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APPLICATION OF ELECTROMAGNETIC BRAKING TORQUE AND DIFFERENT BRAKING MODES PROGRAMMED WITH ATMEGA328P MICROCONTROLLER IN ELECTROMAGNETIC BRAKING SYSTEM

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Abstract: : Electromagnetic braking system uses magnetic force in order to stop the vehicle. In the present design, a disc with requisite number of solenoids has been arranged for achieving the purpose. While trying to stop the vehicle, the pilot needs to turn on the brake switch to supply electric power. Thereby a magnetic field will be developed on the ambience of the solenoids which will prohibit the rotation of the disc and eventually the vehicle will come to a halt. The wheel torque is evaluated from various experimental data and in this paper a comparison is made between the braking torque and wheel torque. Realistic calculation in this paper reveals that value of braking torque using electromagnetic brake can be made greater than the torque of the wheel, which is actually needed to stop any vehicle. Different braking modes have been achieved with Arduino, ATmega328p microcontroller based programming using ultrasonic sensors. This paper aims to find a faster, efficient and safe way of braking with almost no maintenance cost and least possibility of brake failure.

Keywords: Electromagnetic braking, Ultrasonic Sensor, ATmega328p Programming, Automation in braking system.

1. INTRODUCTION

World is developing continuously with the advancement of science and technology. Automobile industry is no exception, and hence, also developing rapidly to cope up with increase in demand. Braking system is one of the most important mechanisms in automobiles. Conventionally hydraulic and pneumatic brakes are used which are quite costly and also require regular thorough maintenance. Also, these braking systems are normally not able to stop the vehicle quickly which results in various mishaps in the roads.

Electromagnetic braking system is a novel idea which can stop high speed vehicles very quickly and effectively, and therefore, can be a useful alternative to such conventional braking systems. Principle of electromagnetism is utilized in electromagnetic braking system whereby electrical energy is converted to mechanical energy. When electricity is supplied to the solenoid there is a relative velocity between the metallic conductor and magnetic field which generates an Eddy current. As per Lenz's law this Eddy current will try to resist the cause of its generation, for which the relative velocity must come to zero. Hence the speed of the disc will be arrested and as the disc is connected to the wheel the car will also come to halt. Since the solenoids are placed in some gap with the disc and the vehicle halted by electromagnetism, there is no possibility of friction generation, thereby the life span of the parts of the vehicle will increase. All the more, there is minimum chance of malfunctioning in electromagnetic braking system which makes it more adorable in recent times than other conventional braking system.

Different types of braking are required under different conditions. From the theory it is found that electromagnetic braking torque is directly proportional to the square of the voltage supplied to the electromagnets. When the vehicle is moving at a slow pace, less voltage is required, while when the car is at higher speed, a higher voltage is necessary, and when there is an emergency braking situation, a much larger voltage is required for obtaining the required braking torque. By varying the input voltage, it is possible to supply different voltages to the electromagnets, although it is quite impossible for the driver to ascertain the particular required voltage. That is why a programmable interface is a must in order to communicate with the driver and the electronic system, and also to collect and process the sensor data. With a little bit of programming a fine communication among the sensors, the electromagnets and the driver is established. Ultrasonic sensors are used to detect an obstacle, if any, in front of the vehicle and L293d IC is used to vary the voltage according to the requirement. Detailed discussions on all these are made in this paper.

2. LITERATURE REVIEW

A number of researchers tried to make some developments in this field over last few years. According to Sudarshan et al., this electromagnetic braking system can be used effectively in heavy commercial vehicles by regulating the magnetic flux. Automated circuit which consists of 7805 Regulator, Relay, RF channel was used by them [1]. Gajbhiye et al. explained electromagnetic braking system as a beneficial alternative of drum, disc, hydraulic and pneumatic types with high power to weight ratio. They also discussed about the conversion of kinetic energy to heat energy as the principle of such braking system [2]. Sevvel et al. found that the electromagnetic brakes can be used as an auxiliary braking system (ABS) along with the conventional friction braking system to avoid overheating and brake failure. ABS usage can be neglected by simply using a micro-controlled electromagnetic disk brake system [3]. Maurya et al. described the working principle of the Eddy current braking mechanism that can be analyzed by the Maxwell 3D Transient solver. Here a linear halfback has been applied from the magnetization mover to a high-speed Eddy current braking system [4]. Akshya Kumar et al. found electromagnetic braking system to be more reliable compared to other braking systems. In oil braking system or air braking system even a small leakage may lead to complete failure of brakes. While in the electromagnetic braking system, since four-disc plates, coils, and firing circuits are attached individually on each wheel, even if one of the coils fail, the other three continue working and hence brake does not fail. This enhanced braking system not only helps in effective braking but also helps in reducing accidents [5]. Land et al. developed a theoretical model for calculating the electromagnetic braking force with the help of magnetic point dipole model. They used ultrasonic position sensors to understand the trajectory of falling magnets of various diameters [6]. Er. Shivanshu Shrivastava discussed about the eddy current brakes by making SIMULINK model. He experimentally analyzed the effects of change in velocity, magnetic field, air gap, thickness of disc, increase in position of center of pole from center of disc, increase in diameter of pole on the effectiveness of the braking system [7]. Dhoot et al. also opined that electromagnetic braking systems would ensure better safety and comfort of the passenger, driver and other road user. They concluded that electromagnetic brakes perform better than conventional brakes in high speeds but it cannot be used at low speeds. Hence it must be used as an auxiliary brake at high speeds [8].

3. METHODOLOGY

First of all, the wheel torque from the engine torque is calculated using various data. For the sake of simplicity of analysis, the vehicle is considered to be moving in a straight path. The torque value of the differential gear is calculated from the engine torque, assuming the wheel tire as 225/55R17 type.

As stated earlier in order to stop a moving vehicle, electricity has to be applied that will create a magnetic field, and due to the rotating disc, an Eddy current will be generated and this Eddy current will resist the cause of its generation. Hence, the amount of electricity supplied will need to produce just enough braking torque which will destroy the Eddy current, and hence stop the vehicle. So, applying various equations Eddy braking torque is calculated here.

Specifications of the disc to be used are also extremely vital. As far as the thickness of the disc is concerned, it has to be just enough thick for Eddy current conductivity and the transmission of braking force. Otherwise, if it is very thin it might be broken or bent and if it is extremely thick then wheel movement may become slow. So, after taking all these constraints into consideration thickness is taken as 10 mm. Disc Radius must also be ideal to minimize the moment of inertia. After considering the need and the wheel radius, disc radius is taken as 20 cm. An air gap must be there between the solenoid and disc which is selected as 2 mm. Another important parameter is the selection of material which is explained in the following section.

3.1 CALCULATION OF WHEEL TORQUE

Assuming no slip condition of the clutch i.e., clutch fully engaged, hence the engine torque (τ_e) is equal to clutch torque (τ_c), i.e.,

$$\tau_e = \tau_c \quad (1)$$

Engine torque is transmitted to gear box. Let the gear ratio be i_x. So, the torque on the shaft coming out from the gearbox (τ_g) becomes,

$$\tau_g = i_x \times \tau_e \tag{2}$$

Then the shaft carrying the torque τ_g from the gear box goes to rear axle where it is connected with the differential gears. Let the gear ratio of the differential gear be i_0. So, the torque on the shaft which is coming out from the differential gear becomes,

$$\tau_d = i_0 \times \tau_g \tag{3}$$

In all cases it can be written that,

$$\tau_{left\ wheel} + \tau_{right\ wheel} = \tau_d \tag{4}$$

For the sake of simplicity, vehicle is assumed to be moving in straight line. As there is no slip condition between the tire and the road,

$$\tau_{left\ wheel} = \tau_{right\ wheel} = \frac{\tau_d}{2} = \frac{i_0 i_x \tau_e}{2} \tag{5}$$

The force exerted on the wheel is,

$$F = \frac{i_0 i_x \tau_e}{2r} \tag{6}$$

The tire is considered to be 225/ 55R17 type, where, 225 mm = tire width, 55 = aspect ratio (in %) = (height of the tire (H) / tire width (W)) x 100 %, R = radial construction

Rim diameter= 17 inches, for which the standard diameter of the wheel is found to be 679.3 mm. Therefore, the radius of the wheel, r = 339.65 mm i.e., 0.33965 m

These experimental values are given in Table 1 to compare the number of gears used and the gear ratios [9].

For the sake of simplicity, vehicle is assumed to be moving in straight line. As there is no slip condition between the tire and the road,

Table 1: Typical Example of a Gear Drive (ZF6HP26)

Transmission Gear Number	Gear Ratio (i_x)	Gear Ratio	τ_{wheel} (Nm)
1	i_1	4.171	1082.37
2	i_2	2.340	607.23
3	i_3	1.521	394.70
4	i_4	1.434	296.61
5	i_5	0.867	224.99
6	i_6	0.691	179.31
Final drive	i_0	3.460	150.0

3.2 BRAKING TORQUE CALCULATION

According to Ampere's Circuital Law, for n number of turns and for $\vec{B}$ and $\vec{dl}$ in the same direction the equation becomes,

$$B = \frac{\mu_0 n I}{l} \tag{7}$$

Now for any electric field $\vec{E}$, $I = \sigma A\vec{E}$,

therefore, Current density, $\frac{I}{A} = \sigma\vec{E}$

$\frac{I}{A} = \sigma(\vec{v} \times \vec{B})$ [from Lorentz equation]

$\frac{I}{A} = \sigma r\omega B$ [because, $\vec{\omega}$ is perpendicular to $\vec{B}$]

(8)

Where, σ = conductivity of the material,

A = cross sectional area, B = magnetic field

Now, in electromagnetic braking system, the objective is to stop the vehicle. If there is any relative velocity between metallic conductor and magnetic field, Eddy current will be generated. The target is to stop the generation of Eddy current in order to stop the vehicle.

Hence, power due to Eddy current ≤ power provided by braking torque

Hence, $\tau_{braking} = \frac{Power_{eddy}}{\omega}$

$$Power_{eddy} = \rho\left(\frac{I}{A}\right)^2 \times volume[\rho = resistivity]$$

$$= \rho(\sigma r \omega B)^2 \times section\ area \times thickness = \rho\sigma^2 r^2 \omega^2 At$$

Hence, $\tau_{braking} = \frac{\rho\sigma^2 r^2 \omega^2 At}{\omega}$ (9)

As, $\rho = \frac{1}{\sigma}$ and, $B = \frac{\mu_0 nI}{l}$,

$$\tau_{braking} = \sigma r^2 \omega^2 At\left(\frac{\mu_0 nI}{l}\right)^2 \quad (10)$$

The disc should be thick enough for Eddy current conductivity and the transmission of braking force. Let, disc thickness (t) = 10 mm. The disc radius must be ideal to minimize the moment of inertia. Let disc radius (r) = 20 cm. The air gap between the metallic disc and the electromagnet is kept 2 mm. Material of the disc must be optimized to minimize the moment of inertia of the disc, so that less force is necessary to rotate the disc. Now, for proper braking torque, the density of the disc should be minimum and the specific conductivity should be high. To fulfill such criteria, aluminium is selected as the disc material.

From equation (10),

$\tau_{braking} \propto volume$ and $\tau_{braking} \propto \sigma$ (specific conductivity).

For aluminium density(ρ) = $2.7 \times 10^3\ kg/m^3$ and specific conductivity(σ) = $35.5 \times 10^6\ S/m$, $\frac{\rho}{\sigma}$ Ratio for aluminium = $7.61 \times 10^{-5}\ kg/m^2s$, Magnetic permeability of aluminium $\mu_0 = 1.00002$.

Volume of the disc = $\pi r^2 t = \pi\left(\frac{20}{100}\right)^2 \times \frac{10}{1000} m^3 = 1.25564 \times 10^{-3} m^3$

Angular velocity, $\omega = \frac{v}{r} = \frac{2\pi rN}{60r} = \frac{2\pi N}{60} = \frac{\pi \times 2 \times 522}{60} = 54.664\ rad/s$ [For 60.96 cm wheel diameter and if the car is moving at 60 km/hr speed, N ≈522 rpm].

Resistance for copper wire of 2 mm diameter through which the current will be transmitted from the driver to rear wheel, effective resistance of that long wire is,

$$R = \rho \times \frac{l}{A} = \frac{0.0171 \times \frac{220}{100}}{\frac{\pi}{4} \times 2^2}\ ohm = 0.011975\ ohm$$

The heat transfer from the wire of the coil of the electromagnets is mainly done through convection. $Q = hA_s(T_2 - T_1)$, Where, h= convective heat transfer coefficient of air.

Considering (at 25°C temperature) h of air = $11\ W/m^2k$, length of copper wire, $l' = 2.2\ m$ and coil wire diameter, $d_1 = 2\ mm$

$$Q = h \times 2\pi \times \frac{d_1}{2} \times l' \times (T_2 - T_1) \quad (11)$$

$$Q = 11 \times 2\pi \times \frac{2}{2000} \times 2.2 \times (T_2 - 298) = 0.15025(T_2 - 298)$$

For, $I = 10\,A$, $Q = I^2R = 10^2 \times 0.011975\ J/s = 1.1975\ J/s$

Now, the wire should not be heated which can disrupt the system. Hence the heat which is convected from the coil wire must be greater than or equal to the heat generated. Mathematically, $\mathbf{Q_{generated}} = \mathbf{Q_{convected}}$

Therefore, $1.1975 = 0.15025(T_2 - 298)$

$=> T_2 = 305.88\ K$

The radius of the copper wire to supply electricity from the driver to the wheel is taken to be of 2 mm diameter and the average length of the wire is assumed to be 220 cm. Thus, the resistance of the wire is calculated. This wire should not store heat which can melt the wire and the supply of the current from the source to the wheel will also be disrupted. So, the heat generated must be equal to the heat convected for terminal calculation purpose. The optimal value of current is selected as 10 A which can also be varied as per requirement. While the current is 10 A the temperature increment is calculated as 7.88 Kelvin per second which is considerable. Now the solenoid length for fulfilling is taken as 44 mm. If single turn of coil is provided in the solenoid, the number of turns will be 18. Hence, the braking torque which is calculated with the help of all the variables is greater than the torque of the wheel.

Now, $l = 2\pi\left(\frac{20}{1000}\right)$ [Let the radius of the solenoid be 20 mm] so, from equation 10,

$$\tau_{braking} = 35.5 \times 10^6 \times \left(\frac{20}{100}\right)^2 \times 54.664 \times 1.25664 \times 10^{-3} \times \left(\frac{1.00002 \times 10 \times n}{2\pi \times \frac{20}{1000}}\right)^2$$

$=> \tau_{braking} = 617.729 \times 10^6 \times n^2$ Nm (for one solenoid) Now, for one solenoid length = 44 mm, if single turn of the coil is provided, the number of turns will be, $n = \frac{44}{2.5} \approx 18$. Now, for three solenoids,

$$\tau_{braking} = 3 \times 617.729 \times 10^6 \times 18^2 Nm = 6.004 \times 10^{11} Nm$$

Clearly, $\boldsymbol{\tau_{braking}} \gg \boldsymbol{\tau_{wheel}}$

Now if the internal resistance of the battery selected is 1.5 ohm and the resistance of the wire selected is 0.011975 ohm. Hence, the total resistance = (1.5 + 0.011975) = 1.511975 ohm

Now, for 1 volt, current, $I = \frac{1}{1.511975} = 0.6614\ A$

So, for 1 volt, $\tau_{braking} = \frac{(6.004\times10^{11}) \times (0.6614^2)}{10^2} = 2.626 \times 10^9\ Nm$

Similarly for 25 volts, current, $I = \frac{25}{1.511975} = 16.53466\ A$

And, for 25 volts, $\tau_{braking} = \frac{(6.004\times 10^{11}) \times (16.53466^2)}{10^2} = 1.641 \times 10^{12}\ Nm$

From this calculation it is clear that for any voltage within 1 volt to 25 volts the brake will be able to stop the car as the braking torque is always greater than wheel torque. Hence, if electromagnetic braking system is applied; the vehicle can be stopped very quickly, thereby reducing the chance of accident when an obstacle is encountered suddenly in front of the vehicle.

4. ELECTRONIC COMPONENTS TO BE USED

4.1 Ultrasonic Sensor

Two ultrasonic sensors are attached, one each under the head lights placed in front of the car, with slightly downward angular alignment. An ultrasonic sensor has 4 pins, namely, one VCC pin (5V), one GND pin, one trigger pin and one echo pin. The trigger pin emits continuous ultrasonic pulses. If there is an obstacle in front of the vehicle, the ultrasonic pulse will get reflected by that obstacle and the reflected pulse will be received by the echo pin. When echo pin receives a signal, it becomes HIGH (1), indicating the presence of an obstacle in front of the car, the distance of which can be calculated from the velocity of sound in air. On the other hand, if the ultrasonic sensor receives no signal, it goes LOW (0) which means there is no obstacle in front of the vehicle.

4.2 Arduino Microcontroller

The input voltage ranges from 6V to 20V, while the recommended range is 7V to 12V and the operating voltage is 5V. Digital and analogue input/output pins are 14 and 6 in numbers respectively. DC for each input/output pin is 40 mA, whereas the same for 3.3V Pin is 50 mA. Flash Memory is 32 KB, SRAM is 2 KB, EEPROM is 1 KB, CLK Speed is 16 MHz. The above specifications indicate that this is an 8-bit ATmega328P microcontroller having various components like serial communication, crystal oscillator and voltage regulator for supporting the microcontroller. The board includes an USB connection, a power-barrel jack, a reset button, an ICSP header along with the pins.

4.3 L293d Motor Driver IC

L293D IC is a typical Motor Driver IC which allows the DC motor to drive in any direction. This IC consists of 16-pins which are used to control a set of two DC motors instantaneously in any direction. This L293D IC works on the basic principle of H-bridge, the motor control circuit allows change in direction of voltage, thereby causing the rotation of the motor in either clockwise or counterclockwise direction. Single L293D IC consists of two H-bridge circuits which facilitates independent rotation of the two DC motors. The L293d IC can be programmed to control the intensity of electromagnetism by varying the voltage supplied to the input pins of IC with the help of Arduino programming.

4.4 Electromagnet

An electromagnet is a magnet that runs on electricity. Unlike a permanent magnet, the strength of an electromagnet can easily be changed by varying the amount of electric current that flows through it. The poles of an electromagnet can even be reversed by reversing the flow of electricity. If a wire carrying an electric current is formed into a series of loops, the magnetic field can be concentrated within the loops. The magnetic field can be strengthened even more by wrapping the wire around it. However, the magnetic field produced by the wire wrapped around the core can force some of the atoms within the core to point in one direction. Cumulative effect of those small magnetic fields ultimately produces a stronger magnetic field.

5. WORKING PROCEDURE OF THE CONTROL SYSTEM

As the strength of the magnetic field is regulated by controlling the voltage input of the electromagnets, it is not possible to adjust the required voltage manually in different braking conditions. Hence, an additional processing unit has to be introduced between the system controlling the electromagnets and the driver. This can be done by using some sensors, a processing unit a voltage modulator and a user-control system interface. In simple words, when the clutch is pressed by the driver, the sensors will sense if there is any obstacle in front of the vehicle, and it will subsequently relay the message to the microcontroller. The driver will also send a message to the microcontroller if the brakes are to be applied or not. Computing these messages and calculating the current speed of the vehicle, the controlling unit will find the optimal voltage required for safe braking of the vehicle and it will transmit the required voltage to the electromagnets. The pulse with modulation process can be applied by using L293d motor driver IC and a microcontroller, in this case ATmega328p microcontroller in Arduino board. A three-dimensional figure (drawn in SOLIDWORKS) of the proposed model showing the arrangement of electromagnets is given in Fig.1.

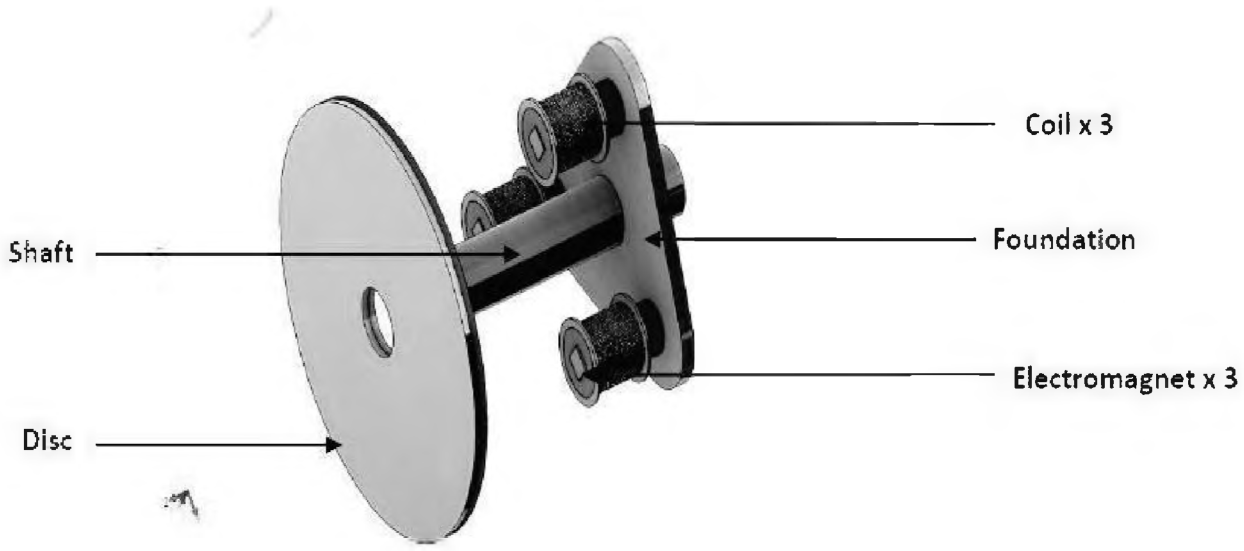

Fig.1 Figure of the Proposed Model

The braking system is activated on pressing the clutch. Pin number 8 of the Arduino is assigned to check if the clutch is pressed or not. When the clutch is pressed, the ultrasonic sensors start sensing if there is any obstacle in close range to the vehicle and also measures the distance from it simultaneously. Pin numbers 6 and 11 have been assigned to control the trigger pins for left and right ultrasonic sensor respectively. These pins are programmed to emit ultrasonic pulses continuously in short time intervals (some microseconds). Pin number 6 and 10 of Arduino monitor the echo pins of the ultrasonic sensors. If any of the emitted ultrasonic waves gets reflected from some obstacle it is received by the echo of the sensors, which is subsequently relayed to the Arduino microcontroller via 6th and 10th pin as 1(HIGH) for further processing. If there is no obstacle in front of the vehicle, 0(LOW) will be relayed. “read_sensors()” function executes this work, program being shown in Fig.2.

```
int read_sensors(){
  digitalWrite(LS_trig,LOW);
  digitalWrite(RS_trig,LOW);
  delayMicroseconds(2);
  digitalWrite(LS_trig,HIGH);
  digitalWrite(RS_trig,HIGH);
  delayMicroseconds(2);
  digitalWrite(LS_trig,LOW);
  digitalWrite(RS_trig,LOW);
  delayMicroseconds(2);
  time_L = pulseIn(LS_echo, HIGH);
  time_R = pulseIn(RS_echo, HIGH);
  distance_L = time_L * 340 / 20000;
  distance_R = time_R * 340 / 20000;
  if (distance_L != 1 && distance_R != 1){
    ch = 1;
  }
  else if (distance_L = 1 && distance_R != 0){
    ch = 1;
  }
  else if (distance_L != 0 && distance_R == 1){
    ch = 1;
  }
  else if (distance_L == 0 && distance_R == 0){
    ch = 0;
  }
  return ch;
  delay(20);
```

Fig.2 Program to Send and Receive Signals from the Sensors

Now, in different cases different combinations of 0 and 1 are obtained as shown in Table 2. A proper framework must be done so to analyze the situation.

Table 2: Truth Table for Sensor Data Analysis and Braking Mode Determination

Clutch	Left Sensor	Right Sensor	ch (a variable to store sensor values)	Brake	Voltage to Be Supplied to the Electromagnets or Not	Type of Braking
1	0	0	0	1	1	Smooth
1	1	1	1	1	1	Emergency
1	1	0	1	1	1	Emergency
1	0	1	1	1	1	Emergency
1	0	0	0	0	0	Gear Changing Condition

In this way, the data coming from the sensors provides a method to determine the type of braking needed to be applied. Arduino pin A2 and A3 are responsible for controlling the pulse provided to the motor driver with the help of pulse with modulation (PWM) method. So, the proper extent of the voltage needed to be supplied can be controlled by programming with these pins. In smooth braking condition just, the exact voltage required for

```
int apply_smooth_brake(){
  double v1,v2;
  while (wheel_torque != 0){
    for (left_pulse == 0; left_pulse <= 255; left_pulse++){
      analogWrite(PWM_left, left_pulse);
      v1= left_pulse;
      left_brake = braking_const * (v1 * v1);
    }
    for (right_pulse == 0; right_pulse <= 255; right_pulse ++){
      analogWrite(PWM_right, right_pulse);
      v2 = right_pulse;
      right_brake = braking_const * (v2 * v2);
    }
```

```
void apply_emergency_brake(){
  double v1, v2;
  while (wheel_torque != 0){
    double new_wheel_torque = mf * wheel_torque;
    for (left_pulse == 0; left_pulse <= 255; left_pulse++){
      analogWrite(PWM_left, left_pulse);
      v1= left_pulse;
      left_brake = braking_const * (v1 * v1);
    }
    for (right_pulse == 0; right_pulse <= 255; right_pulse ++){
      analogWrite(PWM_right, right_pulse);
      v2 = right_pulse;
      right_brake = braking_const * (v2 * v2);
    }
  }
```

Fig.3 Smooth Braking and Emergency Braking Programs

There is also a "void loop()" function that runs in the microcontroller in infinite loops, which reads clutch and brake input, and according to the algorithm calls the above-mentioned functions. The complete circuit diagram is shown in Fig.4.

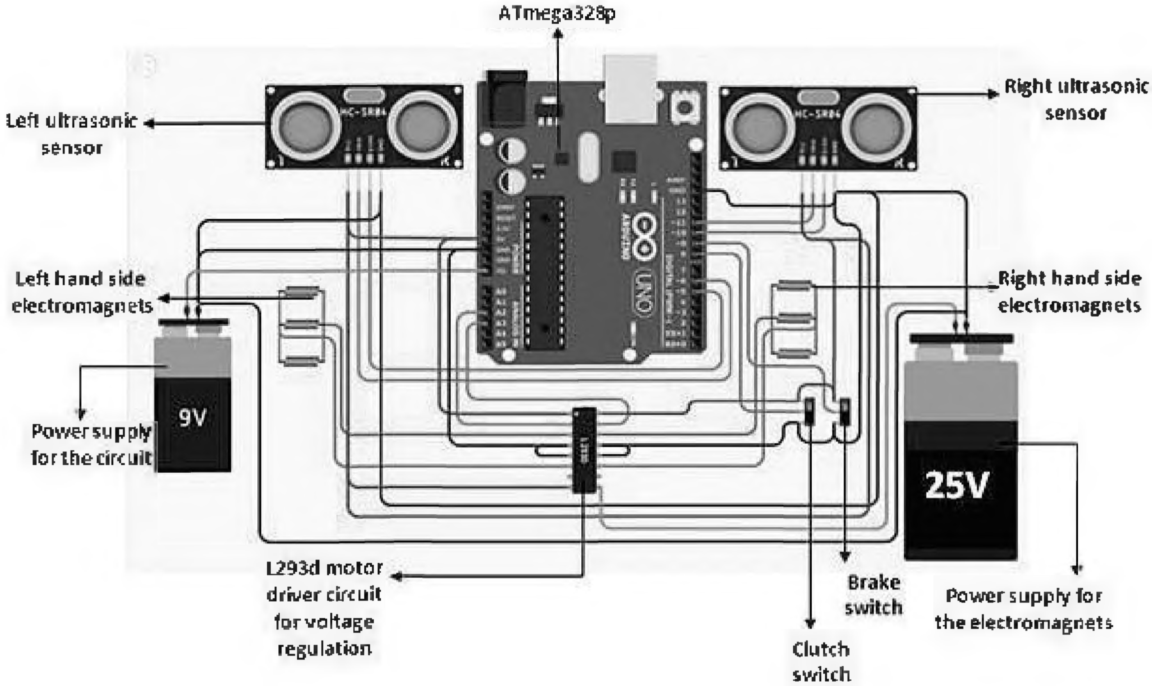

Fig. 4 Circuit Diagram

safe braking is supplied. In the case of emergency braking a message goes to the microcontroller that a higher voltage is required for the electromagnets. This is done by multiplying the actual torque of the wheel with a multiplying factor and sending that amplified torque value to the microcontroller. Seeing the higher wheel torque value, the microcontroller allows the motor driver module to supply a higher voltage to the electromagnets. The most suitable value of the multiplying factor must be calculated experimentally. A graph can be plotted multiplying factor and time required for complete safe braking from which the optimal value of multiplying factor is calculated. Two functions "apply_smooth_brake()" and "apply_emergency_brake()" are developed to deploy two distinct type of braking as shown in Fig.3.

6. FUTURESCOPE AND CONCLUSION

Electromagnetic Braking System can be used as a replacement for conventional brakes in low and high-speed vehicles. This modified braking system not only helps in effective braking but also helps in avoiding accidents. Proper braking can be achieved with different automated braking modes with the help of Ultrasonic Sensor, Microcontroller and PWM control. Electromagnetic Braking with microcontroller increases the working life of the brake with proper heat dissipating ability. Electromagnetic brakes have no wear or tear problem as there is no direct contact between components. It has long life, high efficiency and low cost. With the use of ATmega328p microcontroller the brake can respond effectively according to the situation. The concept designed here is just a theoretical model and framework and it can be modified further. If situation demands then this smart braking system can also be integrated with conventional friction brake as an auxiliary support. In this study, a mathematical model and programming for the automation in braking modes using Arduino microcontroller is proposed.

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