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Electro Magnetic Braking System

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ABSTRACT

Majority of braking systems work on the principle of dissipation of kinetic energy to heat energy. This method has its own drawbacks and must be replaced with a more reliable braking system that is quick in response, doesn't heat up and is maintenance free. In this project the design of an electro-magnetic braking system and optimization for various operational parameters has been done and the advantage of using the electromagnetic braking system in automobile is studied. These parameters have been previously iterated in cited projects and papers and also in the simulation models and are to be cross-checked with the experimental setup.

1. INTRODUCTION

A brake is a mechanical device that inhibits motion by absorbing energy froma moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction. Brakes may be broadly described as using friction, pumping, or electromagnetic. One brake may use several principles: for example, a pump may pass fluid through an orifice to create friction. Most brakes commonly use friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat, though other methods of energy conversion may be employed. For example, regenerative braking converts much of the energy to electrical energy, which may be stored for later use. Other methods convert kinetic energy into potential energy in such stored forms as pressurized air or pressurized oil. Eddy current brakes use magnetic fields to convert kinetic energy into electric current in the brake disc, fin, or rail, which is converted into heat. Still other braking methods even transform kinetic energy into different forms, for example by transferring the energy to a rotating flywheel. Brakes are generally applied to rotating axles or wheels, but may also take other forms such as the surface of a moving fluid (flaps deployed into water or air). Some vehicles use a combination of braking mechanisms, such as drag racing cars with both wheel brakes and a parachute, or airplanes with both wheel brakes and drag flaps raised into the air during landing. Since kinetic energy increases quadratically with velocity ($KE=1/2\ mv^2$), an object moving at 10 m/s has 100 times as much energy as one of the same mass moving at 1 m/s, and consequently the theoretical braking distance, when braking at the traction limit, is 100 times as long. In practice, fast vehicles usually have significant air drag, and energy lost to air drag rises quickly with speed. Almost all wheeled vehicles have a brake of some sort. Even baggage carts and shopping carts may have them for use on a moving ramp. Most fixed-wing aircraft are fitted with wheel brakes on the undercarriage. Some aircraft also feature air brakes designed to reduce their speed in flight. Notable examples include gliders and some World War II-era aircraft, primarily some fighter aircraft and many dive bombers of the era. These allow the aircraft to maintain a safe speed in a steep descent. The Saab B 17 dive

bomber and Vought F4U Corsair fighter used the deployed undercarriage as an air brake. Friction brakes on automobiles store braking heat in the drum brake or disc brake while braking then conduct it to the air gradually. When traveling downhill some vehicles can use their engines to brake. When the brake pedal of a modern vehicle with hydraulic brakes is pushed against the master cylinder, ultimatelya piston pushes the brake pad against the brake disc which slows the wheel down. On the brake drum it is similar as the cylinder pushes the brake shoes against the drum which also slows the wheel Dow. An electromagnetic braking system is a type of braking system that uses the principles of electromagnetism to slow down or stop a moving object, such as a vehicle or a machine. In this system, a magnetic field is used to create a force that opposes the motion of the object, thereby reducing its speed. The basic components of an electromagnetic braking system include an electromagnet, a brake rotor or disc, and a power source. When the brakes are applied, an electric current is sent through the electromagnet, which creates a magnetic field that interacts with the metal rotor or disc. The magnetic field induces eddy currents in the rotor, which create an opposing magnetic field, thus generating a force that slows down the rotation of the rotor and the attached wheel or shaft. One of the advantages of electromagnetic braking systems is that they do not rely on friction to slow down the object, unlike traditional mechanical brakes.

2 LITRATURE SURVEY

The following are the few journals in which the study was on electromagnetic braking system with different modifications

Innovative Electro Magnetic Braking System by Sevvel P and S Mukesh published in International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Volume-3 in April 2014, Second National Conference on Trends in Automotive Parts Systems and Applications (TAPSA- 2014) at Sri Krishna College of Engineering & Technology, Kuniamuthur, Coimbatore,Tamilnadu, India . Mr. Sevvel P and S Mukesh Et al find that the electromagnetic brakes can be used as an auxiliary braking system along with the friction braking system to avoid overheating and brake failure. ABS usage can be neglected by simply using a micro controlled electromagnetic disk brake system. When these brakes are combined with mechanical brakes, it increases the life of brake and act like fully loaded brakes. These electromagnetic brakes can be used in wet conditions which eliminate the anti- skidding equipment. Hence, the braking force produced in this is less than the disc brakes if can be used as a secondary or emergency braking system in the automobiles

Design & Fabrication of Eddy Current Braking System by Oscar Rodrigues, Omkar Taskar, Shrutika Sawardekar, Henderson Clemente, Girish Dalvi published in International Research Journal of Engineering and Technology (IRJET). The purpose of the study was to perform a comparative study of theoretical and practical braking time and establish a practical air gap limit beyond which the electromagnetic brakes lose their effectiveness. From theoretical calculations and experimented braking time values, a maximum reduction in braking time 23.97% is found and max air gap limit of 3 mm is obtained beyond with electromagnetic brakes are found to be ineffective. Further, a magnet of higher magnetic flux density can be used to minimize the braking time. Also, magnets can be positioned at different locations around the disc inradial arrangement to get better breaking torque distribution.

'Modeling and control of electromagnetic brakes for enhanced braking capabilities or automated highway systems' by M. Qian, and P. Kachroo, University of Nevada, LasVegas, IEEE Conference on Intelligent Transportation Systems, pp. 391396, January, 1997. A modified mathematical model is developed for electromagnetic brakes, is proposed to describe their static characteristics i.e. angular speed versus brake torque. This paper describes electromagnetic brakes as a supplementary system for regular friction brakes. This system provides better response time for emergency situations, and in general keeps the friction brake working longer and safer.

To control the brakes, a robust sliding mode controller is designed to maintain the wheel slip at a given value. Simulations show that the controller designed is capable of controlling the vehicle with parameter deviations and disturbances

Design and fabrication of electromagnetic braking system published International Review of Mechanical Engineering (I.RE.M.E.) by M.Z.Baharom, M. Z.Nuawi, S. M. Haris.

The behaviour of electromagnetic braking using eddy current was studied.Start edwith preliminary study investigating 3 difference materials of aluminum, copper and zinc to choose the best material as brake disc. It also looks on effects of increasing current induced into electromagnet. From the experiment that has been conducted, it can be concluded that aluminum is the best material compared to copper and zinc to be use as the disc brake for eddy current braking using electromagnetic. Besides that, we may conclude that A16061 is better than A17075 to be uses as the brake disc material for our electromagnetic braking system using eddy current project. Thicker disc will generate high torque which will approach the motor torque in order to stop the disc rotation which in this study disc of 5 mm is better than 4mm of thickness. Smaller air gap will produce high braking torque and give better performance to the electromagnetic braking which air gap of 1mm shows the best result compared to 3mm and 5mm is better than 4mm of thickness. Smaller air gap will produce high braking torque and give better performance. To the electromotive braking which air-gap of 1mm shows the best result compared to 3mm and 5mm gap. A16061 which has higher electrical conductivity than A17075 shows great performance of braking torque produced in the study. Therefore, finding of mentionedparameters from this study are parallel; with the theory and will be the guidance to extend this project for any potential application.

2. BACKGROUND AND RATIONALS

Electromagnetic brakes (also called electro-mechanical brakes or EM brakes) slow or stop motion using electromagnetic force to apply mechanical resistance (friction). The original name was "electro-mechanical brakes" but over the years the name changed to "electromagnetic brakes", referring to their actuation method. Since becoming popular in the mid-20th century especially in trains and trams, the variety of applications and brake designs has increased dramatically, but the basic operation remains the same. Electromagnetic brakes are the brakes working on the electric power & magnetic power. They work on the principle of electromagnetism. These brakes are an excellent replacement on the convectional brakes due to their many advantages. The reason for implementing this brake in automobiles is to reduce wear in brakes as it frictionless. Electromagnetic brakes are of today's automobiles. The working principle of this system is based on faradays first law of electromagnetic induction i.e when a magnetic flux linking with a conductor changes an emf is induced in the coil. An additional current is supplied to the coils so that it creates an opposing torque. This results in the rotating wheel or rotor comes to rest/ neutral.

3. HISTORY

It is found that electromagnetic brakes can develop a negative power which represents nearly twice the maximum power output of a typical engine, and at least three times the braking power of an exhaust brake. (Reverdin 1994). This performance of electromagnetic brakes make them much more competitive candidate for alternative retardation equipment compared with other retarders. By using by using the electromagnetic brakes are supplementary retardation equipment, the friction brakes can be used less frequently and therefore practically never reach high temperatures. The brake linings would last considerably longer before requiring maintenance and the potentially "brake fade" problem could be avoided. In research conducted by a truck manufacturer, it was proved that the electromagnetic brake assumed 80% of the duty which would otherwise have been demanded of the regular service brake (Reverdin 1974). Furthermore the electromagnetic brakes prevent the danger that can arise from the prolonged use of brake beyond their capability to dissipate heat. This is most likely to occur while a vehicle descending a long gradient at high speed. Ina study with a vehicle with 5 axles and weighting 40 tones powered by a powered by an engine of 310 b.h.p travelling down a gradient of 6% at a steady speed between 35 and 40 m.h.p, it can be calculated that the braking power necessary to maintain this speed ot the order of 450 hp. The brakes, therefore, would have to absorb 300 hp, meaning that each brake in the 5 axels must absorb 30 hp, that a friction brake can normally absorb with self destruction. The magnetic brake is wall suited to such conditions since it will independently absorb more than 300 hp (Reverdin 1974). It therefore can exceed the requirements of continuous uninterrupted braking, leaving the friction brakes cool and ready for emergency braking in total safety. The installation of an electromagnetic brake is not very difficult if there is enough space between the gearbox and the rear axle. If did not need a subsidiary cooling system. It relay on the efficiency of engine components for its use, so do exhaust and hydrokinetic brakes. The exhaust brake is an on/off device and hydrokinetic brakes have very complex control system. The electromagnetic brake control system is an electric switching system which gives it superior controllability.

4 COMPONENETS OF ELECTRO MAGNETIC BRAKING SYSTEM

A BASE FRAME

The components require support during the operation. The base framefacilitates necessary support for this purpose.

Fig. no 01

B BELT AND PULLYS

A pulley is a wheel on an axle or shaft that is designed to support movement and change of direction of a taut cable or belt, or transfer of power between the shaft and cable or belt. A belt and pulley system is characterized by two or more pulleys in common to a belt. This allows for mechanical power, torque, and speed to be transmitted across axles. If the pulleys are of differing diameters are used different speeds can be obtained

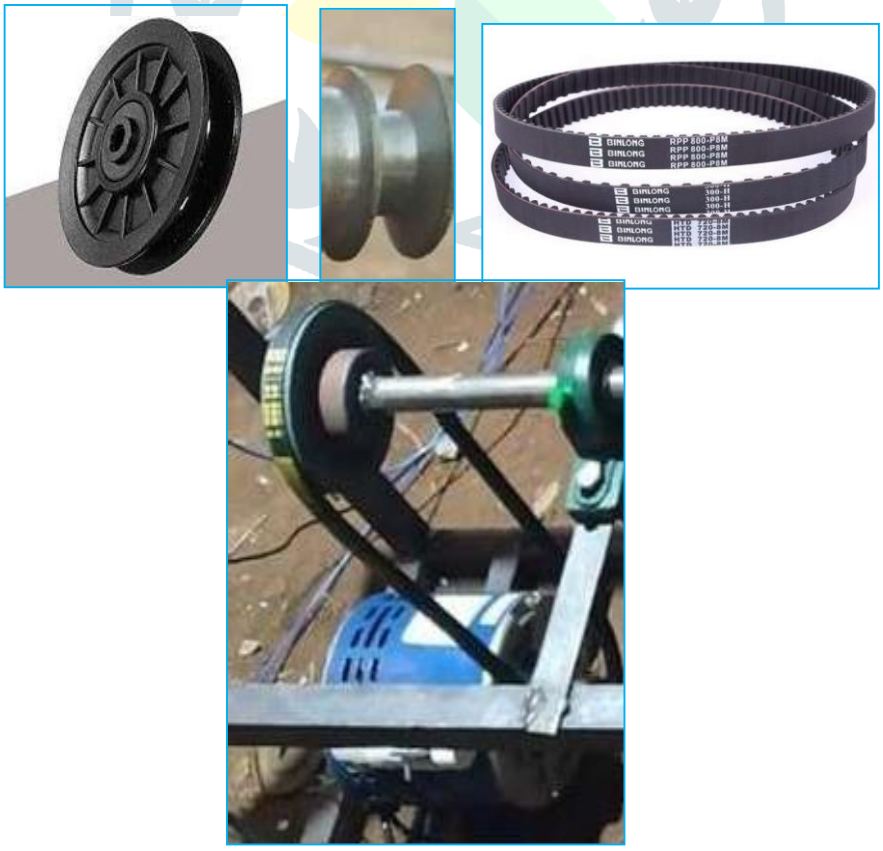

Fig no. 02

C DC MOTOR

A **DC motor** is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic; to periodically change the direction of current flow in part of the motor. DC motors were the first type widely used, since 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 current in its field windings. 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 used in propulsion of electric vehicles, elevator and hoists, or in drives for steel rolling mills. The advent of power electronics has made replacement ofDC motors with AC motors possible in many applications.

Power ratings are 160-240 volts, maximum current is 2.0A and the speed is 0- 8500 rpm.

Fig no. 03

D TIRE OR WHEEL

A wheel is a circular block of a hard and durable material at whose center has been bored a circular hole through which is placed an axle bearing about which the wheel rotates when a moment is applied by gravity or torque to the wheel about its axis, thereby making together one of the six simple machines.

Fig no. 04

E ADAPTER

An (electrical) adapter is a device that converts attributes of one electrical device or system to those of an otherwise incompatible device or system. Some modify power or signal attributes, while others merely adapt the physical form of one electrical connector to another.
Power ratings are 12 volts and maximum current 10A.

Fig no. 05

5 CONSTRUCTION OF ELECTRO MAGNETIC BRAKING SYSTEM

The motor is placed on the bottom of the frame and the motion transmission from motor to shaft is done with the help of pulleys and belt i.e one end of the shaft is connected to a pulley and the shaft pulley is connected is to the motor pulley with the help of belt so that when motor pulley rotates due to the power supply the shaft pulleyrotates and the shaft pulley rotates and the shaft rotates which is mounted on the frame with the help of bearings. Here the other end of the shaft is connected to one side of the wheel so that when shaft rotates wheel also rotates. The braking unit consists of permanent magnet, stator which has 3 spokes of iron winded with copper wires. The permanent magnet is attached to the other side of the wheel and the stator outer frame is welded to the base frame.

6 WORKING OF ELECTRO MAGNETIC BRAKING SYSTEM

There are two methods ofoperations of the braking system.

Braking system with EMF generation effect. - In this type an alternator of bikes is used as an braking unit. The braking unit consists of permanent magnet and stator which has three spokes of iron material winded with copper wires or magnetic wires. The permanent magnet and stator are connected to the equipment as mentioned in the construction above.
When magnet which is attached to the wheel rotates an EMF is generated in the coils according to Faraday's Law of Electromagnetic Induction, This generated EMF can be used to charge batteries with the help of rectifier and regulator because the output EMF is in AC form. So this process of generating EMF when wheel is freely rotating is known as EMF generating effect. In order to apply brakes a reverse current is supplied from the adaptor which should be more than the produced EMF so that the electro magnetic poles gets interchanged and creates an opposing torque to the rotating wheel and tries to stop the wheel. But in this method of operation the EMF generated is more than the reverse current which we are supplying from adaptor. So the brakes are not making the wheel stop. To avoid this either we have to increase the adaptor specifications (current and voltage)

or to stop the EMF generating effect. If we change the adaptor specifications i.e. increasing current and voltage the coils in the electromagnet gets damaged due to coils gauge and less no. of turns. So we have done this experiment in second method of operation which is to eliminate EMF generating effect is as follows.

Braking system without EMF generation. – The construction details are same as the first method. But only difference is the magnetic replaced by circular steel plate in the braking unit. So when electromagnet is energized by supplying current from adaptor it creates a magnetic field which attracts the rotating circular steel plate creating an opposing torque to stop the rotation of the wheel. In this there is a gap of 2mm between the steel plate and electromagnet so this is frictionless braking system which is major advantage. As the rotating circular plate does not produce any EMF, so the brakes are applied without any EMF generation. So we used 2nd method of operation to apply brakes in order to overcome the difficulties obtained in the first method.

7 CAD DESIGN

Commonly referred to as a 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development, including conceptualization, design (CAD), engineering (CAE) and manufacturing (CAM). CATIA facilitates collaborative engineering across disciplines around its 3DEXPERIENCE platform, including surfacing & shape design, electrical, fluid and electronic systems design, mechanical engineering and systems engineering.

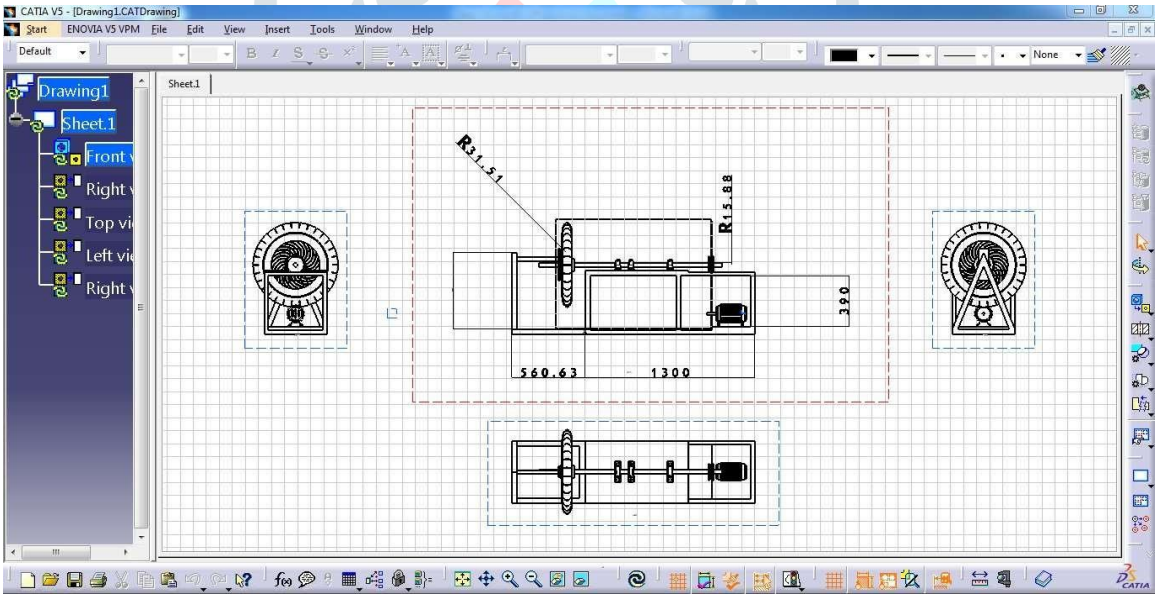

Fig no. 06

Fig no. 07

7 CALCULATIONS

Sl.No	Parts	Specifications
1.	Base Frame	
2.	DC Motor	Voltage:160-240 VoltsCurrent: 2A HP:0.25 Power : 180W Maximum Speed: 1425 RPMNo .of Poles: 2 Frequency: 50HZ
3.	Adapter	Power Ratings:Voltage: 12V Current: 10A
4.	Braking Unit	Stator having 3 poles with copper windingNo of turns in the copper winding: Diameter of circular plate:
5.	Pulleys	Motor Pulley Diameter: 3.3cmShaft Pulley Diameter: 10.5 cm Center to center distance between pulleys = 37cm
6.	Shaft	Diameter:2cm Material : Mild Steel
7.	Bike Tire (or)Wheel	Mass :7kg Diameter :60.94cm
8.	Bearings	2cm DiameterPlain Bearing

Fig no.08

DESIGN CALCULATIONS

Max speed

N x D = n x d

1425 x 3.3 = n x 10.5

N = (1425 x 3.3) / 10.5N = 457.85RPM

Checking the centre to centre distance between pulley$C \geq (D + d) / 2$

37 > (10.5+3.3) / 2

37cm > 6.79cm

Braking Torque and Braking timeFormula for Braking Torque

We know that

Power = Force x distance per minute--------(1)

Force = Torque .....(2)Radius

Now distance per revolution = Radius x 2 π

Distance per minute = Radius x 2 π x RPM------(3)

Substituting equation (2) & (3) in (1) then we getPower = Torque x ~~Radius~~ x 2 π x RPM
~~Radius~~

= Torque x 2 π x RPM

Divide both sides by 33000 to find HP in Pb then we getHP = Torque x RPM x 2 π
33000

HP = Torque x RPM x 6.2831
33000

HP = Torque x RPM x 1
5252

Torque= HP x 5252
RPM

Formula for braking time in imperical units

$T = I \alpha$

$T = W \times R^2 \times \alpha$

$T = M \times R^2 \times \alpha$ (Since $W = Mg)_g$ .and $\alpha = \omega / t$

Here g is in m/sec^2

$T = M \times R^2 \times \omega$ and 1m = 3.2208 ft
32.2 t

then 10m = 32.2 ftg

$\omega = 2\pi N$ 10 m/sec^2 = 32.2 ft

$/sec^2$60

$$T = \frac{M \times R^2 \times 2\pi \times N}{60 \times t}$$

$$T = \frac{M \times R^2 \times N}{308 \times t}$$

1. At speed N = 150 rpm

$$T = \frac{5252 \times 0.25}{150}$$

$T = 8.753$ ft-pb

Here M = 7 kg

R = 0.3047 m

$MR^2 = 7 \times 0.3047^2$

$= 0.6498$ kg- m^2 1 kg-m^2 = 23.73 Pb Ft^2

Then 0.6498 kg-m^2 = 15.422 Pb-Ft^2

$$t = \frac{15.422 \times 150}{308 \times 8.753}$$

t = 0.857 sec

8 RESULTS

The Theoretical braking time is obtained from the formulas mentioned in the previous chapter at suitable speeds by taking some assumptions. The experimental braking time is calculated by taking readings from fabricated model using stop watch at required speeds. These experimental and theoretical values are compared in this experiment.
The values of time taken by the wheel to stop when brakes are applied, when brakes are not applied and also theoretically are shown in the table. And graphs are plotted for speed of the wheel and theoretical experimental braking time, speed of the wheel and time taken by the wheel to stop and when brakes are applied , when brakes are not applied as shown in the graph
The value variation between speed of the wheel and braking time are observedin XY plane which shows that the time taken by the wheel to stop increases within increase in speed of the wheel. From the graph it is shown that these brakes aremost effective at high speeds.

Sl.No.	Speed	Experimental Time takenwhen		Theoretical Time taken
		Brakes are applied	Brakes are not applied	
1.	150	2.10	4.41	0.85
2.	200	2.70	5.13	1.52
3.	250	3.37	5.80	2.38
4.	300	4.34	6.91	3.50
5.	350	5.81	8.26	4.67
6.	400	6.79	8.91	6.10
7.	450	7.95	9.69	7.72

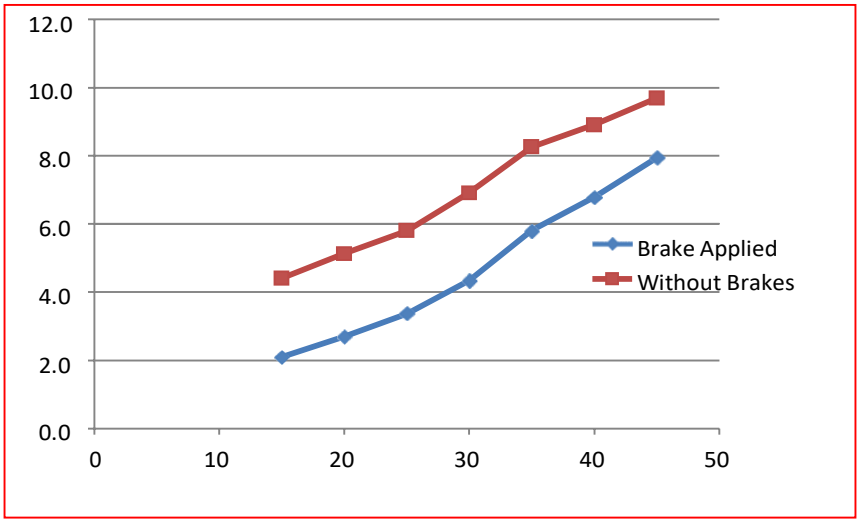

Fig no. 10

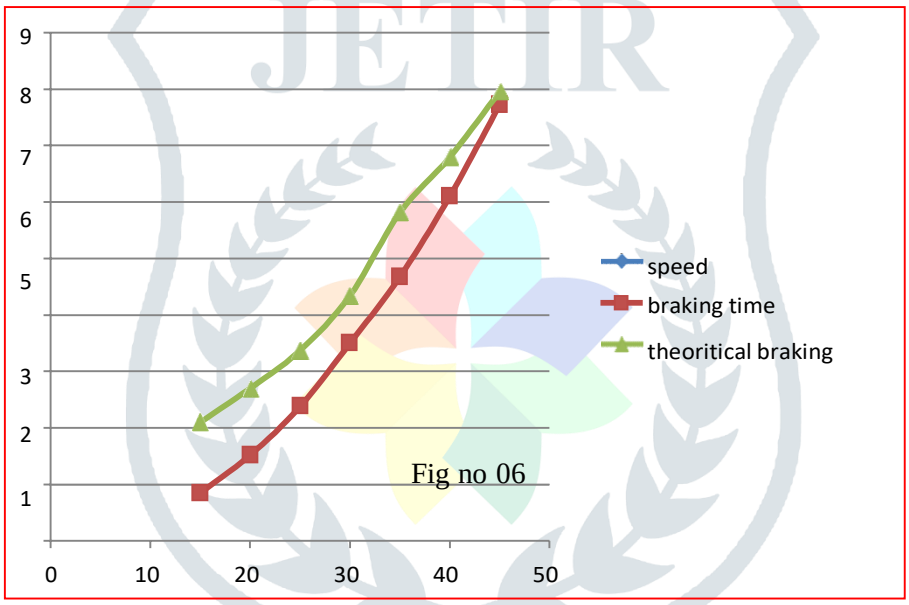

Fig no 06

Fig no. 11

12 CONCLUSION

Electromagnetic brakes are important supplementary retardation equipment in addition to the regular friction brakes. They have been used in heavy vehicles such as coaches, buses, trucks under conditions such as reducing speed in motorways and trunk roads and braking for prolonged periods during down slope operations. New types of electromagnetic brakes have been under development for lighter vehicles as well. Regular friction brakes have an outstanding and vital load absorbing capability if kept cool. Electromagnetic brakes help friction brakes to retain this capability under all conditions by absorbing energy at a separate location based on a totally different working principle.

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