STUDY AND ANALYSIS OF ELECTRICAL CONTINUOUS VARIABLE TRANSMISSION THROUGH STEPPER MOTOR FOR ELECTRIC TWO-WHEELER

Panchal Akshat[1], Mer Ajay Nareshbhai[2], Panchal Kavan[3], Shiv Kamlesh Patel[4]

[1]*Student, Gujarat Technological University, Ahmedabad, Gujarat*
[2]*Student, Gujarat Technological University, Ahmedabad, Gujarat*
[3]*Student, Gujarat Technological University, Ahmedabad, Gujarat*
[4]*Student, Dharmsinh Desai Institute of Technology, Vadodara, Gujarat*

Abstract - *The Electric Continuously Variable Transmission (E-CVT), represents a significant innovation in the electric two-wheeler industry. It addresses a critical challenge faced by electric vehicles today – limited range, a factor deterring many potential users from adopting electric mobility. E-CVT offers a promising solution to extend the range of electric vehicles, making them a more practical choice for consumer. One of the key advantages of E-CVT is the enhanced control it provides to drivers. It allows for dynamic mode adjustments tailored to various driving conditions such as city, highway, and traffic. This adaptability is achieved through the variable ratio capability of E-CVT, optimizing vehicle performance and energy efficiency, E-CVT technology not only extends the range of electric two-wheelers but also empowers drivers with greater control, making electric vehicles a more appealing and versatile option for modern transportation needs.*

Key Words: E-CVT, Electric vehicle Powertrain, Vehicle Efficiency, Range Extender, Stepper Motor.

1.INTRODUCTION

The growing concerns over global warming and soaring fuel prices have propelled a shift toward electric vehicles (EVs). However, a major roadblock for EV adoption, particularly two-wheelers, is their limited range, which has deterred potential buyers. This chapter introduces the concept of a Variable Driveline tailored for two-wheelers to address this challenge. The Continuously Variable Transmission (CVT), a pivotal element in the proposed solution. A CVT is described as a transmission system capable of seamlessly adjusting through an infinite range of gear ratios, maintaining a constant angular velocity across various speeds. It highlights how integrating a CVT into an electric vehicle can enhance road load resistance performance, reduce motor power requirements, and elevate overall vehicle performance. the Electric Continuously Variable Transmission (E-CVT) concept, outlining its potential advantages. E-CVTs are specifically designed for electric vehicles, which are powered by electric motors instead of internal combustion engines. In an E-CVT-equipped EV, the transmission system manages the flow of electric power from the motor to the wheels while continuously adjusting the gear ratio to optimize performance.

1.1 Why E-CVT

The E-CVT system allows for seamless transitions between the Electric motor to Wheel. It combines elements of both a traditional continuously variable transmission (CVT) and an electric motor. The goal of an E-CVT system is to maximize Electric Vehicle Range by using the electric motor. There are multiple number of components in an e cvt which are Pulleys, Bearings, Variable speed belt. Motor, Motor mountings, Stepper motors, 3d printed stepper motor casing

2. DESIGN METHODOLOGY

Pulley is one of the main components in the CVT, it transmits the rotation motion from driver pulley to driven pulley. Pulleys are designed in such a way that it can change its diameter according to need, which changes the ratio for driver and driven pulley. After considering many research papers for the angle of the pulley, 22 degree was decided as this angle is the most efficient according to many research papers. Cast iron is considered based on its strength and load transferring properties. Selection of the diameter is a very crucial part which was decided after several calculations The outer diameter of the pulley is considered.

2.1 Orientations of the pulleys

1. Primary pulley at minimum ratio

In this type of orientation, the stepper motor will reduce the distance between the two ends of the pulley as shown in the figure 2.1.1

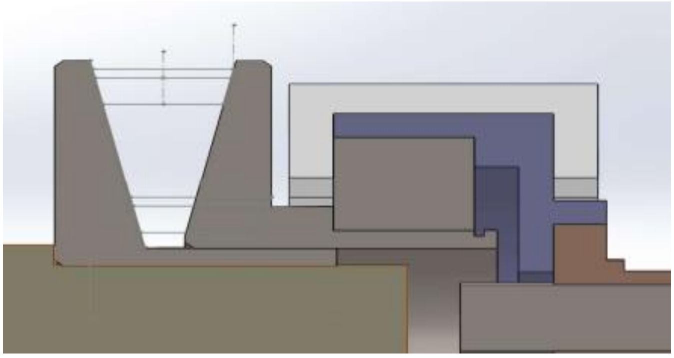

Figure 2.1.1 Primary Pulley at Minimum Ratio

2. Primary pulley at maximum ratio – In this type of orientation the stepper motor will increase the distance between the two ends of the pulley as shown in the figure 2.1.2

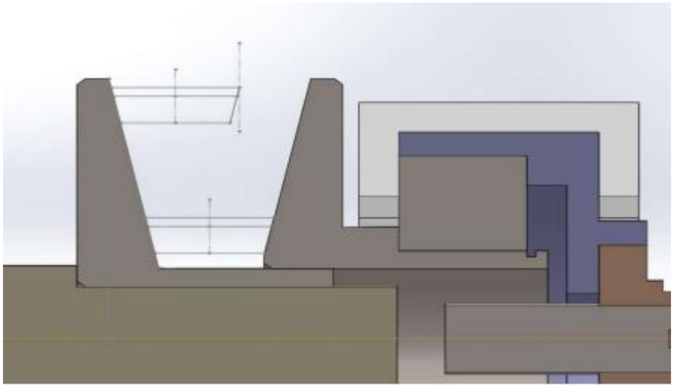

Figure 2.1.2 Primary Pulley at Maximum Ratio

3. Secondary pulley at maximum ratio - In this type of orientation the stepper motor will increase the distance between the two ends of the pulley as shown in the figure 2.1.3

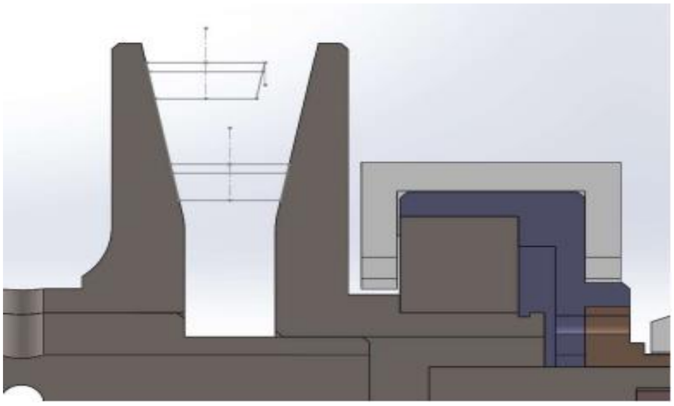

Figure 2.1.3 Secondary Pulley at Maximum Ratio

4. Secondary pulley at minimum ratio - In this type of orientation the stepper motor will reduce the distance between the two ends of the pulley as shown in the figure 2.1.4

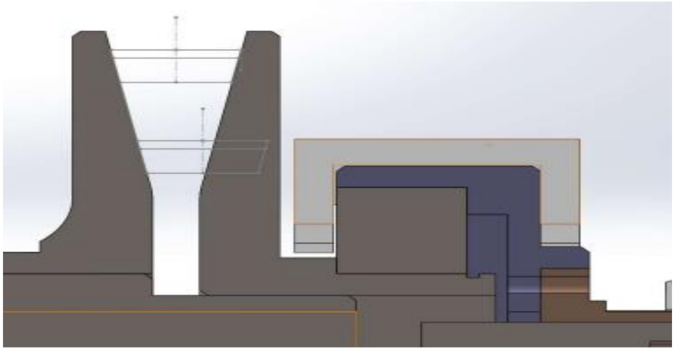

Figure 2.1.4 Secondary Pulley at Minimum Ratio

2.2 selection of variable speed belt

Variable speed cog-belts are designed for use with industrial variable speed pulleys to gain a wide range of driven speeds. Timken Belts is a leader in variable speed belt technology. Belts are made of Ethylene Propylene Diene Monomer (EPDM) that is durable and resistant to oil, heat, hardening and glazing. Variable Speed Belts are specified for applications where changes in speed during operation are common. Part of the V-belt family, it differs in shape considerably to the standard v-belt - having a distinctly broader width and a narrower thickness.

2.3. Role of stepper motor

The motor's position can be commanded to move and hold at one of these steps without any position sensor for feedback (an open-loop controller), if the motor is correctly sized to the application in respect to torque and speed. Stepper motor will move the pulley front and back according to the speed of the vehicle. Arduino will command the stepper motor to change the ratio of the pulleys when needed. Arduino is programmed in such a way that it provides maximum efficiency.

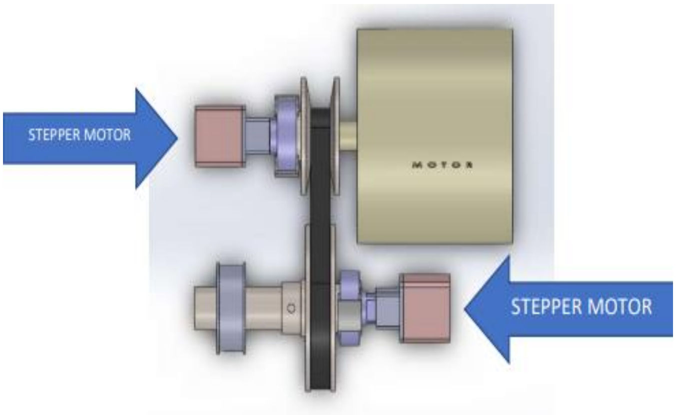

Figure 2.3.1 visual Representation of Stepper Motor

3. MATLAB EXPERIMENTATION

The above shown picture is a snapshot of MATLAB Simulink block set for electric 2 wheelers. The Simulink block set is created for simple simulation. It is created from reference of MATLAB videos and skill Lync videos from YouTube. The main blocks are highlighted and numbered and the details of them is given in the table below.

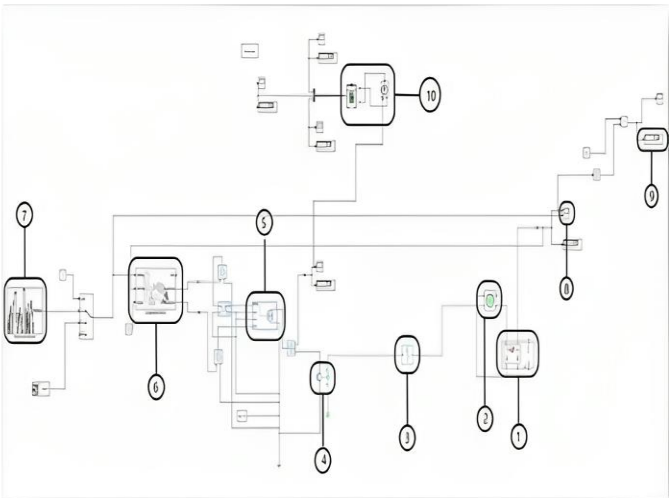

Figure 3.1 MATLAB Flow Chart

Table -1: MATLAB Data

No.	Name	Description
1	Vehicle body	Data like mass, drag coefficients, vehicle details are to be entered.
2	Tire	Tire size and properties are to be entered
3	Reduction ratio	Final Reduction ratio for vehicle
4	Motor	Motor specifications are to be entered
5	PWM controller	Controls the motor with PWM according to driver
6	Simulink driver	Simulink defined driver for drive cycles
7	Drive cycle source	Different drive cycles as per requirement can be selected
8	Telemetry scope	It shows us graph of ideal drive cycle and simulated vehicle for comparing the performance
9	distance scope	It shows us the distance covered in given time
10	Power source	It powers the vehicle with given battery specifications

For simulation we have considered following things given in the table below.

Table -2: Vehicle Data

Mass	180 kg
Drag coefficient	0.04
Tire radius	0.306 m
Motor rated power	1500 W
Motor rated voltage	48 V
Driver	Simulink defined driver
Drive cycle	LA92 drive cycle(1435s)

The LA92 drive cycle is of duration 1435 seconds with top speed 105kmph and consists of sudden acceleration and deacceleration events which is like experience of driving a vehicle in city. To check the regenerative braking efficiency based on reduction ratios we have used braking from vehicles resistance instead of braking system. This way the regenerative energy recovered can be checked.

We have run simulations with 3 different reduction ratios which are:

1. Reduction ratio – 8.85 (maximum)

2. Reduction ratio – 6

3. Reduction ratio – 3.09 (minimum)

The reduction ratios are considered in order to give maximum acceleration possible at 8.85 reduction ratio and to achieve a top speed like current average ICE 2 wheelers we have considered 3.09 reduction ratio. In our model, CVT is not present because in this version of the software CVT model has many running issues. Therefore, we have chosen and compared 3 different reduction ratios resulting in good usage of maximum reduction ratio at low speeds and minimum reduction ratio at high speeds

3.1. Simulation for reduction ratio 8.85 (la 92drive cycle)

Considering 35 AH battery with 100% soc. The range obtained for this belt ratio is 15.82 kms. The top speed obtained for this belt ratio is 75 kmph as seen on telemetry graph, blue line indicates the LA92 drive cycle and yellow line indicates our simulated vehicle.

The X-Axis indicates time in seconds and Y-Axis indicates speed of vehicle in Kmph. At 8.85 reduction ratio the top speed reaches up to 75 kmph and can cover 15.82 km in 1435 seconds of drive cycle. Yellow line and blue lines are very near to each other at low speeds which shows that at low speed the reduction ratio of 8.85 is optimal. The acceleration at 8.85 ratio is also good enough to follow the low-speed throttle changes easily. We can also see the speed of vehicle reducing quickly with high reduction ratio without braking i.e., at no throttle and no brake.

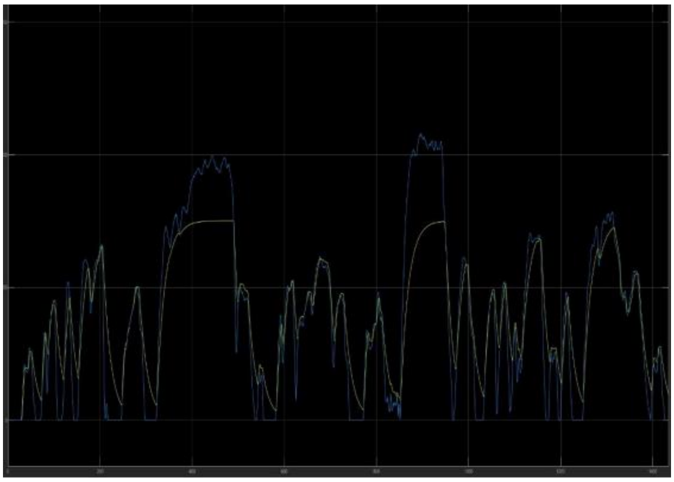

Figure 3.1.1 Simulation For 8.85 Reduction Ratio

3.2. Simulation for reduction ratio 3.09 (la 92drive cycle)

As seen on telemetry graph, blue line indicates the LA92 drive cycle and yellow line indicates our simulated vehicle. The X-Axis indicates time in seconds and Y-Axis indicates speed of vehicle in Kmph. At 6 reduction ratio the top speed reaches up to 102 kmph and can cover 21.49 km in 1435 seconds of drive cycle. We can see at 3.09 reduction ratio vehicle is able to reach at top speed of LA92 drive cycle but the acceleration of vehicle is poor and takes time to reach at high speed. At this reduction ratio vehicle's speed is not reducing significantly without braking, i.e., at no throttle and no brake

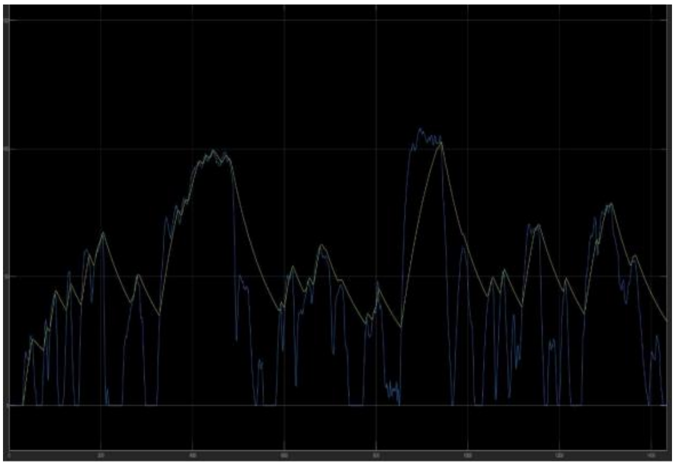

Figure 3.2.1 Simulation For 3.09 Reduction Ratio

4. RESULTS AND DECLARATION

4.1 Benefits obtained after adopting E-CVT

Electric motors have full torque at 0 rpm and a much wider operating RPM range than ICEs (internal combustion engines). Despite this feature, the efficiency of electric motors still varies at different speeds – they operate at a peak efficiency of around 90-95% but this can fall to 60-70%, particularly at low speed.

4.2 The results obtained

1. Keeps e-motor(s) in higher efficiency range improving overall efficiency of EV powertrain to deliver more range, or alternatively same range with a smaller battery pack, hence cost and weight reduction of the powertrain.

2. Lower torque motor can be used which results in cost benefits and an overall reduction in the weight of the powertrain or alternatively, with same motor, it can deliver better performance at higher level of efficiency.

3. Offer better launch acceleration, lower noise, and a higher cruising speed, while the hill climbing ability of utility vehicles can be improved.

4. Simpler, lighter, and cheaper power electronics, and because the motor can be kept within its optimum speed range there is less wear.

5. For both high acceleration requirements and extreme top speed requirements, to avoid extremely wide RPM e-motors/controllers, multi-speed is required.

6. For extreme grade, terrain and carrying load requirements, multi-speed is required or the motor/controller sizing will not be cost-effective.

5. CONCLUSIONS

From all the comparisons between single speed transmission and variable speed transmission it can be concluded that variable speed transmission is more efficient than single speed transmission. Multiple ratios are an effective solution to improve performance and efficiency. Two speed transmission allows system optimization which reduces the size of electric motor and inverter of the electric vehicle. Multiple speed transmission allows the various gear ratios and thus maximum speed of vehicle can be achieved. Design of the two-speed transmission is very easy but it has more cost.

6. REFERENCES

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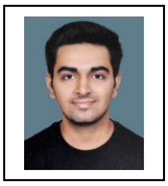
7. BIOGRAPHIES

Mr. Panchal Akshat, Completed Bachelor's Degree in Mechanical Engineering from LJ Institute of Engineering and Technology, Gujarat Technological university

Mr. Mer Ajay Nareshbhai, Completed Bachelor's Degree in Automobile Engineering from LJ Institute of Engineering and Technology, Gujarat Technological university



Mr. Panchal Kavan, Completed Bachelor's Degree in Automobile Engineering from LJ Institute of Engineering and Technology, Gujarat Technological university

Mr. Shiv Kamlesh Patel, Completed Bachelor's Degree in Mechanical Engineering from Dharmsinh Desai Institute of Technology, Gujarat Technological university