# DESIGN A CUT LUBRICANT TEST DEVICE

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MASTER IN INNOVATION AND ENGINEERING DESIGN
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# DESIGN A CVT LUBRICANT TEST DEVICE

By

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# ABSTRACT

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NOVEMBER 2006

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**Faculty : Engineering**

The technology of metal pushing V-belt (MPVB) Continuously Variable Transmission (CVT) is now commercially available in the market but to date the questionable reliabilities and limited torque capabilities have inhibited their growth. Belt slip is one of the major losses that cause inefficiency in CVT and limited the transferred torque from the engine to the tyres. One of the factors that believe cause this belt slip is because of unstable in oil lubricant behaviour especially due to operate in high temperature and pressure. Therefore, this report presents the work which has been carried out on designing a CVT Lubricant Test Device which capable to investigate the phenomena of film collapse in a CVT mechanism. Modern design concepts and methods have been applied in designing this device where a five phase design model as proposed by Eggert has been used. The five phase designs are formulation, conceptual design, configuration design, parametric design and detail design. The device is significant because, hence to study and investigate film collapse, this device also capable to study and investigate the other specific parameters which affect the transmission efficiency such as differ in contact angle, contact area and material used.

# ABSTRAK

## REKABENTUK ALAT UJIAN PELINCIR CVT

**Oleh**

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**NOVEMBER 2006**

**Pengerusi : Dr. Abdul Rahim Bin Abu Talib**

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Teknologi Transmisi Berubah Berterusan (CVT) yang menggunakan talisawat jenis logam atau dikenali sebagai "*Metal Pushing V-Belt*" (MPVB) telah dikomersialkan dan terdapat di pasaran masakini, walaubagaimanapun keraguan dari segi keboleharapan dan keupayaan daya kilas yang terhad telah menyekat pertumbuhan dan kepesatannya. Kegelinciran talisawat adalah penyebab utama kehilangan kecekapan pada CVT dan seterusnya menghadkan penghantaran daya kilas dari enjin ke tayar. Salah satu faktor utama yang mengakibatkan kegelinciran talisawat adalah disebabkan oleh sifat minyak pelincir yang tidak stabil terutamanya ketika beroperasi di dalam suhu dan tekanan yang tinggi. Oleh itu, laporan ini membentangkan kerja yang telah dijalankan di dalam merekabentuk alat ujian pelincir CVT di mana ia boleh digunakan untuk menyiasat fenomena kegagalan filem di dalam mekanisme CVT. Alat ini telah direkabentuk dengan menggunakan kaedah dan konsep rekabentuk terkini yang telah dicadangkan oleh Eggert di mana rekabentuk model lima fasa telah digunakan. Lima fasa tersebut adalah, persediaan, rekabentuk konsep, rekabentuk konfigurasi, rekabentuk parametrik dan rekabentuk terperinci. Alat ini penting kerana, selain digunakan untuk mempelajari dan menyiasat kegagalan filem, alat ini juga boleh digunakan untuk mempelajari dan menyiasat parameter-parameter lain khususnya yang memberi kesan terhadap kecekapan transmisi seperti kelainan pada sudut sentuhan, luas sentuhan dan bahan yang digunakan.

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Last but not least, author would like to acknowledge the role played by his wife Nor Hasrina Hasni, son Najmi, daughter Nazihah and other family members, especially to both his parents and parent in laws for their continual support and understanding.

## APPROVAL

I certify that an Examination Committee has met on **23th November 2006** to conduct the final examination of **Mohd Azwir bin Azlan** on his **Master in Innovation and Engineering Design** project report entitled **"Design a CVT Lubricant Test Device"** in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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**DECLARATION**

I hereby declare that the project report is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(.....................................)
**MOHD AZWIR BIN AZLAN**
Date: 4 Disember 2006

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

A vehicle that is powered by an internal combustion engine will be quite impossible to be driven smoothly and comfortably without the aid of a transmission system. These by itself explained the purpose and importance of a transmission unit in a vehicle. That is, they are the components that made it possible to transfer the power or torque from the engine to the driving wheels (Tawi, 1997). Power is the rate or speed at which work is performed, while torque is turning or twisting force. Multiple ratio gearboxes are necessary because the engine delivers its maximum power at certain speeds, or *rpm* (rotations per minute). It is necessary to change the gear ratio between the engine and the drive wheels in order to use the same engine *rpm* at different road speeds and this occurs inside the transmission.

Generally, transmission can be classified into two categories, "steply" and continuously variable transmission (CVT). Both of them can be further classified as manual and automatic transmission as shown in Figure 1.1. "Steply" transmissions or gearboxes are those that use gears as their means to steply vary the gear ratios. The manual steply gearboxes usually consist of six sets of gear train. Namely first, second, third, forth, fifth and reverse gears. The forward gears are usually of helical type because of its smooth and quiet performance, while the reverse gears are of spur type, which is a bit noisy (drivers should be able to recognise this) but can be easily dogged with its meshing spur gear via an idler spur gear, hence eliminate the use of synchromesh as in the forward gears. These types of gearboxes are usually manual in nature, i.e. the drivers select the required gear ratios themselves through gear linkages.

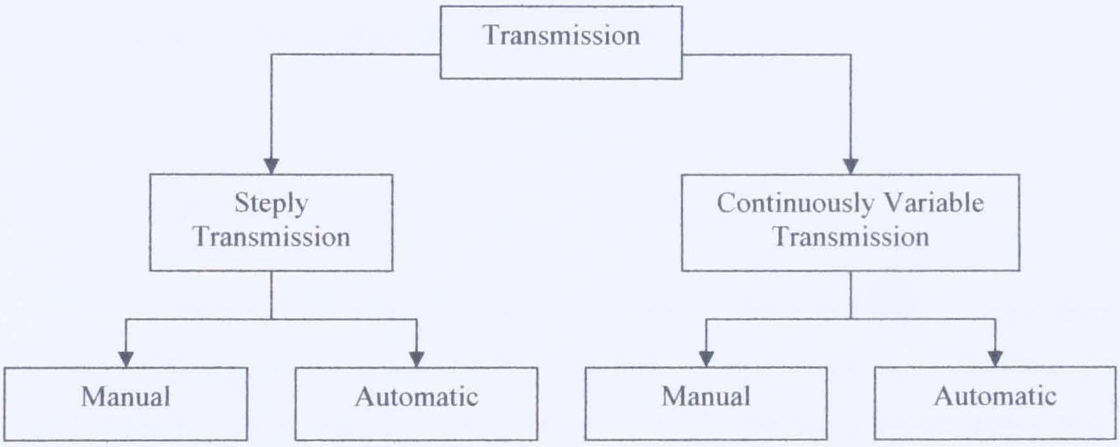



Figure 1.1: Types of Transmission

Currently for automatic steply gearboxes, most cars use epicyclic gear train and they are hydraulically controlled. Epicyclic gear train (Figure 1.2) consists of sun, planet and ring gears. They can be of spur type (noisier but cheaper) or helical type (quieter, smoother but a bit expensive). The advantage of epicyclic gear train is that gear ratio change can be done easily by just stopping either the sun, planet or ring gear to change gear (two forwards and one reverse).

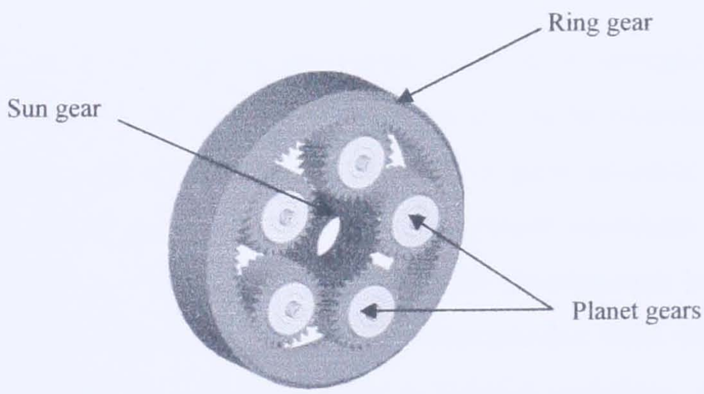



Figure 1.2: Epicyclic Gear Train

Other categories of transmission are known as CVT. CVT also can be further classified as manual, automatic or combination of these. More detail about CVT will be explained in the background. Nowadays, we can see many car manufacturer is start to get involve into the continuously variable types due to the promising of their performance. Many well-known car manufacturers like Audi, General Motor, Honda and Nissan have been produced their own product.

## 1.2 Background

Transmission development started with very simple designs of a manual gear boxes. Then, an automatic step gear transmission was introduced due to demand for more comfort. Even though the control of automatic transmission getting better, they still have jerking during changing gear ratio causes uncomfortable drive. The third generation of gear box was called continuous variable transmission (CVT).

Brace (1992) has studied in comparison between manual, automatic and continuously variable transmission. He concluded in the graph as shown in Figure 1.3, which he had concluded each of transmission has advantages and disadvantages. These advantages and disadvantages are set in scale one to five rating which one represent unsatisfactory and five represent very good. Manual transmission has disadvantages in the performance of driving, but this disadvantage can be overcome by both automatic and CVT. Size, cost, mass, and fun of driving become less value in both automatic and CVT.

The CVT concept allows the engine speed to be operated independently of the vehicle speed and therefore the engine can always be operated in its most fuel-efficient operating point. Therefore CVTs have a great potential to offer both fuel consumption and lower output of harmful exhaust emissions, which has been confirmed by different research projects. Torotrak Development Ltd. claimed (2006) 20% less fuel consumption for their CVT transmission than with a conventional automatic gearbox along with a reduction in harmful emissions. A simulation study by Kriegler (1997) of AVL compares different CVT concepts with a manual transmission for gasoline and diesel engines and show up to 10% less fuel consumption for gasoline engines and up to 19% for diesel engines.

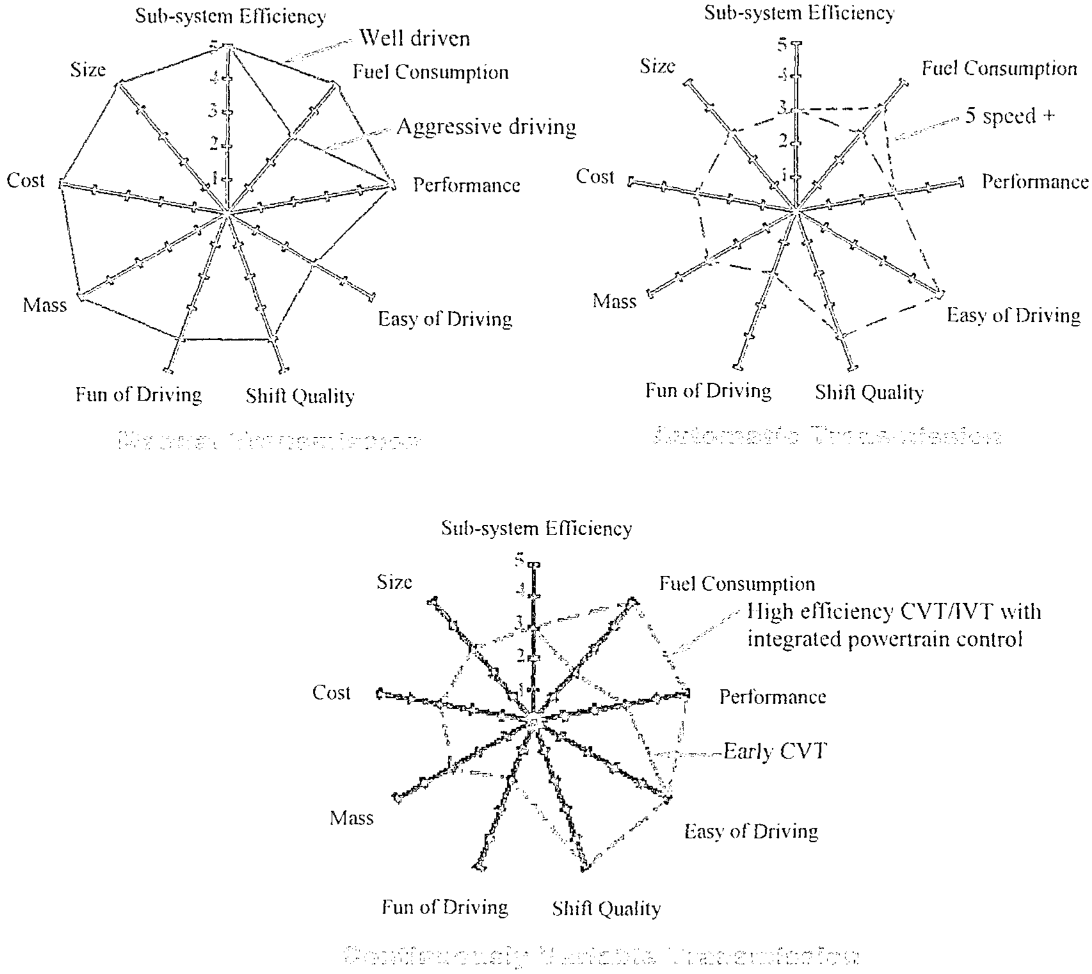


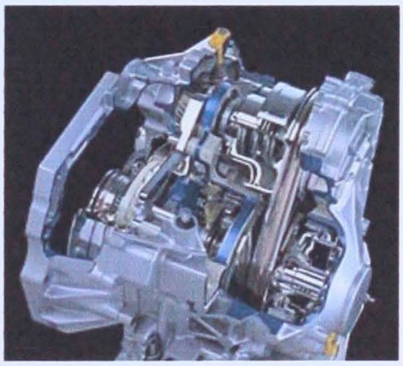

Figure 1.3: Transmission Characteristic. (Brace, 1992)

The first commercially available belt type CVT was introduced in 1958 and was based on rubber V belt (Birch, 2000). Meanwhile the CVT principle has evaluated to a fully electronic controller transmission system, based on a metal belt, and is capable to be adapted to engines of almost size.

A number of studies have been conducted on the CVT because it is regarded as an ideal transmission for internal combustion engine vehicles. CVT tended to be regarded as just a transmission without shift shock and this causes more comfort comparing with the conventional automatic transmission. CVT eliminated the two major problem of the automatic transmission which is shift shock and time lag resulting in better fuel consumption (Kevin, 2000).

CVT used the entire range of ratios between low and high gears compare to a conventional automatic transmission, which shifts among up to five gear ratios. It achieves better fuel economy and drivability by constantly changing ratios to keep the engine running in its most efficient rpm range based on driver demands.

CVT is beyond all doubt the theoretically optimum gearbox for automotive applications. There are four basic concepts on which extensive modern-day CVT developments have been or are currently based that are belt drive CVT, hydrostatic pump and motor combinations CVT, friction or traction drive CVT and lastly variable stroke CVT (Gott, 1991). Currently there are only two types of CVT commercially success to the market that are belt drive CVT and traction drive CVT as shown in Figure 1.4(a) and 1.4(b). Both types have already powering more than million cars including Fiat, Ford, Nissan, Honda, Subaru, Toyota, General Motor, Audi and Volvo.



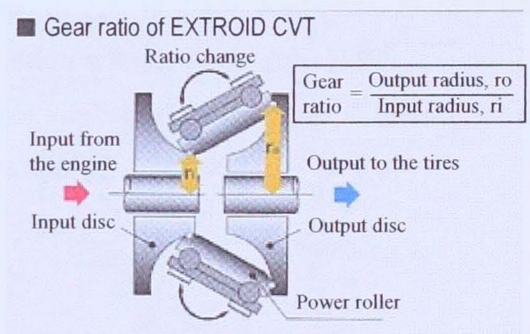



Figure 1.4(a): Pushing Metal V-belt CVT Figure 1.4(b): Metal Disk type CVT
(Transmission: CVT (Continuous Variable Transmission), Mark, 1998)

Early belt drive CVT used simple rubber band and cone system as low power industrial drives and light-duty vehicle applications such as snowmobiles, go-karts and all-terrain vehicle. In 1958 DAF (now Volvo) introduced a small passenger car equipped with a rubber belt CVT. However, the maximum torque, which can be transmitted, is limited by the strength of the belt and the coefficient of friction between the belt and the pulley (Gott, 1991). Then, a new belts which its power-rating can now meet the requirement of automotive application has been introduced in the market since late 80s. It is called as Metal Pushing V-Belt (MPVB), which develops by Van Doorne from Van Doorne's Transmissie (a company spun out of DAF-van Doorne's Automobile Factory). This belt consists of a large number of flat segments, which are held together by two packs of steel bands, each pack containing eight to ten bands for flexibility. Then this belt has been put into production by Ford, Subaru and Fiat. Borg-Warner and Fiat had formed a consortium with van Doorne in the mid'70s to develop a CVT based on the van Doorne belt (Gott, 1991). Borg-Warner later removed them from the consortium to pursue their own interests. They have developed a similar variable cone pulley transmission concept using a chain, which produced, by Suzuki in early 1990s. Another approach is by PIV-Reimers chain-type CVT that is reportedly being examined by Ford, Volvo and ZF (Gott, 1991).

In 1999, Nissan was the first automaker to introduce a CVT for the front-transverse driveline in conjunction with an engine having greater than 100-kW (135-hp) output. The Primera features engine torque of about 190 N.m. One of the latest CVTs is the CFT 23 developed by ZF, which is designed for engine torque up to 250 N.m and features an overall gear-ratio span of 5.8. In 2000, Audi introduced a CVT for a front-longitudinal driveline in connection with a six-cylinder 2.8-L engine. The VL 300 was the first CVT for high torque applications-280 N.m. It has wet clutch and chain and an overall gear-ratio span of 6.05 (Birch, 2000).

## 1.3 Problem Statement

CVT have been used in automobiles for decades; however limited torque capabilities and questionable reliability have inhibited their growth. Today ongoing CVT research has led to ever more robust transmissions and thus ever more diverse automotive applications. The trend toward greater performance in small cars and the development of higher-torque diesel engines have sharpened the design focus on overcoming the CVT's torque limitations.

The efficiency of a vehicle transmission system is an important factor in the overall efficiency of any vehicle. It is important to understand where the inefficiencies lie within a transmissions design in term of emissions and fuel consumption because the increased environmental constraints which today vehicle much reach.

CVT should allow better matching of the engine operating conditions to the variable driving conditions that may be experienced by effecting having an infinite number of gear ratios. However, the reduced fuel consumption and emissions predicted for CVT have not been realized by production cars. Comparison fuel consumption between CVT and equivalent fixed ratio has resulted they have been at best equal and in most cases considerably lower. This can be concluded that existing CVT system have a lower efficiency that their fixed ratio counterparts although the control strategy for reduced fuel consumption is well founded. This inefficiency has been linked to a number of possible inherent parasitic losses associated with pushing V-belt CVT, namely torque losses within the belt mechanism itself, belt slip and hydraulic control system pumping losses. Belt slip is one of the major losses that caused inefficiency in CVT. There are two reasons why this belt slip happens. The first factor is caused by insufficient clamping force that used to squeeze the belt for transferring torque from input shaft to output shaft. Another factor is lubricant film collapse due to operating temperature increase.

Lubricants used in CVT have a large number of performance characteristics to satisfy, such as lubrication, heat transfer, pump ability and traction transfer. Belt drive CVT and traction drive CVT use special lubricant formulations which added with more traction additives to increase the torque transfer capability. These traction additives increase the coefficients of friction between other surfaces in relative motion to each other and avoid slip between belt and pulley, but too many will make the oil become condense and cause the transmission need more power from engine to rotate  hence decrease its efficiency. Slip must be minimized to protect the CVT mechanism from wear. However, unstable in oil lubricant behaviour, especially when it viscosity change due to operate in extreme condition such as in high temperature and high pressure, will effect the transmission efficiency.

Hence, this study is one of the pioneer works in UPM towards acquiring the knowledge and technology of CVT system. A design for basic clutch-like CVT mechanism and experimental facilities set-up are proposed, to study the phenomena of lubricant film collapse between the power transmitting plates. This film collapse is crucial as a result of slip between the plates, affecting the overall transmission efficiency.

## 1.4 General Objective :

To design a CVT lubricant test device that capable to investigate the phenomena of film collapse in a CVT mechanism.

## 1.5 Specific Objectives :

i. To conduct literature study based on the Van Doorne Metal Pushing V-Belt CVT.
ii. To produce detail design of a CVT lubricant test device suitable for small size car, (less than 1 litre engine).
iii. To propose an experimental facility for film collapse investigation in a CVT mechanism.

## 1.6 Significance of Design

As stated previously, existing CVT are usually limited in their performance. Most CVT have drawbacks such as limited range of variability, limited power handling capabilities and efficiency. All these factors have encouraged the author to rise to the challenge of designing a lubricant test devise in a CVT mechanism. The main purpose is to investigate the phenomena of film collapse in actual condition which the author believes it is the main reason that affect the transmission efficiency. Its also hope that by using this devise, other specific parameters that are related to the power transferred such as belt-pulley contact angle, belt-pulley contact area, material used, clamping force needed and other parameters can also be investigate.