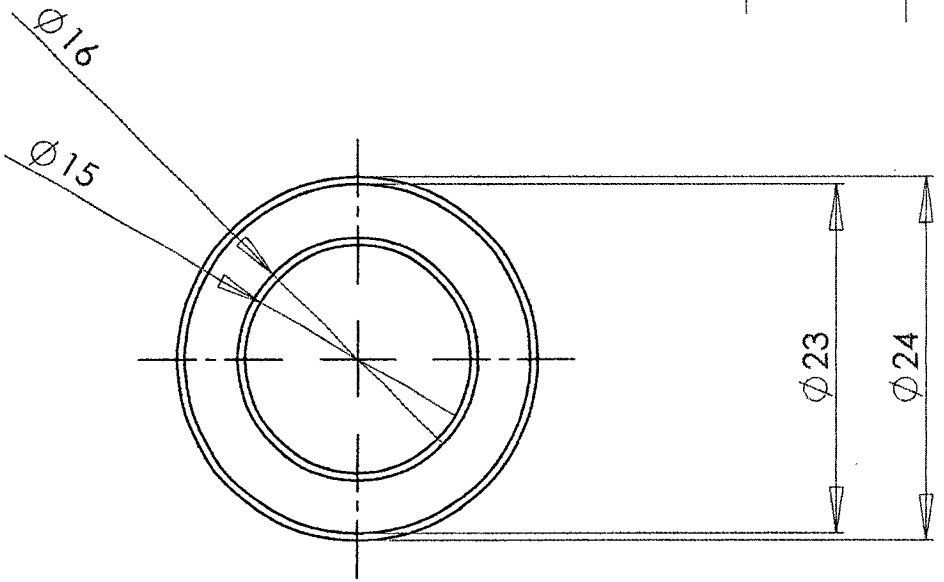


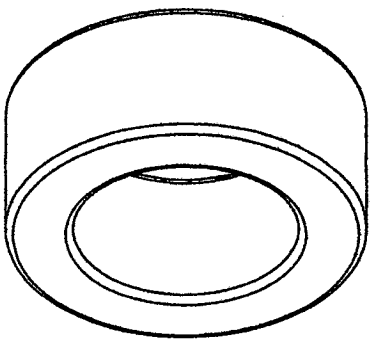




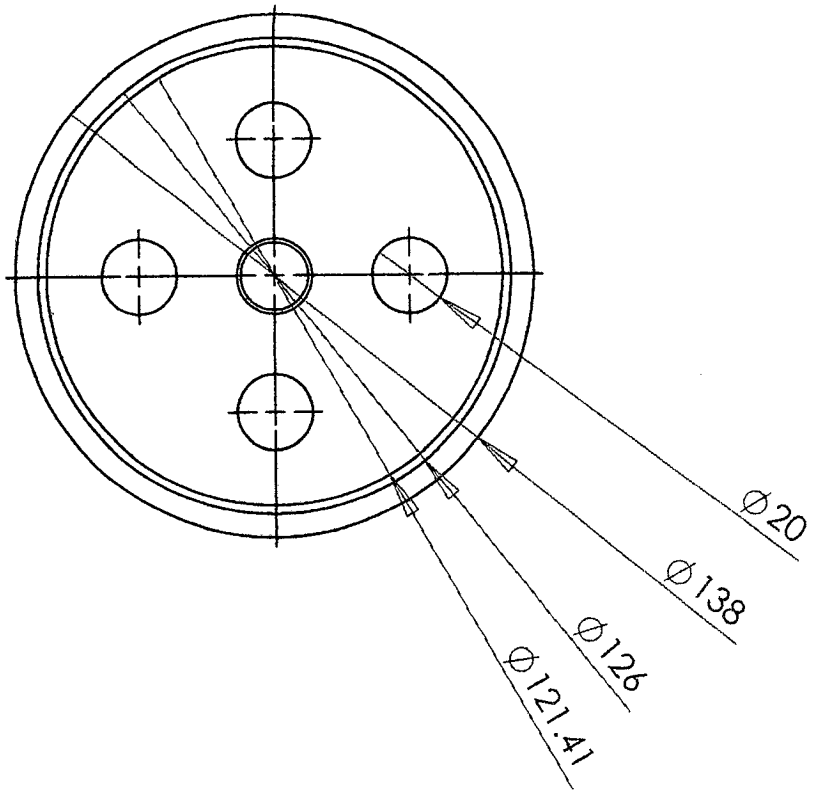
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: CLUTCH NUT
DRAWN	fadzli						
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. N-10020 / A4

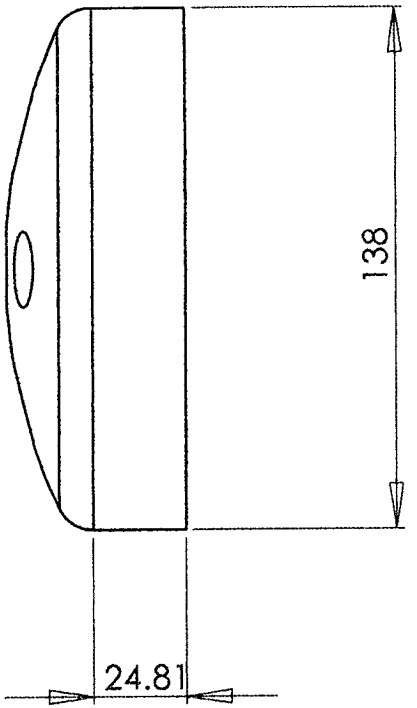


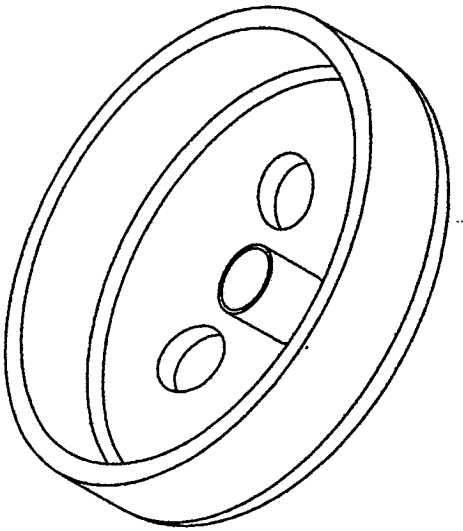


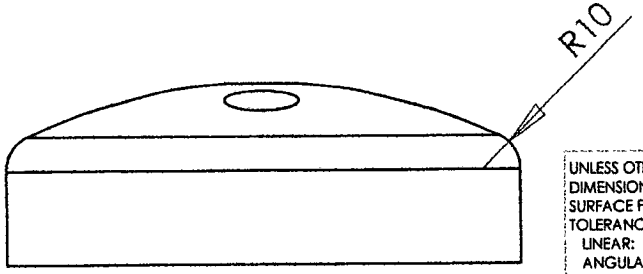


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE:
DRAWN							BUSH
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. B-10021 / A4

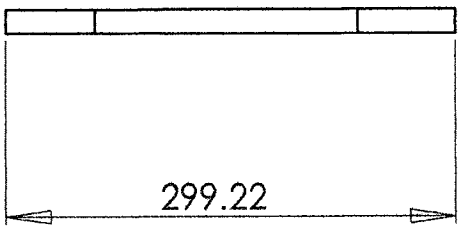


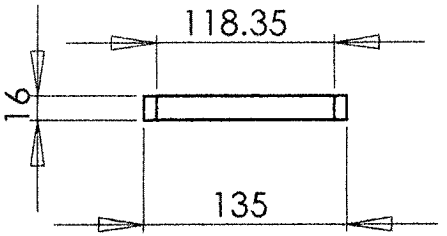


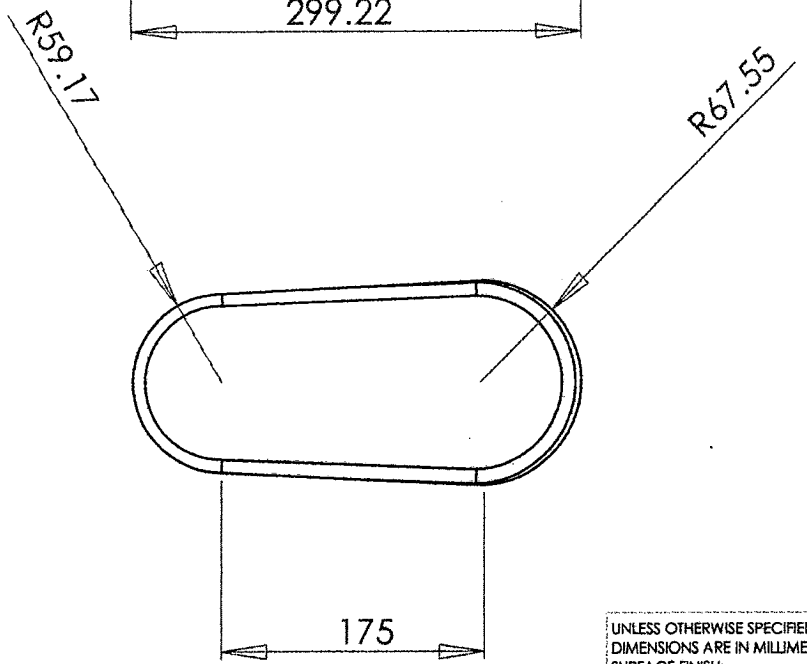


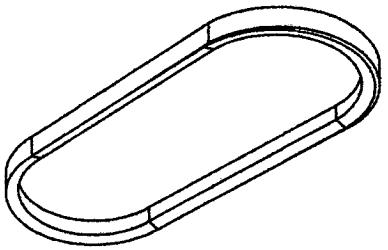


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN						CLUTCH BELL	
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A
						C-10022	

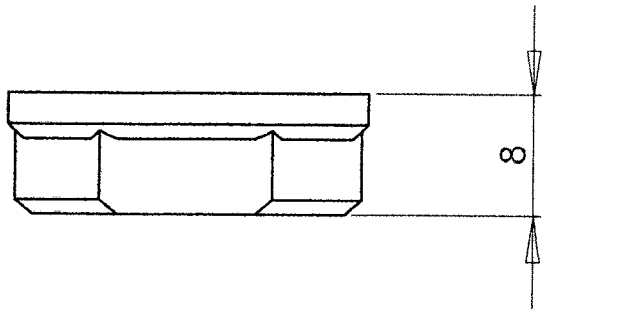


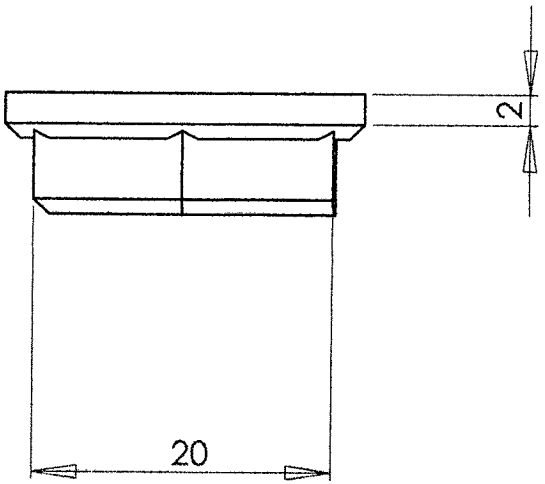


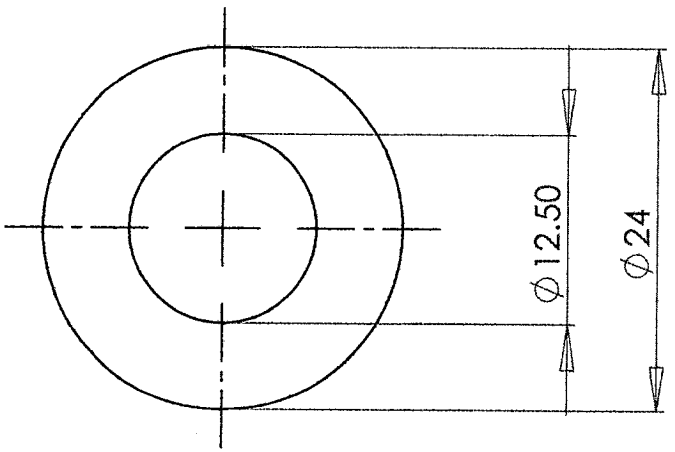




UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN	Fadzli					BELT	
CHK'D	Dr.Sugeng						
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	
						B -10023	B







UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE: NUT
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. N-10024 / A4