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"Study of Conversion of Continuous Variable Transmission to Infinitely Variable Transmission Using Power Split Concept"

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Abstract - *In modern power transmission systems, many advancements have taken place to improve efficiency and hence the performance of the vehicle. One such innovation has been the use of Continuous Variable Transmission. Despite having various advantages it has significant disadvantages too such as it provides only positive ratios (forward driving ratios), hence, reverse gear and clutch/torque converter are required. Moreover, CVT exhibits poor efficiency due to reasons like belt slippage, heating, vibrations etc. To further enhance the transmission unit, Infinite variable transmission (IVT) has been considered which not only retains the advantages of CVT but also offers compact, lightweight unit and improved performance.*

Key Words: **Continuous Variable Transmission (CVT), Infinitely Variable Transmission (IVT), Power Split, Powertrain, Efficient Transmission.**

1. INTRODUCTION

Infinite Variable Transmission (IVT) is a type of CVT with added restriction that a speed ratio of zero must be available. CVT providing negative as well as positive ratio speed ratios would also be considered an IVT since its range passes through speed ratio of zero. The ratio range of IVT is infinite since it is calculated as finite ratio divided by zero. The above mentioned condition can be achieved by using planetary/epicyclical gear set to convert CVT to IVT by "power split".

1.1 Power Split

Power Split principle was developed to partially overcome the poor efficiency of CVTs. Basic idea is to send only part of the power through Continuous Variable Unit with remainder of power going through straight mechanical path (path of higher efficiency).The two components of power are then added in "mechanical differential" at the output of power split CVT. Planetary gear type of mechanical differential is logical choice for practical design.

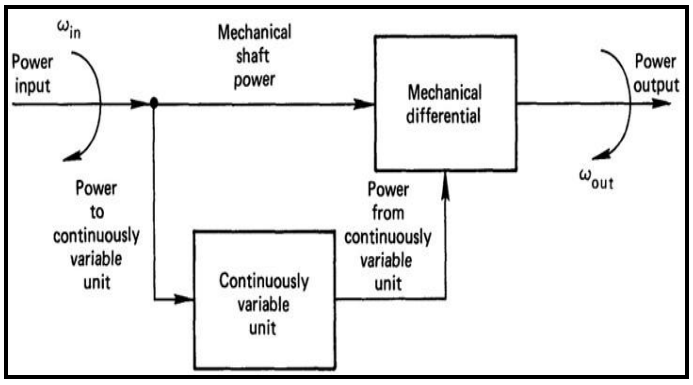

Fig -1: Power- split continuously variable transmission principle

CVT is not included directly in the power flow but in one of the power branches after a split.

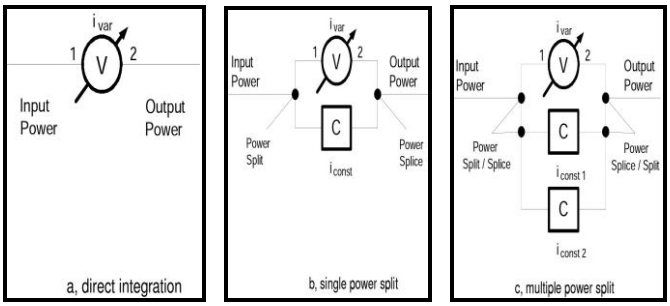

Fig -2: Options for mounting a CVT into drivetrain

Four basic structural components are required for producing simplest IVT structures namely: coupling member for constant speed, coupling member for constant torque, power branch of constant gear and power branch of Infinitely variable gear.

If coupling member of constant speed is on input side, resulting system with input coupled (IC) with split torque.

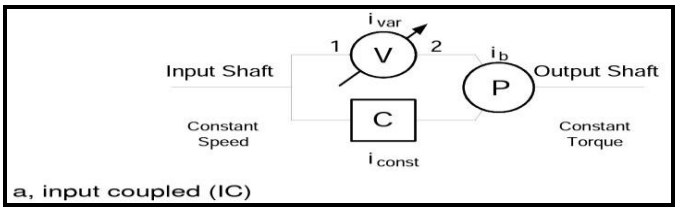

Fig -3: Input Coupled Setup

If it is on output side, resulting system will be output coupled (OC) with split speed.

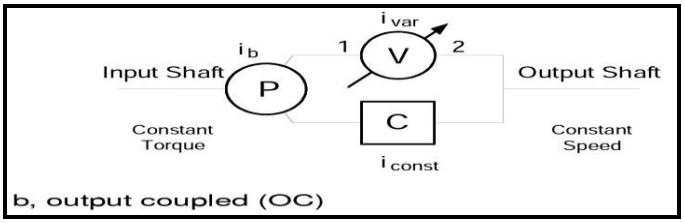

Fig -4: Output Coupled Setup

Where P stands for planetary gear set.

1.2 Conversion to IVT using power split

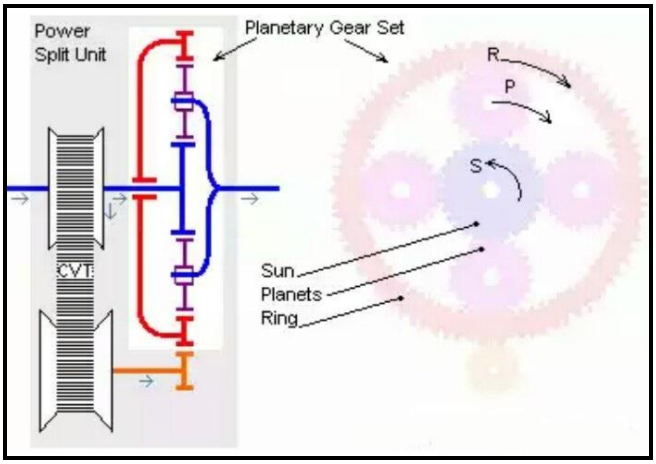

Fig -5: Power split using planetary gear set

Gear/sprocket arrangement is used to transfer power from CVT secondary sheave to ring gear. Gears reverse the sense of rotation of engine shaft for ring gear.
Input to CVT from engine shaft also acts as input to sun gear, the sense of rotation being opposite to that of ring gear.
The final output is taken from planet carriers.
Most IVTs result from combination of epicyclic which is equal to the difference between two other speeds within IVT.
For neutral, the speed of ring gear and sun gear are equal and opposite. Hence, the displacement of planet carriers is zero.

IVT configuration uses its CVT as continuously variable regulator (CVR) of the rotation speed of any one of the three rotators of planetary gear system.

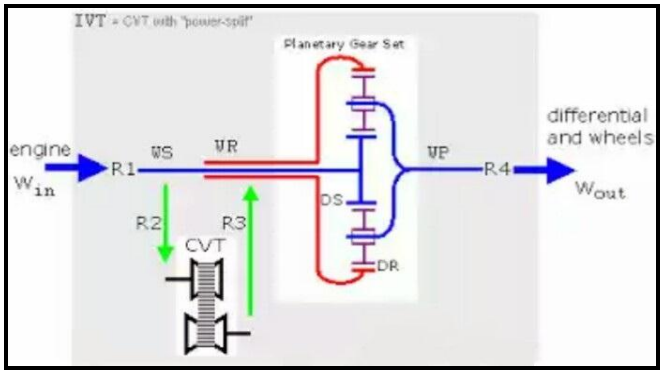

Fig -6: Depiction of IVT internal ratios

The formula for final output angular velocity of IVT is:

$$W_{out} = \frac{((W_{in}/(R1 \times R2 \times R_{cvt} \times R3)) \times DR - (W_{in}/R1) \times DS)}{(DR + DS) \times R4}$$

(Win = engine speed ; Rcvt = CVT ratio)

And the formula for overall IVT gear ratio is:

$$R_{ivt} = \frac{(DR + DS) \times R1 \times R2 \times R3 \times R4 \times R_{cvt}}{DR - DS \times R2 \times R3 \times R_{cvt}}$$

Overall six combinations of CVT and planetary gear system are possible as follows:

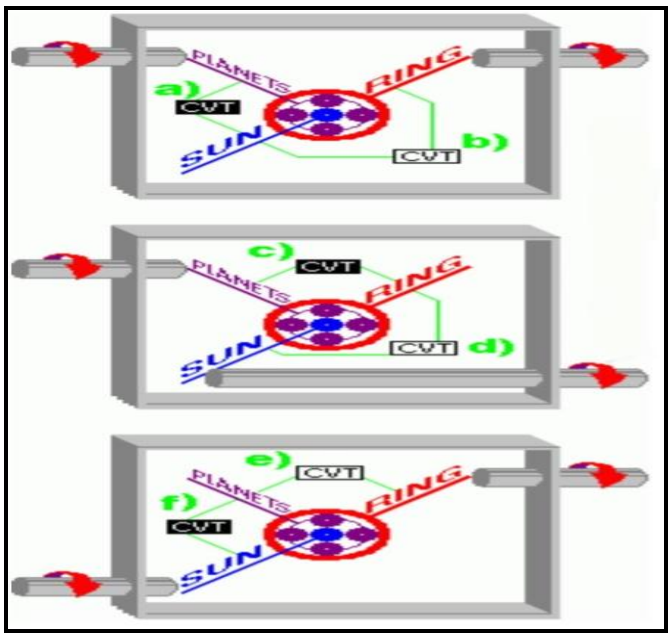

Fig -7: Combinations of CVT and epicyclic systems

IVT is used for two purposes:

- To improve total efficiency by subtracting some power from CVT where efficiency is low.
- To increase transmission ratio range, i.e., include reverse (negative ratios), neutral (zero ratio) along with positive ratios.

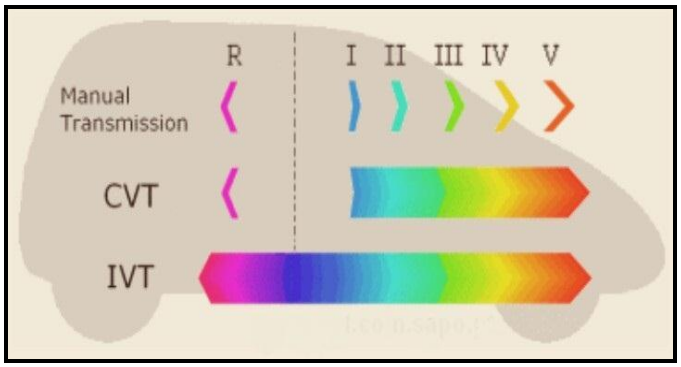

Fig -8: Comparison of ratios provided by different transmission systems

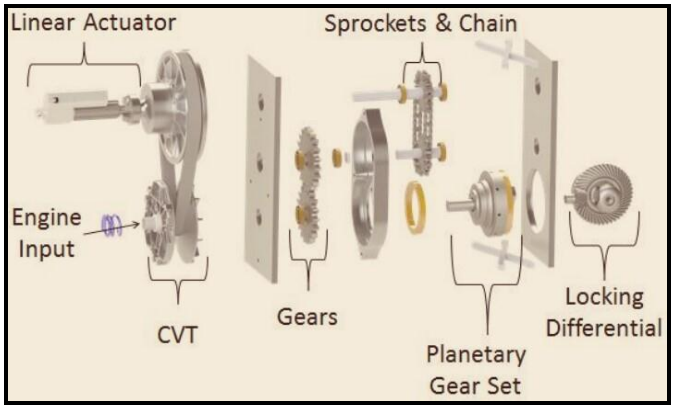

Fig -9: Practical example of IVT setup using planetary gear setup

2. Performance of IVT

IVT powertrain is designed to maximize potential of engine. In CVT system, engine rpm follows a linear curve. IVT holds the engine at constant rpm from neutral position to maximum velocity.

Since the engine can be held at constant rpm, which can be easily adjusted, maximum power from engine can always be obtained.

The following graph depicts the time period for which engine runs at optimum speed for manual, continuous variable and infinitely variable transmission.

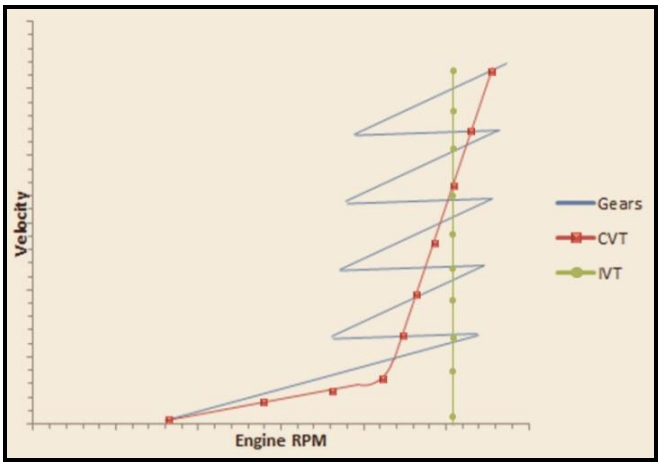

Fig -10: Graph depicting performance of MT,CVVT and IVT

Some advantages of IVT are as follows:

- Able to provide gearing to keep engine within optimum power band.
- Capable of forward and reverse drives.
- Compact and relatively light because of planetary gearing which reduces size as well as weight.
- Efficient by maximizing performance output with minimal power losses using “power split”.
- As planetary gear system is used in IVT, engine is in continuous contact with gear even at zero output thus eliminating wastage of fuel during shifting of gears as in manual transmission.
- This mechanism eliminates sudden engagement of engine to gear assembly thus reducing wear and tear of gear.
- Engine is permanently connected to wheels so clutch and reverse gear are not required.

3. Controls of IVT

The output of an engine in a normal vehicle is controlled by a foot pedal that has a direct effect on speed of vehicle . However, because an IVT does not produce output the same way a normal vehicle would , methods of controlling it are different.

Some proposed control actions are as follows:

- Foot Pedal

“Gas Pedal” will not control throttle position. Instead foot pedal will control throttle secondary clutch position through linear actuator (refer the practical IVT example above). So, driver would control the overall ratio of powertrain.

- Throttle Position

Since the throttle to engine is held at a constant position, the control can be independent of foot controlled “gas pedal”. Throttle control will be on the dash board & will hold its

position after driver has selected desired position allowing driver to keep both hands on steering wheel too increase performance.

- Hand Control Lever

To reverse vehicle with IVT, driver will need to remove their foot from "gas pedal" and pull the reverse lever. The reverse lever moves the CVT position past the neutral zone and into the reverse zone. The reverse lever would be held to engage motion & spring back to neutral upon release. When released, vehicle will be instantly ready to drive forward.

3. CONCLUSIONS

Unlike a geared transmission, where only finite ratios can be achieved the IVT system allows for wide range of ratio outputs. Full range of output ratios extends from full speed in forward direction, through neutral to a full output speed in reverse direction. The IVT system delivers better performance because it allows the engine to operate at its maximum power at all times. But, today only a limited number of industries make use of IVTs .Applications and benefits of IVT can only increase based on today's research and development. As development continues, fuel efficiency and performance benefits will inevitably increase.

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