

Continuously Variable Transmission (CVT)

Ms. Tanvi Dilip Challirwar

BE, Mechanical Engineering, Gokhale Education society's college of Engineering.

Abstract

This paper examines and compares the five basic principles that can be used in continuously variable transmission (CVT) and how the CVTs are more dominant over a Geared transmission system. The term continuously variable transmission also usually implies that torque may be controlled independently of speed ratio and vice versa. In other words, the torque converter of the conventional automobile should not be considered a CVT because the speed ratio is set by the torque transmitted. In contrast, traditional automatic and manual transmissions have several fixed transmission ratios forcing the engine to operate outside the optimum range. The need for a transmission system, the working principle and the constructional features of CVT has been discussed in depth

Keywords - Transmission system, Speed ratio, Torque converter, Constructional Features, Actuators.

Objectives

- To understand the working principle of CVT.
- To know the difference between CVT and Gear Transmission system.
- Familiarize yourself with parts of CVT.

I. INTRODUCTION

A Continuously Variable Transmission (CVT) has been around for more than a 100 years, but has only recently found its way into automotive applications. The overwhelming majority of transmissions in road going vehicles are either manual or conventional automatic in design. These transmissions use meshing gears that give discrete ratio steps between engine and the vehicle speed. However, alternative designs exist that can transmit power and simultaneously give a step less change of ratio; in other words a Continuously Variable Transmission. Continuously Variable Transmission is a type of automatic transmission that provides an uninterrupted range of speed ratios, unlike a normal transmission that provides only a few discrete ratios. However, until recently it was reserved for industrial applications like running lathes or light duty drill presses. But with the introduction of improved materials, such as high density belts, advanced hydraulics and more recently, high speed sensors and microprocessors, the stage was set for CVT's rise in the automobile arena. Many small tractors for home

and garden use have simple rubber belt CVTs. For example, the John Deere Gator lines of small utility vehicles use a belt with a conical pulley system. They can deliver an abundance of power and can reach speeds of 10–15 mph (16–24 km/h), all without need for a clutch or shifting gears. Nearly all snowmobiles, old and new, and motor scooters use CVTs, typically the rubber belt/variable pulley variety.

A. About CVT

How CVTs work and how they improve performance, etc....

- The purpose of CVTs-To vary the transmission ratio continuously.
- Working of CVT depends on the type of CVT:
 - o Friction CVTs vary the radius of the contact point between two rotating objects, thus the tangential velocity;
 - o Hydrostatic CVTs vary the fluid flow with variable displacement pumps into hydrostatic motors
 - o Ratcheting CVTs vary the stroke of a reciprocating motion, which is connected to a free-wheel, resulting unidirectional rotation.
- CVT improves efficiency by allowing the engine to operate always in its optimum R.P.M., whatever the vehicle's speed.
- What are the benefits of operating in the optimum R.P.M.?
- Lower consumption;
- Less greenhouse gas emissions;
- Better performance;

CVT is the ideal transmission, so why are there so few CVT cars?

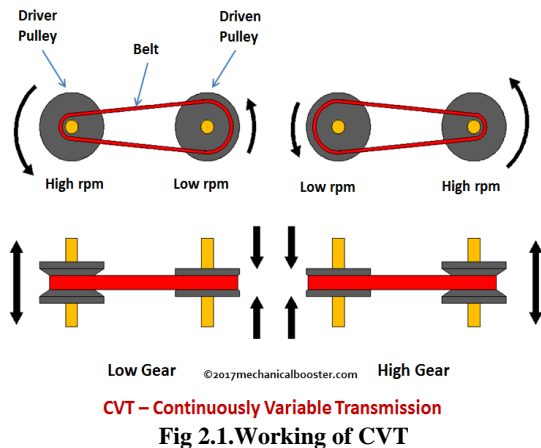
The existing inventions are based on

- o Friction
- o Hydrostatic
- o Ratcheting which are all mechanical systems with inherent limitations, (compared to traditional transmissions).

How to extract the full CVT potential?

- A conceptual innovation is the only way out. Although, research continues improving the friction CVTs and ratcheting CVTs, these efforts are accomplished by expensive high tech materials and precision manufacturing. This is to overcome the inherent limitations of these concepts (friction and ratcheting).

B. Working Principle of CVT



A Continuously Variable Transmission operates by varying the working diameter of the two main pulleys in the transmission. The pulleys have V-shaped grooves on which the connecting belt is mounted. One side of the pulley is fixed; the other side is moveable, operated by a hydraulic actuator. The hydraulic actuator can increase or decrease the amount of space between the two sides of the pulley. This makes the belt to ride lower or higher along the inner walls of the pulley, depending on driving conditions, thereby changing the gear ratio. This action is infinitely variable with no “steps” in between. Thus a CVT can maintain the engine in its optimum rpm range, in turn boosting the efficiency and gas Mileage. As explained above the two pulley widths are adjusted by oil pressure in the hydraulic actuator which responds to position of the throttle, speed, and other conditions, which are sensed by microprocessors & other sensor.

C. Types of CVT

1. Frictional Type CVTs / Pulley based CVT or Reeves Drive

The most common type of CVT is the frictional type, in which two bodies are brought into contact at points of varying distance from their axes of rotation, and allowing friction to transfer motion from one body to the other. Sometimes there is a third intermediary body, usually a wheel or belt. The simplest CVT seems to be the "disk and wheel" design, in which a wheel rides upon the surface of a rotating disk; the wheel may be slid along it's splined axle to contact the disk at different distances from its center. The speed ratio of such a design is simply the radius of the wheel divided by the distance from the contact point to the center of the disk. Friction plays an important part in frictional CVT designs - the maximum torque transmissible by such a design is

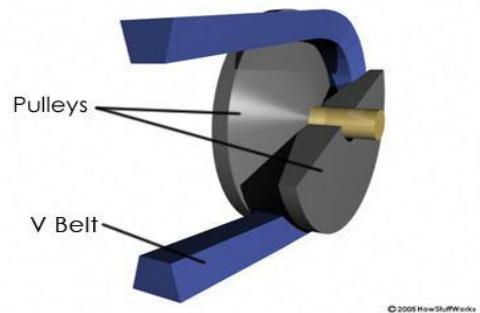
$$[T_{max} = C_f \times F_N \times R_o]$$

Where T_o is the torque output, C_f is the coefficient of friction between the wheel and the disk, F_N is the force pushing the wheel into the disk (normal force), and R_o is the radius of the output wheel or disk. The coefficient of friction depends on the materials used; rubber on steel is typically around 0.8 to 0.9.



Fig 3.1. Friction CVT

Very similar to the "disk and wheel" is the "cone and wheel" design, in which the disk is replaced by a cone. There is little advantage to using a cone instead of a flat disk, except to decrease the differential slip of the contact surface by minimizing the difference in the radius traveled by the inner and outer edges of the contact area. Other designs have used different shapes, but the principle remains the same.



2. Toroidal CVTs

The simplest toroidal CVT involves two coaxial disks bearing annular grooves of a semi-circular cross section on their facing surfaces. The spacing of the disks is such that the centers of the cross sections coincide. Two or more (in patent-speak, "a plurality of") idler wheels, of a radius equal to the radius of the cross sections of the grooves, are placed between the disks such that their axes are perpendicular to, and cross, the axes of the disks.

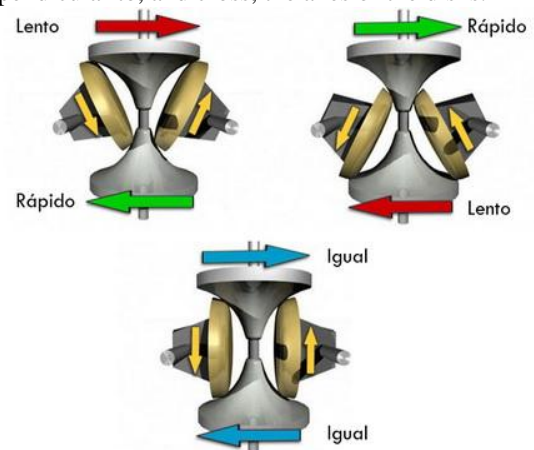


Fig 3.3. Toroidal CVT

3. Hydrostatic CVT

Hydrostatic CVTs convert rotational motion into fluid flow (hydrostatic pump), and then back to rotational motion (hydrostatic motor)

In some cases the fluid flow is continuously varied by variable displacement pump. There are other cases where the variable displacement unit is the hydrostatic motor, or both.

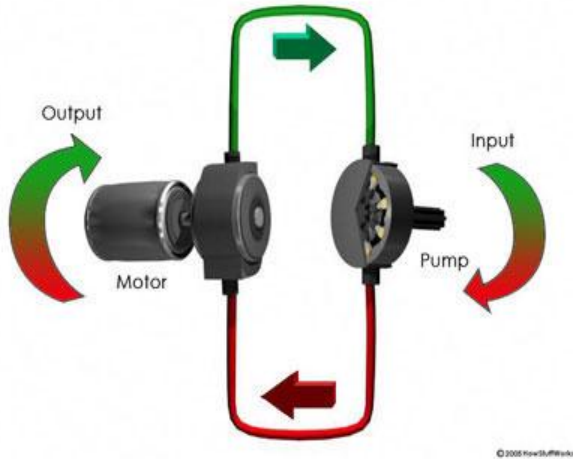


Fig 3.4. Hydrostatic CVT

D. Positive Infinitely Variable Transmission (PIV Drive)

PIV, or positively infinitely variable chain, is a roller chain designed for transmission gearboxes that are used in a variety of industrial applications, such as textile production lines, printing press machines, packaging line equipment and other machinery. The main feature of the PIV roller chain is its variable pitch. The construction of the chain features batches of thin plates that are capable of moving independently of each other. This flexibility allows the chain to mesh with grooves that taper from the edge to the center of the gearbox wheel face at different effective pitch diameters.

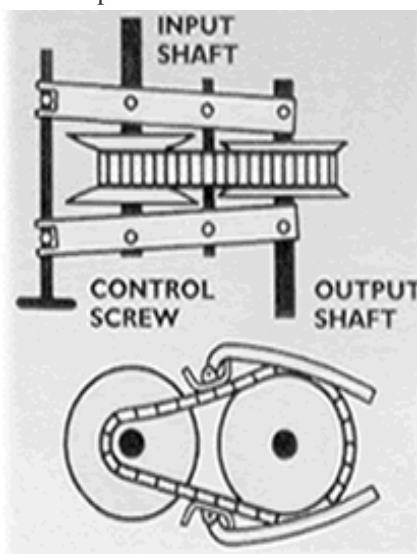


Fig 3.5. PIV Drive

II. MAIN COMPONENTS OF CVT

- A high power/density belt.
- A set of Cone pulleys.
- Hydraulic Actuator.
- Mechanical torque sensor.
- Microprocessor.
- Torque Converter or Multi-layered clutch (replacing conventional clutches).

A. Torque Converter

An engine is connected to a transmission by way of a clutch. Without this connection, a car would not be able to come to a complete stop without killing the engine. But cars with CVT have no clutch that disconnects the transmission from the engine. Instead, they use an amazing device called a torque converter. As shown in the figure below, there are four components inside the very strong housing of the torque converter:

- Pump
- Turbine
- Stator

• Transmission fluid the housing of the torque converter is bolted to the flywheel of the engine, so it turns at whatever speed the engine is running at. The fins that make up the pump of the torque converter are attached to the housing, so they also turn at the same speed as the engine. The cutaway below shows how everything is connected inside the torque converter.

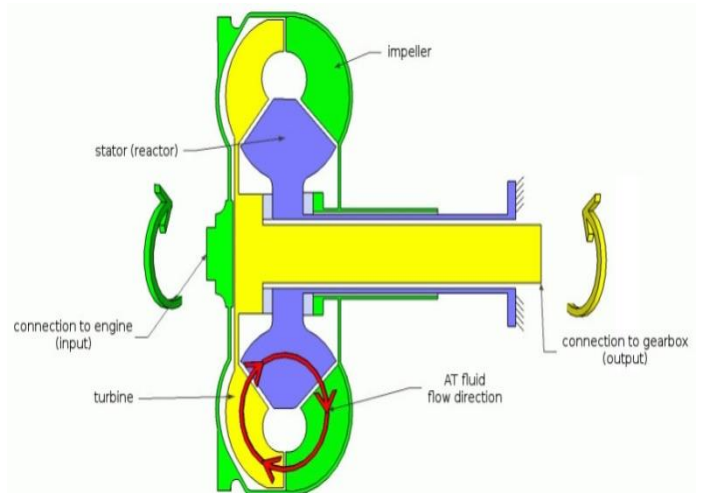


Fig.5. Torque Converter

III. METHODOLOGY

CVT is one of the latest transmission system now use in automobile vehicle, it has greater advantages over Manual transmission system.

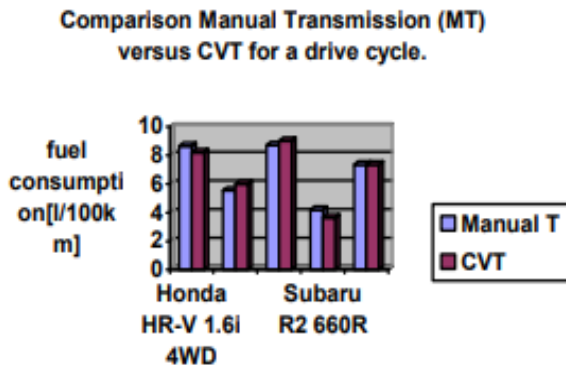


Table 6.1. Comparative graph between CVT & Manual Transmission

The Above Graph shows the Fuel Efficiency comparison of the following vehicles:

1. Honda HR-V 1.6i 4WD
2. Honda Jazz 1.4i
3. Nissan Primera 2.0
4. Subaru R2 660R
5. Mercedes Benz A-class A200

A. Advantages of CVT

1. CVTs provide unlimited gear ratios and improved performance.
2. Pulleys and a belt inside the CVT seamlessly change the gear ratios without any “shift shock” or delay.
3. The infinite ratios help in maintaining a steady cruising speed, reducing the fuel emissions and thus improve fuel economy.
4. Due to its ability to change the ratios continuously, a CVT helps to keep the engine in its optimum rpm range, thereby increasing the fuel efficiency.
5. The 2012 model of the Honda Jazz sold in the UK actually claims marginally better fuel consumption for the CVT version than the manual version.
6. CVTs provide quicker acceleration than a conventional automatic.
7. A key advantage of a CVT for a manufacturer is that its production costs lesser than a conventional multispeed automatic because it uses fewer parts.
8. CVT eliminates the gear shifts of a manual transmission and the accompanying rise and fall of engine speed.

B. Limitations of CVT

1. CVTs use steel metal belts, which have less torque transmitting capacity and thus a CVT cannot be used in heavy vehicles. Its application is limited to small vehicles.
2. Friction between the belt and the pulley causes greater wear.
3. The transmission fluid is a little expensive.

IV. CONCLUSION

“A Continuously Variable Transmission or CVT blends the ease of an automatic transmission with the efficiency of a manual transmission.” This statement made by the Honda Motors completely summarizes the concept of CVT. CVT is definitely a technology of the future with its higher fuel efficiency, infinite gear ratios, lower manufacturing costs, steady cruising speeds & better acceleration capabilities. This technology has found such wide applications only recently. Thus most of us have to get used to the dynamics of a CVT-equipped vehicle for its better appreciation.

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