COMPARISON OF AUTOMATIC AND CVT TRANSMISSION FOR A CAR UNDER 1 LITER ENGINE

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2010

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **COMPARISON OF AUTOMATIC AND CVT TRANSMISSION FOR A CAR UNDER 1 LITER ENGINE.**

SESI PENGAJIAN: **2010/2011**

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I certify that the project entitled "*Comparison of Automatic and CVT Transmission for a Car Under 1 Liter Engine* "is written by *Ahmad Mustakim Bin Mohd Rusli*. 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.

Tuan Hj. Amirruddin Abdul Kadir	....
Examiner	Signature

COMPARISON OF AUTOMATIC AND CVT TRANSMISSION FOR A CAR UNDER 1 LITER ENGINE

AHMAD MUSTAKIM BIN MOHD RUSLI

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

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

AWARD FOR DEGREE

Bachelor Final Year Project Report

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

SUPERVISOR’S DECLARATION

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

Signature ....
Name of Supervisor: DR SUGENG ARIYONO
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Date: 6 DECEMBER 2010

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 ....

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Dedicated,

encouragements and always be there during hard times,

my beloved family.

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Dr Sugeng Ariyono for his 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 appreciate his consistent support from the first day I applied to graduate program to these concluding moments. I also sincerely thanks for the time spent proofreading and correcting my many mistakes.

My sincere thanks go to all my mates and members of the staff of the Mechanical Engineering Department, UMP, who helped me in many ways and made my stay at UMP pleasant and unforgettable. Many special thanks go to instructor engineer and assistance instructor for their excellent co-operation, inspirations and supports during this study.

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

This thesis presented about the comparison of automatic transmission and CVT transmission. Automatic transmission had been used widely nowadays and the use of CVT transmission progressively increasing. Automatic transmission and CVT transmission have their own advantages and disadvantages. In chapter 4, the performance of each transmission were analysed and the comparison between two transmissions in term of performance is different. Other than the performances, the transmissions also were differentiated in terms of fuel consumption and compatibility to build in a car under 1 litre engine. This performance is found by using calculation method and the results have been plot as a graph and.

ABSTRAK

Tesis ini mempersembahkan tentang perbandingan antara transmisi automatik dan CVT. Transmisi automatik telah digunakan secara meluas dewasa ini dan penggunaan transmisi CVT semakin meningkat. Transmisi automatik dan CVT mempunyai kelebihan dan kelemahan tersendiri. Dalam bab 4, prestasi setiap transmisi dianalisis dan perbandingan antara dua transmisi dari segi prestasi adalah berbeza. Selain daripada prestasi, perbezaan juga dianalisis dari segi penggunaan bahan bakar dan kesesuaian untuk digunakan terhadap kereta di bawah 1 liter enjin. Prestasi ini ditentukan dengan menggunakan kaedah pengiraan manual dan hasilnya dipersembahkan dalam bentuk graf.

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LIST OF SYMBOLS

r	Radius of tire
ρ	Air density
C_d0	aerodynamic drag coefficient
v	Vehicle speed
A	Maximum vehicle cross-section area
c_a	Constant
c_b	Constant
m	Mass of vehicle
g	Gravitational acceleration
θ	Road slope
$\dot{v}$	Acceleration in the direction of motion of the vehicle
ω_e	Engine angular velocity
ω_M	Engine angular velocity at maximum power
ω_{min}	Minimum engine speed
n_g	Overall transmission ratio
n_d	Differential transmission ratio
n_i	Gearbox transmission ratio
v_x	Vehicle speed
η	Overall efficiency

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Type of transmission becomes one of the main aspects chosen by the buyer in buying a car other than the size of car, type of engine, and also the manufacturer of car. Nowadays, there are about three popular most popular types of transmission being used in the whole world wide. Those transmissions are manual transmission, automatic transmission, and also continuously variable transmission (CVT). But automatic transmission and CVT provides better handling compared to manual transmission where the driver don’t need to shift the clutch manually using a gear knob. Therefore, a lot of buyer nowadays chose a car with automatic transmission and CVT compared to the car with manual transmission. Both conventional automatic and CVT has their own advantages and disadvantages. One of the advantages of CVT is that it can work to keep engine at optimum power range and simply raises and lowers the engine speed as needed. There are rumors saying that CVT provide better performance than conventional automatic transmission. Therefore, an experiment will be conducted to compare both transmissions from their performance, fuel economy and also the possibility of using continuously variable transmission for a car under 1 liter engine. The car selected for conducting the experiment is Viva Elite 1000cc. For the continuously variable transmission, Honda Insight 2005 will be selected as a reference. This is because of Perodua Viva Elite only comes with conventional automatic transmission. After the experiment is finished, the collected data will be presented in the graph and the performance between the transmissions will be compared.

1.2 PROBLEM STATEMENTS

The world has advanced once more in automotive field in using Automatic transmission and also CVT transmission for a car. These two great achievements have been used widely in cars. Nowadays, there are many car manufacturers has use these two kinds of transmission such as Audi, Nissan, Mercedes Benz, and many other bigger manufactures of car. A research will be developed to find which one has better performance for the car under 1 liter engine, Viva Elite 1000cc. To understand the performance of these two transmissions, a calculation will be needed to estimate which one have a better performance. The best method to compare the performance is by developing a graph of gear ratios by certain velocity of both transmissions.

1.3 PROJECT OBJECTIVES

i. To analyze the performance of the Automatic Transmission and the CVT for a car under 1 liter engine.
ii. To compare the Automatic Transmission and CVT Transmission.
iii. To study the possibility using CVT for a car under 1 liter engine.

1.4 PROJECT SCOPES

i. Study of the Automatic Transmission mechanism.
ii. Study of the CVT Transmission mechanism.
iii. Analyze the project by plotting the graph.
iv. Based on Viva Elite 1000cc.

1.5 PROJECT FLOW CHART

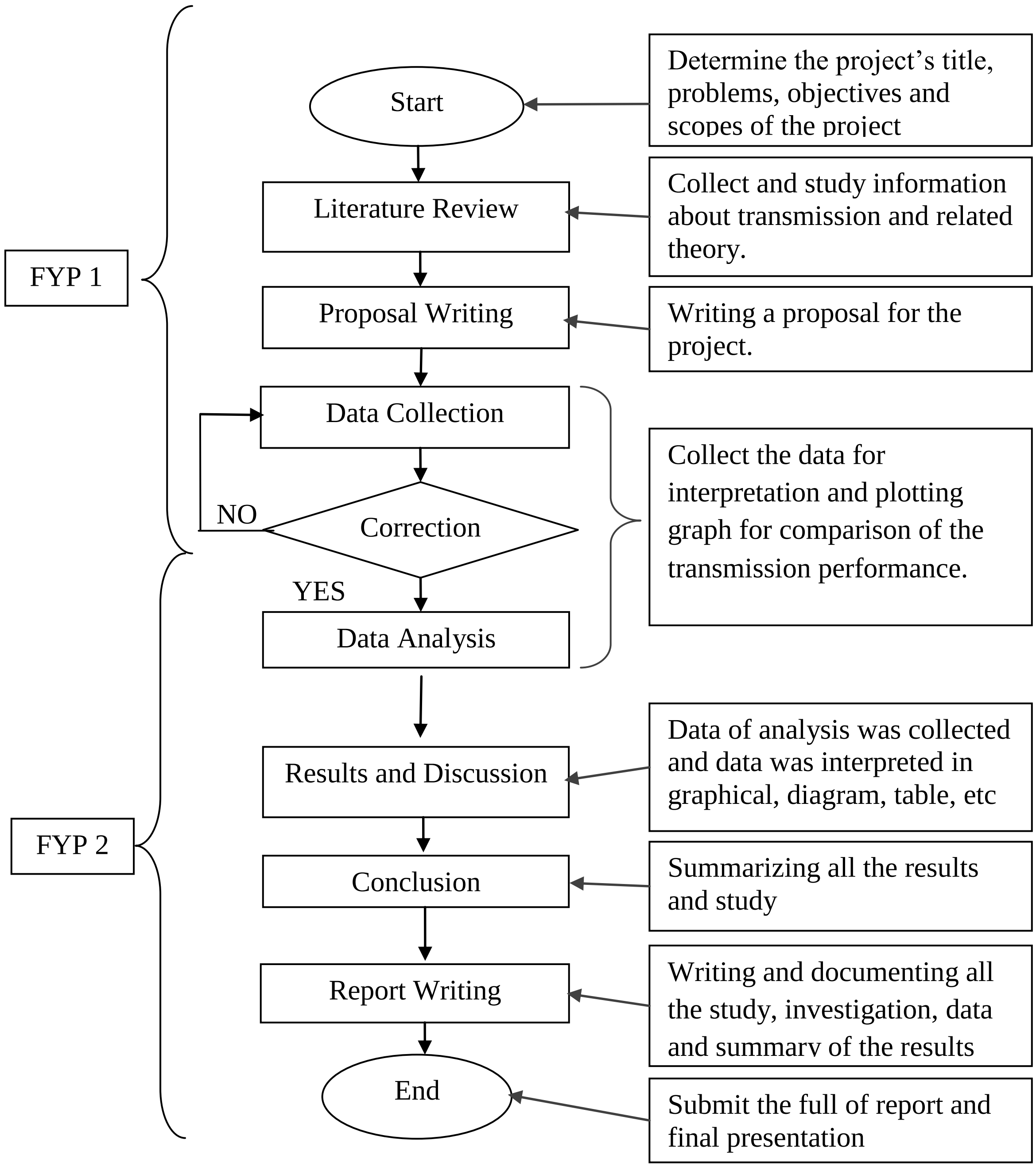


Figure 1.1: Flow chart of the overall methodology.

1.6 STRUCTURE OF THESIS

This thesis is about the comparison of the conventional automatic transmission with the continuously variable transmission (CVT). Both transmissions are compared in terms of its performance, fuel economy, and also its feasibility to be put in the car under 1 liter engine. Other than that, this thesis also is about the study of basic principle of conventional automatic transmission and continuously variable transmission.

In chapter one, it is about the main goals and targets to be achieved after finishing this project including the objectives, problem statements, and also the scopes of the project. Other than that, the briefing about the project is also included in this chapter.

Chapter two is consists of the literature review of the project. It is about the study of automatic transmission and CVT. The study is including the basic principle of both transmissions and also the types of each transmission.

In chapter three, the methodology to carry out this project is presented. It is about the related formulas and equations needed in order to find the performance of each transmission mostly. This chapter also explained about how to use each equation based on the output needed.

Chapter four is about the results and discussion. The results obtained are being showed in graph. Each graph represented certain results such as the relation of the engine speed with the vehicle speed. The comparison between conventional automatic transmission and continuously variable transmission is also including in this chapter.

Lastly, in chapter six, the conclusion about the project is made. The conclusion is made to state that either the project is achieving the goal or not. Also, in this chapter also explained about the further study and recommendations to conduct a similar project in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 CONTINUOUSLY VARIABLE TRANSMISSION (CVT)

A continuously variable transmission is a transmission which can change steplessly 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.

Figure 2.1: Example of continuously variable transmission (Geuns, 2003).

2.1.1 Trends of CVT

Generally, continuously variable transmissions are mainly classified into mechanical, hydraulic and electric type (Asano, 2004). Various systems have been developed for each type. However, a mechanical type continuously variable transmission is typically used in automotive applications.

As shown in Table 1, automotive CVT mainly classified into a belt type and toroidal type. The belt type includes metal V-belt, dry hybrid belt type, and chain type, and is mainly used for an FF vehicle having an engine displacement of 2.8 liter or less. Most of belt CVTs practically used are metal V-belt (Asano, 2004).

Table 2.1: Types of continuously variable transmission (CVT) in automotive (Asano, 2004).

	Belt CVT			Toroidal CVT	
	Metal V-belt	Dry hybrid belt	Chain	Half	Full
Transmission torque, Nm	200 ~ 250	100 or less	300	380	600
Starting device	Yes	Yes	Yes	Yes	No
Engine applied	2.5 L or less	1 L or less	2 L	3.5 L	5.5 L
feature		No hydraulic apparatus required		Speed ratio control	Torque control

2.1.2 Belt Type CVT

The CVT was first used in an automobile at the end of 19th century and a V-belt type was used. By 1958, the Dutch company, DAF had manufactured more than a million rubber V-belt type CVTs but could not improve the product due to technical limitations in the movement for a higher output engine. However, this experiment is said to have spurred the development of a chain type (Borg Warner) CVT or a metal V-belt type (Van Doorne) CVT (Asano, 2004). The Van Doorne metal V-belt is a push type belt, which differs from the chain type in that the drive side pushes the follower side to transmit power. This belt was introduced into the market for the first time when it was mounted in Subaru JUSTY in 1987 (Asano, 2004). Subsequently, the Van Doorne metal V-belt has been used in many other types of vehicles and now constitutes approximately 10% of automatic transmissions.

On the other hand, a chain type CVT was mounted in an Audi A4 which entered the market in 2001 (Umeno, 2001). A Currently-practiced metal V-belt CVT has the maximum transmission torque of 350 Nm, whose value is now required to be significantly larger in order to be used in large vehicles (Asano, 2004). The chain type CVT has a possibility of providing larger torque capacity as compared to metal V-belt type. Figure 2.3 shows an example of the structure of the belt type CVT.

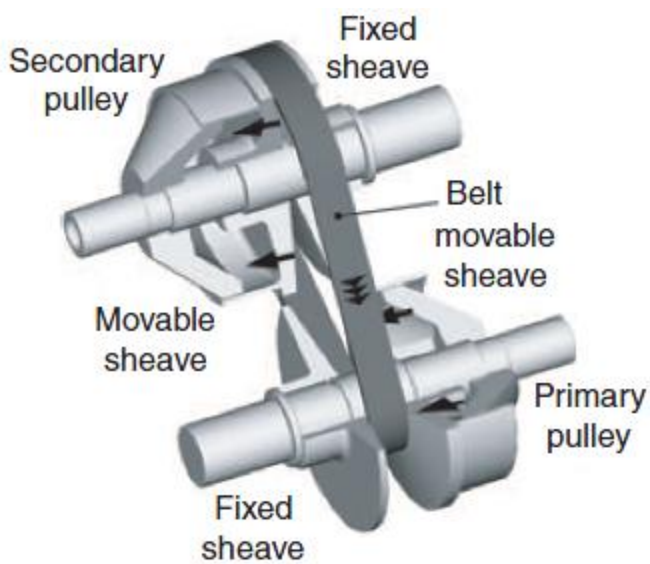


Figure 2.2: Belt-type CVT (Fuchs et al, 2006).

2.1.3 Toroidal CVT

A traction drive CVT had been proposed far back in the past and was first developed for an automobile by General Motors (GM) in the 1930s (Asano, 2004). However, the realization of the traction drive CVT had to wait for remarkable progress in the tribology and control technology. Specifically, the development of a traction fluid with relatively large friction coefficient, exploding the conventional concept, the advancement of EHL theory (Dowson, 1979), and the development of a long-life bearing steel (Ohta, 1998) were required.

The traction drive CVT developed for an automotive transmission is a toroidal one. Current toroidal CVT is a half Toroidal CVT (Sugano et al, 2000). Toroidal means a donut-like three-dimensional shape. The toroidal CVT is so-called because a part of a curved surface at the inner side of two disks constitutes the shape. Figure 2.3 shows an example of the structure of the half-toroidal CVT.

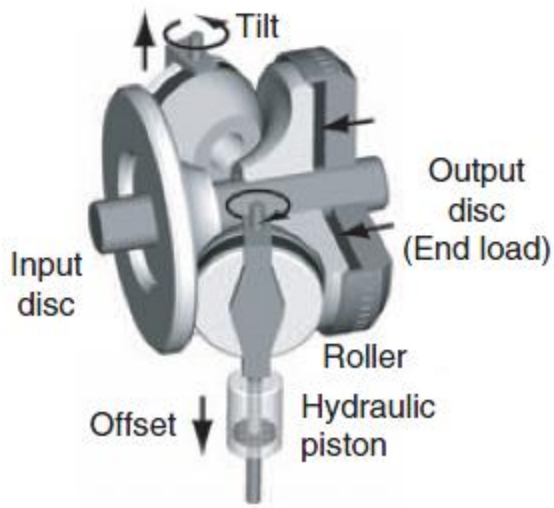
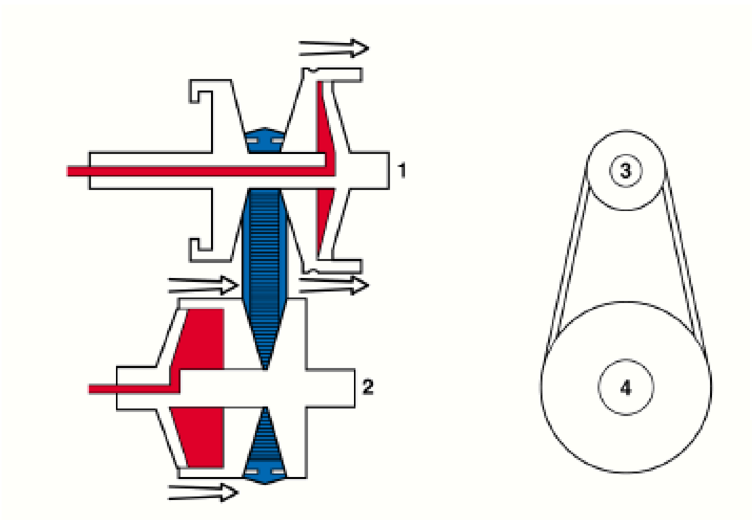


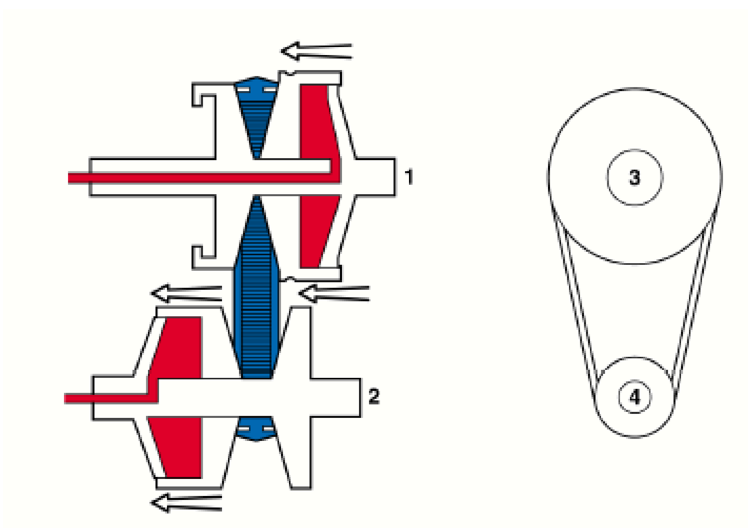
Figure 2.3: Half-toroidal CVT (Fuchs et al, 2006).

2.1.4 Basic Principles of CVT



1. Input from the engine
2. Output to the wheels
3. Drive pulley at minimum diameter (Low)
4. Driven pulley at maximum diameter (Low)

Figure 2.4: Pulleys in low position (Geuns, 2003).



1. Input from the engine
2. Output to the wheels
3. Drive pulley at maximum diameter (Overdrive)
4. Driven pulley at maximum diameter (Overdrive)

Figure 2.5: Pulley position in high ratio (overdrive) (Geuns, 2003).

Unlike conventional planetary automatic transmissions that provide a limited number of gear ratios, usually four, five or six, the CVT, as its name suggests, continuously varies the gear ratio. A low gear (low ratio) makes it easier to pull away from a rest position, the drive pulley diameter being relatively small, while the driven pulley diameter is large by comparison. The drive belt is used to transmit power and torque. As acceleration takes place it becomes possible to select a higher ratio by increasing the diameter of the drive pulley while at the same time, decreasing the diameter of the driven pulley. This degree of change can be controlled to ensure that the most suitable ratio is provided (Geuns, 2003).

The CVT uses a primary pulley and a secondary pulley. Both pulleys have one fixed half and one mobile half, controlled by hydraulic pressure. The position of the drive belt on the pulleys will determine the ratio. If the mobile half of the pulley is close to its opposite half then the drive belt is forced to travel around the outer circumference. When the pulley is open wide, then this circumference is reduced. The primary and secondary pulley mobile halves are diagonally opposed so when the drive belt diameter is reduced on the primary pulley, is increases on the secondary pulley (Geuns, 2003).

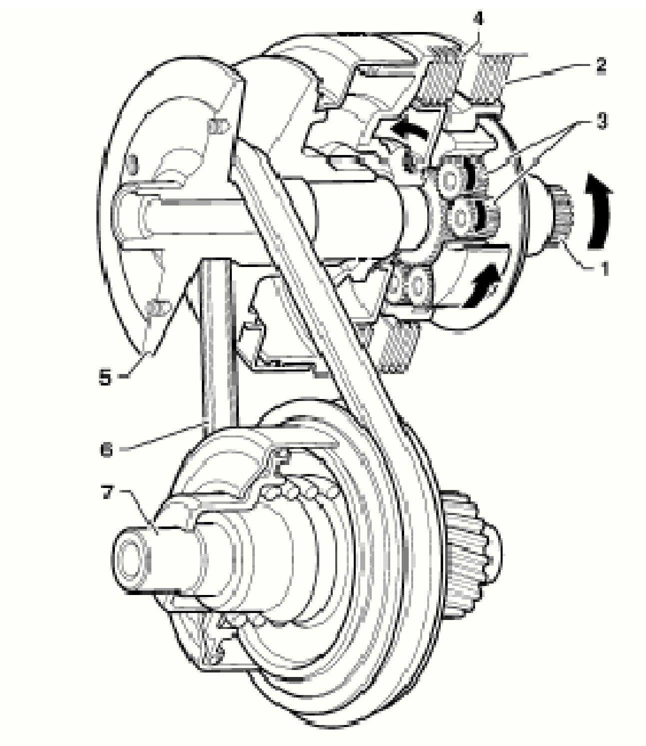
To pull away, a low ratio is required. To provide this, the primary pulley is open allowing the drive belt to sit down into the pulley and forcing it to run around the outer of the closed secondary pulley. As vehicle speed increases, a higher gear ratio is required. To do this, the primary pulley gradually moves towards its fixed partner, increasing the pulley circumference. At the same time, the secondary pulley is forced apart reducing pulley diameter, therefore creating a higher gear ratio. An overdrive ratio is obtained when the primary pulley is fully closed and the secondary pulley is fully open. The secondary pulley is now forced to rotate approximately two and a half time for every turn of the primary pulley (Geuns, 2003).

2.1.5 Mechanical Operation

2.1.5.1 Selector lever in the park or neutral position

In this condition, motion is not transferred to the wheels as both clutches for reverse (2) and forward gears (4) are disengaged (Geuns, 2003).

- The transmission input shaft (1) turns at the same speed as the engine.
- The reverse gear clutch (2) is disengaged.
- The forward gear clutch (4) is disengaged.
- The planetary gears (3) idle around the sun gear.
- As the sun gear does not move, neither does the primary pulley (5), the secondary pulley (7) and subsequently, the vehicle.



1. Input shaft
2. Reverse gear clutches
3. Planetary gears
4. Forward gear clutches
5. Primary pulley
6. Steel drive belt
7. Secondary pulley

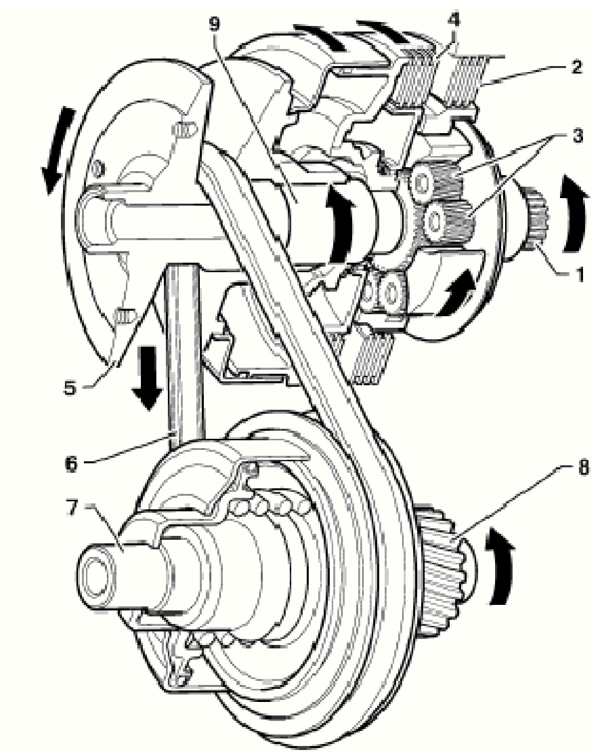
Figure 2.6: Pulleys and gear train in park or neutral position (Geuns, 2003).

2.1.5.2 Selector lever in the drive position

Under this condition, the forward motion is transferred to the wheels as the forward clutch (4) is engaged (Geuns, 2003).

- The transmission input shaft (1) turns at the same speed as the engine.
- The reverse clutch (2) is disengaged.
- The forward clutch (4) is engaged.

- The planetary gears (3), the sun gear and the annular ring gear of the epicyclical train rotate together.
- The primary pulley (5) turns at the same speed as the engine in the forward gear direction.
- The secondary pulley (7) turns in the forward gear direction at a speed that depends upon the belt ratio for that operating condition.



1. Input shaft
2. Reverse gear clutches
3. Planetary gears
4. Forward gear clutches
5. Primary pulley
6. Steel drive belt
7. Secondary pulley
8. Secondary pulley
9. Input shaft

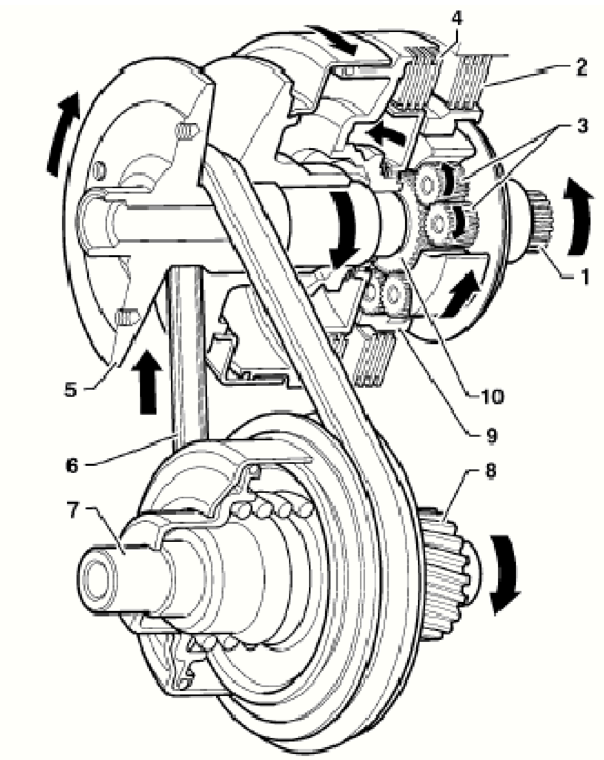
Figure 2.7: Pulleys and gear train in drive position (Geuns, 2003).

2.1.5.3 Selector lever in the reverse position

Under this condition, the reverse clutch (2) is engaged and makes the annular ring gear (9) lock to the transmission case. The planetary (3) force the sun gear (10), the primary pulley (5) and the secondary pulley (7) to turn in the opposite direction to the transmission input shaft (1). Therefore reverse gear is selected (Geuns, 2003).

- The transmission input shaft (1) turns at the same speed as the engine.

- The reverse clutch (2) is engaged.
- The forward clutch (4) is disengaged.
- The annular gear (9) is linked with the transmission case by means of the reverse clutch (2).
- The planetary gears (3), which are driven directly by the transmission input shaft (1), turn around the annular gear (9). Therefore they force the sun gear (10), the pulley (5) and the secondary pulley (7) to turn in the reverse gear direction.



1. Input shaft
2. Reverse gear clutches
3. Planetary gears
4. Forward gear clutches
5. Primary pulley
6. Steel drive belt
7. Secondary pulley
8. Secondary pulley
9. Annular gear
10. Sun gear

Figure 2.8: Pulleys and gear train in reverse position (Geuns, 2003).

2.2 AUTOMATIC TRANSMISSION (AT)

An automatic transmission, often informally shortened to auto, and abbreviated to AT is a motor vehicle transmission that can automatically change gear ratios as the vehicle moves, freeing the driver from having to shift gears manually. Most automatic transmissions have a defined set of gear ranges, often with a parking pawl feature that locks the output shaft of the transmission.

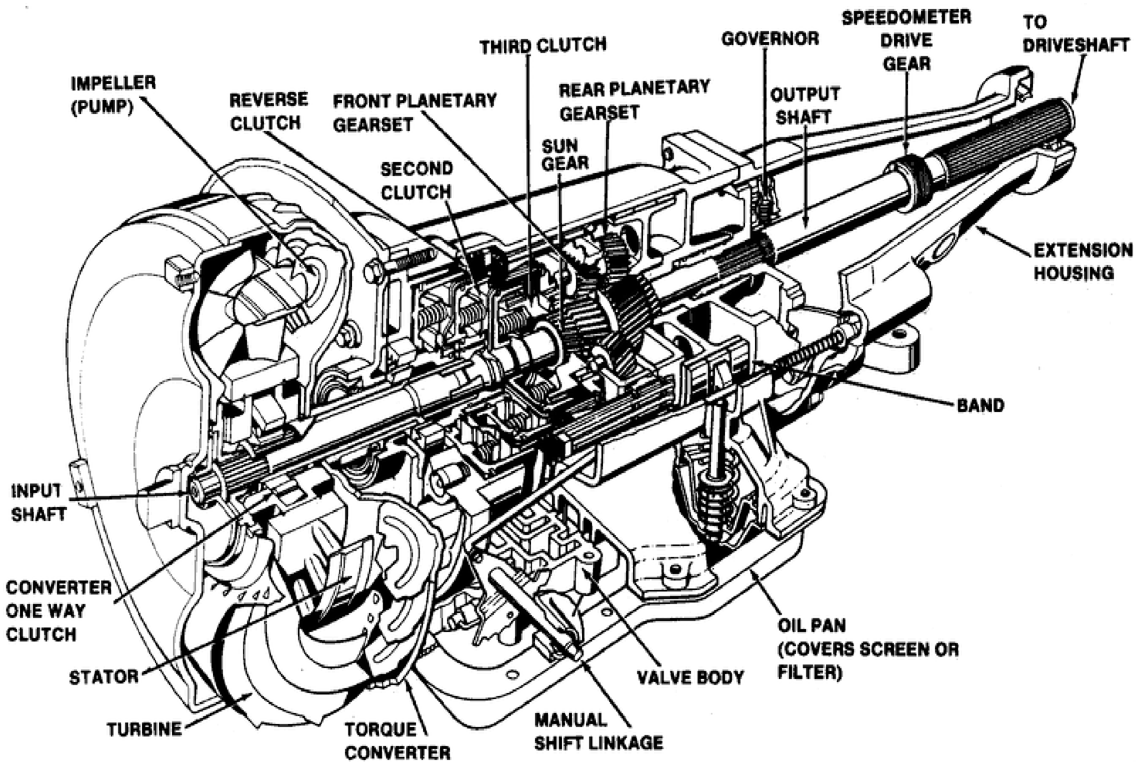


Figure 2.9: Example of an automatic transmission (Heisler, 1991).

2.2.1 Types of Automatic Transmissions

Automatic Transmissions can be basically divided into two types: those used in front-engine, front-wheel drive (FF) vehicles and those used in front-engine, rear-wheel drive (FR) vehicles.

Transmissions used in front-wheel drive vehicles are designed to be more compact than transmissions used in real-wheel drive vehicles because they are mounted in the engine compartment. They are commonly referred to as a “transaxle”. Figure 2.10 shows the type and position of the front-wheel (FF) and real-wheel drives (FR) are mounted.

The differential is an integral part of the front-wheel drive transmission, whereas the differential for the rear-wheel drive transmission is mounted externally. The external differential is connected to the transmission by a driveshaft. The basic function and purpose for either front or rear drive automatics are the same. They share the same planetary gear train design.

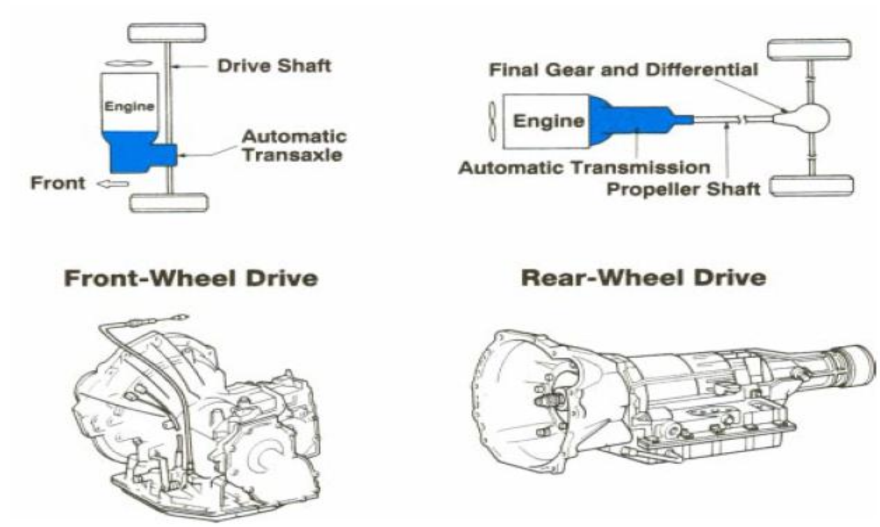


Figure 2.10: Type of automatic transmissions and the position they are mounted (TOYOTA Technical Training).

2.2.2 Planetary Gear Set Ratios

One of the planetary gearsets from transmission has a ring gear with 72 teeth and a sun gear with 30 teeth. Lots of different gear ratios can be getting out of this gear set.

Table 2.2: Planetary gear set ratios (Heisler, 1991).

	Input	Output	Stationary	Calculation	Gear Ratio
A	Sun (S)	Planet Carrier (C)	Ring (R)	1 + R/S	3.4:1
B	Planet Carrier (C)	Ring (R)	Sun (S)	1 / (1 + R/S)	0.71:1
C	Sun (S)	Ring (R)	Planet Carrier (C)	-R/S	-2.4:1

Also, locking any two of the three components together will lock up the whole device at a 1:1 gear reduction. Notice that the first gear ratio listed above is a reduction -- the output speed is slower than the input speed. The second is an overdrive -- the output speed is faster than the input speed. The last is a reduction again, but the output direction is reversed. There are several other ratios that can be gotten out of this planetary gear set, but these are the ones that are relevant to our automatic transmission (Heisler, 1991).

So this one set of gears can produce all of these different gear ratios without having to engage or disengage any other gears. With two of these gearsets in a row, we can get the four forward gears and one reverse gear our transmission needs.

Table 2.3: Summary of the gear ratios, inputs, and outputs (Heisler, 1991).

Gear	Input	Output	Fixed	Gear Ratio
1st	30-tooth sun	72-tooth ring	Planet Carrier	2.4:1
2nd	30-tooth sun	Planet carrier	36-tooth ring	2.2:1
	Planet carrier	72-tooth ring	36-tooth sun	0.67:1
			Total 2nd	1.67:1
3rd	30- & 36-tooth suns	72-tooth ring		1.0:1
OD	Planet carrier	72-tooth ring	36-tooth sun	0.67:1
Reverse	36-tooth sun	72-tooth ring	Planet carrier	-2.0:1

2.2.3 Mechanical Operation

2.2.3.1 First Gear

In first gear, the smaller sun gear is driven clockwise by the turbine in the torque converter. The planet carrier tries to spin counterclockwise, but is held still by the one-way clutch (which only allows rotation in the clockwise direction) and the ring gear turns the output. The small gear has 30 teeth and the ring gear has 72, so the gear ratio is (Heisler, 1991):

$$\textbf{Ratio} = -R/S = -72/30 = -2.4:1 \qquad (2.1)$$

So the rotation is negative 2.4:1, which means that the output direction would be opposite the input direction. But the output direction is really the same as the input direction -- this is where the trick with the two sets of planets comes in. The first set of planets engages the second set, and the second set turns the ring gear; this combination reverses the direction. This would also cause the bigger sun gear to spin; but because that clutch is released, the bigger sun gear is free to spin in the opposite direction of the turbine (counterclockwise) (Heisler, 1991).

2.2.3.2 Second Gear

This transmission does something really neat in order to get the ratio needed for second gear. It acts like two planetary gearsets connected to each other with a common planet carrier. The first stage of the planet carrier actually uses the larger sun gear as the ring gear. So the first stage consists of the sun (the smaller sun gear), the planet carrier, and the ring (the larger sun gear). The input is the small sun gear; the ring gear (large sun gear) is held stationary by the band, and the output is the planet carrier. For this stage, with the sun as input, planet carrier as output, and the ring gear fixed, the formula is (Heisler, 1991):

$$1 + R/S = 1 + 36/30 = 2.2:1 \qquad (2.2)$$

The planet carrier turns 2.2 times for each rotation of the small sun gear. At the second stage, the planet carrier acts as the input for the second planetary gear set, the larger sun gear (which is held stationary) acts as the sun, and the ring gear acts as the output, so the gear ratio is (Heisler, 1991):

$$1 / (1+S/R) = 1 / (1 + 36/72) = 0.67:1 \tag{2.3}$$

To get the overall reduction for second gear, we multiply the first stage by the second, 2.2 x 0.67, to get a 1.47:1 reduction.

2.2.3.3 Third Gear

Most automatic transmissions have a 1:1 ratio in third gear. You'll remember from the previous section that all we have to do to get a 1:1 output is lock together any two of the three parts of the planetary gear. With the arrangement in this gearset it is even easier -- all we have to do is engage the clutches that lock each of the sun gears to the turbine (Heisler, 1991).

If both sun gears turn in the same direction, the planet gears lockup because they can only spin in opposite directions. This locks the ring gear to the planets and causes everything to spin as a unit, producing a 1:1 ratio (Heisler, 1991).

2.2.3.4 Overdrive

By definition, an overdrive has a faster output speed than input speed. It's a speed increase -- the opposite of a reduction. In this transmission, engaging the overdrive accomplishes two things at once. In order to improve efficiency, some cars have a mechanism that locks up the torque converter so that the output of the engine goes straight to the transmission.

In this transmission, when overdrive is engaged, a shaft that is attached to the housing of the torque converter (which is bolted to the flywheel of the engine) is connected by clutch to the planet carrier. The small sun gear freewheels, and the larger sun gear is held by the overdrive band. Nothing is connected to the turbine; the only input comes from the converter housing. Let's go back to our chart again, this time with the planet carrier for input, the sun gear fixed and the ring gear for output (Heisler, 1991).

$$\textbf{Ratio} = \mathbf{1 / (1 + S/R) = 1 / (1 + 36/72) = 0.67:1} \tag{2.4}$$

So the output spins once for every two-thirds of a rotation of the engine. If the engine is turning at 2000 rotations per minute (RPM), the output speed is 3000 RPM. This allows cars to drive at freeway speed while the engine speed stays nice and slow.

2.2.3.5 Reverse

Reverse is very similar to first gear, except that instead of the small sun gear being driven by the torque converter turbine, the bigger sun gear is driven, and the small one freewheels in the opposite direction. The planet carrier is held by the reverse band to the housing. So, according to the equations (2.1), we have (Heisler, 1991):

$$\textbf{Ratio} = \mathbf{-R/S = 72/36 = 2.0:1} \tag{2.5}$$

So the ratio in reverse is a little less than first gear in this transmission.

Figure 2.11 below shows the mechanical operation of the automatic transmission for each gear from first gear to overdrive and reverse.

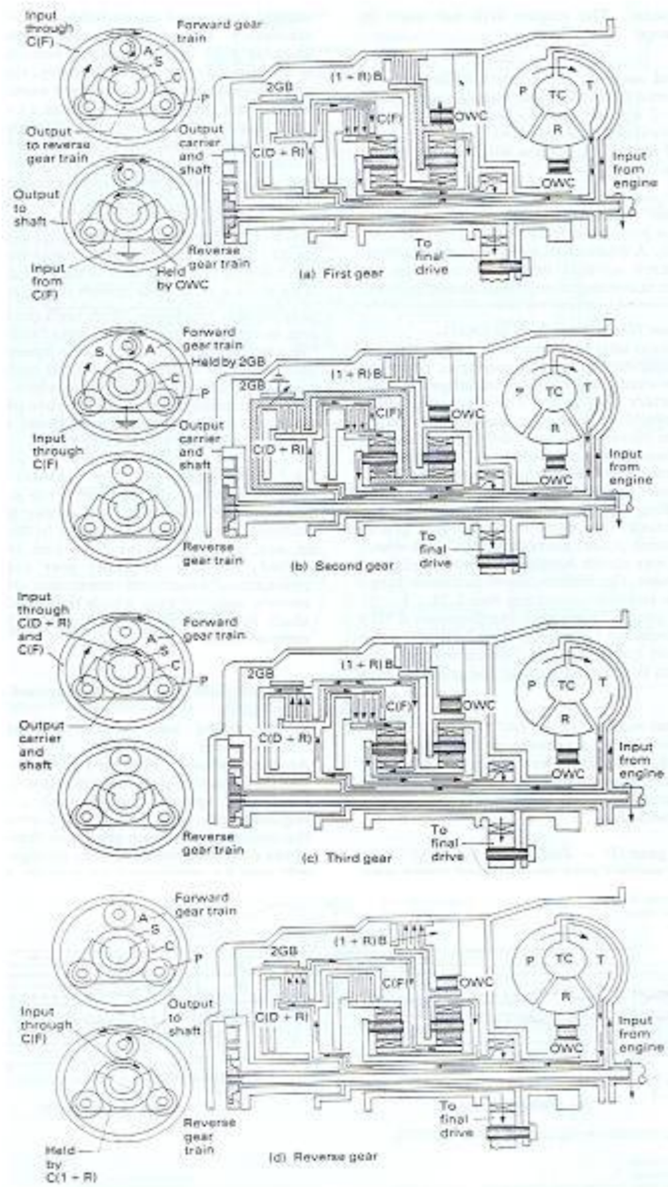
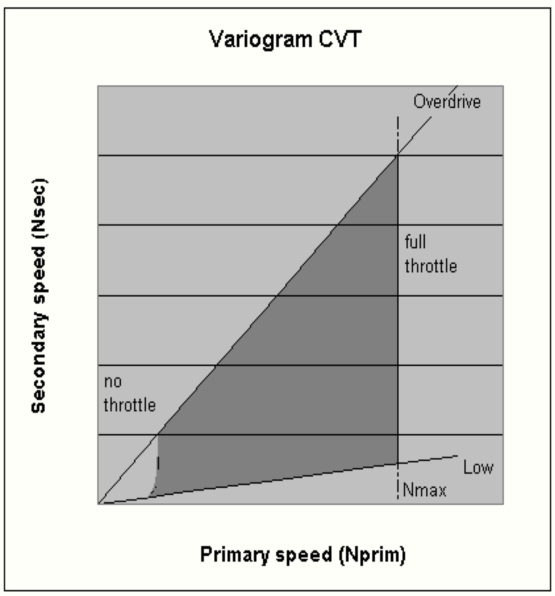


Figure 2.11: Three speeds and reverse automatic transmission transaxle units (Heisler, 1991).

2.3 Conventional AT vs. CVT

In the figure below is the variograms of a hand shifted or normal automatic transmission and the CVT are compared with each other. With the conventional automatic transmission, maximum 6 ratios' (gears) are available, but mostly even less. When the transmission upshifts, it has to follow the bold or dotted lines of the first image depending on the amount of throttle. With the CVT, the whole range of ratios between the Low and the Overdrive lines is available for shifting as shown in the right image (Geuns, 2003).

The shift point of both transmissions related to the amount of throttle. As more throttles are applied, the transmission upshifts at a higher engine speed. With the conventional transmission it is clear that the engine speed drops back when shifting to a higher gear. This is not the case with the CVT. The CVT will upshift at a constant engine speed by moving the pulleys. However, alternative shifting strategies are also possible. This can help to create a quicker acceptance by new CVT drivers (Geuns, 2003).



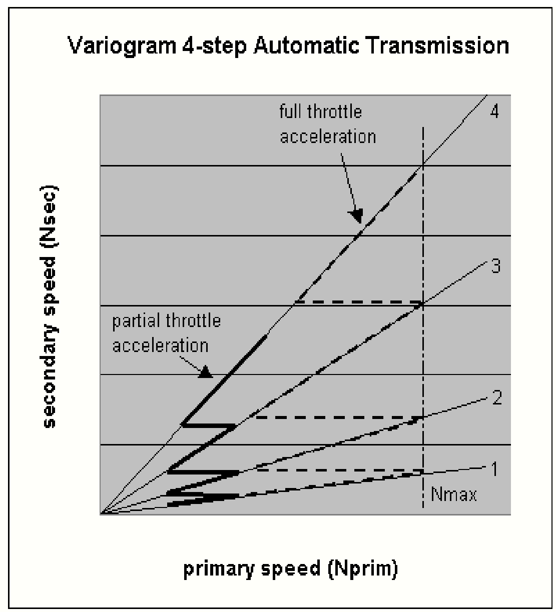


Figure 2.12: Variogram of 4 step automatic transmission and CVT transmission (Geuns, 2003).

2.4 CAR SELECTION

This section is about the car selected to be used as a references in this thesis. For the conventional automatic transmission, the car selected is Perodua VIVA ELITE AT. The table below shows the specifications of the Viva Elite AT.

Table 2.4: Technical Specifications of Perodua Viva Elite (www.perodua.com.my).

MODEL			VIVA ELITE AT
Overall length		mm	3575
Overall width		mm	1475
Overall height		mm	1530
Wheelbase		mm	2390
Couple distance		mm	840
Track	Front	mm	1300
	Rear	mm	1290
Kerb weight		kg	805
Minimum ground clearance		mm	145
Minimum turning radius (tyre)		m	4.4
Total displacement		cc	989
Bore x stroke		mm	72 x 81
No. of cylinders			3
Compression ratio			10
Max. output (DIN)		Kw/rpm	45/6000
Max. torque (DIN)		Nm/rpm	90/3600
Fuel tank capacity		L	36.0
Transmission	Type	Auto - AT	
Transmission gear ratio		1st	2.731
		2nd	1.526
		3rd	1
		4th	0.696
		Reverse	2.29
		Final gear ratio	4.439
Tires			165/55/R14
Disc Wheel			14” alloy rims

Since Perodua VIVA ELITE AT only comes with 4-step automatic transmission, therefore Honda Insight 2005 is taken as a reference as it comes with continuously variable transmission (CVT). Other than that, the specifications of the car are almost similar with Perodua VIVA ELITE AT. Below is the table that shows the specifications of Honda Insight 2005.

Table 2.5: Technical Specifications of Honda Insight 2005 (automobiles.honda.com).

MODEL			HONDA INSIGHT 2005
Overall length		mm	3940
Overall width		mm	1694
Overall height		mm	1354
Wheelbase		mm	2400
Track	Front	mm	1435
	Rear	mm	1326
Kerb weight		kg	896
Total displacement		cc	995
No. of cylinders			3
Compression ratio			10.3:1
Max. output (SAE net / with IMA)		Kw/rpm	50@5700 / 54@5700
Max. torque (SAE net / with IMA)		Nm/rpm	89@4800 / 123@2000
Transmission	Type	CVT	
Transmission gear ratio		1st 2nd 3rd 4th 5th	2.441 ~ 0.407
		Reverse	4.359 ~ 3.214
		Final gear ratio	5.69
Tires			165/65/R14
Disc Wheel			14” alloy rims

CHAPTER 3

ROAD VEHICLE DYNAMICS

3.1 VEHICLE RESISTANCE AND ROAD DISTURBANCE

Figure 3.1 shows the forces acting on a vehicle with mass, *m*, and speed, *v*. By applying Newton's second law in the longitudinal direction, the friction force (R_w) is described by (Gillespie, 1992):

$$R_w = R_a + R_r + R_g + R_i \tag{3.1}$$

Where,

R_a : the aerodynamic drag resistance

R_r : rolling resistance

R_g : gravitational resistance

R_i : acceleration resistance,

The external torque could be modeled as

$$T_w = R_w \times r \tag{3.2}$$

where,

r : the radius of the tyre (m)

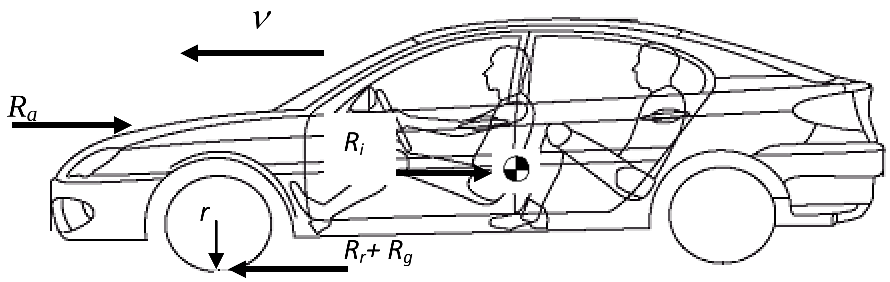


Figure 3.1: Force acting on a vehicle (S. Ariyono, 2009)

3.1.1 Aerodynamics Resistance

On modern cars and trucks, the road load is dependent on the aerodynamic factor. The aerodynamic forces of a vehicle arise from two source-forms, drag and viscous friction. Since airflow over a vehicle is so complex, it is necessary to use semi-empirical model to represent the effect (Gillespie, 1992). Thus the aerodynamic drag, R_a, is characterised by equation:

$$R_a = \tfrac{1}{2}\rho C_d\, A v^2 \tag{3.3}$$

Where,

ρ : the air density (kg/m^3)

C_d : the aerodynamic drag coefficient

A : the maximum vehicle cross-section area (m^2)

v : vehicle speed (m/sec).

3.1.2 Rolling Resistance

The other major resistance on level ground is the rolling resistance of the tires. At low speed on hard pavement, the rolling resistance is the primary motion resistance force. Aerodynamic resistance becomes equal to the rolling resistance only at the speed of 80 – 100 km/h (Gillespie, 1992). There are several factors affecting rolling resistance such as tyre temperature, tire inflation pressure, vehicle velocity, and type of tyre. The coefficient is proportional to the speed but the effect is small at moderate and low speeds and is often assumed to be constant. The influence of speed becomes more pronounced when coupled with lower inflation pressure. Because of the complexity of factors affecting rolling resistance, it is necessary to simplify the equation and the rolling resistance, R_r, and approximated as

$$R_r = (c_a + c_b v)mg \qquad (3.4)$$

Where,

c_a : constant (0.013) (Gillespie, 1992)

c_b : constant (0.00004) (Gillespie, 1992)

m : mass of vehicle (kg)

g : gravitational acceleration (m/sec^2).

3.1.3 Gravitational Resistance

When a vehicle climbs an inclined road, force due to gravity needs to be considered. This extra force due to inclined road has to be overcome by the engine. When the road slope is declining the engine should be able to provide engine break by increasing its transmission ratio.

Gravitational force, R_g, is approximated by

$$R_g = mg\sin\theta \qquad (3.5)$$

Where,

θ : The road slope (%)

3.1.4 Acceleration Resistance

Assuming the mass is fixed, the acceleration resistance (R_i) is equal to

$$R_i = m\frac{dv}{dt} = m\dot{v} \tag{3.6}$$

Where,

$\dot{v}$: Acceleration in the direction of motion of the vehicle.

3.2 DRIVELINE DYNAMICS

The maximum achievable acceleration of a vehicle is limited by two factors; maximum torque at driving wheels and maximum traction force at tire prints. The first one depends on engine and transmission performance and the second one is depends on tire-road friction. In this chapter, engine and transmission performance were examined.

3.2.1 Engine Dynamics

The maximum attainable power P_e of an internal combustion engine is a function of the engine angular velocity ω_e. This function must be determined experimentally, however, the function $P_e = P_e\ (\omega_e)$, which is called the *power performance function*, can be estimated by a third-order polynomial,

$$P_e = \sum_{i=1}^{3} P_i \omega_e^i \tag{3.7}$$

$$= P_1\omega_e + P_2\omega_e^2 + P_3\omega_e^3 \tag{3.8}$$

Where,

P_i : Coefficient of the power performance function (W)

ω_e : Engine angular velocity (rad/s)

If we use ω_M to indicate the angular velocity, measured in [rad/s], at which the engine power reaches the maximum value P_M, measured in [W=Nm/s], then for spark ignition engines we use,

$$P_1 = \frac{P_M}{\omega_M} \tag{3.9}$$

$$P_2 = \frac{P_M}{\omega_M^2} \tag{3.10}$$

$$P_3 = -\frac{P_M}{\omega_M^3} \tag{3.11}$$

Where,

P_M : Maximum engine power (W)

ω_M : Engine angular velocity at maximum power (rad/s)

The driving torque of the engine T_e is the torque that provides P_e,

$$T_e = \frac{P_e}{\omega_e} \tag{3.12}$$

$$= P_1 + P_2\omega_e + P_3\omega_e^2 \tag{3.13}$$

Where,

P_e : Maximum attainable power of an engine (W)

ω_e : Engine angular velocity (rad/s)

3.2.2 Gearbox Dynamics

The internal combustion engine cannot operate below a minimum engine speed ω_{min}. Consequently, the vehicle cannot move slower than a minimum speed v_{min} while the engine is connected to the drive wheels. Therefore, minimum speed v_{min} can be calculated by using the equation below,

$$v_{min} = \frac{R_\omega \omega_{min}}{n_g n_d} \tag{3.14}$$

Where,

R_w : Effective tire radius (m)

ω_{min} : Minimum engine speed (rad/s)

n_g : Overall transmission ratio

n_d : The differential transmission ratio

At starting and stopping stages of motion, the vehicle needs to have speeds less than v_{min}. A clutch or a torque converter must be used for starting, stopping, and gear shifting.

Consider a vehicle with only one drive wheel. Then the forward velocity v_χ of the vehicle is proportional to the angular velocity of the engine ω_e,

$$\omega_e = \frac{n_i n_d}{R_\omega} v_\chi \tag{3.15}$$

Where,

n_i : Gearbox transmission ratio

n_d : The differential transmission ratio

R_w : The effective tire radius (m)

Having the torque performance function, $T_e = T_e\ (\omega_e)$ enables us to determined the wheel torque, T_w as a function of vehicle speed, v_x at each gear ratio n_i

$$T_w = \eta n_i n_d T_e(\omega_e) \tag{3.16}$$

Where,

η : Overall efficiency

n_i : Gearbox transmission ratio

n_d : The differential transmission ratio

T_e : Engine torque (Nm)

ω_e : Angular velocity (rad/s)

Using the approximate equation (3.13) for T_e provides

$$T_w = \eta n_i n_d \left[P_1 + P_2\left(\frac{n_i n_d}{R_w} v_x\right) + P_3\left(\frac{n_i n_d}{R_w} v_x\right)^2\right] \tag{3.17}$$

$$= \eta\left(P_1 n_d n_i + \eta\frac{P_2}{R_w} n_d^2 n_i^2 v_x + \eta\frac{P_3}{R_w^2} n_d^3 n_i^3 v_x^2\right) \tag{3.18}$$

CHAPTER 4

RESULT AND DISCUSSION

4.1 ENGINE POWER, P_e AND ENGINE TORQUE, T_e

4.1.1 Example Calculation of Engine Power, P_e and Engine Torque, T_e

At engine speed = 600 rpm for the conventional automatic transmission;

$$600\ rpm = \frac{600 \times 2\pi}{60} = 62.83\ rad/s$$

$$P_e = \sum_{i=1}^{3} P_i \omega_e^i = P_1 \omega_e + P_2 \omega_e^2 + P_3 \omega_e^3$$

$$P_1 = \frac{P_M}{\omega_M} = \frac{45000}{628.32} = 71.6196$$

$$P_2 = \frac{P_M}{\omega_M^2} = \frac{45000}{628.32^2} = 0.1140$$

$$P_3 = -\frac{P_M}{\omega_M^3} = -\frac{45000}{628.32^2} = -1.8141 \times 10^{-4}$$

$$P_e = 71.6196\omega_e + 0.1140\omega_e^2 - 1.8141 \times 10^{-4}\omega_e^3$$

$$P_e = (71.6196 \times 62.83) + (0.1140 \times 62.83^2) - (1.8141 \times 10^{-4} \times 62.83^3)$$

$$P_e = 4.9049\ kW$$

$$T_e = \frac{P_e}{\omega_e}$$

$$T_e = \frac{4.9049 \times 10^3\ W}{62.83\ rad/s}$$

$$T_e = 78.0661\ Nm$$

Table 4.1: Table of the value for engine power and engine torque at different engine speed for Perodua VIVA ELITE.

Engine speed, rpm	Angular velocity, ωe (rad/s)	Engine torque, Te (Nm)	Engine power, Pe (kW)
600	62.83	78.0661	4.9049
1200	125.66	83.0803	10.4399
1800	188.50	86.6627	16.3359
2400	251.33	88.8121	22.3211
3000	314.16	89.5293	28.1265
3600	376.99	88.8142	33.4821
4200	439.82	86.6668	38.1178
4800	502.66	83.0865	41.7643
5400	565.49	78.0744	44.1503
6000	628.32	71.6299	45.0065
6600	691.15	63.7533	44.0631
7200	753.98	54.4443	41.0499

Table 4.2: Table of the value for engine power and engine torque at different engine speed for Honda Insight 2005.

Engine Speed, rpm	Angular Velocity, ωe (rad/s)	Engine Torque, Te (Nm)	Engine Power, Pe (kW)
600	62.83	91.653	5.7586
1200	125.66	97.6837	12.2749
1800	188.5	101.8587	19.2004
2400	251.33	104.1766	26.1827
3000	314.16	104.6382	32.8731
3600	376.99	103.2436	38.9218
4200	439.82	99.9928	43.9788
4800	502.66	94.8847	47.6947
5400	565.49	87.9211	49.7185
6000	628.32	79.1013	49.7009
6600	691.15	68.4251	47.292
7200	753.98	55.8928	42.1421

4.1.2 Graph Discussion

Figure 4.1 and Figure 4.2 shows the output engine torque and engine power for Perodua VIVA ELITE and Honda Insight 2005 respectively. The output torque and power for both cars are different since the cars selected are different. As for Perodua VIVA ELITE AT which comes with 4-step automatic transmission, the maximum engine torque is 90 Nm at the engine speed of 3000 rpm whereas the maximum engine torque for Honda Insight 2005 which suited with conventional variable transmission is 104 Nm at the engine speed of 3000 rpm. In term of the engine power, the maximum power for Perodua VIVA ELITE is 45 kW at the engine speed of 6000 rpm whereas for the Honda Insight 2005 the maximum engine power is 50 kW at the engine speed of 5400 rpm.From this result, it shows that Honda Insight 2005 with CVT have better performance compared to Perodua VIVA ELITE AT. Car which comes with CVT reach the maximum engine torque and engine power early compared to car which suited with conventional automatic transmission. The intersection point indicated the optimum condition whereas the engine operates at high engine torque and engine power.

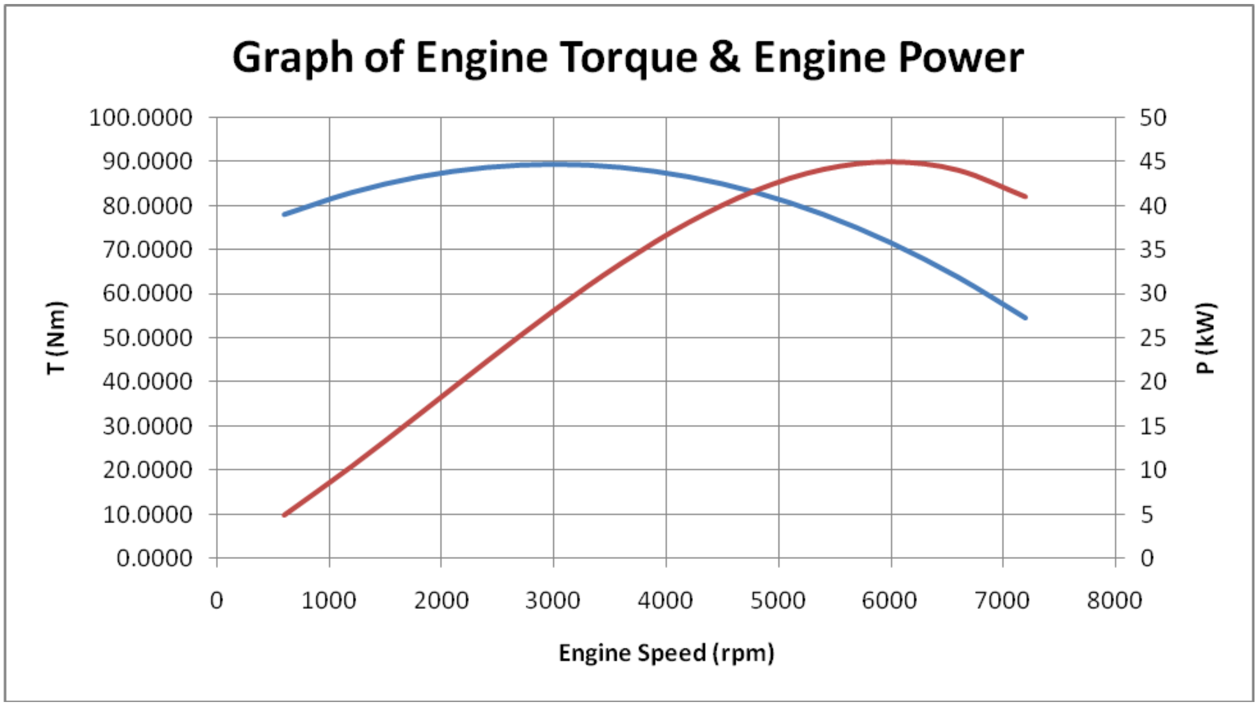


Figure 4.1: Graph of engine torque and engine torque for Perodua VIVA ELITE.

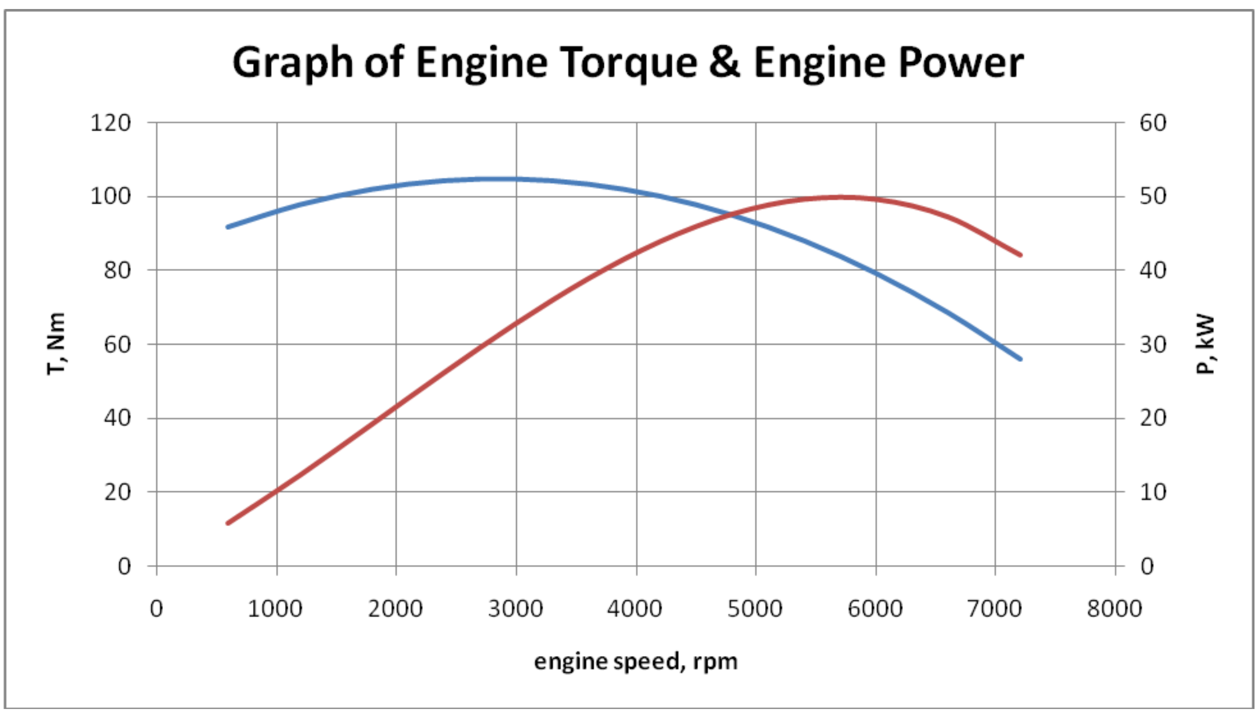


Figure 4.2: Graph of engine torque and engine power for Honda Insight 2005.

4.2 TRANSMISSION POWER, P_T, VEHICLE SPEED, *v*, AND POWER REQUIRED, P_{req}.

4.2.1 Example Calculation of Transmission Power, P_T

Engine speed = 600 rpm at 1st gear for the conventional automatic transmission;

$$v = \frac{N_e 2\pi r}{60G}$$

$$v = \frac{600 \times 2\pi \times 0.2686}{60 \times 2.731 \times 4.439} = 1.3921\ m/s$$

$$P_T = \frac{T_e G v}{r}$$

$$P_T = \frac{78.0661 \times 2.731 \times 4.439 \times 1.3921}{0.2686} = 4.9053\ kW$$

4.2.2 Example Calculation of Power Required, P_{req}

At v = 5 m/s for the conventional automatic transmission;

$$R_a = \frac{1}{2}\rho C_d A v^2$$

$$R_a = \frac{1}{2} \times 1.2 \times 0.32 \times 1.8280 \times 5 = 8.7744\ N$$

$$R_r = (c_a + c_b v)mg$$

$$R_r = [0.013 + (0.00004 \times 5)] \times 805 \times 9.81 = 104.2411 N$$

$$P_{req} = \frac{T_w \omega_w}{\eta} = \frac{R_w v}{\eta}; \qquad R_w = R_a + R_r$$

$$P_{req} = \frac{(8.7744 + 104.2411) \times 5}{0.85} = 0.6648\ kW$$

Table 4.3: Table of the value for transmission power and vehicle speed at each gear-ratio at different engine speed for Perodua VIVA ELITE.

Engine Speed, rpm	1st gear		2nd gear		3rd gear		4th gear	
	v (m/s)	P (kW)	v (m/s)	P (kW)	v (m/s)	P (kW)	v (m/s)	P (kW)
600	1.3921	4.9053	2.4914	4.905	3.8019	4.905	5.4626	4.9051
1200	2.7843	10.4403	4.9828	10.4401	7.6038	10.4402	10.9252	10.4402
1800	4.1764	16.3356	7.4743	16.3356	11.4057	16.3355	16.3877	16.3355
2400	5.5685	22.3209	9.9657	22.321	15.2076	22.3209	21.8503	22.3209
3000	6.9606	28.1263	12.4571	28.1265	19.0095	28.1265	27.3129	28.1265
3600	8.3528	33.4823	14.9485	33.4821	22.8114	33.4822	32.7755	33.4822
4200	9.7449	38.1181	17.4399	38.118	26.6133	38.1181	38.238	38.118
4800	11.137	41.7637	19.9314	41.7639	30.4152	41.7638	43.7006	41.7638
5400	12.5292	44.1502	22.4228	44.1501	34.2171	44.15	49.1632	44.15
6000	13.9213	45.0064	24.9142	45.0064	38.019	45.0064	54.6258	45.0064
6600	15.3134	44.0631	27.4056	44.0631	41.8209	44.0631	60.0884	44.0632
7200	16.7055	41.0499	29.8971	41.0501	45.6228	41.05	65.5509	41.05

Table 4.4: Table of the power required to overcome the friction force at different vehicle speed for Perodua VIVA ELITE.

Vehicle speed, v (m/s)	friction force component (N)			P_{req} (kW)
	R_a	R_r	R_W	
5	8.7744	104.2411	113.0155	0.6648
10	35.0976	105.8205	140.9181	1.6579
15	78.9696	107.3999	186.3695	3.2889
20	140.3904	108.9793	249.3697	5.8675
25	219.36	110.5587	329.9187	9.7035
30	315.8784	112.1381	428.0165	15.1065

35	429.9456	113.7175	543.6631	22.3861
40	561.5616	115.2969	676.8585	31.8522
45	710.7264	116.8763	827.6027	43.8143
50	877.44	118.4558	995.8958	58.5821

Table 4.5: Table of the value for transmission power and vehicle speed at each gear-ratio at different engine speed for Honda Insight 2005.

Engine Speed,rpm	**1st gear-ratio**		**Last gear-ratio**	
	v (m/s)	**P (kW)**	**v (m/s)**	**P (kW)**
600	1.2897	5.7586	7.7353	5.7587
1200	2.5795	12.2756	15.4706	12.2753
1800	3.8692	19.2001	23.2058	19.1999
2400	5.1589	26.1825	30.9411	26.1824
3000	6.4486	32.873	38.6764	32.8731
3600	7.7383	38.9217	46.4117	38.9219
4200	9.0281	43.9793	54.147	43.9792
4800	10.3178	47.6943	61.8822	47.6942
5400	11.6075	49.7182	69.6172	49.7182
6000	12.8972	49.7007	77.3528	49.7008
6600	14.187	47.2922	85.0881	47.2921
7200	15.4767	42.1422	92.8234	42.1422

Table 4.6: Table of the power required to overcome the friction force at different vehicle speed for Honda Insight 2005.

Vehicle Speed, v (m/s)	**friction force components (N)**			**P_{req} (kW)**
	R_a	**R_r**	**R_W**	
10	27.867	117.7828	145.6498	1.7135
20	111.468	121.2987	232.7667	5.4769
30	250.803	124.8146	375.6176	13.2571
40	445.872	128.3305	574.2025	27.0213
50	696.675	131.8464	828.5214	48.7366
60	1003.212	135.3623	1138.574	80.3699
70	1365.483	138.8782	1504.361	123.8886
80	1783.488	142.3941	1925.882	181.2595
90	2257.227	145.91	2403.137	254.4498

4.2.3 Graph Discussion

Figure 4.3 and 4.4 both show the transmission power, P_T and engine power, P_{req} required to overcome the friction force at different vehicle speed. As can be seen in Figure 4.3, the transmission power for conventional automatic transmission is increase at the first gear until reaches the engine peak power, 45 kW at engine speed of 6000 rpm and then drops down before shifting to second gear and then it increase again until reaches engine peak power before drops. This phenomenon is repeated over and over until the fourth gear. This is because of the conventional is built based on separated gear with different gear-ratio. For Figure 4.4, it shows that the transmission power for continuously variable transmission is increase gradually before reaching the engine peak power, 50 kW at engine speed of 5700 rpm. After that the transmission power is constant and maintain at engine peak power. This is due to the concept of continuously variable transmission which has no gear-ratio since it is built based on pulley system.

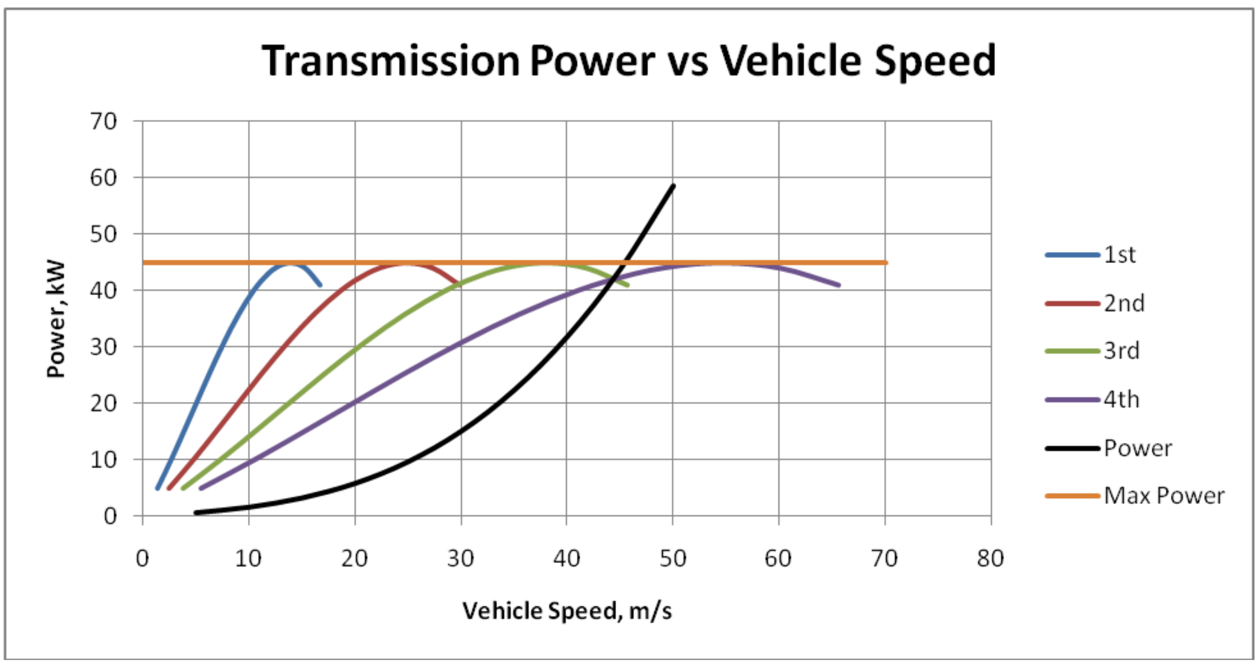


Figure 4.3: Graph of transmission power and power required versus vehicle speed of conventional automatic transmission for Perodua VIVA ELITE.

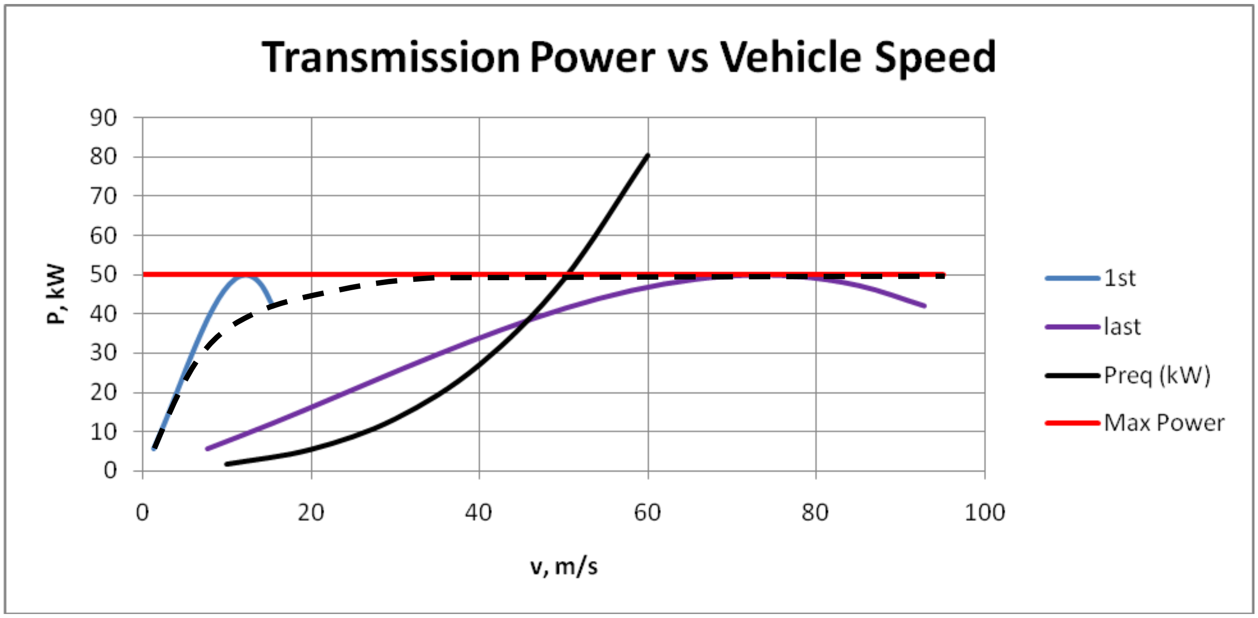


Figure 4.4: Graph of transmission power and power required versus vehicle speed of continuously variable transmission for Honda Insight 2005.

4.3 ANGULAR VELOCITY, ω_e.

4.3.1 Example Calculation of Angular Velocity, ω_e

For the first gear (n_i = 2.731) at v = 10 m/s;

$$\omega_e = \frac{n_i n_d}{R_\omega} v_x$$

$$\omega_e = \frac{2.731 \times 4.439}{0.2686} \times 10 = 451.3366\ rad/s$$

Table 4.7: Table of the value for angular velocity at each gear-ratio on different vehicle speed for Perodua VIVA ELITE.

Vehicle speed, v (m/s)	**Angular velocity, ω_e (rad/s)**			
	1st	**2nd**	**3rd**	**4th**
0	0	0	0	0
5	225.6683	126.0964	82.6489	57.1116
10	451.3366	252.1929	165.2978	115.0223
15	677.0048	378.2893	247.9468	172.5335
20	902.6731	504.3857	330.5957	230.0447
25	1128.3414	630.4821	413.2446	287.5559
30	1354.0097	756.5786	495.8935	345.067
35	1579.678	882.675	578.5424	402.5782
40	1805.3462	1008.7714	661.1914	460.0894
45	2031.0145	1134.8678	743.8403	517.6005
50	2256.6828	1260.9643	826.4892	575.1117

Table 4.8: Table of the value for angular velocity at each gear-ratio on different vehicle speed for Honda Insight 2005.

Vehicle Speed, v (m/s)	**Angular Velocity, ω_e (rad/s)**	
	1^{st} gear-ratio	**Last gear-ratio**
0	0	0
5	243.5862	40.6143
10	487.1723	81.2287
15	730.7585	121.843
20	974.3447	162.4573
25	1217.9309	203.0716
30	1461.517	243.686
35	1705.1032	284.3003
40	1948.6894	324.9146
45	2192.2755	365.5289
50	2435.8617	406.1433

4.3.2 Graph Discussion

Figure 4.5 and 4.6 both are show the angular velocity, ω_e or engine speed at different gear-ratio and different vehicle speed for conventional automatic transmission and continuously variable transmission respectively. For conventional automatic transmission, it shows that the engine speed is increase until it reaches maximum, 550 rad/s. Then, to shift to next gear, engine speed will be reduced and it is repeated again and again until the last gear-ratio. For continuously variable transmission, it is different with the conventional automatic transmission. Figure 4.6 shows that the engine speed is increase until maximum engine speed, 500 rad/s and then it maintain at the maximum engine speed until it reaches the last gear-ratio. In this case, it is shown that continuously variable transmission can shift to other gear-ratio with maintaining the engine speed compared to the conventional automatic transmission. This will result the car built with CVT will have smooth shifting compared to conventional automatic transmission.

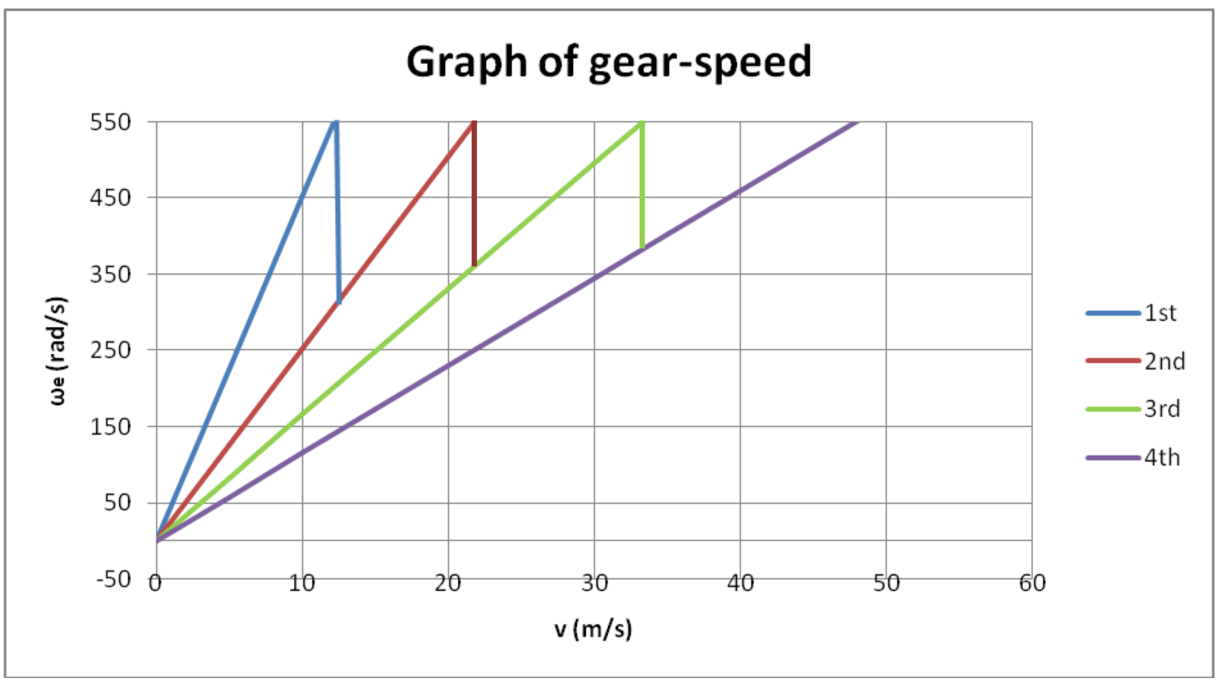


Figure 4.5: Graph of gear-speed for conventional automatic transmission of Perodua VIVA 1000cc.

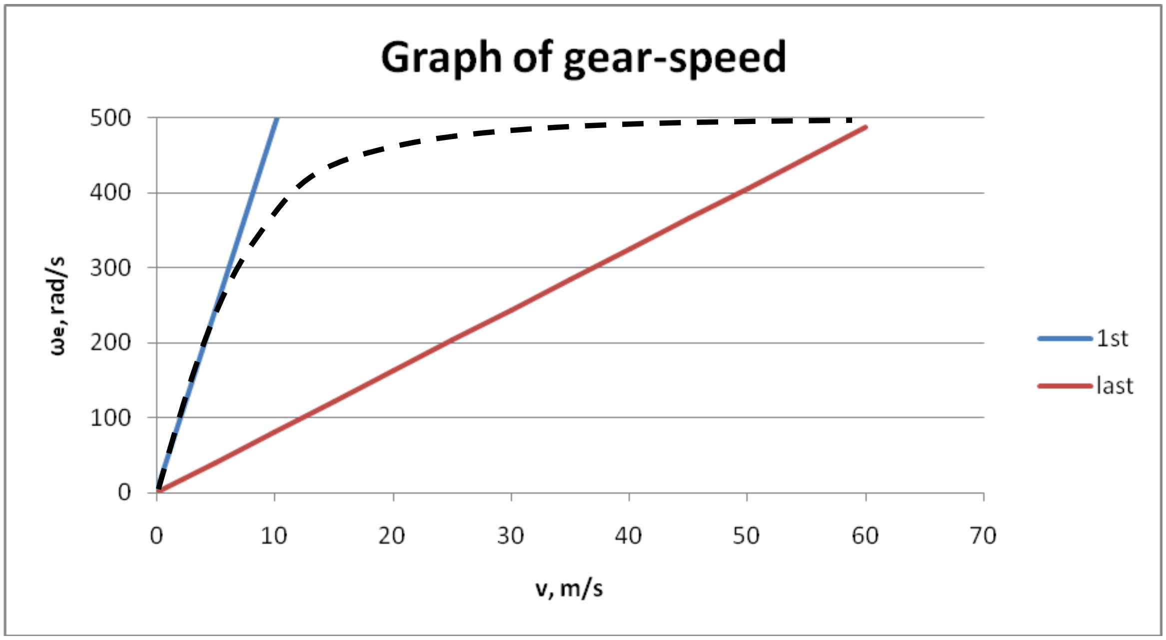


Figure 4.6: Graph of gear-speed for continuously variable transmission of Honda Insight 2005.

4.4 WHEEL TORQUE, T_w.

4.4.1 Example Calculation of Wheel Torque, T_w;

For the first gear (n_i = 2.731) at vehicle speed, v = 1.3921 m/s of conventional automatic transmission;

$$T_w = \eta n_i n_d T_e(\omega_e)$$

$$T_e = P_1 + P_2\omega_e + P_3\omega_e^2$$

$$T_e = 71.6196 + 0.1140\omega_e - (1.8141 \times 10^{-4}.\omega_e^2)$$

$$\omega_e = \frac{n_i n_d}{R_\omega} v_\chi$$

Substitute equation of engine torque, T_e and equation of angular velocity, ω_e into equation of wheel torque, T_w provides;

$$T_w = \eta n_i n_d \left[P_1 + P_2\left(\frac{n_i n_d}{R_w} v_x\right) + P_3\left(\frac{n_i n_d}{R_w} v_x\right)^2\right]$$

$$T_w = \eta\left(P_1 n_d n_i + \frac{P_2}{R_w} n_d^2 n_i^2 v_x + \frac{P_3}{R_w^2} n_d^3 n_i^3 v_x^2\right)$$

$$T_w = 0.30\left[(71.6196 \times 4.439 \times 2.731) + \left(\frac{0.1140}{0.2686}(4.439^2)(2.731^2)(1.3921)\right) + \left(\frac{-1.8141 \times 10^{-4}}{0.2686}(4.439^2)(2.731^2)(1.3921^2)\right)\right]$$

$$T_w = 283.9134\ Nm$$

Table 4.9: Table of wheel torque at each gear-ratio based on the vehicle speed for Perodua VIVA ELITE.

1st gear		2nd gear		3rd gear		4th gear	
v (m/s)	**T_w (Nm)**	**v (m/s)**	**T_w (Nm)**	**v (m/s)**	**T_w (Nm)**	**v (m/s)**	**T_w (Nm)**
1.3921	283.9134	2.4914	158.6423	3.8019	103.9596	5.4626	72.356
2.7843	302.1419	4.9828	168.8274	7.6038	110.634	10.9252	77.0014
4.1764	315.1544	7.4743	176.0988	11.4057	115.3989	16.3877	80.3177
5.5685	322.9523	9.9657	180.456	15.2076	118.2542	21.8503	82.305
6.9606	325.5355	12.4571	181.8994	19.0095	119.2001	27.3129	82.9633
8.3528	322.9038	14.9485	180.4289	22.8114	118.2365	32.7755	82.2925
9.7449	315.0574	17.4399	176.0446	26.6133	115.3634	38.238	80.2927
11.137	301.9964	19.9314	168.7461	30.4152	110.5808	43.7006	76.9638
12.5292	283.7194	22.4228	158.5339	34.2171	103.8888	49.1632	72.3059

13.9213	260.2288	24.9142	145.408	38.019	95.2872	54.6258	66.3189
15.3134	231.5236	27.4056	129.3682	41.8209	84.7761	60.0884	59.0029
16.7055	197.6038	29.8971	110.4137	45.6228	72.3556	65.5509	50.358

Table 4.10: Table of wheel torque at each gear-ratio based on the vehicle speed for Honda Insight 2005.

Engine Speed, rpm	**1st gear-ratio**		**Last gear-ratio**	
	v (m/s)	**T_w (Nm)**	**v (m/s)**	**T_w (Nm)**
600	1.2897	381.8981	7.7353	63.6759
1200	2.5795	407.0258	15.4706	67.8654
1800	3.8692	424.4144	23.2058	70.7647
2400	5.1589	434.0662	30.9411	72.3741
3000	6.4486	435.9813	38.6764	72.6929
3600	7.7383	430.1596	46.4117	71.7224
4200	9.0281	416.5998	54.147	69.4615
4800	10.3178	395.304	61.8822	65.9106
5400	11.6075	366.2714	69.6172	61.0697
6000	12.8972	329.5021	77.3528	54.9384
6600	14.187	284.9923	85.0881	47.5172
7200	15.4767	232.7488	92.8234	38.8059

4.4.2 Graph Discussion

Figure 4.7 and 4.8 shows the wheel torque of conventional automatic transmission and continuously variable transmission respectively. The dotted lines in both Figure 4.7 and 4.8 represent the constant engine power which is equal to the maximum power of the engine. It is only approached when the engine reaches the speed at which it develops maximum power. For the conventional automatic transmission, it shows that there are deficiencies of the transmission in providing maximum acceleration performance. But the situation is different for continuously variable transmission where as it has no deficiency in providing maximum acceleration performance.

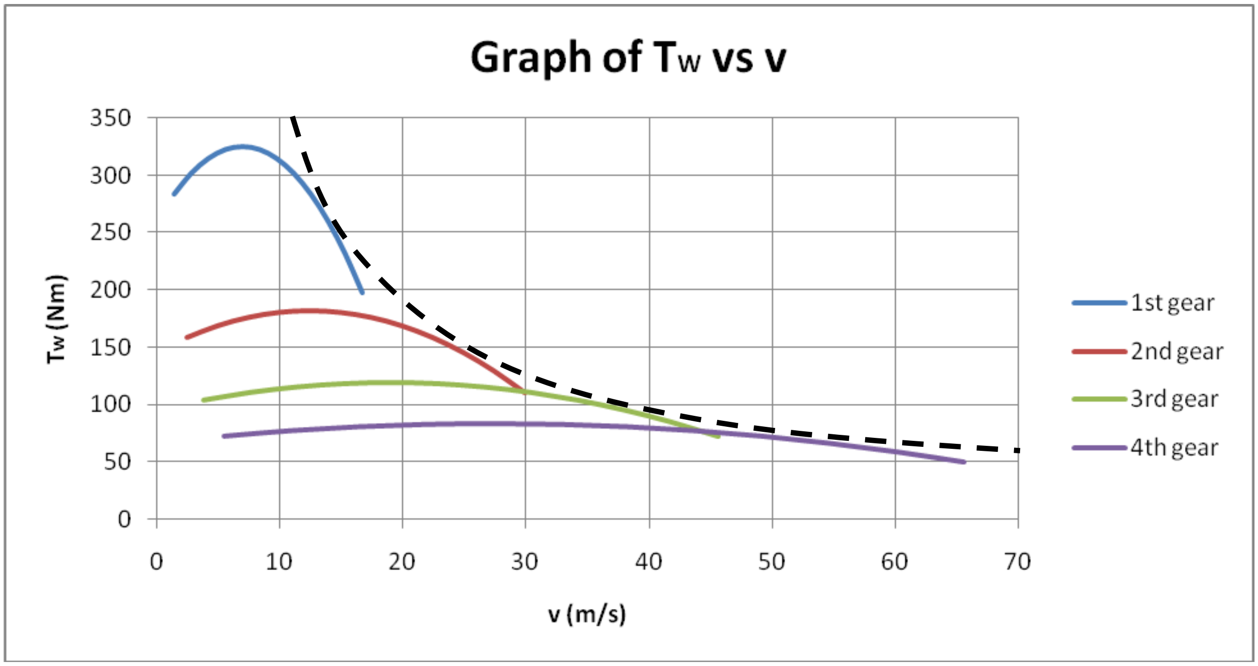


Figure 4.7: Graph of wheel torque versus vehicle speed for conventional automatic transmission of Perodua VIVA 1000cc.

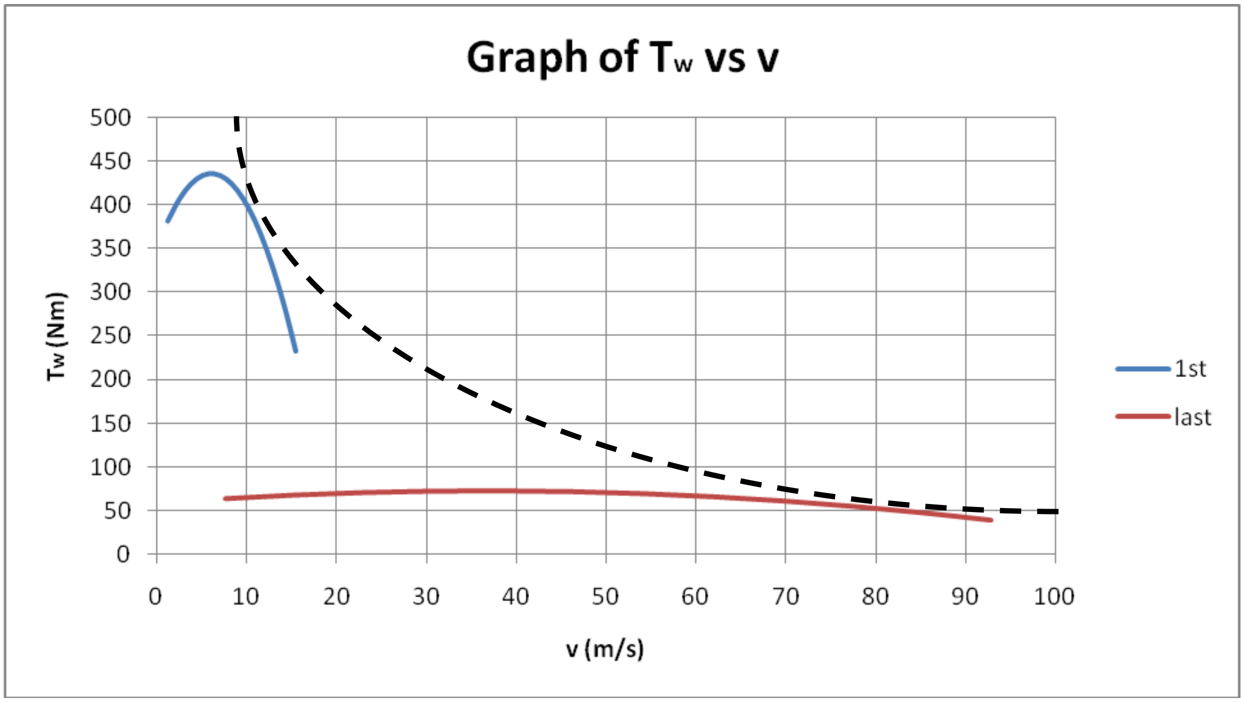


Figure 4.8: Graph of wheel torque versus vehicle speed for continuously variable transmission of Honda Insight 2005.

4.5 COMPARISON OF CONVENTIONAL AT WITH CVT

The controls for a CVT are the same as conventional automatic transmission. It has two pedals without clutch and P-R-N-D-L-style shift pattern. But while conventional automatic transmission has a set number of gear ratios, usually 4, 5 or 6, the CVT allows an almost limitless number of engine speeds to vehicle speed ratios. The stepless nature of a CVT can work to keep the engine in its optimum power range. It simply raises and lowers the engine speed as needed, calling up higher engine speed for better acceleration and lower engine speeds for better fuel economy while cruising.

On a conventional automatic transmission, the engine must turn faster during accelerating. When getting out of the engine speeds where the engine's peak power output is, the gear ratios must be changed to get the engine back into its power band to continue accelerate rapidly. When accelerating briskly, the transmission will start revving the engine up and when it leaves its power band, it will shift gears dropping engine speeds back to where it makes the most torque several times. The period where the engine slows, and is temporarily disconnected from the wheels will be felt as either a small or a large jolt depending on the quality of the vehicle or also known as shift shock.

But, when large amounts of acceleration is demanded on a CVT, the transmission and engine control systems will rev the engine to one of its sweet spot where it can make the most power for the load demanded hand hold it there. The transmission will vary the gear ratios many times per second, mostly independent of vehicle speed until the power required decreases. CVT will rev the engine to the sweet spot and hold that engine speed until the desired speed is reached and the driver backs off the throttle.

Even though CVT provides lots of advantages, it also has some disadvantages. Because of the CVT allows the engine to rev at any speed, the noises coming from under the hood sound add to ears accustomed to conventional AT. The gradual changes in engine note sound like a sliding transmission or a slipping clutch. It is a perfectly normal for a CVT but signs of trouble with a conventional AT. Other than the irritating noise created, another problem associated with CVT is the inability to check the fluid level on our own. One need to get it checked by the dealer and the fluid is a little expensive as well.

In term of the fuel consumption, CVT provides better fuel economy compared to conventional automatic transmission. For Honda Insight 2005, the fuel efficient is 4.9 L/100km (Garrett, 2006) and for Perodua VIVA ELITE AT is 6.6 L/100km (paultan.org). It is proven that car with CVT provides less fuel consumption compared to car with conventional AT. This is because CVT can work to keep the engine in its optimum power range. For the conventional automatic transmission, the engine speeds must be drop in order to shift the gear. High power is required to shift the gear and accelerating for the conventional automatic transmission while for CVT less power is required since it allows engine operates at optimum power range.

It is proven that car with CVT is better than conventional AT in all aspects from the performance to fuel consumption. Even though CVT is better than conventional AT, CVT is more expensive than conventional AT. Although CVT is expensive compared to conventional AT, it is suitable to be installed in cars less than 1 litre engine. The price of cars installed with CVT might be increased and expensive than cars with conventional AT. But, the increasing will not be too high. Therefore, cars with CVT are still affordable for customers whose prefer low cost vehicle. The benefits offered to customers are better than its disadvantages.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion from this project, learning process on the conventional automatic transmission (AT) and continuously variable transmission (CVT) is well-achieved accordingly the objectives stated in chapter one. The conventional AT is a transmission based on the gearing system. It consists of several gears with different ratios which provide limited gear ratios. While CVT is a transmission which operates based on the pulley system. It has limitless gear ratios and it can change steplessly through an infinite number of effective gear ratios between maximum and minimum values.

In case of the performance, CVT provides better performance and less fuel consumptions compared to conventional AT. This is due to its stepless nature that allows engine to works in it optimum power range. It simply raises and lowers the engine speed as needed, calling up higher engine speed for better acceleration and lower engine speeds for better fuel economy. It is different with conventional AT where a certain engine speed will be dropped in order to shift gears. To accelerate, large power is required to increase the engine speed and at the same time more fuel is needed for combustion to supply large power needed.

As this thesis covers the condition of a car less than 1 litre engine, therefore CVT is not suitable to be placed in compared to the conventional AT. Even though CVT provides better performance and fuel economy, it is more expensive compared with conventional AT. The cost to build the CVT is expensive as well as the maintenance. Other than that, the size of CVT is bigger and needed bigger space compared to conventional AT. Therefore, it is impossible to be placed in a car under 1 litre engine which is usually small and compact compared with car more than 1 litre engine.

5.2 FURTHER STUDY RECOMMENDATIONS

Even though the project is done successfully, but the results found are not really accurate where the project is based on manual calculation. Therefore, some recommendations were listed below to improve this project for better results. The recommendations are:

1) Construct the experiment by using engineering software such as MATHLAB instead of manual calculation for better result and analysis and also to validate the data.
2) Run the experiment practically and not only focus on theoretical. It will give more knowledge about the experiment conducted.

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APPENDIX A

GANTT CHART FOR FYP 1

Activities/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Title of project briefing by supervisor																
Verify the project title, objectives and scopes																
Write down the background, abstract, objective and scope																
Literature Study																
Study of transmission theory																
Study of transmission																
Determine best method of methodology																
Detailed Methodology																
Submit proposal and draft of report																
Presentation of Proposal																

APPENDIX B

GANTT CHART FOR FYP 2

Activities/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Literature Study																
Analysis project																
Collect the data																
Analysis of data and results																
Data validation																
Conclusion of the project																
Final Presentation																
Preparing and submit report																

APPENDIX C

LIST OF COEFFICIENTS

Coefficients		**Value**
Density of air, ρ		1.2 kg/m^3
Gravitational acceleration, g		9.81 m/s^2
Constant c_a		0.013
Constant c_b		0.00004
Overall efficiency, η		0.30
Engine efficiency, η_e		0.85
Perodua VIVA ELITE	Drag coefficient, C_d	0.32
	Surface area, A	1.8280 m^2
	Radius of tire	0.2686 m
Honda Insight	Drag coefficient, C_d	0.25
	Surface area, A	1.8578 m^2
	Radius of tire	0.2851 m