

**A GENERAL PAPER ON “ELECTRO-MAGNETIC DISC BRAKING SYSTEM
WITH SMART ASSIST”****¹Rohan H. Bhoir, ²Sahil S. Mali, ³Kunal B. Mhatre, ⁴Mrunal K. Mhatre**Mechanical Department Vishwaniketan iMEET, Khalapur^{1,2,3,4}rohanhbhoir909@gmail.com¹,sahilmali2000@gmail.com² kunalmhatredd411@gmail.com³ mrunalkmhatre572000@gmail.com⁴**ABSTRACT**

The design of an electromagnetic disc brake requires a multidisciplinary approach. Its performance is an outcome of the usage of concepts from various fields viz. mechanical, electrical, magnetic and material engineering. This paper describes a new type of electromagnetic disc brake for retarding the motion of a vehicle. In this study, a comprehensive design procedure for electromagnetic disc brake is presented to ensure maximum efficiency along with effective braking. Varied magnetic materials are discussed in terms of minimizing the cost while meeting electromagnetic performance characteristics. Nowadays road accidents are more frequent to occur largely in number. These accidents cause much damage to the vehicle and serious injury or even death of passengers. Most of the accidents take place due to the reaction time of the driver. The reaction time or response time is the time taken by the driver to respond from observing the hurdle to applying the brakes which makes the vehicle comes to rest. On reviewing the multiple accidents caused by brake failure in automobile, it was to use a different yet safely engineered method over the usual conventional methods of braking (drum brake, air brake, hydraulic brake). It was seen that electromagnetic brakes have been used extensively in different segments as retarders but has not been used for automobile braking and ours is a genuine effort to bring this technology in all automobile segments. A few decades ago, it would have seemed quite impossible that your car would able to "see" objects such as other vehicles or pedestrians anticipate collisions and capable to apply brakes automatically. Development of the project would make travel safer and optimal to use for everyone.

***Index Terms:* Electromagnetic Brakes, Accidents, Reaction Time, Pedestrian/Object, Sensors, Arduino, Brake**

1. INTRODUCTION

When a safety factor of a vehicle is considered, a primary factor is its brakes or braking system. So, the braking system is such a vital component that is necessarily required when a vehicle is considered. It reduces the kinetic energy of the vehicle in conditions when a vehicle has to slow down or also it has to be stopped. Thus, making sure the vehicle and the passengers inside it are safe. Thus, a braking system is always needed to ensure the safety of the driver's and passenger's uncountable, valued lives.

The main aim of this project is to design a special kind of braking system as a part of Collision Avoidance System (CAS) which can apply brakes when the time taken for collision becomes less than a specified limit of response time based on studies so that vehicle can be driven safely in case of less human attention. This system will continuously keep the record of time taken for a collision based on the relative speeds and distance between the vehicles with the help of ultrasonic and gyroscopic sensors. This system can also work effectively when vehicles are oblique to each other. This system can be further upgraded to work with ABS (Antilock Braking System) equipped in the vehicle to increase the control over the vehicle during braking.

The project is to design and develop a control system based on an automotive braking system. The braking system with an ultrasonic sensor would alert the driver when the distance between vehicle and obstacle is within the sensing range zone then the brakes are applied. This function in this project design could be possibly used for all the vehicles. By making it safer, this system will provide a better guarantee for the vehicle's safety and

avoid losses. Therefore, the safety system of vehicles will be developed and may have more market demands. It can be further used for a large type of heavy vehicles like buses, trucks, cranes, tractors, etc. We can surely get the information about the obstacle detection sense zone according to vehicle condition. It is verily useful to the public sector and users. It is also avoiding accidents in large or metropolitan cities. So, we feel it is a better idea for automatically braking the vehicle with moderate cost.

2. RELATED WORK

a. Marc Green

“How Long Does It Take to stop? Methodological Analysis of Driver Perception Brake Times” (2000):

In this paper, the author proposed that By analysing a large number of data sets he proposed the response time for various situations, however, these times are affected by some other factors such as driver's age, gender, cognitive load and urgency.

b. Erik Coelingh, Lotta Jakobsson, Henrik Lind, Magdalena Lindman:- "Collision Warning With Auto Brake - A Real-Life Safety Perspective" (2008),

Author proposed the idea of research in reaction time as age advances response time increases. Based on a study performed by the authors on 120 persons gives the Mean value of brake reaction time 0.5282s & 0.7306s for younger (Age <55) & older (Age >55) persons respectively.

c. Robert B. Isler, Nicola J. Starkey:- "Evaluation of a Sudden Brake Warning System: Effect on the response time of following driver" (2010),

In this paper authors, proposed that a vehicle comprising a Sudden Brake Warning System made vehicle turn on hazard lights along with standard braking lights during sudden braking which makes the response time 0.34s which is 19% faster as compared to standard brake lights. The above findings are based on the studies performed by the authors on 25 persons of which 16 were female.

d. Divya Thakur, Prof. A. P. Thakare

“Implementation of Automatic Reverse Braking System” (2019):

In this paper, Authors proposed that we need to develop systems which enhances the performance and safety of vehicles when it moves in the reverse direction. A model designed on reversing of vehicles provided detection of obstacle, speed control mechanism based on binocular cameras.

e. Smit Patel, Meet Patel, Anand Patel, Chetan Sanghani, Diptesh Patel

“Development of the Electro-Magnetic Brake” (2015):

The authors proposed that electromagnetic brakes can be used as a replacement that is frictionless. And due to which there is no question of wear and tear of parts and unnecessary temperature issues as there is no friction in this braking system. This results in stable efficiency of the braking system for a longer service span, longer life span of the braking system without any wear and tear. This also answers the replacement of the cooling system.

f. C Grover, I Knight, F Okoro, I Simmons, G Couper, P Massie and B Smith

“Automated Emergency Braking System” (2015):

The author proposed an idea by which a vehicle can apply brakes using ultrasonic sensors and microcontroller by keeping the record of vehicle Speed, Distance between vehicles and the feed values of braking distances at that speed.

3. METHODOLOGY

This electromagnetic disc braking system comprises ultrasonic sensors, gyroscope sensors, microcontroller unit (Arduino MEGA).

The motor is directly coupled to the gear, is used to chain drive the driving shaft connected to the rear wheels.

The front wheels have the brake discs mounted on them. The disc contains the assembly of the callipers over them. The brake callipers are controlled using cable wires.

The cable wires are mounted connected to the linear electromagnetic actuators which are mounted on the frame.

The activators are directly connected with the ARDUINO MEGA unit. The ARDUINO is also directly connected with the UDS sensor and Gyroscopic sensor which are mounted on the front side of the frame.

So, the braking can be controlled by 3 input mediums as explained further. All the 3 braking mediums can also control the braking while simultaneously working with each other.

Manual Braking:

The manual braking of the system can be obtained by toggling a switch that transcends to a Bluetooth module, thus applying the brakes.

When the switch is pressed the signals are transferred via Bluetooth module to the ARDUINO.

ARDUINO transform to the signal and conveys the signal to the actuator which applies the brake by pulling the cable

Braking using UDS Sensor:

As the UDS sensor senses any object further, it relatively starts sending the signal to the ARDUINO based on the distance between the sensor and the object.

The ARDUINO then sends the exact amount of signal, relative to the distance measured, to both the linear actuators.

So, the only respective amount of brake is applied, which either slows down the vehicle according to need or stops the vehicle completely.

Braking using Gyroscopic Sensor:

As the elevation of the ground change, the gyroscope sends in the respective signal to the ARDUINO and it slows down the vehicle or completely removes the brake forces applied over it.

When the vehicle is going uphill, the gyroscope senses the amount of elevation obtained and sends the signal to the ARDUINO. So, all forces applied on the brakes are removed and the vehicle can freely accelerate.

When the vehicle is going downhill, the gyroscope senses the elevation of downhill and conveys a signal to the ARDUINO. Then the exact amount of brake force needed is applied based on the slope of the road.

4. CALCULATIONS

Notations:

m Total mass

u Velocity of the setup

μ_T Coefficient of friction for tyres

μ_d Coefficient of friction for disc

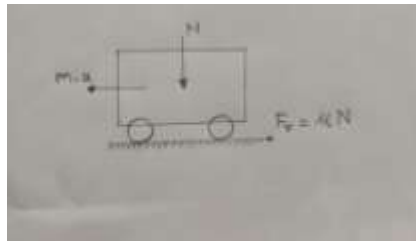
d_w Diameter of wheel

r_w Radius of wheel

d_d Diameter of disc

r_d Radius of disc

Forces acting on the setup,



Normal forces,

$$F_N = mg$$

Resultant forces,

$$F_r = ma$$

$$\mu F_N = ma$$

$$\mu mg = ma$$

$$a = \mu g$$

$$F_r = ma$$

For distance required to stop,

$$d = u^2 / 2\mu_T g$$

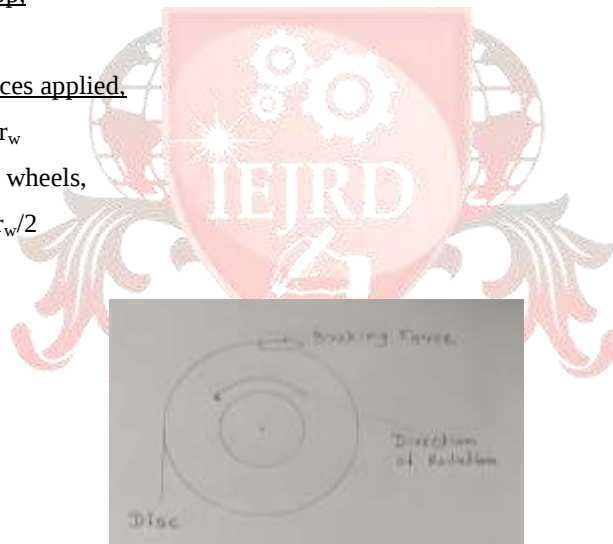
For finding the braking forces applied,

$$\text{Braking torque, } (T_B) = F_r \cdot r_w$$

Brakes are applied on both wheels,

$$\text{So, } T_B \text{ on one wheel} = F_r \cdot r_w / 2$$

Now,



For braking force on one wheel (F_{disc}),

$$T_B = \mu_d \cdot F_{disc} \cdot r_d$$

Therefore, the force required for an electromagnet to brake is 83.92N

For braking pressure,

$$P_b = F_{disc} / \text{cs area}$$

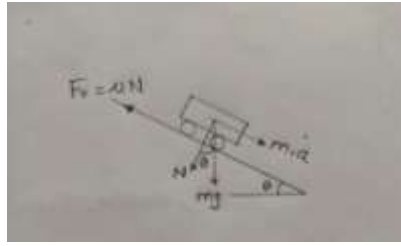
For the c/s area,

$$A = (\pi/4 \cdot D_d^2) - (\pi/4 \cdot d_d^2)$$

Therefore,

$$P_b = F_{disc} / \text{cs area}$$

For forces acting on the inclined road,



For inclination θ ,

$$FN = mg \cdot \cos\theta$$

$$Fr = ma + mg \cdot \sin\theta$$

$$\mu FN = ma + mg \cdot \sin\theta$$

$$\mu mg \cdot \cos\theta = ma + mg \cdot \sin\theta$$

$$a = \mu g \cdot \cos\theta - g \cdot \sin\theta$$

Since, $\mu \cdot \cos\theta = \sin\theta$ can also be written as $\mu = \tan\theta$.

So,

$$\mu = \tan\theta$$

For acceleration on slope,

$$a = \mu g \cdot \cos\theta - g \cdot \sin\theta$$

For stopping distance on slope,

$$d = u^2/2a$$

$$d = u^2/2(\mu g)$$

For selection of Motor,

$$N = 60 \cdot u / \pi \cdot d_d$$

For torque required,

$$\text{Thrust force } (F_T) = gkm$$

$$F_T = gkm$$

For mechanical Power of the motor,

$$P = F_T \cdot u$$

For torque needed,

$$T = \frac{1}{2} \cdot D/2 \cdot F_T$$

Therefore, a 60W 150rpm 20kg-cm torque DC motor is required.



5. DESCRIPTION OF COMPONENTS

a. ARDUINO MEGA –

Arduino is an open-source platform used for building electronic projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board. The Arduino does not need a separate piece of hardware (called a programmer) to load a new code into the board, you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program.

Microcontroller - AT MEGA 2560

Operating - 5V

I/P Voltage(recommended) - 7-12V

I/P Voltage (limit) – 6.2V

Digital I/O – 54pins

b. Gyroscopic Sensor –

A gyroscope sensor is a device that can measure and maintain the orientation and angular velocity of an object. These are more advanced than accelerometers. These can measure the tilt and lateral orientation of the object whereas the accelerometer can only measure the linear motion. Measured in degrees per second, angular velocity is the change in the rotational angle of the object per unit of time.

Supply Voltage – 5V

Communication – 12-c protocol

Range - +/- 250⁰/s

Sensitivity Scale Factor – 131LSB(count)⁰/s

c. Ultrasonic Distance Sensor –

An ultrasonic distance sensor is an electric device that measures the distance of a target object by emitting ultrasonic sound waves and converts the reflected sound into an electric signal. Ultrasonic waves travel faster than the speed of audible sound. Ultrasonic sensors have two main components: the transmitter and receiver (which encounters the sound after it has travelled to and from the target).

Supply voltage – 5V

Supply Current – 15mA

Modulation Frequency – 40Hz

Beam Angle – max 15⁰

Range – 2cm to 400cm

d. Push-Pull Linear Electromagnetic Actuator

The linear solenoid/actuator works on the same basic principle as the electromagnetic relay seen in the previous tutorial and just like relays, they can also be switched and controlled using bipolar transistors or MOSFET's. a "Linear Solenoid" is an electromagnetic device that converts electrical energy into mechanical pushing or pulling force or motion. Linear solenoids consist of an electrical coil wound around a cylindrical tube with a ferromagnetic actuator or plunger that is free to move or slide 'in' and 'out of the coil body. The solenoid can be used to electrically open doors and latches, open or close valves, move and operate robotic limbs and mechanism and even actuate electrical switches just by energising its coil.

No. of turns on electromagnet - 800 (24-gauge wire)

Current & Voltage supplied (I/V) - 7amp/230volts.

Length of electromagnet - 25 mm

Force – 90N

e. DC Motor –

DC motors were the first form of motor widely used, as they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of the current in its field winding. Small DC motors are used in tools, toys and appliances. The universal motor can operate on direct current but is a lightweight brushed

motor used for portable power tools and appliances. Larger DC motors are currently used in the propulsion of electric vehicles, elevators and hoists and drives for steel rolling mills.

Type – Brush DC Motor

Power Consumption – 60W

Load Speed – 150rpm

Torque – 20kg-cm

f. U-PVC Frame: -

UPVC pipes have high tensile and impact strength which make them a long-lasting solution for all types of plumbing needs. UPVC pipes are also rustproof and UV resistant, which, along with their flexibility, makes them incredibly long-lasting. This lightweight feature makes it easy to handle, transport and install. They are cheaper to handle, transport, and reduces labour costs during installation. The frame made is of 36inch length with two sections, with a height of 6inches. The width of the frame is kept 24inches. The tires are mounted on the bottom section of the frame.

g. Wheels: -

Rubber wheels require less/minimal maintenance. They are more durable (3x longer lifespan) than any other conventional similar category wheels. They offer a smooth ride on road surfaces reducing the jerks and bumps. They're bonded to rims to prevent tire slippage. The extra-deep tread provides greater traction on the road. The 14inch diameter tyres are used with the plastic frame to provide needed strength and keep the total mass low.

h. Brake Callipers: -

It offers greater stopping power, useful on long descents or in emergencies. It does not have the problem of sticking as it is made of aluminium which is less prone to rust and corrosion. It has better life and durability. There is no loss of braking torque due to sliding as the fixed calliper does not move. *Cable-operated bicycle brake callipers are used in the setup considering its size.*

i. Chain: -

The chain can is very energy efficient with efficiencies as high as 98.6%. Constant lubrication of chain is not required for chain drive, periodic lubrication does the job. Wear and tear of the chain is minimal as compared to that of a conventional belt drive. Slippage of the chain doesn't occur easily. The length of the chain can be easily increased or decreased according to needs.

j. Bearings: -

The bearing uses grease with a higher dripping point (195 degrees). They have a large operating range temperature (-40 ~ 180 degree). They offer a better sealing shield to prevent leaking of lubricant and avoid foreign particles. Easy bearing replacement when any problem observed. It increases motor performance as less motor friction is obtained.

k. Brake Disc: -

Disc brakes offer greater stopping power, which can be helpful on long descents. Disc brakes don't heat the rim. Disc brakes allow for more precise braking, making wheel lockup less likely. Changing rotor sizes allows you to adjust how much braking power you want. 6inch brake discs are used in the setup as they produce ample braking power to stop the setup.

CONCLUSION

Electromagnetic braking for automobiles like the bike, the car has an effective braking system. In addition, by using these electromagnetic brakes, the life of the braking unit can be increased. An electromagnetic braking system is found to be more reliable as compared to other braking systems. In an electromagnetic braking system, disc plates, coils and firing circuits are individual on each wheel, so even if any coil fails the brake it does not completely fail, and the other coils work properly. Also, the system needs little maintenance. The smart assist features are found to be of great use for the driver's safety, providing maximum safety and help to the driver. The system is more reliable as compared to the conventional braking systems, and with less maintenance required. In addition, electromagnetic brakes make up approximately 80% of all power applied brake application.

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