A

Seminar report

On

Continuously Variable Transmission (CVT)

Submitted in partial fulfillment of the requirement for the award of degree
Of Mechanical

SUBMITTED TO:

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SUBMITTED BY:

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Preface

I have made this report file on the topic **Continuously Variable Transmission (CVT);** I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

Thirdly, I would like to thank my friends who helped me to make my work more organized and well-stacked till the end.

Next, I would thank Microsoft for developing such a wonderful tool like MS Word. It helped my work a lot to remain error-free.

Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

CONTENT

INTRODUCTION

After more than a century of research and development, the internal combustion (IC) engine is nearing both perfection and obsolescence: engineers continue to explore the outer limits of IC efficiency and performance, but advancements in fuel economy and emissions have effectively stalled. While many IC vehicles meet Low Emissions Vehicle standards, these will give way to new, stricter government regulations in the very near future. With limited room for improvement, automobile manufacturers have begun full-scale development of alternative power vehicles. Still, manufacturers are loath to scrap a century of development and billions or possibly even trillions of dollars in IC infrastructure, especially for technologies with no history of commercial success. Thus, the ideal interim solution is to further optimize the overall efficiency of IC vehicles.

One potential solution to this fuel economy dilemma is the continuously variable transmission (CVT), an old idea that has only recently become a bastion of hope to automakers. CVTs could potentially allow IC vehicles to meet the first wave of new fuel regulations while development of hybrid electric and fuel cell vehicles continues. Rather than selecting one of four or five gears, a CVT constantly changes its gear ratio to optimize engine efficiency with a perfectly smooth torque-speed curve. This improves both gas mileage and acceleration compared to traditional transmissions.

The fundamental theory behind CVTs has undeniable potential, but lax fuel regulations and booming sales in recent years have given manufacturers a sense of complacency: if consumers are buying millions of cars with conventional transmissions, why spend billions to develop and manufacture CVTs?

Although CVTs have been used in automobiles for decades, limited torque capabilities and questionable reliability have inhibited their growth. Today, however, ongoing CVT research has led to ever-more robust transmissions, and thus ever-more-diverse automotive applications. As CVT development continues, manufacturing costs will be further reduced and performance will continue to increase, which will in turn increase the demand for further development. This cycle of improvement will ultimately give CVTs a solid foundation in the world's automotive infrastructure.

CVT THEORY & DESIGN

Today's automobiles almost exclusively use either a conventional manual or automatic transmission with "multiple planetary gears sets that use integral clutches and bands to achieve discrete gear ratios". A typical automatic uses four or five such Years, while a manual normally employs five or six. The continuously variable transmission replaces discrete gear ratios with infinitely adjustable gearing through one of several basic CVT designs.

Push Belt

This most common type of CVT uses segmented steel blocks stacked on a steel ribbon, as shown in Figure (1). This belt transmits power between two conical pulleys, or sheaves, one fixed and one movable . With a belt drive:

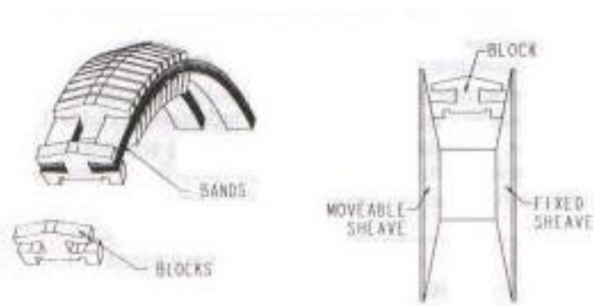

Figure (1) – Metal Push Belt CVT
From [3]

In essence, a sensor reads the engine output and then electronically increases or decreases the distance between pulleys, and thus the tension of the drive belt. The continuously changing distance between the pulleys—their ratio to one another—is analogous to shifting gears. Push-belt CVTs were first developed decades ago, but new advances in belt design have recently drawn the attention of automakers worldwide.

Toroidal Traction-Drive

These transmissions use the high shear strength of viscous fluids to transmit torque between an input torus and an output torus. As the movable torus slides linearly, the angle of a roller changes relative to shaft position, as seen in Figure (2). This results in a change in gear ratio .

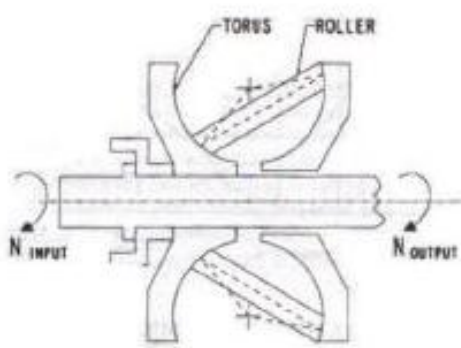

Figure (2) – Toroidal CVT
From [3]

Variable Diameter Elastomer Belt

This type of CVT, as represented in Figure (2), uses a flat, flexible belt mounted on movable supports. These supports can change radius and thus gear ratio. However, the supports separate at high gear ratios to form a discontinuous gear path, as seen in Figure (3). This can lead to the problems with creep and slip that have plagued CVTs for years.

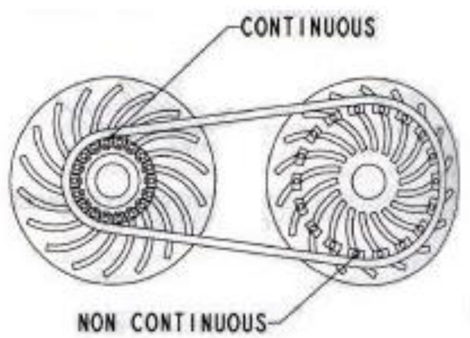

Figure (3) – Variable Diameter Belt CVT
From [3]

This inherent flaw has directed research and development toward push belt CVTs.

Other CVT Varieties

Several other types of CVTs have been developed over the course of automotive history, but these have become less prominent than push belt and toroidal CVTs. A nutating traction drive uses a pivoting, conical shaft to change “gears” in a CVT. As the cones change angle, the inlet radius decreases while the outlet radius increases, or vice versa, resulting in an infinitely variable gear ratio . A variable geometry CVT uses adjustable planetary gear-sets to change gear ratios, but this is more akin to a flexible traditional transmission than a conventional CVT.

RESEARCH & DEVELOPMENT

While IC development has slowed in recent years as automobile manufacturers devote more resources to hybrid electric vehicles (HEVs) and fuel cell vehicles (FEVs), CVT research and development is expanding quickly. Even U.S. automakers, who have lagged in CVT research until recently, are unveiling new designs:

General Motors plans to implement metal-belt CVTs in some vehicles by 2002.

Figure (4) – GM's New CVT design
From [6]

The Japanese and Germans continue to lead the way in CVT development. Nissan has taken a dramatic step with its "Extroid" CVT, offered in the home-market Cedric and Gloria luxury sedans. This toroidal CVT costs more than a conventional belt-driven CVT, but Nissan expects the extra cost to be absorbed by the luxury cars' prices. The Extroid uses a high viscosity fluid to transmit power between the disks and rollers, rather than metal-to-metal contact. Coupled with a torque converter, this yields "exceptionally fast ratio changes". Most importantly, though, the Extroid is available with a turbocharged version of Nissan's 3.0 liter V6 producing 285 lb-ft of torque; this is a new record for CVT torque capacity.

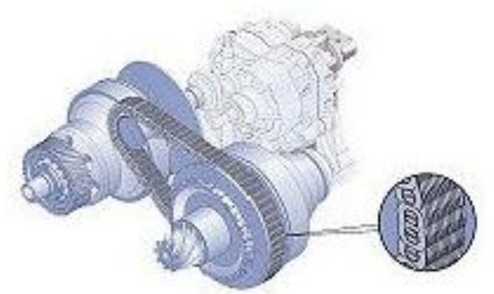

Figure (5) – Audi CVT with link chain
From [1]

Audi's new CVT offers both better fuel mileage than a conventional automatic and better acceleration than even a manual transmission. Moreover, Audi claims it can offer the CVT at only a slight price increase. This so-called "multitronic" CVT uses an all-steel link plate chain instead of a V-belt in order to handle up to 280 lb-ft of torque. In addition, "Audi claims that the multitronic A6 accelerates from 0-100 km/h (0-62 mph) 1.3 s quicker than a geared automatic transmission and is 0.1 s quicker over the same speed than an equivalent model with "optimum" use of a five speed manual gearbox". If costs were sufficiently reduced, a transmission such as this could be used in almost any automobile in the world.

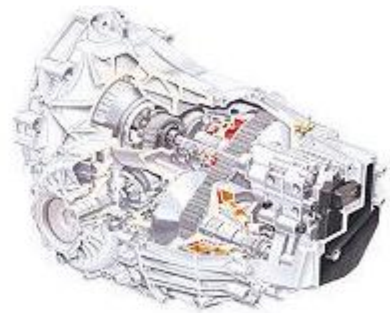

Figure (6) – Cutaway of Audi CVT
From [1]

Many small cars have used CVTs in recent years, and many more will use them in the near future. Nissan, Honda, and Subaru currently use belt-drive CVTs developed with Dutch company Van Doorne Transmissie (VDT) in some of their smaller cars. Suzuki and Daihatsu are jointly developing CVTs with Japanese company Aichi Machine, using an aluminum/plastic composite belt reinforced with Aramid fibers. Their CVT uses an auxiliary transmission for starts to avoid low-speed slip. After about 6 mph, the CVT engages and operates as it normally would. “The auxiliary geartrain’s direct coupling ensures sufficiently brisk takeoff and initial acceleration”. However, Aichi’s CVT can only handle 52 lb-ft of torque. This alone effectively negates its potential for the U.S. market. Still, there are far more CVTs in production for 2000 than for 1999, and each major automobile show brings more announcements for new CVTs.

New CVT Research

As recently as 1997, CVT research focused on the basic issues of drive belt design and power transmission. Now, as belts by VDT and other companies become sufficiently efficient, research focuses primarily on control and implementation of CVTs.

Nissan Motor Co. has been a leader in CVT research since the 1970s. A recent study analyzing the slip characteristics of a metal belt CVT resulted in a simulation method for slip limits and torque capabilities of CVTs. This has led to a dramatic improvement in drive belt technology, since CVTs can now be modeled and analyzed with computer simulations, resulting in faster development and more 8 efficient design. Nissan's research on the torque limits of belt-drive CVTs has also led to the use of torque converters, which several companies have since implemented. The torque converter is designed to allow "creep," the slow speed at which automatic transmission cars drive without driver-induced acceleration. The torque converter adds "improved creep capability during idling for improved driveability at very low speeds and easy launch on uphill grades". Nissan's Extroid uses such a torque converter for "smooth starting, vibration suppression, and creep characteristics".

CVT control has recently come to the forefront of research; even a mechanically perfect CVT is worthless without an intelligent active control algorithm. Optimal CVT performance demands integrated control, such as the system developed by Nissan to "obtain the demanded drive torque with optimum fuel economy". The control system determines the necessary CVT ratio based on a target torque, vehicle speed, and desired fuel economy. Honda has also developed an integrated control algorithm for its CVTs, considering not only the engine's thermal efficiency but also work loss from drivetrain accessories and the transmission itself. Testing of Honda's algorithm with a prototype vehicle resulted in a one percent fuel economy increase compared to a conventional algorithm. While not a dramatic increase, Honda claims that its algorithm is fundamentally sound, and thus will it become "one of the basic technologies for the next generation's powerplant control".

Although CVTs are currently in production, many control issues still amount to a “tremendous number of trials and errors” . One study focusing on numerical representation of power transmission showed that “both block tilting and pulley deformation meaningfully effected the pulley thrust ratio between the driving and the driven pulleys” . Thus, the resultant model of CVT performance can be used in future applications for transmission optimization. As more studies are conducted, fundamental research such as this will become the legacy of CVT design, and research can become more specialized as CVTs become more refined.

As CVTs move from research and development to assembly line, manufacturing research becomes more important. CVTs require several crucial, high-tolerance components in order to function efficiently; Honda studied one of these, the pulley piston, in 1998. Honda found that prototype pistons “experienced a drastic thickness reduction (32% at maximum) due to the conventional stretch forming method”. A four-step forming process was developed to ensure “a greater and more uniform thickness increase” and thus greater efficiency and performance. Moreover, work-hardening during the forming process further increased the pulley piston’s strength .

Size and weight of CVTs has long been a concern, since conventional automatics weigh far more than manual transmissions and CVTs outweigh automatics. Most cars equipped with automatic transmissions have a curb weight between 50 and 150 pounds heavier than the same cars with manual transmissions. To solve this problem, Audi is currently developing magnesium gearbox housings, a first for cars in its class. This results in nearly a 16 pound weight reduction over conventional automatics.

Future Prospects for CVTs

Much of the existing literature is quick to admit that the automotive industry lacks a broad knowledge base regarding CVTs. Whereas conventional transmissions have been continuously refined and improved since the very start of the 20th century, CVT development is only just beginning. As infrastructure is built up along with said knowledge base, CVTs will become ever-more prominent in the automotive landscape. Even today's CVTs, which represent first-generation designs at best, outperform conventional transmissions. Automakers who fail to develop CVTs now, while the field is still in its infancy, risk being left behind as CVT development and implementation continues its exponential growth.

Moreover, CVTs are do not fall exclusively in the realm of IC engines.

CVTs & Hybrid Electric Vehicles

While CVTs will help to prolong the viability of internal combustion engines, CVTs themselves will certainly not fade if and when IC does. Several companies are currently studying implementation of CVTs with HEVs. Nissan recently developed an HEV with "fuel efficiency … more than double that of existing vehicles in the same class of driving performance". The electric motor avoids the lowspeed/ high torque problems often associated with CVTs, through an innovative double-motor system. At low speeds:

A low-power traction motor is used as a substitute mechanism to accomplish the functions of launch and forward/reverse shift. This has made it possible to discontinue use of a torque converter as the launch element and a planetary gearset and wet multiplate clutches as the shift mechanism.

Thus use of a CVT in a HEV is optimal: the electric portion of the power system avoids the low-speed problems of CVTs, while still retaining the fuel efficiency and power transmission benefits at high speeds. Moreover, “the use of a CVT capable of handling high engine torque allows the system to be applied to more powerful vehicles”. Obviously, automakers cannot develop individual transmissions for each car they sell; rather, a few robust, versatile CVTs must be able to handle a wide range of vehicles.

Korean automaker Kia has proposed a rather novel approach to CVTs and their application to hybrids. Kia recently tested a system where “the CVT allows the engine to run at constant speed and the motor allows the engine to run at constant torque independent of driving conditions”. Thus, both gasoline engine and electric motor always run at their optimal speeds, and the CVT adjusts as needed to accelerate the vehicle. Kia also presented a control system for this unified HEV/CVT combination that optimizes fuel efficiency for the new configuration.

OTHER APPLICATIONS

- **Tractors** just as cars have the need for a flexible system to convey power from their engine to their wheels. The C.V.T. will provide just this and at high fuel savings with low atmospheric pollution.

- **Golf Carts** stand to benefit from the C.V.T. as well in the way electric cars do. that is: Large range of speeds, longer driving range between charges, Fewer baterries, lower maintenance cost, less weight.

- **Ride on Lawn Mowers** like small tractors are gas powered and contribute to the air pollution problem. The C.V.T. approach can prevent ride-ons to pollute the air to the extend they currently do.

- **Motorized Wheelchairs.** Battery run, speed controlled by a rheostat. Going up a ramp slowly, causes a drop in power (when it's most needed). C.V.T. is a form of transmission, lower speed means MORE POWER.

- **Bicycles.** Ever try to shift gears while pedaling uphill? Good news; the KINESIS C.V.T. will automaticaly select the appropriate for the situation "gear" ratio. No hasle, no trouble. End of story.

- **Power tools** and household appliances, that vary from benchtop drills to wash machines and blenders need to depart from the centuries old belt and pulley configuration for smoother operation and more reliability.

- **Industrial Equipment** and production machinery often use either gears or cumbersom belt and pulley configurations. C.V.T. can do away with all that and additionaly give them infinite ratios.

- **Minimachines**. Small devices that need to operate in a wide range of speeds, as the need arises. Our unique design allows the production of an inexpensive miniature C.V.T. to enable them does just that!

Advantage

- Better fuel consumption than a regular automatic transmission as the CVT is able to keep the car in its optimum power range regardless of speed .
- There is improved acceleration due to the lower power loss experienced.
- Stepless transmission.
- It has the ability to allow the engine to rev almost immediately which delivers maximum torque.
- Provides a smoother ride than automatic transmission.
- Adapts to varying road conditions and power demands to allows for a better ride.
- Better emission control and less green house gas emissions because of improved control of the engine’s speed range.

Disadvantage

- Higher cost.
- Belt-driven CVTs (VDP system) have a limited amount of torque; however the technology is constantly being improved.
- Transmitting motion by friction causes greater wear
- Require special oil and other materials.

CONCLUSION

Today, only a handful of cars worldwide make use of CVTs, but the applications and benefits of continuously variable transmissions can only increase based on today's research and development. As automakers continue to develop CVTs, more and more vehicle lines will begin to use them. As development continues, fuel efficiency and performance benefits will inevitably increase; this will lead to increased sales of CVT-equipped vehicles. Increased sales will prompt further development and implementation, and the cycle will repeat ad infinitum. Moreover, increasing development will foster competition among manufacturers—automakers from Japan, Europe, and the U.S. are already either using or developing CVTs—which will in turn lower manufacturing costs. Any technology with inherent benefits will eventually reach fruition; the CVT has only just begun to blossom.

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