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Electromagnetic Braking System

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ABSTRACT
An electromagnetic brake is a new and revolutionary concept. Electromagnetic braking system is a modern technology braking system used in light motor & heavy motor vehicles. This system is a combination of electro-mechanical concepts. The frequency of accidents is now-a-days increasing due to inefficient braking system. It is apparent that the electromagnetic brake is an essential complement to the safe braking of heavy vehicles. It aims to minimize the brake failure to avoid the road accidents. It also reduces the maintenance of braking system. An advantage of this system is that it can be used on any vehicle with minor modifications to the transmission and electrical systems. An Electromagnetic Braking system uses Magnetic force to engage the brake, but the power required for braking is transmitted manually. The disc is connected to a shaft and the electromagnet is mounted on the frame. When electricity is applied to the coil a magnetic field is developed across the armature because of the current flowing across the coil and causes armature to get attracted towards the coil. As a result, it develops a torque and eventually the vehicle comes to rest. These brakes can be incorporated in heavy vehicles as an auxiliary brake. The electromagnetic brakes can be used in commercial vehicles by controlling the current supplied to produce the magnetic flux. Making some improvements in the brakes it can be used in automobiles in future. Electromagnetic brakes are the brakes working on the electric power & magnetic power. They work on the principle of electromagnetism. The working principle of this system is that when the magnetic flux passes through and perpendicular to the rotating wheel the eddy current flows opposite to the rotating wheel/rotor direction. This eddy current trying to stop the rotating wheel or rotor. This results in the rotating wheel or rotor comes to rest/ neutral. These are totally friction less. Due to this, they are more durable & have longer life span. Less maintenance is there. 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 friction less. Therefore, there will also be no heat loss. The electromagnetic brakes are much effective than conventional brakes & the time taken for application of brakes is also smaller. There is very few need of lubrication. Electromagnetic breaks gives such better performance with less cost, which is today's need.

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I. INTRODUCTION

BRAKE

A brake is a device, which inhibits motion. Its opposite component is a clutch. Most commonly, brakes use friction to convert kinetic energy 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. The principle of braking in road vehicles involves the conversion of kinetic energy into thermal energy (heat). When stepping on the brakes, the driver commands a stopping force several times as powerful as the force that puts the car in motion and dissipates the associated kinetic energy as heat. Brakes must be able to arrest the speed of a vehicle in short periods regardless how fast the speed is. As a result, the brakes are required to have the ability to generating high torque and absorbing energy at extremely high rates for short periods. 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. The conventional friction brake system is composed of the following basic components: the "master cylinder" which is located under the hood is directly connected to the brake pedal, and converts the drivers' foot pressure into hydraulic pressure. Steel "brake hoses" connect the master cylinder to the "slave cylinders" located at each wheel. Brake fluid, specially designed to work in extreme temperature conditions, fills the system. "Shoes" or "pads" are pushed by the slave cylinders to contact the "drums" or "rotors", thus causing drag, which slows the car. Two major kinds of friction brakes are disc brakes and drum brakes.

TYPES OF BRAKES

1. FRICTION BRAKE
2. ELECTROMAGNETIC BRAKE

FRICTION BRAKE

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TYPES OF FRICTION BRAKE

1. DRUM BRAKE
2. DISC BRAKE

DRUM BRAKE

In a motor vehicle, the wheel is attached to an auxiliary wheel called drum. The brake shoes are made to contact this drum. In most designs, two shoes are used with each drum to form a complete brake mechanism at each wheel. The brake shoes have brake linings on their outer surfaces. Each brake shoe is hinged at one end by on anchor pin; the other end is operated by some means so that the brake shoe expands outwards. The brake linings come into contact with the drum. Retracting spring keeps the brake shoe into position when the brakes are not applied. The drum encloses the entire mechanism to keep out dust and moisture. The wheel attaching bolts on the drum are used to contact wheel and drum. The braking plate completes the brake enclosure, holds the assembly to car axle, and acts the base for fastening the brake shoes and operating mechanism.

DISC BRAKE

The dissipate quickly the considerable amount of heat generated when braking a fast moving heavy car large brake drums would be required. Disc brakes do the job more efficiently, for the cooling air can get to the rubbing between each piston and the disc, there is a friction pad held in position by retaining pins, spring plates etc. Passages are drilled in the caliper for the fluid to enter or leave the each housing. These passages are also connected to another one for bleeding. Each cylinder contains a rubber-selling ring between the cylinder and the piston.

The brakes are applied, hydraulically actuated piston move the friction pads into contact with the disc, applying equal and opposite forces on the later. On releasing the brakes, the rubber sealing rings act as return springs and retract the pistons and the friction pads away from the disc.

ELECTROMAGNETIC BRAKE

1) Electromagnetic brakes slow an object through electromagnetic induction, which creates resistance and in turn either heat or electricity. Friction brakes apply pressure on two separate objects to slow the vehicle in a controlled manner.
2) In locomotives, a mechanical linkage transmits torque to an electromagnetic braking component.
3) Trams and trains use electromagnetic track brakes where the braking element is pressed by magnetic force to the rail. They are distinguished from mechanical track brakes, where the braking element is mechanically pressed on the rail.
4) Electric motors in industrial and robotic applications also employ electromagnetic brakes.
5) Recent design innovations have led to the application of electromagnetic brakes to aircraft applications. In this application, a combination motor/generator is used first as a motor to spin the tires up to speed prior to touchdown, thus reducing wear on the tires, and then as a generator to provide regenerative braking.

II. CONSTRUCTION OF EM BRAKE

The construction of the electromagnetic braking system is very simple. The parts needed for the construction are electro magnets, rheostat, sensors, and magnetic insulator. A cylindrical ring shaped electro magnet with winding is placed parallel to rotating wheel disc/ rotor. The electro magnet is fixed, like as stator and coils are wounded along the electromagnet. These coils are connected with electrical circuit containing one rheostat, which is connected with brake pedal. In addition, the rheostat is used to control the electric current flowing in the coils, which are wounded on the electro magnet, and a magnetic insulator is used to focus and control the magnetic flux. In addition, it is used to prevent the magnetization of other parts like those that axle and it act as a support frame for the electromagnet. The sensors used to indicate the disconnection in the whole circuit. If there is any error, it gives an alert, so we can avoid accident.

The parts of Electromagnetic Disc Brake are:

- DC Motor
- Disc
- Frame
- Electromagnet
- Circuit Board
- Shaft

WORKING PRINCIPLE

If a piece of copper wire was wound, around the nail and then connected to a battery, it would create an electro magnet. The magnetic field that is generated in the wire, from the current, is known as the "**right hand thumb rule**". The strength of the magnetic field can be changed by changing both wire size and the amount of wire (turns). The fields of EM brakes can be made to operate at almost any DC voltage and the torque produced by the brake will be the same as long as the correct operating voltage and current is used with the correct brake. A constant current power supply is ideal for accurate and maximum torque from a brake. If a non-regulated power supply is used the magnetic flux will degrade as the resistance of the coil goes up. The hotter the coil gets the lower the torque will be produced by about an average of 8% for every 20°C. If the temperature is constant, and there is a question of enough service factor in the design for minor temperature fluctuation, by slightly over sizing the brake can compensate for degradation. This will allow the use of a rectified power supply, which is far less expensive than a constant current supply. Based on $\mathbf{V = I \times R}$, as resistance increases available current falls. An increase in resistance, often results from rising temperature as the coil heats up, according to:

$$\mathbf{Rf = Ri \times [1 + aCu \times (Tf - T)]}$$

Where Rf = final resistance, Ri = initial resistance, aCu = copper wire's temperature coefficient of resistance, 0.0039 °C-1, Tf = final temperature, and Ti = initial temperature.

The working principle of the electric retarder is based on the creation of eddy currents within a metal disc rotating between two electromagnets, which set up a force opposing the rotation of the disc. If the electromagnet is not energized, the rotation of the disc is free and accelerates uniformly under the action of the weight to which its shaft is connected. When the electromagnet is energized, the rotation of the disc is retarded and the energy absorbed appears as heating of the disc. If a rheostat varies the current exciting the electromagnet, the braking torque varies in direct proportion to the value of the current. The basic operation of magnetic field that is generated in the wire, from the current, is known as the "right hand thumb rule. This rule is known as faraday's law. Electromagnetism is one of the four fundamental interactions in nature. The other three are the strong interaction, the weak interaction, and gravitation. Electromagnetism is the force that causes the interaction between electrically charged particles; the areas in which this happens are called electromagnetic fields.

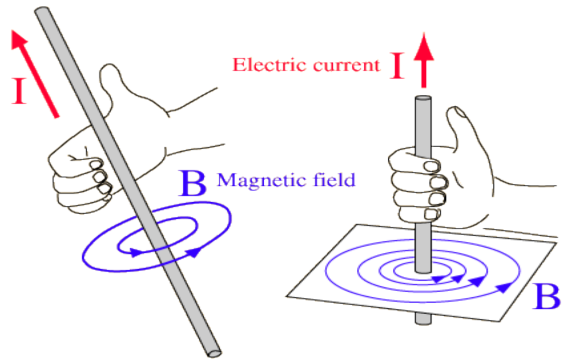


Figure11-Right Hand Thumb Rule

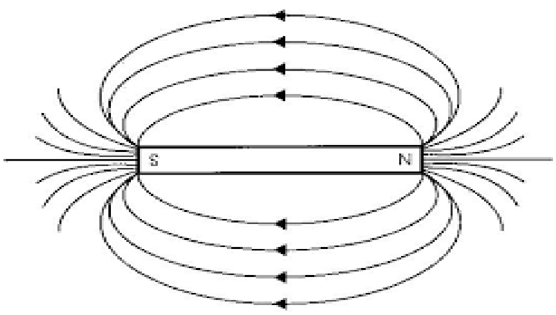


Figure-12.Magnetic Field Lines

A typical retarder consists of stator and rotor. The stator holds 16 induction coils, energized separately in groups of four. The coils are made up of varnished aluminum wire mounded in epoxy resin. The rotor is made up of two discs, which provide the braking force. When subject to the electromagnetic influence when the coils are excited. Careful designs of the fins, which are integral to the disc, permit independent cooling of the arrangement. At the initial stage, brake pedal and rheostat are in rest. When we apply the brake through the brake pedal, the rheostat allows the current to flow through the circuit and this current energizes the electromagnet. The rheostat controls the amount of current flow. Depending on the current flow, different amount of magnetic flux can be obtained. By this varying magnetism flux, different mode of brakes can be obtained. For example, if we want to suddenly stop the vehicle then press the brake pedal fully, then the rheostat allows maximum current, which is enough to stop the vehicle. Similarly, we can reduce the speed of the vehicle by applying the brake gradually.

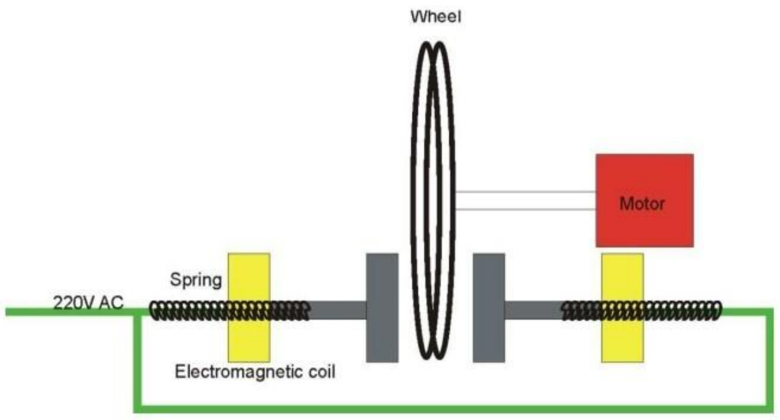


Figure-13. Arrangement of EM Brake

Magnetic Effect of Current The term “Magnetic effect of current" means that "a current flowing in a wire produces a magnetic field around it". The magnetic effect of current was discovered by Oersted in 1820. Oersted found that a wire carrying a current was able to deflect a magnetic needle

Electromagnet An electric current can be used for making temporary magnets known as electromagnets. An electromagnet works on the magnetic effect of current. It has been found that if a soft iron rod called core is placed inside a solenoid, then the strength of the magnetic field becomes very large because the iron ore is magnetized by induction.

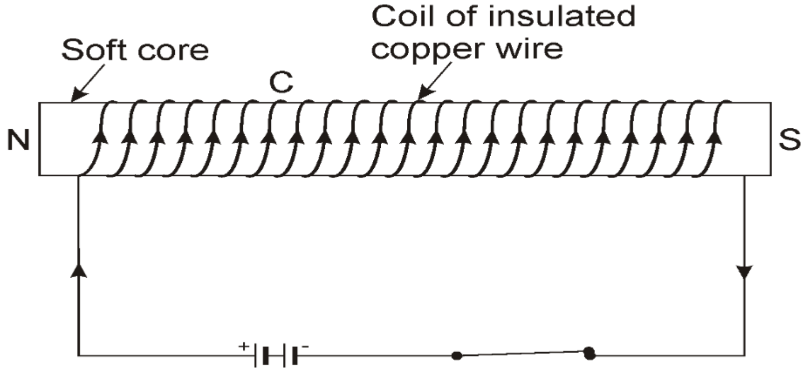


Figure-14. Electromagnet

Factors affecting strength of an Electromagnet

The strength of an electromagnet is:

- Directly proportional to the number of turns in the coil.
- Directly proportional to the current flowing in the coil.
- Inversely proportional to the length of air gap between the poles.

In general, an electromagnet is often considered better than a permanent magnet because it can produce very strong magnetic fields and its strength can be controlled by varying the number of turns in its coil or by changing the current flowing through the coil.

Working Of Electromagnetic Disc Brake

The electromagnet is energized by the AC supply where the magnetic field produced is used to provide the braking mechanism. When the electromagnet is not energized, the rotation of the disc is free and accelerates uniformly under the action of weight to which the shaft is connected. When the electromagnet is energized, magnetic field is produced thereby applying brake by retarding the rotation of the disc and the energy absorbed is appeared as heating of the disc. Therefore, when the armature is attracted to the field the stopping torque is transferred into the field housing and into the machine frame decelerating the load. DC motor makes the disc to rotate through the shaft by means of pulleys connected to the shaft.

CHARACTERISTIC OF ELECTROMAGNETIC BRAKES

It was found that electromagnetic brakes could 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. These performances of electromagnetic brakes make them much more competitive candidate for alternative retardation equipments compared with other retarders. By using the electro-magnetic brake as supplementary, retardation equipment, the frictions 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. 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. It does not need a subsidiary cooling system. It does not rely on the efficiency of engine components for its use, as do exhaust and hydrokinetic brakes. The electromagnetic brake also has better controllability. The exhaust brake is an on/off device and hydrokinetic brakes have very complex control system. The electro- magnetic brake control system is an electric switching system, which gives it superior controllability. It is apparent that the electro-magnetic brake is an attractive complement to the safe braking of heavy vehicles.

Electromagnetic brakes operate electrically, but transmit torque mechanically. This is why they used to be referred to as electro-mechanical brakes. Over the years, EM brakes became known as electromagnetic, referring to their actuation method. The variety of applications and brake designs has increased dramatically, but the basic operation remains the same. Single face electromagnetic brakes make up approximately 80% of all of the power applied brake applications. Characteristics of Electromagnetic Brakes- It was 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. These performances of electromagnetic brakes make them much more competitive candidate for alternative retardation equipment is compared with other retarders. The brake linings would last considerably longer before requiring 28 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 percentage of the duty, which would otherwise have been demanded of the regular service brake. Furthermore, the electromagnetic brake prevents the dangers that can arise from the prolonged use of brakes beyond their capability to dissipate heat. This is most likely to occur while a vehicle descending a long gradient at high speed.

ENGAGEMENT TIME

There are actually two engagement times to consider in an electromagnetic brake. The first one is the time it takes for a coil to develop a magnetic field, strong enough to pull in an armature. Within this, there are two factors to consider. The first one is the amount of ampere-turns in a coil, which will determine the strength of a magnetic field. The second one is air gap, which is the space between the armature and the coil shell. Magnetic lines of flux diminish quickly in the air. The further away the attractive piece is from the coil, the longer it will take that piece to actually develop enough magnetic force to be attracted and pull in to. Overcome the air gap. For very high cycle applications, floating armatures can be used that rest lightly against the coil shell. In this case, the air gap is zero; but more importantly, the response time is very consistent since there is no air gap to overcome. Air gap is an important consideration especially with a fixed armature design because as the unit wears over many cycles of engagement the armature and the coil shell will create a larger air gap, which will change the engagement time of the brakes. In high cycle applications, where registration is important, even the difference of 10 to 15 milliseconds can make a difference, in registration of a machine. Even in a normal cycle application, this is important because a new machine that has accurate timing can eventually see a "drift" in its accuracy as the machine gets older.

The second factor in figuring out response time of a brake is actually much more important 29 than the magnet wire or the air gap. It involves calculating the amount of inertia that the brake needs to decelerate. This is referred to as "time to stop". In reality, this is what the end-user is most concerned with. Once it is known how much inertia is present for the brake to stop then the torque can be calculated and the appropriate size of brake can be chosen. Most CAD systems can automatically calculate component inertia, but the key to sizing a brake is calculating how much inertia is reflected back to the brake. To do this, engineers use the formula: $T = (WK2 \times \Delta N) / (308 \times t)$ Where T = required torque in lb-ft, WK2 = total inertia in lb-ft2, ΔN = change in the rotational speed in rpm, and t = time during which the acceleration or deceleration must take place. Inertia Calculator There are also online sites that can help confirm how much torque is required to decelerate a given amount of inertia over a specific time. Remember to make sure that the torque chosen, for the brake, should be after the brake has been burnished.

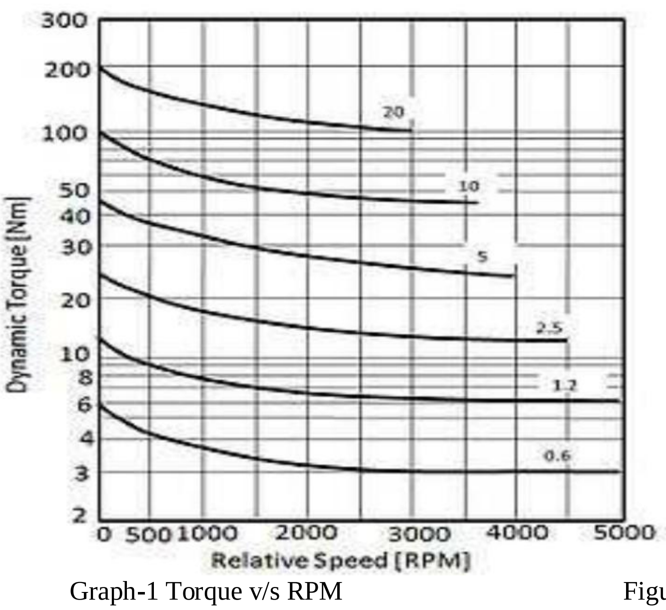
BURNISHING

Burnishing is the wearing or mating of opposing surfaces. When the armature and brake faces are produced, the faces are machined as flat as possible. (Some manufacturers also lightly grind the faces to get them smoother.) However, even with that the machining process leaves peaks and valleys on the surface of the steel. When a new “out of the box” brake is initially engaged most peaks on both mating surfaces touch which means that the potential contact area can be significantly reduced. In some cases, an out of box brake may have only 50% of its torque rating. Burnishing is the process of cycling the brake to wear down those initial peaks, so that there is more surface contact between the mating faces. Even though burnishing is required to get full torque out of the brake, it may not be required in all applications. Simply put, if the application torque is lower than the initial out of box torque of the brake, burnishing would not be required; however, if the torque required is higher, then burnishing needs to be done. In general, this tends to be required more on higher torque brakes than on smaller lower torque brakes.

The process involves cycling the brake a number of times at a lower inertia, lower speed, or a combination of both. Burnishing can require from 20 to over 100 cycles depending upon the size of a brake and the amount of initial torque required. For bearing mounted brakes where 30 the rotor and armature is connected and held in place via a bearing, burnishing does not have to take place on the machine. It can be done individually on a bench or as a group at a burnishing station. Two-piece brakes that have separate armatures should try to have the burnishing done on the machine verses a bench. The reason for this is if burnishing on a two piece brake is done on a bench and there is a shift in the mounting tolerance when that brake is mounted to the machine the alignment could be shifted so the burnishing lines on the armature, rotor or brake face may be off slightly preventing that brake from achieving full torque. Again, the difference is only slight so this would only be required in a very torque sensitive application.

TORQUE

Burnishing can affect initial torque of a brake but there are also factors that affect the torque performance of a brake in an application. The main one is voltage /current. In the voltage/current section, we showed why a constant current supply is important to get full torque out of the brake. When considering torque, the question of using dynamic or static torque for the application is key. For example, if running a machine at relatively low rpm (5 – 50 depending upon size) there is minimal concern with dynamic torque since the static torque rating of the brake will come closest to where it is running. However, when running a machine at 3,000rpm and applying the brake at its catalog torque, at that rpm, is misleading. Almost all manufacturers put the static rated torque for their brakes in their catalog. So, when trying to determine a specific response rate for a particular brake, the dynamic torque rating is needed. In many cases, this can be significantly lower. It can be less than half of the static torque rating. Most manufacturers publish torque curves showing the relationship between dynamic and static torque for a given series of brake.



Graph-1 Torque v/s RPM

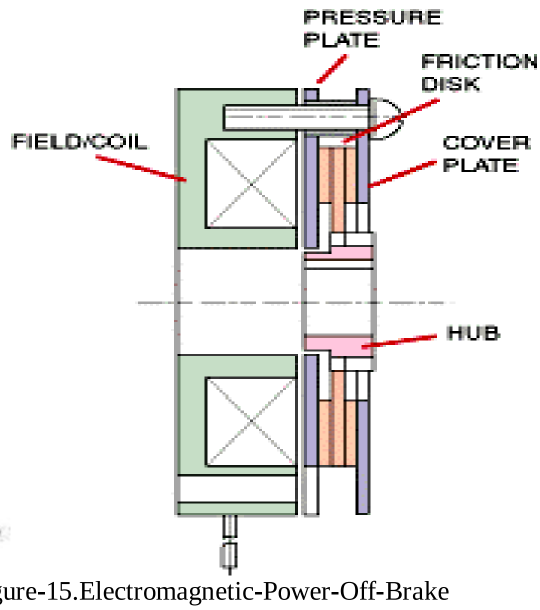


Figure-15.Electromagnetic-Power-Off-Brake

OVER EXCITATION

Over-excitation is used to achieve a faster response time. It is when a coil shortly receives a higher voltage then its nominal rating. To be effective, the over-excitation voltage must be significantly, but not to the point of diminishing returns, higher than the normal coil voltage. Three times the voltage typically gives around 1/3 faster response. Fifteen times the normal coil voltage will produce a three times faster response time. With over-excitation, the in-rush voltage is momentary. Although it would depend upon the size of the coil, the actual time is usually only a few milliseconds. The theory is, for the coil to generate as much of a magnetic field as quickly as possible to attract the armature and start the process of deceleration. Once the over-excitation is no longer required, the power supply to the brake would return to its normal operating voltage. This process can be repeated a number of times as long as the high voltage does not stay in the coil long enough to cause the coil wire to overheat.

WEAR

It is very rare that a coil would just stop working in an electromagnetic brake. Typically, if a coil fails it is usually due to heat, which has caused the insulation of the coil wire to break down. That heat can be caused by high ambient temperature, high cycle rates, slipping or applying too high of a voltage. Most brakes are flanged mounted and have bearings but some brakes are bearing mounted and like the coils, unless bearings are stressed beyond their physical limitations or become contaminated, they tend to have a long life and they are usually the second item to wear out.

+ The main wear in electromagnetic brakes occurs on the faces of the mating surfaces. Every time a brake is engaged during rotation, a certain amount of energy is transferred as heat. The transfer, who occurs during rotation, wears both the armature and the opposing contact surface. Based upon the size of the brake, the speed, and the inertia, wear rates will differ. With a fixed armature design, a brake will eventually simply cease to engage. This is because the air gap will eventually become too large for the magnetic field to overcome. Zero gap or auto wear armatures can wear to the point of less than one-half of its original thickness, which will eventually cause missed engagements.

Thermal Dynamics-

Thermal stability of the electromagnetic brakes is achieved by means of the convection and radiation of the heat energy at high temperature. The major part of the heat energy is imparted to the ventilation air, which is circulating vigorously through the fan of the heated disc. The value of the energy dissipated by the fan can be calculated by the following expression:

$$Q = MCpD$$

Where:

M = Mass of air circulated;

Cp = Calorific value of air;

D= Difference in temperature between the air entering and the air leaving the fan;

The electromagnetic brakes has excellent heat dissipation efficiency owing to the high temperature of the surface of the disc which is being cooled and because the flow of air through the centrifugal fan is very rapid. Therefore, the curie temperature of the disc material could never been reached .The practical location of the electromagnetic brakes prevents the direct impingement of air on the brakes caused by the motion of the vehicle. Any airflow movement within the chassis of the vehicle is found to have a relatively 12 insignificant effect on the airflow and hence temperature of both front and rear discs. Due to its special mounting location and heat dissipation mechanism, electromagnetic brakes have better thermal dynamic performance than regular friction brakes.

ADVANTAGES

- Electromagnetic brakes can develop a negative power, which represents nearly twice the maximum power output of a typical engine.
- Electromagnetic brakes work in a relatively cool condition and satisfy all.
- The energy requirements of braking at high speeds, completely without the use of friction. Due to its specific installation location (transmission line of rigid vehicles), electromagnetic brakes have better heat dissipation capability to avoid problems that friction brakes face times the braking power of an exhaust brake.
- Electromagnetic brakes have been used as supplementary retardation equipment in addition to the regular friction brakes on heavy vehicles.
- Electromagnetic brakes have great braking efficiency and have the potential to regain energy lost in braking.
- Its component cost is less.
- Quick operation & more accuracy.
- It reduces the manual effort.

- In electromagnetic braking system, maintenance is very less. Electromagnetic braking system work is done very fast, because of electronic component and flowing of current is very fast.
- Very less effort is required to apply the brake. It is reasonable as compare with other brakes.
- Due to its special mounting location and heat dissipation mechanism, electromagnetic brakes have better thermal dynamic performance than regular friction brakes.

DISADVANTAGES

- The installation of an electromagnetic brake is very difficult if there is not enough space between the gearbox and the rear axle.
- Maintenance of the equipment components such as hoses, valves has to done periodically.
- Dependence on battery power to energize the brake system drains down the battery much faster.
- Due to residual magnetism present in electromagnets, the brake shoe takes time to come back to its original position.
- A special spring mechanism needs to be provided for the quick return of the brake shoe.

APPLICATIONS

- Used in crane control system.
- Used in winch controlling.
- Used in lift controlling Used in automobile purpose.
- In locomotives, a mechanical linkage transmits torque to an electromagnetic braking component.
- Trams and trains use electromagnetic track brakes where the braking element is pressed by magnetic force to the rail. They are distinguished from mechanical track brakes, where the braking element is mechanically pressed on the rail.
- Electric motors in industrial and robotic applications also employ electromagnetic brakes.

FUTURE SCOPE

The lots of new technologies are arriving in world. They create a lot of effect. Most industries got their new faces due to this arrival of technologies. Automobile industry is also one of them. There is a boom in World's automobile industry. Therefore, lot's of research is also going here. As an important part of automobile, there are also innovations in brakes. Electromagnetic brake is one of them. This enhanced braking system not only helps in effective braking but also helps in avoiding the accidents and reducing the frequency of accidents to a minimum. Furthermore, the electromagnetic brakes prevent the danger that can arise from the prolonged use of brake beyond their capability to dissipate heat.

III. CONCLUSION

An electromagnetic braking for automobiles like bike, car has an effective braking system. In addition, by using these electromagnetic brakes, we can increase the life of the braking unit. The working principle of this system is that when the electromagnetic flux passes through and perpendicular to the rotating wheel the eddy current is induced in the rotating wheel or rotor. This eddy current flows opposite to the rotating wheel. This eddy current tries to stop the rotating wheel or rotor. This results in the rotating wheel or rotor comes to rest. Electromagnetic braking system is found to be more reliable as 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 electromagnetic braking system as four disc plates, coils and firing circuits are attached individually on each wheel, even any coil fails the brake does not completely fails remaining three coil works properly. In addition, this system needs very little of maintenance. In addition, it is found that electromagnetic brakes make up approximately 80% of all of the power applied brake applications. Electromagnetic brakes have been used as supplementary retardation equipment in addition to the regular friction brakes on heavy vehicles. The frictions 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.

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