Regenerative Braking System without Conventional Brakes

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Abstract- ***Regenerative braking without the assistance of the frictional brakes is achieved in this project. Energy is recovered while braking and the wheels are made to brake completely as well. Although, maintenance of new parts has emerged like maintenance of battery, motor, etc. But there still left the maintenance of brake pads because they are still used in EVs. This project has showed the probability of a braking system that is regenerating energy while braking and does not require much help or any help of brake pads for completely stopping the vehicle.***

Indexed Terms- ***Regenerative braking, conventional brakes, brake pads, Electric Vehicle, Maintenance free.***

I. INTRODUCTION

Regenerative braking system involves the removal of the kinetic energy of a moving object by converting it into another form of useful energy, such as electric, pneumatic, or stored kinetic energy [6]. The use of regenerative braking can increase the overall efficiency of a motor vehicle by conserving some of its kinetic energy which can then be used to bring the vehicle back up to speed. In Regenerative Braking System the vehicle still need an assistance of Frictional/Conventional brakes to completely stop. And due to this there will be still some wear and tear of brake pads.

The main objective of this project is design and develop a Regenerative braking system that retrieves an amount of energy from the kinetic energy of wheels and convert it to electric energy which further can be used for charging the battery or other use. Also, Regenerative Braking System the vehicle still need an assistance of frictional/conventional brakes to completely stop. Therefore, this project pro-posed a Regenerative braking system that can completely stop the wheels electrically and does not require mechanical/friction brakes.

II. EXISTING SYSTEM

The most common form of regenerative brake involves an electric motor functioning as an electric generator. In electric railways, the electricity generated is fed back into the traction power supply. In battery electric and hybrid electric vehicles, the energy is stored chemically in a battery, electrically in a bank of capacitors, or mechanically in a rotating flywheel. Hydraulic hybrid vehicles use hydraulic motors to store energy in the form of compressed air. In a hydrogen fuel cell powered vehicle, the electrical energy generated by the motor is stored chemically in a battery, similar to battery- and hybrid electric vehicles [8].

Regenerative braking is not by itself sufficient as the sole means of safely bringing a vehicle to a standstill, or slowing it as required, so it must be used in conjunction with another braking system such as friction-based braking. The regenerative braking effect drops off at lower speeds, and cannot bring a vehicle to a complete halt reasonably quickly with current technology, although some cars like the Chevrolet Bolt can bring the vehicle to a complete stop on even surfaces when the driver knows the vehicle's regenerative braking distance. This is referred to as One Pedal Driving.

- How does One-Pedal Driving Work? One-pedal driving allows a driver to bring a vehicle to a full stop without using the brake pedal. In most cases, there is an on-off button that engages this feature,

as shown in the photo above. The button activates the one-pedal driving system in the 2022 Chevrolet Bolt EUV [7].

As the driver anticipates a stop ahead due to a traffic light or a stop sign, they can ease their foot off the accelerator pedal. The vehicle will begin to decelerate at a force of approximately .2g. This deceleration force is equivalent to 20% of full braking force, gradually slowing the car compared to the typical application of the hydraulic brakes. Once the vehicle stops entirely, the hydraulic brakes engage to keep the vehicle at a full stop until the driver presses the accelerator pedal to move forward again [7].

- Pro-posed System

The regenerative braking system which is discussed in this paper works without any frictional brakes/conventional brakes. Although this system is not a one-pedal drive system like the one in 2022 Chevrolet Bolt EUV. When the brake pedal is pressed the motor acts as a generator and converts the kinetic energy of wheel into electrical energy and store it in any storage device like battery, ultra-capacitors. In this case halogen bulb is used for the indication of regenerative energy.

As an effect of this the motor will slow down due to increase in magnetic reluctance. But the deceleration will be up to a particular speed of the wheels after this the system need this assistance of frictional brakes or hydraulic brakes to stop the wheels completely. But in this pro-posed system the motor inputs will get shorted at this condition with the help of a controller and the motor will stop completely and so the wheels.

III. METHODOLOGY

The following Methodology has been carried out throughout the project in the manner as given below:

- Designing
- 3D Modelling
- Prototyping

- Design of circuit diagram. We have first designed Circuit Diagram of the Regenerative Braking System which the entire system will work. The circuit diagram consists of certain relays and switches, voltage sensor, a driving motor, a load and the Battery. The circuit is designed with the help of a tool known as TinkerCAD.

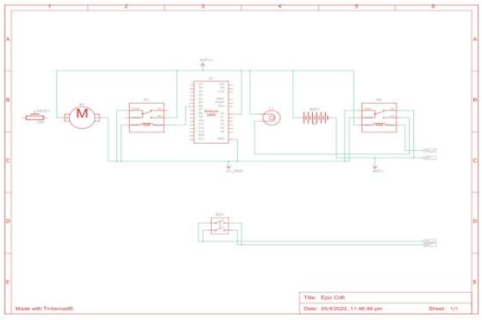

Figure 1 . Schematic View of Circuit Diagram

Now for the simulation and testing of the circuit we used tool i.e. TINKERCAD which will basically show how the entire circuit will work in an animation for a better understanding.

(Please note that the voltage sensor is not shown in the circuit diagram as the TinkerCAD library does not include that).

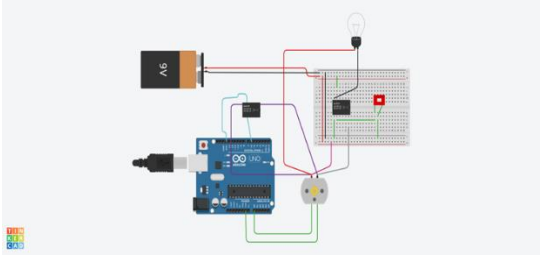

Figure 2 . Circuit in TinkerCAD

- 3D Modelling/Setup design. Designing of setup includes selection of motor, battery, designing of gear train, axle, bearing. And then, preparing a Cad model for the setup. To show this entire set-up a 3D software i.e. SOLIDWORKS is used.

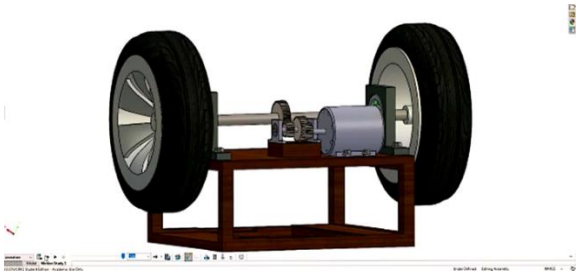

Figure 3. CAD Model of Setup

- Analysis. After Design comes the analysis part, for checking if the design is safe or not. Analysis is done using Ansys Workbench mainly on the gear train.
- Prototyping. Prototyping, this includes fabrication and assembly of the parts involved in the setup of the prototype.

IV. DESIGN AND ARCHITECTURE

- Parts and Components used:

Spur gears:
Spur gears are used in mechanical applications to increase or decrease the speed of a device or multiply torque by transmitting motion and power from one shaft to another through a series of mated gears. The gears used in this Project is made up of Mild Steel Grade EN3B. Tensile Strength: 300 - 400 MPa.

Wheels:
A wheel is a circular component that is intended to rotate on an axle bearing. The Wheels used in this Project is 9.8 inch Air type Mild Duty Wheels.

Pillow block bearing:
A pillow block usually refers to a housing with an included anti-friction bearing, wherein the mounted shaft is in a parallel plane to the mounting surface, and perpendicular to the center line of the mounting holes, as contrasted with various types of flange blocks or flange units.

Electric DC motor:
An electric motor operated by DC (direct current) is known as a DC motor (unlike an induction motor that operates via an alternating current). A DC motor converts DC electrical energy into mechanical energy. The DC motor used in this Project is a 24V 250W DC motor. of

Battery:
An electric battery is a source of electric power consisting of one or more electrochemical cells with external connections for powering electrical devices. When a battery is supplying power, its positive terminal is the cathode and its negative terminal is the anode. The battery used for this project is 24V lead acid battery.

Arduino Uno:
The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. In this project the Arduino Uno is used for monitoring the voltage of DC motor while Regenerative braking and also braking the DC motor accordingly.

Relay SPDT:
A relay is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. Relays are used where it is necessary to control a circuit by an independent low-power signal, or where several circuits must be controlled by one signal. Relays used in this Project are 24V and 5V SPDT Relays. This 5V Relay is controlled by the Arduino Uno to brake the DC motor completely.

Voltage sensor:
The voltage sensor module is a small size 0-25 DC voltage sensing device. The design of the module is based on a resistive voltage divider circuit. It is a voltage sensor module that reduces the input voltage signal by the factor of 5 and generates a corresponding analog output voltage with respect to step down voltage factor. This is used to measure the voltage across the motor and feed it to the analog input of the Arduino Uno.

Design Procedure. Design of Gear Train:
Considering the wheel speed to be around 1000Rpm Weight of the wheels Now Torque Required to rotate a

Wheel is T=1/2 I$*\propto$ $I = M.I$ of Wheel, $\propto$ is Angular Acceleration

Also $\propto = \omega/t$ whereas t is acceleration time which is assumed as 2 sec Weight of wheels =3.2kg Weight of gear on axle = 470g=0.47 kg M.I of both wheel and gear =0.0507 kgm^2. Therefore Required Torque = 2.65 N-m.

Input torque is 1 N-m. The gear ratio assumed should be more than 2.65 N-m

Therefore assuming Gear ratio of 2.8 Assuming teeth on motor pinion to be 12 for minimum interference.

T1 is the number of teeth on motor pinion.

T2 is the number of teeth on idler gear.

T3 is the number of teeth on wheel shaft.

(T2/T1)x(T3/T2) = 2.8

Since T1 = 12 Hence T3 = 30 And T2 is assumed to be 17

ASSUMED GEAR TEETHS TO GET THE REQUIRED GEAR RATIO T1=12 T2=17 T3=30

ASSUMED MODULE OF GEAR = 2.5

Therefore P.C.D of gears D1=2.5x12=30mm D2=2.5x17=42.5mm D3=2.5x30=75mm

Face width of spur gears can be taken 60% of Pinion diameter

Pinion diameter = 30mm, b = 0.6*30= 18mm ~ 20mm.

Construction of the Setup. The constructing of the project is as follows:

- The unit has been assembled on a wooden base on a wooden base (30x16 inches).
- The wheel and axle is simply supported on two pillow block bearings.
- The gears are welded on the shafts and the gear train is assembled in proper orientation for power transmission.
- The counter shaft is also support on block bearing. The block bearings are bolted on the base with required torque.
- Motor is also bolted to the base with its pinion meshing correctly with the gear.
- The motor is connected to the 24V battery by a copper wire.
- The input terminals of the motor are also connected to the voltage sensor and a relay which will be operated by Arduino Uno.
- The motor is connected to the battery and the regenerative load via a 24V relay.
- This relay will be operated by the battery through a switch which will be under the brake pedal.

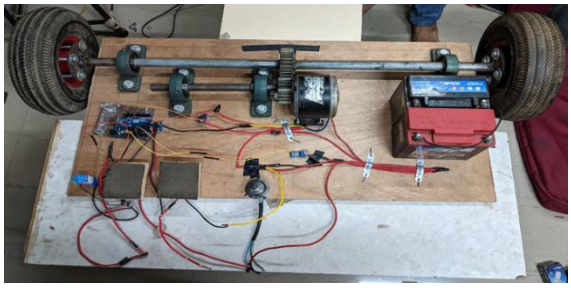

Figure 4. Assembled Setup

Working. The working of the project is as follows:

- The demonstration begins from the acceleration of the wheel, the wheels are accelerated to its top speed i.e. rated motor speed by pressing the accelerator pedal (RHS pedal).
- Then when it comes to braking the brake pedal (LHS pedal) i.e. the switch between the relay and the battery is pressed. At this moment the switch energized the 24V relay.
- The relay then disconnect the motor from the battery and connect it to the load.
- Due to inertia of wheels the motor is still spinning and while connected to the load. Now motor is acting as a generator.
- The load is consuming power of the motor. Since the current is flowing outwards from the motor, a braking torque is acting on the motor which is now slowing down the wheels.
- After a time the load stops consuming power from the motor and the bulbs starts to dim but the wheels are still spinning. Therefore we need a assistance of external force to completely stop the wheels. In conventional regenerative braking this is achieved by applying frictional brakes/brake pads.
- But in this project frictional brakes are eliminated. Because in this setup electrical braking comes into play. Electric motor, if short circuited in regenerative mode can be stopped immediately [3].
- During regenerative mode the voltage across the motor is also decreasing with its speed. And at a certain voltage the rate of decreasing of motor speed reduces and we require assistance of electrical braking. This comes out to be around 6V.

- The two input of the motor is also connected to Normally open (NO) and Common terminal of the relay which will be operated by Arduino.
- This relay is connected to digital pin 06 of Arduino. This pin will be high if the voltage of the motor drops below 6V.
- This condition is checked with the help of voltage sensor module which is connected to the analog input of the Arduino, and to voltage sensor the input terminals of the motor are also connected.

As the voltage drops below 6V the Arduino set the pin no. 06 high which will energized the second relay i.e. 5V relay.

- Therefore when this relay is energized, Normally Open and Common terminal are connected to each other i.e. both the input of the motor is shorted. When both the input of the motor is shorted, the motor stops completely and hence the wheels.
- Hence, Regenerative Braking is done without the assistance of frictional brakes/conventional brakes.

Arduino programming. The programming f the Arduino is given below.

```
int offset =20;// set the correction offset value
void setup() {  pinMode(A0, INPUT);
pinMode(6, OUTPUT);
Serial.begin(9600);        }

void loop() {
int volt = analogRead(A0);// read the input
double voltage = map(volt,0,1023, 0, 2500) + offset;//
map 0-1023 to 0-2500 and add  correction offset
voltage /=100;// divide by 100 to get the decimal values
if (voltage<6){
digitalWrite(6, HIGH);
 }
 else {
digitalWrite(6, LOW);
 }
 delay(500); // Wait for 500 millisecond(s)
}
```

Code Explained. The programed code is explained below:

- First, an offset value of 20 is set for the correction.
- All the digital and analog pins that are included in the programing are addressed i.e. pin no. 06 and analog pin A0.
- To read the input and store the value a variable is set which 'volt'.
- The 'double' voltage is used to map the value store in 'volt' from 0-1023 to 0-2500 and correction offset is added to the 'voltage'.
- Now 'voltage' is divided by 100 to get decimal values.
- Finally the 'If else' condition is applied.
- In 'if else' loop, if the voltage is less than 5V then set pin to high else low. A delay of 500milliseconds is added after the loop.

Result and Discussion. Wheels are accelerated for 5 seconds.

- Translational energy of wheels = E_{trans} = mv2/2
- Rotational energy of wheels = $E_{rot} = I.\omega^2/2$
- Energy required for braking
- E-Brake = Energy consumed by the load
- We will use a 24V DC motor
- Peak current in regenerative mode = I_a=2.5A
- Peak voltage = E_a=12.24V
- K.E.wheels= $E_{trans} + E_{rot}$
  - $= mv^2/2 + I\,\omega^2/2$
- Since the setup is mounted on a base therefore neglecting $mv^2/2$.
- Therefore K.E. of wheels = $E_{rot} = I\,\omega^2/2$.
- Energy consumed by the Load
- The load connected is a 35W halogen bulb which glowed for 2 seconds with its full luminescence during regenerative mode.
- Energy consumed by the Bulb = 35W × 2s = 70J
- Now the rotational energy of the wheels is = 0.5×0.0507×104.72^2 = 277.9 J
- Let Energy consumed by the load = E_{reg}
- (E_{reg} / K.E_{wheels}) x 100 = %Energy Restored
- = (70J/277.9 J) x 100
- = 25.3%
- Braking time noted 1.19 s

CONCLUSION

The regenerative braking system recovers significant amount of energy lost during braking in the form of frictional heat. Regenerative braking without the

assistance of the frictional brakes is achieved in this project. Energy is recovered while braking and the wheels are made to brake completely as well. By shorting motor inputs after a certain value of regenerative voltage across motor this is achieved. Thus, neglecting or minimizing the use of brake pads in an Electric Vehicle.

This project has showed the probability of a braking system that is regenerating energy while braking and does not require much help or any help of brake pads for completely stopping the vehicle.

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