A REVIEW PAPER ON CONTINUOUSLY VARIABLE TRANSMISSION SYSTEM IN 2-WHEELERS

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Abstract—The aim of the project is to improve fuel economy of two wheeler by providing Continuously Variable Transmission (CVT) system. A continuously variable transmission, or (CVT), is a type of automatic transmission that provides better fuel economy and a smoother driving experience than a traditional manual transmission. It includes parameter changes of CVT such as power transmission capabilities and variable transmission ratio at different speed & improves linearity between vehicle speed and engine speed more than manual transmission system.

Keywords—pulley; rubber belt; variable diameter; transmission system; fuel economy.

I. INTRODUCTION

1.1 BACKGROUND

Automobiles have become a necessity in recent times. So for increasing use of automobile, the transmission of power from the engine to the wheels of an automobile efficiently is one of the greatest challenges. In manual transmission of automobiles the gear box is used for power transmission. Gear box is using one or more sets of gear pairs. Recently automatic planetary gear system is also used for automatic transmission. This both types of gearboxes provide fixed gear ratio changes. This results in the engine not running at optimum performance at all times leading to insufficient performance and high emission from the engine.

The disadvantages of fixed speed ratio change gear boxes can be eliminated by Continuously Variable Transmission (abbreviated by CVT). Though the concept of CVT has been around more than century, difficulties with manufacturing processes, robust control techniques have limited the use of CVT. Increase in fuel economy with other advantages like better drive ability, smoothness of operation, power full acceleration and the most important an infinite range of speed ratios has made CVT a better option for automobile industry.

1.2 INTRODUCTION OF CVT

A continuously variable transmission, or (CVT), is a type of automatic transmission that provides better fuel economy and a smoother driving experience than a traditional manual transmission. It also gives more useable power.

An extended version of CVT is known as the Infinitely Variable Transmission (IVT), allows the transmission which drives a vehicle in both condition backwards as well as forwards. A CVT is a one type of an automatic transmission, which can change continuously an infinite number of gear ratios between maximum and minimum values.

It will allow engine to work at or near to its best bsfc rate (Brake specific fuel consumption= r/P), which means the engine fuel economy and its performance will increase. The concept of continuously variable transmission (CVT) was developed by Leonardo Da Vinci in 1460. Due to the limitation of technologies in the earlier time, CVT was unsuitable for a car which transmits power more than 100 HP.

An automobile company named proton, has stated that they are using CVT in their model. The new saga flax run with CVT technology adapted the new technology in automotive technology history which is started by Nissan.

Engine transmission can be classified into two categories, “stepwise” and “Continuously Variable Transmission (CVT)” or the word as manual and automatic transmission. The manual and
automatic are classified in “steeply” transmission use gears as their mean to steeply vary the gear ratios. Manual gearboxes basically consist of six sets of gear trains, which are first, second, third, fourth, fifth and reverse gears while in automatic it have the same gear train but with less of number of gears.

CVT can further be classified as the hybrid of automatic and manual transmission. The detail about of CVT will be explained in the background.

Nowadays, car manufacturer start involve the new type of gearboxes such as Nissan, Audi, Honda and also our national car manufacturer PROTON have use this technologies in their new model.

### 1.3 HISTORY OF CVT

Leonardo Da Vinci (1490) developed a concept of staples continuously variable transmission. The first patent was applied in Europe of a friction-based belt CVT by Daimler and Benz (1886), and a US Patent for a Toroidal CVT was granted (1935).

Zenith Motorcycles made a Gradua-Geared V2 engine motorcycle, that was a CVT. Hill climbing event was achieved by Gradua (1910).

The Multi was a much improved version of Zenith’s Gradua-Gear made by Rudge Multigear (1912). Browne made a variable-stroke ratchet drive motorcycle with using a face ratchet (1922) Van Doorne's manufactured the first DAF car of CVT (1958). Van Doorne's patents were transferred to a company named VDT (Van Doorne Transmission B.V.) and was bought by Volvo (1975); its CVT was used in the Volvo 340, Robert Bosch GmbH accepted concept of CVT & developed a new model with VDP (1995).

A motorcycle with a rubber belt was modified with Rokon CVT (1974). Some ATVs are developed with CVTs. The first ATV car was developed as CVT system was Polaris’s Trail Boss (1985).

Ford Fiesta and Fiat Uno was major mainstreems of European cars to be acquired with steel-belt CVT as rubber-belt DAF design was less robust (1987). By using that CVT, Ford developed Ford CTX (1976).

Nissan- a well-known car manufacturer designed its own CVT named Xtronic CVT for higher torque application (1990). It also included a torque converter. Xtronic CVT was applied as primary transmission system in a number of Japanese models. Nissan is also the only car manufacturer who developed and introduced a roller-based CVT to the market.

They had also developed a Toroidal CVT (Extroid) was used in the Japanese market Y34 Nissan Gloria and V35 Skyline GT-8.. The Nissan Murano (2003) and the Nissan Rogue (2007) also introduced with CVT in their automatic transmission models.

Nissan announced a huge shift to CVT with XTronic CVT (12 July 2006) technology for all automatic vehicle of the Cube, Maxima, Sentra, Altima and Versa vehicles in North America. One major motivation for Nissan to make a switch to CVT as a part of their 'Green Program 2010' as CVT is reducing $CO_2$ emissions (2010).

Honda also developed its own version on the 1995 Honda Civic VTI. Multi Matic CVT is of higher torque than traditional pulley CVTs. The CVT is also recently used in the Honda City ZX in India and Honda City Vario in Pakistan.

BMW also used a CVT which is driven by belt as an option for the low range and middle-range made by ZF Friedrichshafen. Ford introduced a chain-driven CVT also named the CFT30 (2005), Ford Five Hundred and Mercury Montego.

The Mitsubishi Lancer model is launched with CVT transmission as the automatic transmission (2008). A standard CVT with NRDL gears applied in DE and ES models.

SEAT Exeo is launched an option for the petrol engine CVT automatic transmission (multitronic), with 'six-speeds' (2009). Subaru had also again come back with CVT for its new 2010 Legacy and 2010 outback. It will be made to a 2.5l 4 cylinder boxer engine.
1.4 ABOUT CVT

1.4.1 Variable-diameter pulley (VDP) or Reeves drive

In the most of CVT system, there are two V-belt pulleys that are splined with driving and driven shafts and moves perpendicular to their axes of rotation with V-belt running between them. The speed ratio is varied by splitting the two sheaves which of one pulley near to each other and the two sheaves of the other pulley apart from each other. The belt is moving at higher or lower position of pulleys due to the v shape of the belt. The changes in the effective diameters of the pulleys change the overall speed ratio. The centre distance between the driver and driven pulleys does not change, and neither the length of the belt. Thus continuous variation in the speed ratio done by means of both pulleys’ adjustment in diameter (one larger in diameter, the other smaller in diameter) simultaneously maintains the proper amount of tension on the belt.

![Fig.1.1 Variable-Diameter Pulley CVT](image1)

The efficiency of a CVT depends on stiffness of V-belt in the pulley's direction of axis perpendicular to it in order to make only less radial changes while sliding in and out of the pulleys. Each element of the chain has conical, which is accurately fits and slides to the pulley if running of the belt is on the outer radius of the pulley. As the belt runs into the pulleys the contact area would be small. The contact area depends upon the contact of the number of elements of chain, thus the chain is made of lots of very small elements. The radial thickness of the pulley of the belt is changing between maximum gear ratio and minimum gear ratio according to torque. That is why the axis between the pulleys is kept as thin as possible. A lubricant film is applied to the sheaves of the pulleys. It should be required thick in proportion so that so that the pulley and the belt don’t touch and must be thin in order not to lose power. Additionally, the chain elements stabilize by 12 steel bands. And from this each band must be thin enough so that it bends easily. In the stack of bands each band responds to a slightly different speed ratio, and so they always slide over each other so lubrication oil is required between them. The centre bands are used as the chain linkages and the outer bands slide to stabilize chain.

1.4.2 Toroidal or roller-based CVT (Extroid CVT)

![Fig 1.2:- Toroidal CVT](image2)
Toroidal CVTs are made of the torus which is combination of discs and rollers that transmit power between the discs. The discs are same as two conical parts, with the sides dished so that the two parts would fill up the centre of a torus. One disc would be input, and the other would be the output. There are rollers that may vary the ratio and transmit power from one torus to the other torus. When the axis of the conical parts and the roller axis are perpendicular to each other, it makes contact with the near-conical parts at exactly same diameter and gives a 1:1 i.e. direct gear ratio. The roller can be rolled towards axis of the conical parts, by angle change as needed to maintain contact. This makes the roller to contact the near-conical parts and gives a gear speed ratio of other than 1:1. Systems may be partially or fully toroidal. Fully toroidal systems are efficient while partial toroidal may require a torque converter, and hence less efficiency.

Some of toroidal CVTs are also continuously variable. And in toroidal CVT the direction of the thrust force can be reversed.

1.4.3 Magnetic CVT or MCVT

The magnetic continuous variable transmission system was invented at the University of Sheffield in 2006. MCVT takes an electrically controlled gear ratio (Variable magnetic transmission). It is used as a power split device and matches an input speed from a prime-mover by changing load and through a variation in path by means of electrical power. The MCVT is a more efficient power-split device for hybrid vehicles, but also it has applications in an industrial drive sectors as well as marine propulsion. The magnetic CVT can’t transmit more torque than electric motor of the same size, so it is not a better option for automobile transmission.

1.4.4 Ratcheting CVT

The ratcheting CVT is a one type of continuous variable transmission that is totally based on static friction as the static friction is the major reason for transmission of power and is based on a set of elements that engages successively and then disengages in between the driving and the driven system, using oscillating motion with one-way clutches or ratchets that rectifies and sums only "forward" movement. Varying linkage assembly within the oscillating elements adjust the transmission gear ratio, so that the maximum linkage speed is changed, even when the mean linkage speed would be constant. Power is transmitted from input to output only when the ratchet is engaged, and hence when it is kept locked to a static friction mode where the driving & driven rotating surfaces rotate together without slippage.

These CVTs can transfer the variable torque, because of their static friction actually increases relatively as increase in torque, so slippage can be eliminated by designing the system properly. Efficiency of this system is generally higher, because of the dynamic friction is come into chapter by very slight transitional clutch speed changes. A major disadvantage of ratcheting CVTs is that causes vibration by the transition in speed needed to accelerate the element.

Ratcheting CVTs are differed from VDPs and roller-based CVTs as they all are static friction-based systems, and opposed to that was dynamic friction-based devices that lose significant energy by slippage at twisting surfaces. The ratcheting CVT was used in one prototype of a bicycle with the CVT transmission which is under U.S. Patent 5,516,132 in which strong pedalling torque makes the mechanism to react against the spring, and changing the position of the ring gear/chain wheel assembly to a concentric, lower gear position. When the pedalling relaxes to lower level, and the transmission system adjusts to higher gears automatically, by increasing in transmission vibration.

1.4.5 Hydrostatic CVT

Hydrostatic transmission system uses a variable displacement pump and also a hydraulic motor. The power is transmitted by means of transmission of hydraulic fluid. The torque transmission efficiency of this type is more, but it can be sensitive to contamination. Some designs are more costlier. However, the advantage that they have, the hydraulic motor can be placed directly on the wheel hub, and that allows suspension system more flexible and eliminates the losses the friction in between differential components and the drive shaft. Hydrostatic transmission of CVT is
easier to the application area because all forward as well as reverse speeds can be achieved using a single lever.

Some heavy equipment also be used by a hydrostatic transmission; i.e. agricultural machinery including foragers and some tractors. Heavy earth-moving equipment manufactured by Caterpillar. Hydrostatic CVTs are generally not used for the applications where high torque is required because heat is produced by the feeding oil.

The Honda had launched the first on road vehicle DN-01 motorcycle is with hydrostatic drive that causes a variable displacement of the axial piston pump by varying an angle of swash plate.

1.4.6 Cone CVT

The cone known as evens friction cone, in the cone CVT, changes the effective gear or speed ratio by means of one or more conical rollers. In the simplest cone CVT, the single-cone that uses a wheel which moves through the slope of the cone, and vary the diameter between lower and wider position of diameter.

The twin cone mesh system is also a more-sophisticated type of cone CVT.

In a cone CVT, the torque is transmitted via oscillating cones by friction from a variable number of cones to a central and barrel-shaped hub. The convex surface of the hub with a radius of curvature which is smaller than the radius of the cones. Each cone and hub makes contact at only one point.

The Warko was introduced which is made of cone CVT in Berlin during the 6th International CTI Symposium of Innovative Automotive Transmissions (2007).

A major advantage of the Warko is that is not using a clutch: the engine is giving power to the wheels, and the rear drive is carried by using an epicyclic system in output.

1.4.7 Radial Roller CVT

The working principle of Radial roller CVT is same as an oil compression engines, common steel rollers are compressed in place of compressing oil.

The traction fluid transmits the motion between rollers and rotors, so that the proper friction between the surfaces and slows down wearing is ensured. The tangential speed variation is not showed by radial rollers. So mechanical efficiency and reliability increases.

1.4.8 Planetary CVT

In a planetary CVT, The adjustment of gear ratio depends upon tilting the axes of spheres in a continuous manner, to provide different contact radius, which turns drive input and output discs. The system has multiple "planets" to transfer torque through multiple fluid patches. One commercial implementation of this type is the NuVinci Continuously Variable Transmission.

1.5 WORKING OF CVT

In the traditional transmission system the gears are used that provides a given number of speed ratios (or speeds). The transmission changes gears to have the most appropriate ratio for a given speed i.e. Lowest gears for starting, middle gears for acceleration, and higher gears for fuel-efficient cruising.

Although there are different types of CVT, uses a pair of variable-diameter pulley sheaves, each is shaped like a pair of opposing sheaves, with a metal belt, rubber belt or chain running between them. One pulley is connected to the engine (input shaft), the other to the drive wheels (output shaft).

The sheaves split on the axis perpendicular to the rotation of the pulleys and changes the diameter of the pulleys. The variation in pulleys diameter is due to centrifugal force. Different infinitely gear ratios can be achieved by changing the diameter of the both pulleys (driving and driven) simultaneously.

In the starting of the vehicle the low speed gear ratios can be achieved. Then to accelerate the vehicle, infinitely speed ratio can be achieved. And for higher speed the condition of overdrive also be achieved.
1.6 INFORMATION ABOUT VEHICLE

SUZUKI MAX 100

Suzuki max 100 was widely used in India. It gave more competition to the other bikes of the same feature like Hero-Honda CD 100, Kawasaki, Bajaj CT 100 etc.

Body
- Light weight, easy to handle.
- Kick start
- Telescopic oil damped suspension.(front)
- Swinging Arm Hydraulic Shock Absorber with coaxial spring (rear)
- Minimum ground clearance – 156 mm
- Overall length – 1895 mm.

Control
- Kick start.
- 98.2 cc engine deliver maximum output of 5.74 KW @ 5500 rpm.
- 12-volt 2.5 Ah/10 hr Battery.
- 4 speed constant mesh transmission.
- Rear suspension with swinging arm hydraulic shock absorbers.
- Front & rear drum brakes.
- 12.0 L fuel tank.
- Small size vehicle.
- Low price of vehicle.

Mileage and Economy
- Average of above 60 km/l.
- Fuel tank capacity - 12.0 Litters.
- Almost 100 cc engine.

Fig 1.3 Vehicle selected for Study (Suzuki Max 100)

II. LITERATURE REVIEW

Bunches of literature is present on power train analysis and on various types of Continuously Variable Transmissions (CVT) use in small size vehicles.. The work reviewed in this chapter would deal with power train analysis for small size vehicle, performance of continuous variable transmission system in vehicle, result data analysis of CVT used in vehicles & ways of operating CVT system in vehicle.

2.1 DESIGN AND FABRICATION OF CONTINUOUS VARIABLE TRANSMISSION IN FOUR WHEELER [5]

M. Anand Partheeban

SUMMARY:- The transmission is being very easy. A CVT system changes the driven pulley diameter (i.e. Distance between two conical pulleys) with respect to speed and hence it changes infinite gear ratio. Here in this paper, the driving pulley is kept constant. Only the driven pulley changes the dimension accordingly speed. The simulation of the vehicle acceleration performance is
carried out and that gives result that both drivability and fuel economy for the vehicle with CVT are better than the one with manual transmission or multi ratio automatic transmission. CVTs use infinitely gear ratios instead of gears to attain optimal speed. CVT is the better option for transmission system in modern automobile vehicles.

Here in the paper Mr. Anand partheeban concludes the data for four wheeler vehicle. And it gives better results then manual transmission.

2.2 FUEL OPTIMAL CONTROL OF CVT POWER TRAINS

R. Pfiffner, L. Guzzella, C.H. Onder

SUMMARY: - Here in this paper the authors described that CVT changes gear ratio infinitely, this change of speed ratio can be carried accordingly speed. CVT gives a better efficiency because it changes the speed ratio according to quasi static curve i.e the best efficiency of the curve. Here in the paper numerical optimum control is carried out.

The optimal control problem was solved by numerical optimization package DIRCOL by descritizing continuous time interval. The optimal solution consists by bringing the system to the engine’s best efficiency curve. So that fuel economy improvements of approximately 2.5% to 5% can be achieved, depending on the classical approach used.

2.3 OPTIMIZATION AND EVALUATION OF A BELT DRIVEN CVT FOR 125 CC, 4 STROKE SCOOTER

Vivek adyanathaye, N.B. Joshi, A.D Samant

SUMMARY: - Here in this paper the authors carried out the optimization and evaluation of a belt driven CVT. The belt driven CVT gives optimum efficiency, if the losses due to belt transmission is less. The optimization and evaluation of rubber ‘V’ belt CVT used with a 125CC, 4 stroke scooter. The programmable controlled pulleys are designed and commissioned on Test Rig. Parameter such as fuel economy and acceleration is compared. They found that major loss of CVT occurs largely due to belt. The belt which is stiffer in bending be more efficient.

Evaluation of the CVT system is carried out using test rig. They found that a CVT system is a good for two wheeler.

2.4 AN EXPERIMENTALLY-VALIDATED MODEL OF RUBBER BELT CVT MECHANICS

G. Julio, J.S. Plant

SUMMARY: - Rubber-belt CVTs are implemented in many vehicles to get comfort. Their better control mechanism makes the engine to run at constant RPM, at any driving conditions. This behaviour is not accepted, considering today’s comfort and pollution standards. So, better control system is required to vary the transmission ratio in real time. They have developed a new technology, a dynamic model of rubber-belt CVT system is developed by them to predict the axial force to be applied by the system.

Rubber-belt CVT is working accordingly Newton’s law of motion on a discretized belt. Simulation results are carried out. It shows that it is good fit with experiments for both steady-state condition and dynamic conditions.

We can improve the control ability of the driven pulley axial forces by using a device similar to the drive pulley rather than torque-cam mechanism is useful to validate the model. The discrete model developed in this paper would be improved to predict rubber-belt CVT mechanism under clutching conditions.

2.5 PERFORMANCE OPTIMIZATION OF CVT FOR TWO-WHEELED VEHICLES

C.H.ZHENG, W.S LIM and S.W CHA

SUMMARY- Here in this paper the first objective of the authors was to improve the efficiency of the CVT. Dynamic model was carried out for CVT using the dynamic equations. A simulation program was applied in Matlab/Simulink to analyse the performance of CVT. From the simulation, it
gave results that the radius of the driven pulley increases due to the torque given to the output shaft of the CVT increase with the friction coefficient between the belt and the driven pulley is constant.

As the objective of the paper was to improve the total efficiency of two-wheeler vehicle systems with a CVT. The CTCF was an important factor to improve the total efficiency of vehicles. The CTCF determines the operating conditions of the power source, from the ideal effective region. The CTCF depends upon several CVT design parameters, and these parameters have to be taken into consideration while designing the CVT to produce effective vehicle system.

2.6 CONTINUOUSLY VARIABLE TRANSMISSION

MICHEL PESGENS, BAS VROEMEN, BART STOUTEN

SUMMARY: This paper gives the information on the transmission ratio controller for a hydraulically actuated metal push-belt CVT. The total ratio controller helps to clamp pressure set point is minimal, and also avoid belt slip. It will increase the efficiency of the CVT. Here the distinction made between micro-slip, required for torque transfer between belt and pulleys, and macro-slip, which have to be avoided for its negative effects on efficiency and especially the risk of some belt and pulley wear.

From the test vehicle experiments it is concluded that on a roller bench have been used to validate the new ratio controller. To improve a non-synchronized operation of throttle and CVT ratio, the signal coming from the accelerator paddle has been become as the input for the validation experiments. The controller will find and give the maximum engine efficiency operating points. In this paper belt sleep has been avoided by using a clamping strategy. The maximum varying speed of the CVT is limited due to limited forces and variation in speed. The coefficient of friction in the outer slip region of a push-belt lower with slip speed it will cause an unstable dynamic control and hence slip speed will increase when the torque capacity of a V-belt is exceeded.

2.7 EXPERIMENTAL INVESTIGATION ON THE EFFICIENCY OF THE PULLEY-DRIVE CVT

C.ZHU, H.LIU, J.TIAN, Q.XIAO, X.DU

SUMMARY: The rubber V-belt CVT is used in low-power vehicles such as scooters & snowmobiles because its significant advantages over other transmissions. As the engine speed increases, flyweights on primary pulley swing open and push the movable sheave. As the transmission efficiency depends on power loss (Torque loss and Speed loss). Many parameters, such as friction coefficient between these rotating parts and elasticity of belt affect transmission efficiency of rubber V-belt CVT. The belt creeps only slightly more than slip on a load below 50 Nm. By increasing the input speed or improving the output torque we can improve efficiency. Efficiency of CVT is increased by using high elastic modulus belt or optimizing the belt tension with multi-angle& tuning
on secondary pulley. By improving the development of high strength belt & design of driving and driven pulleys, rubber belt CVT will finally be applicable for wider automotive application.

![Fig.2.2 The experimental setup-v belt CVT](image)

![Fig.2.3 Efficiency comparison of the CVT with different torque](image)

Graph shows the efficiency of CVT transmission system is increase with increase with speed of engine. Because, at high speed the performance of CVT is improve. Graph shows the efficiency of CVT transmission system is reduced with increase with speed ratio of engine. Because, at low speed ratio the performance of CVT is improve.

### III. DESIGN OF CVT

**3.1 Determination of the "highest ratio"**

Usually the "highest ratio" is selected so it allows achieving the maximum speed. The advantage of higher ratio is it gives better fuel economy at highway. (But it would not get the top speed.)

#### 3.1.1. Available power

Considering that the maximum engine power of the bike is $P_e = 7.8$ BHP, the transmission efficiency (incl. rolling resistance),
The available power \( P_t \) of the transmission will be:
\[
P_t = P_e \times \eta_t = 3442.0 \text{ (w)}.
\]

3.1.2. Thrust force
At a speed \( v \) (m/s), the Thrust force will be
\[
T_f = \frac{P_t}{v} = 3442.0 \div v \text{ (N)}
\]

3.1.3. Drag force
To find the maximum speed we have to consider the Drag force \( D_f \)
\[
D_f = \frac{1}{2} \times C_d \times r \times v^2 \times A
\]
Where:
- \( C_d \): Drag force coefficient = 0.5
- \( A \): Frontal area =1 (m²)
- \( r \): Air density =1.2 (kg/m³)
- \( v \): Vehicle velocity (m/s)

3.1.4. Maximum speed
So the maximum velocity can be determined by equating the Thrust force to the Drag force \( (T_f = D_f) \),
\[
v_{max}^2 = \frac{P_t}{\frac{1}{2} (C_d \times r \times A)}
\]
Thus \( v_{max} \) = 22.55 [m/s] = 81.18 [Km/h]

3.1.5. Highest speed ratio
Considering that the engine speed at maximum power is at \( (rpm_p) = 5500 \),
\( w_d = 18 \text{ (inch)} \) and \( diff_r = 1:1 \),
The highest ratio \( (H_{sr}) \) will be calculated by the equation:
\[
v_{max} = (rpm_p \times 2 \times \frac{\pi}{60}) \times \left( \frac{1}{2} (w_d \times 0.0254)/(H_{sr} \times diff_r) \right)
\]
\[
H_{sr} = (rpm_p \times 2 \times \frac{\pi}{60}) \times \left( \frac{1}{2} (w_d \times 0.0254)/(v_{max} \times diff_r) \right)
\]
\[ H_{sr} = 5.83 \]
Note: The “highest speed ratio” value was selected by using the data regarding to optimize the maximum speed

3.2 Determination of the lowest ratio
3.2.1. Force due to the slope?
Consider that the bike should be able to start moving uphill, fully loaded.
The vehicle’s dry mass is 100 (Kg)
The load of the vehicle is carried 120(Kg) (incl. passengers).
The % of slope inclination, \( \% incl = 5\% \),
Safety factor = 2.0.
The force due to the slope can be formulated as follows:
\[
F_{slope} = (m_d + L) \times 9.81 \times \left( \frac{\% \text{ incl}}{100} \right) \times \frac{\text{ safety}}{\eta_t} \text{ [N]}
\]
(note: \( \eta_t \) = transmission efficiency).

3.2.2. Available tangential force in the tyres:
The maximum torque from the engine, \( T_{max} = 9.8 \text{ [Nm]} \)
Due to clutch slip efficiency of the multi-plate clutch is near to 90%
Clutch Efficiency, $n_c = 90\%$

So the tangential force in the tyres will be:

$$F_{slope} = (T_{max} \times n_c \times L_{sr} \times diff_r)/((w_d \times 0.0254)/2)$$

### 3.2.3. Lowest speed ratio

Equating $F_{slope} = F_{slope}$ and calculating lowest speed ratio $L_{sr}$ results:

$$L_{sr} = F_{slope} \times \left(\frac{1}{2} (w_d \times 0.0254)/(T_{max} \times n_c \times diff_r)\right)$$

Now we get the required “lowest speed ratio” and “highest speed ratio”.

### 3.3 Addition of an external fixed ratio to obtain symmetric ratios:

We get the results from the calculations are:

**Low speed ratio, $L_{sr} = 18.64:1$**

**High speed ratio, $H_{sr} = 5.83:1$**

Symmetric extreme ratios to be found:

$C_f = 0.91$ is a correction factor.

Therefore, we have to add (in series) a final (fixed) reduction with a ratio of $k$.

$$k = \sqrt{L_{sr} \times H_{sr} \times C_f}$$

Now we have to find the new CVT’s high and low speed ratios. These gives result by dividing initial low speed ratio and high speed ratio by $k$.

$$S.L_{sr} = L_{sr}/k \quad \& \quad S.H_{sr} = H_{sr}/k$$

**Conclusion:** So we get the CVT’s symmetric ratios will be $S.L_{sr} = 1.87 \quad \& \quad S.H_{sr} = 0.5862$

### 3.4 Pulley diameter calculation

Considering that the smaller diameter of the pulley ($D_1$) is 50 [mm] and that the bigger is ($D_2$) will be so that

$$D_1 = D_2 \times S.H_{sr}$$

$$\therefore D_2 = D_1/S.H_{sr}$$

$$\therefore D_2 = 85.29 \text{ (mm)}$$

The pulley groove angle: $\beta = 20^\circ$

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*Fig 3.1: CAD Design of VDP (High Speed Ratio)*
IV. EXPERIMENTAL SET UP

The aim of our project is to improve the performance of two wheelers by using CVT system. In the manual gear box system, the power transmission efficiency of lowering gears is less. Whereas higher gears have more power transmission capacity. The bike with manual gearbox does not give comfort drive as it is required to change gears at particular time. It may cause driving discomfort in traffic. Whereas the continuously variable transmission system provides better driving comfort.

The study of different parameters such as speed ratio, acceleration time, fuel economy and transmission efficiency of both with CVT system and without CVT system (i.e manual gear box system) are carried out by different tests such as dynamo testing, bottle testing, acceleration testing and speed ratio testing by pulse tachometer and stroboscope.

After the parameter study of bike with manual gear box system, the CVT system is implemented in place of gear box in the bike. After the implementation CVT system, the same parameters study are carried out with CVT system. The placement of CVT system required some attachments to implement it on the bike. so the attachments are made according to design of placement of CVT system. The placement of CVT system is shown in fig below.
V. PARAMETRIC STUDY

We have designed a CVT system (i.e. Variable Diameter Pulley) which will is going to be implemented in bike SUZUKI MAX 100. We will study different parameters of both manual gear transmission bike and CVT transmission bike.

The placement of CVT is carried out by doing some modifications in bike. As we are using only CVT transmission system with multi plate clutch which have more transmission efficiency then centrifugal clutch.

The parameter study of this project will be:
- Gear ratio
- Fuel economy
- Acceleration time
- Transmission Efficiency

The parameter study of different parameters of bike (without CVT & with CVT) have are carried out. They are explained following.

5.1 PARAMETRIC STUDY OF GEAR RATIO

We have measured different gear ratios for different gears. The gear ratios are measured in terms of speed of engine and wheel. Engine rpm was measured by the pulse tachometer. The wheel rpm are measured by stroboscope. The final gear ratios for different gears are measured approximately closer to the gear ratios specified by the company. Which is given in table.

\[ Gear \ Ratio = \frac{Ne}{Nw} \]

Where \( Ne \) = engine rpm
\( Nw \) = wheel rpm

The gear ratio of the vehicle gives the reduction in the speed from engine to wheel. As there is another chain sprocket system is used for reduction of speed. The parametric study of gear ratio is measured in terms of whole reduction system i.e. gear reduction and chain reduction. The speed reduction of both CVT system and gear system is measured.

5.1.1 PARAMETRIC STUDY OF GEAR RATIOS WITHOUT CVT SYSTEM

The gear ratios of the bike (without CVT system i.e. manual gear box system) are carried out. They are explained in tabular form.

<table>
<thead>
<tr>
<th>GEAR</th>
<th>ENGINE RPM</th>
<th>GEAR SHAFT RPM</th>
<th>GEAR RATIO</th>
<th>AVG.GEAR RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ST</td>
<td>2800</td>
<td>950</td>
<td>2.94</td>
<td>2.906</td>
</tr>
<tr>
<td></td>
<td>3500</td>
<td>1200</td>
<td>2.91</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4500</td>
<td>1570</td>
<td>2.87</td>
<td></td>
</tr>
<tr>
<td>2ND</td>
<td>2800</td>
<td>1500</td>
<td>1.91</td>
<td>1.83</td>
</tr>
<tr>
<td></td>
<td>3500</td>
<td>2000</td>
<td>1.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4500</td>
<td>2430</td>
<td>1.85</td>
<td></td>
</tr>
<tr>
<td>3RD</td>
<td>2800</td>
<td>2150</td>
<td>1.34</td>
<td>1.31</td>
</tr>
<tr>
<td></td>
<td>3500</td>
<td>2910</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4500</td>
<td>3210</td>
<td>1.40</td>
<td></td>
</tr>
<tr>
<td>4TH</td>
<td>2800</td>
<td>2780</td>
<td>1.02</td>
<td>1.025</td>
</tr>
<tr>
<td></td>
<td>4500</td>
<td>4360</td>
<td>1.03</td>
<td></td>
</tr>
</tbody>
</table>

5.1.2 PARAMETRIC STUDY OF GEAR RATIOS WITH CVT SYSTEM

The gear ratios of the bike (without CVT system i.e. manual gear box system) are carried out. They are explained in tabular form.
## Table 5.2: Gear ratio’s for CVT system

<table>
<thead>
<tr>
<th>Driving pulley RPM</th>
<th>Driven pulley RPM</th>
<th>Gear Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>2800</td>
<td>1040</td>
<td>2.40</td>
</tr>
<tr>
<td>3000</td>
<td>1120</td>
<td>2.32</td>
</tr>
<tr>
<td>3200</td>
<td>1560</td>
<td>2.05</td>
</tr>
<tr>
<td>3400</td>
<td>1890</td>
<td>1.79</td>
</tr>
<tr>
<td>3600</td>
<td>2660</td>
<td>1.35</td>
</tr>
<tr>
<td>3800</td>
<td>3170</td>
<td>1.19</td>
</tr>
<tr>
<td>4000</td>
<td>3960</td>
<td>1.01</td>
</tr>
<tr>
<td>4200</td>
<td>4330</td>
<td>0.96</td>
</tr>
<tr>
<td>4500</td>
<td>4730</td>
<td>0.95</td>
</tr>
</tbody>
</table>

## 5.2 PARAMETRIC STUDY OF FUEL ECONOMY

Automobiles have become a necessity in recent times. Without automobile vehicle, transportation cannot be imagined. If we see the today’s market it may be too much costly. So in today’s market, everyone consider the vehicle’s fuel economy as important parameter while buying the vehicle. So it is necessary to take the fuel consumption as an important study parameter to be study.

Here fuel economy is measured practically by bottle test. We have measured fuel consumption on highway which is suitable condition to measure bike’s fuel economy.

### 5.2.1 PARAMETRIC STUDY OF FUEL ECONOMY WITHOUT CVT SYSTEM

The tabulated data regarding the bottle test for the fuel economy of the bike with manual gear box system is given below.

<table>
<thead>
<tr>
<th>FUEL CONSUMPTIONS (mL)</th>
<th>KILOMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>4.0</td>
</tr>
<tr>
<td>100</td>
<td>3.8</td>
</tr>
<tr>
<td>100</td>
<td>3.7</td>
</tr>
</tbody>
</table>

## 5.3 PARAMETRIC STUDY OF ACCELERATION TIME

In today’s world the youth generation wants sudden acceleration in their vehicle. So acceleration is another important parameter to be studied. The parametric study of acceleration time is carried out by measuring the different speed at different time. The time for acceleration is measured by stop watch.

### 5.3.1 PARAMETRIC STUDY OF ACCELERATION TIME WITHOUT CVT

The acceleration time for the different speeds in different gears is measured. The tabulated data regarding the acceleration time is shown below.

<table>
<thead>
<tr>
<th>GEAR</th>
<th>INITIAL VELOCITY</th>
<th>FINAL VELOCITY</th>
<th>Time (t1)</th>
<th>Time (t2)</th>
<th>Time (t3)</th>
<th>Avg time (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>0</td>
<td>20</td>
<td>9.10</td>
<td>8.26</td>
<td>8.43</td>
<td>8.606</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>40</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2nd</td>
<td>0</td>
<td>20</td>
<td>5.20</td>
<td>4.50</td>
<td>4.20</td>
<td>4.63</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>40</td>
<td>22.15</td>
<td>22.20</td>
<td>19.30</td>
<td>21.21</td>
</tr>
<tr>
<td>3rd</td>
<td>0</td>
<td>20</td>
<td>5.08</td>
<td>5.01</td>
<td>5.84</td>
<td>5.31</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>40</td>
<td>13.04</td>
<td>13.73</td>
<td>14.08</td>
<td>13.62</td>
</tr>
</tbody>
</table>
5.3.2 PARAMETRIC STUDY OF ACCELERATION TIME WITH CVT

The acceleration time for CVT system is measured. The data regarding the acceleration time for the CVT system is given in tabular form.

Table 5.5: Parametric study of acceleration time with CVT

<table>
<thead>
<tr>
<th>INITIAL VELOCITY</th>
<th>FINAL VELOCITY</th>
<th>TIME (s)</th>
<th>AVG TIME (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>0</td>
<td>20</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>0</td>
<td>20</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>0</td>
<td>20</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>0</td>
<td>40</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>0</td>
<td>40</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>0</td>
<td>40</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>0</td>
<td>40</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

5.4 PARAMETRIC STUDY OF TRANSMISSION EFFICIENCY

The transmission efficiency is an important parameter to study as the transmission efficiency increases then automatically fuel economy improves and vehicle performance improves. So transmission efficiency is the major aspect to be studied in terms of mechanical study of different parameters.

The transmission efficiency can be defined as,” the ratio of brake power to the indicated power”.

\[ \eta = \frac{B.P}{I.P} \]

Where \( B.P \) = Brake Power

\( I.P \) = Indicated Power

The parametric study of transmission efficiency is carried out by using dynamo testing of the bike. For studying the transmission efficiency by the dynamo testing, different equipment are required. They are U-tube manometer, pulse tachometer, tachometer or stroboscope, weights for different load conditions etc.

The u-tube manometer is used for measuring the pressure of air which is used to calculate the indicated power of the vehicle. Whereas engine speed is measured by pulse tachometer. Pulse tachometer measures the vibration pulses generated at spark plug and gives the engine speed. Engine speed is also used for calculating indicated power.

Indicated power is known as input power of dynamo and it can be calculated by following formula.

\[ \text{Indicated Power} = I.P = \frac{PmLANe}{60000} \]

Engine rpm is measured by the pulse tachometer. But in case of measurement of wheel rpm, tachometer or stroboscope is used. The weight is placed so that wheel rim becomes a dynamo. The weight of 5 kg and 10 kg are used to give different loads. Weights are used to calculate the torque. Which is further used to calculate the brake power.

Brake power is known as the output power of the dynamo and it can be calculated by following formula.

\[ \text{Brake Power} = B.P = \frac{2\pi NwT}{60000} \]
5.4.1 PARAMETRIC STUDY OF TRANSMISSION EFFICIENCY WITHOUT CVT

The parametric study of transmission efficiency of the vehicle without CVT system is given below in tabulated form.

**Table 5.6: Dynamo testing (without CVT)**

<table>
<thead>
<tr>
<th>GEAR</th>
<th>Ne (rpm)</th>
<th>Nw (rpm)</th>
<th>LOAD (Kg)</th>
<th>TORQUE (Nm)</th>
<th>I.P (watt)</th>
<th>B.P (watt)</th>
<th>η</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ST</td>
<td>3350</td>
<td>800</td>
<td>5</td>
<td>11.45</td>
<td>2680</td>
<td>959.2</td>
<td>35.79</td>
</tr>
<tr>
<td></td>
<td>2700</td>
<td>385</td>
<td>10</td>
<td>22.91</td>
<td>2592</td>
<td>901.75</td>
<td>34.78</td>
</tr>
<tr>
<td>2ND</td>
<td>2980</td>
<td>1000</td>
<td>5</td>
<td>11.45</td>
<td>2384</td>
<td>1199.04</td>
<td>50.02</td>
</tr>
<tr>
<td></td>
<td>2520</td>
<td>500</td>
<td>10</td>
<td>22.91</td>
<td>2419.2</td>
<td>1167.74</td>
<td>48.26</td>
</tr>
<tr>
<td>3RD</td>
<td>2730</td>
<td>1330</td>
<td>5</td>
<td>11.45</td>
<td>2184</td>
<td>1594.72</td>
<td>73.01</td>
</tr>
<tr>
<td></td>
<td>2400</td>
<td>704</td>
<td>10</td>
<td>22.91</td>
<td>2304</td>
<td>1647.12</td>
<td>71.48</td>
</tr>
<tr>
<td>4TH</td>
<td>2600</td>
<td>1500</td>
<td>5</td>
<td>11.45</td>
<td>2080</td>
<td>1801.04</td>
<td>86.58</td>
</tr>
<tr>
<td></td>
<td>2200</td>
<td>765</td>
<td>10</td>
<td>22.91</td>
<td>2112</td>
<td>1788.23</td>
<td>84.66</td>
</tr>
</tbody>
</table>

5.4.2 PARAMETRIC STUDY OF TRANSMISSION EFFICIENCY WITH CVT

The parametric study of transmission efficiency of the vehicle without CVT system is given below in tabulated form.

**Table 5.7: Dynamo testing (with CVT)**

<table>
<thead>
<tr>
<th>Ne (rpm)</th>
<th>Nw (rpm)</th>
<th>LOAD (Kg)</th>
<th>TORQUE (Nm)</th>
<th>I.P (watt)</th>
<th>B.P (watt)</th>
<th>η</th>
</tr>
</thead>
<tbody>
<tr>
<td>2637</td>
<td>550</td>
<td>5</td>
<td>11.45</td>
<td>2116.23</td>
<td>659.47</td>
<td>31.16</td>
</tr>
<tr>
<td>2863</td>
<td>930</td>
<td>5</td>
<td>11.45</td>
<td>2297.74</td>
<td>1115.32</td>
<td>48.54</td>
</tr>
<tr>
<td>3150</td>
<td>1470</td>
<td>5</td>
<td>11.45</td>
<td>2526.54</td>
<td>1762.59</td>
<td>69.76</td>
</tr>
<tr>
<td>3680</td>
<td>1980</td>
<td>5</td>
<td>11.45</td>
<td>2953.43</td>
<td>2374.10</td>
<td>80.39</td>
</tr>
<tr>
<td>3150</td>
<td>658</td>
<td>10</td>
<td>22.91</td>
<td>2528.15</td>
<td>1578.62</td>
<td>62.44</td>
</tr>
<tr>
<td>3370</td>
<td>846</td>
<td>10</td>
<td>22.91</td>
<td>2704.65</td>
<td>2029.66</td>
<td>75.04</td>
</tr>
<tr>
<td>3780</td>
<td>1015</td>
<td>10</td>
<td>22.91</td>
<td>3033.72</td>
<td>2436.91</td>
<td>80.32</td>
</tr>
<tr>
<td>4200</td>
<td>1230</td>
<td>10</td>
<td>22.91</td>
<td>3370.83</td>
<td>2950.92</td>
<td>87.54</td>
</tr>
</tbody>
</table>

5.5 COMPARATIVE ANALYSIS

The aim of our project is to improve the performance of two wheeler by using the CVT system, for that different parameters such as speed ratios, acceleration time, fuel economy and transmission efficiency are carried out.

To get a proper result, both the transmission system of the vehicle that is gear box and CVT system are implemented on the same vehicle and analysis of different parameters are carried out for both the system.

**Comparative Analysis of Gear Ratios**

As the name suggests the CVT system continuously changes the speed ratios with the speed. Where as in the gear box system it is required to changes the speed ratios or gear ratios. The CVT system sets gear ratio automatically and gives comfort drive. CVT system gives the continuously changing speed ratios from 0.95 to 2.4 where as with gear system it gives the practical gear ratios from 0.99 to 2.909. Which gives that the CVT system transmits lower starting torque compare to gear box system. where as after the actuating some speed, the CVT system gives better speed compare to gear box system.

If we compare the acceleration time for both the system, it is having less time to carry the vehicle to the speed of 20 to 40 km/h in the CVT system then the gear box system. As the CVT system takes much time to get the speed of 20 km/hr due to its lower torque transmission system.
The transmission efficiency of the CVT system improves at higher speed. If we compare the transmission efficiency of both the system, at the higher speed the transmission efficiency of the CVT system is 87.5% whereas the transmission efficiency of the gear system at higher speed (i.e. forth gear) is around 86.5%. So the transmission efficiency improves 1%.

![Comparative Analysis of Acceleration Time](image1)

The comparative analysis shows the result that the fuel economy with CVT system and without the CVT system is increased at higher speed i.e on highway condition. So CVT improvise the performance of two wheeler in terms of smoothen drive.

**VI. CONCLUSION**

The aim of the project was to improve fuel economy of two wheeler by providing continuously variable transmission (CVT) system. A continuously variable transmission, or CVT, is a type of automatic transmission that provides more useable power, better fuel economy and a
A smoother driving experience than a traditional manual transmission. CVT, that is lighter in weight and more efficient will be used, which has large and variable transmission ratio. CVT gives different-different speed outputs at same acceleration level. The transmission efficiency and fuel economy improves 1% and 5% respectively by using the CVT system. It provides a better speed ratios and smoother drive compare to the manual gearbox transmission system.

VII. FUTURE SCOPE

We have designed a CVT system (i.e. Variable Diameter Pulley). And we have implemented the CVT system in the motorcycle with two stroke engine. As the two stroke engine has more power loss then two stroke engine. Still in the two stroke engine it gives better performance but in the four stroke engine it improves the performance. The compactness in the placement of the CVT system is required. It would be necessary to have modifications in the frame of the vehicle in order to accommodate the CVT system in place of conventional gearbox system.

Based on our theoretical study, it is our prediction that the following mentioned parameters can be improved more with 4 stroke engine.

Acceleration Time to carry different speeds
Fuel Economy
Efficiency

REFERENCES

[8] URL: global.yamaha-motor.com/yamahastyle/technology/spread/003/img/img03_l.gif