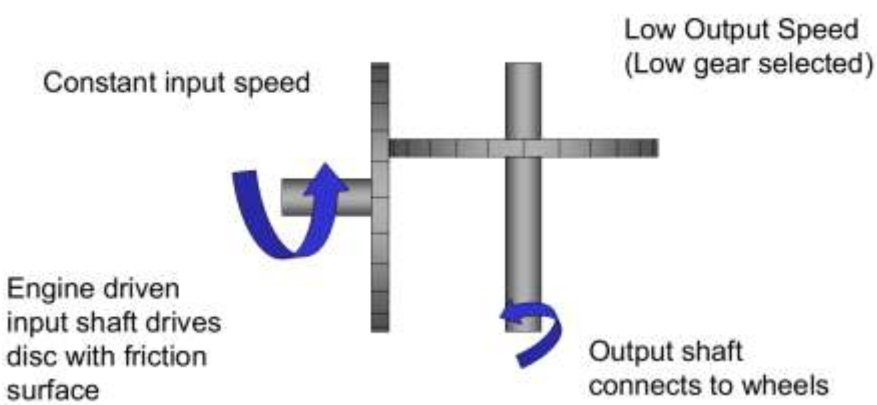
Continuously Variable Transmission(CVT)

What is CVT?

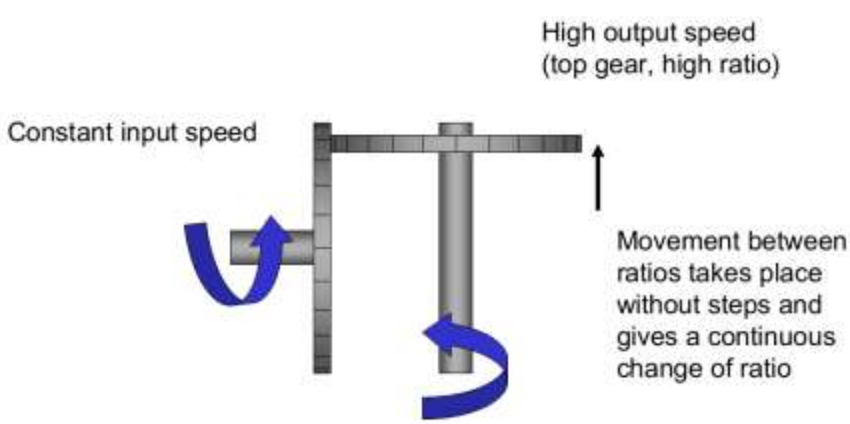
- CVT stands for Continuously Variable Transmission which allows for the operation at the lowest possible speed and highest possible load, partially avoiding the low efficiency region of the engine map.
- A continuously variable transmission (CVT) transfers power through a range of speed/torque ratios from engine input to output, continuously without interruption.
- Contrast with either manual or conventional automatic transmissions that use discrete ratios and normally disengage when changing ratio.
- The CVT category includes infinitely variable transmissions (IVT) that give a zero output speed within the operating range.

To understand the principle of CVT lets first understand the **Simple friction drive** principle.



At high speed the friction drive arrangement can be illustrated below.

Friction Drive: High Speed



Similarly the following arrangement can be granted for zero output means no output in the output shaft.

Friction Drive: Zero Output

Geared Neutral with input rotating gives IVT

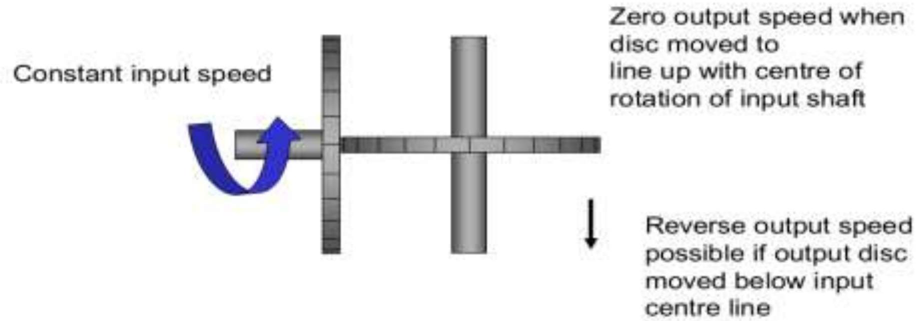
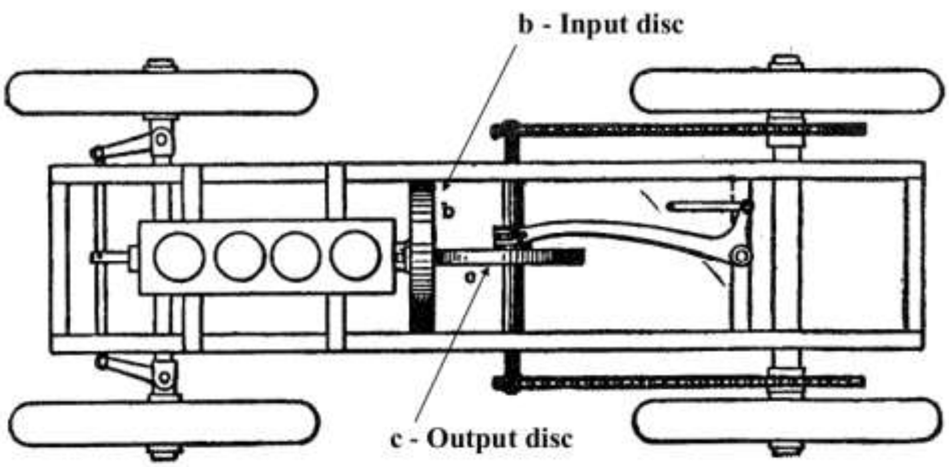
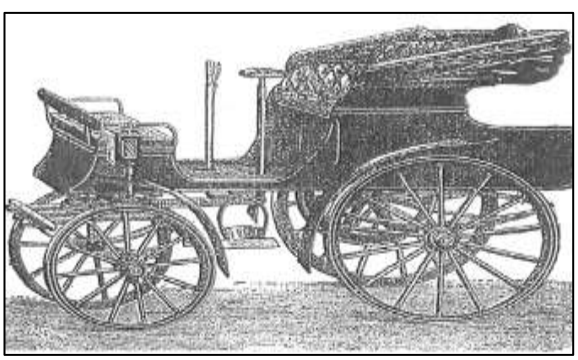


Illustration of CVT placement in a four wheeled vehicle



History of CVT applied in automobile industries



First Car-Tenting France 1891

GWKof Maidenhead 1910-1931, two seat cyclecar

CVT Categories & Targets

• Successful CVT will resolve the compromises in reliability, durability, efficiency, and controllability with low cost

• Implementation of commercially produced CVTs transmit drive through friction

• Variable pulleys with flexible belt or chain

  – sliding friction

• Traction drives with rotating surfaces

  – rolling contact, shear friction

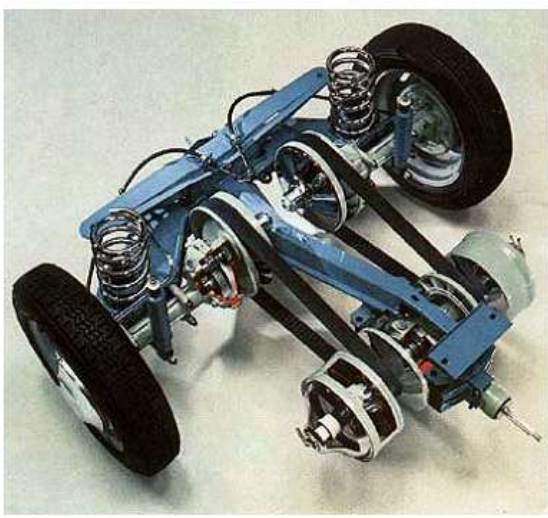
Variable Pulley

• Variable pulley systems are based on the common v-belt pulley fixed ratio layout with power transfer through a flexible element connecting between two pairs of pulley sheaves.

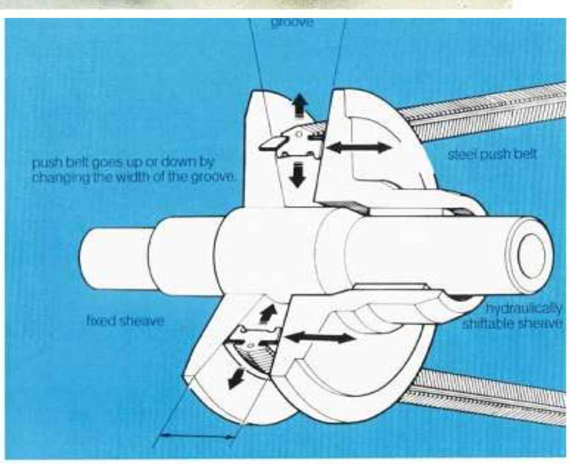
• Flexible element may be a belt or chain

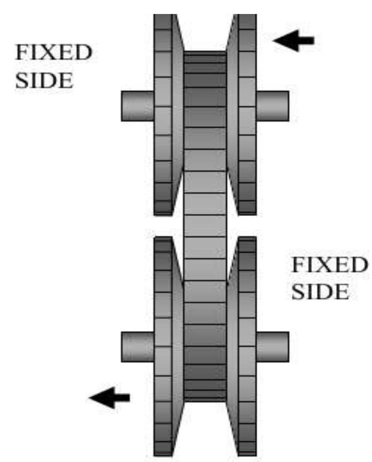
• Sheave movement usually controlled by hydraulic or electrical means

DAF Variomatic Rubber V-Belts



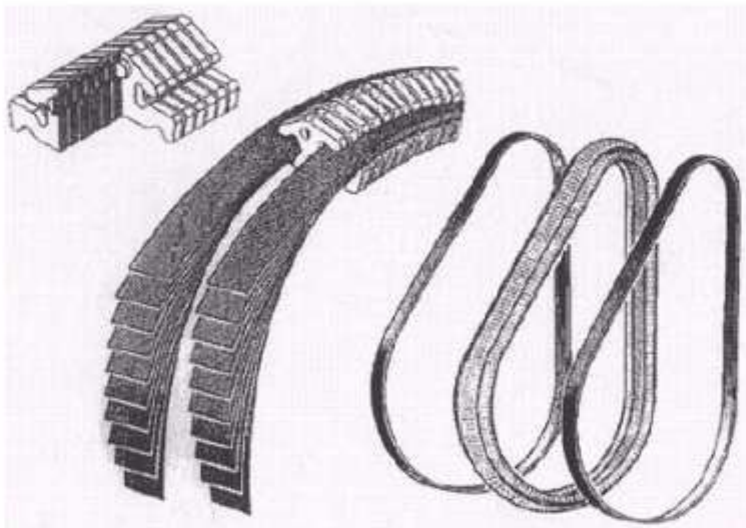
- Introduction in 1958
- Over 1 million DAF and Volv cars produced in 20 year period
- Shown is DAF 55 drive used with 1100 cc Renault engine from 1968





Metal V-Belt Construction

Introduced by Van Doorne's Transmissie in 1987



Traction Drives

• Many physical alternative layouts that give the mechanical geometry changes suitable to give a CVT.

• "Traction" requires transmission through a fluid film under elastic-hydrodynamic lubrication (EHL) conditions.

CVT Benefits

• No gear shift
• Continuous transmission of torque
• Control of engine speed independently of vehicle speed
• Ability to operate engine at peak power over wider range of vehicle speeds
• Ability to operate at most fuel efficient point for required output power

Control Objectives

• Good fuel economy
• Good driver feel – drivability
• Easy driving as an automatic
• Comfort and smoothness for passengers
• Performance – acceleration capability
• Electronic control enables these

CVT Disadvantages

• Mechanical efficiency of variator
• Parasitic efficiency of transmission system and controller
• Compromise between fuel economy and torque margin to achieve drivability (avoid elastic band feel)

CVT Efficiency

• All CVT variators have losses due to the power transfer which appears as a speed or slip loss across the variator

• CVTs are hydraulically controlled and the pump takes power as in a conventional automatic transmission

• Efficiency is more variable for CVT than geared discrete ratio systems

Drivability Compromise

• Driveability describes the longitudinal dynamic behavior of a vehicle in Response to driver inputs, in a comprehensive range of driving situations, and the related driver subjective perception of that behavior

• Less torque available immediately with a CVT than with a gear transmission

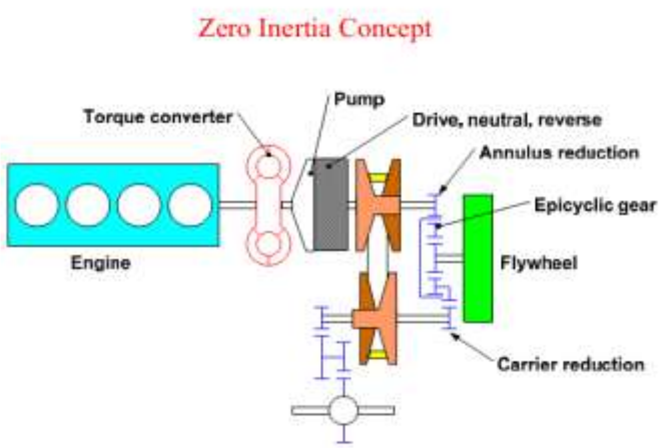
Solutions for Improved Drivability

• Torque boosters
  –flywheel
  – Integrated electrical machine (motor/generator)
• Control – modified calibration
• Match the CVT with the most appropriate engine

• Modify engine characteristics to those of the transmission by design and/or Control

Matching engine

• Diesel engines have higher torque and lower speed range than petrol
• Modify engine systems to develop higher torque at low speeds – interest in this as engine downsizing for conventional transmissions too
• Use of lean burn techniques to operate engine more efficiently at higher speeds
  – Experimental studies have shown both improvement in steady fuel consumption and transient response
• Development of homogeneous charge compression ignition (HCCI) and controlled auto ignition (CAI) is also appropriate for CVTs
• CVT has a bright future



• Market share increasing
• Research and development still required
  – Improve efficiency
  – Torque booster
  – Engine integration
  – System control
• CVT drivability is a key to customer acceptance, particularly in Europe
• CVTs share some drivability characteristics with hybrid vehicles
• Control and calibration with new concepts and an integrated approach to total powertrain calibration can give drivability solutions.

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 20^{th} 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 doubles that of Existing vehicles in the same class of driving performance" [14]. The electric motor avoids the low-speed/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 gear set 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.

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.

Reference:

1. Research Papers obtained from www.google.com
2. www.wikipaedia.org
3. www.asme.org