COMPARATIVE STUDY ON REGNERATIVE BRAKING SYSTEM

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Abstract - *Regenerative braking system (RBS) is an efficient system to reduce vehicle emission and fuel consumption. RBS is a system which converts mechanical energy to electrical energy during braking action. It will become an important system for future vehicle such as hybrid and electrical car. This study will start with literature review about the Regenerative braking system (RBS). The basic design and components used in the Regenerative braking for current vehicle will also be reviewed. Through the study, a RBS model can be design and develop for future study. The working mechanism was studied to understand how the RBS could convert mechanical energy to electrical energy. The important components used in RBS will be determined such as electric motor, motor controller and battery. To produce a RBS model, an e-bike conversion kit has been bought from Hong Kong and an alternator was selected to be installed in the bicycle. The results and calculations show that both devices can function properly, that means both devices can form recovery energy to charge battery during braking. During the recovery energy working, brake effects are formed to decelerate the bike. The recovery energy during braking for both devices are taken and compared to found out which one can produce high recovery energy during braking. In addition this RBS model can be used for future study.*

***Key Words*:** Regenerative braking system model, conventional brake pads, Electric motors, electric generators, hybrid cars, *electric motor, motor controller and battery*.

1. INTRODUCTION

An energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be either used immediately or stored until needed. In this mechanism, the electric motor uses the vehicle's momentum to recover energy that would be otherwise lost to the brake discs as heat. Regenerative braking is not by itself sufficient as the sole means of safely bringing a vehicle to a standstill, or slowing it as required, so it must be used in conjunction with another braking system such as friction-based braking. The regenerative braking effect available is limited, and mechanical braking is still necessary for substantial speed reductions, to bring a vehicle to a stop, or to hold a vehicle at a standstill. Systems use friction to counteract the forward momentum of a moving car. As the brake pads rub against the wheels (or a disc connected to the axle), excessive heat energy is also created. This heat energy dissipates into the air, wasting up to 30% of the cars generated power[1]. Over time, this cycle of friction and wasted heat energy reduces the car's fuel efficiency. More energy from the engine is required to replace the energy lost by braking. Hybrid gas/electric automobiles now use a completely different method of braking at slower speeds. While hybrid cars still use conventional brake pads at highway speeds, electric motors help the car brake during stop-and-go driving. As the driver applies the brakes through a conventional pedal, the electric motors reverse direction. The torque created by this reversal counteracts the forward momentum and eventually stops the car but regenerative braking does more than simply stop the car. Electric motors and electric generators (such as a car's alternator) are essentially two sides of the same technology. Both use magnetic fields and coiled wires, but in different configurations. Regenerative braking systems take advantage of this duality. Whenever the electric motor of a hybrid car begins to reverse direction, it becomes an electric generator or dynamo.

Regenerative braking takes energy normally wasted during braking and turns it into usable energy. It is not, however, a perpetual motion machine. Energy is still lost through friction with the road surface and other drains on the system. The energy collected during braking does not restore all lost the energy during driving. It does improve energy efficiency and assist the main alternator. If we are using the diesel or gasoline driven cars the power is mainly provided by the combustion engine there is no electric motor so in such case for utilizing the brake energy Electromagnetic clutch is used to couple the motor with the axle during braking or deceleration which is the main concept of our project.

1.1 Parallel Hybrid System

One of the most popular of all, this system incorporates both an electric motor and an internal combustion engine (ICE) connected with a mechanical transmission system to power the wheels.

1.2 Series Hybrid System

This system works by the engine driving the electric generator rather than the engine directly powering the wheels.

1.3 Combined Hybrid System

The wheels in this system can be powered by either electrical or mechanical transmissions needed. This is made possible by the use of power-split devices that enable power paths from the engine to the wheels, and disconnect any one of the sources to let the other takeover.

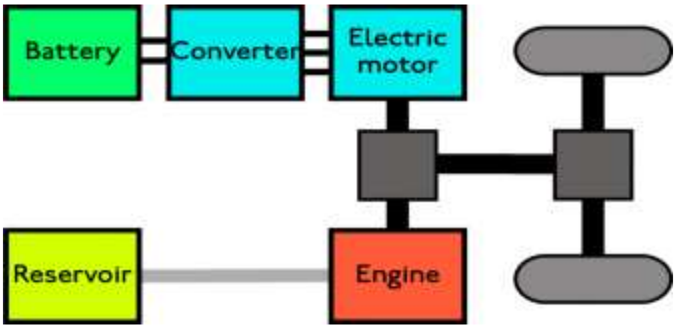

Fig -1: Combined hybrid system

1.4 Regenerative Braking Systems or Kinetic Energy Recovery System (KERS)

This is the other technology to be employed controls vehicle speed by converting a portion of its kinetic energy (energy of motion) into another useful form of energy. The energy so produced could then be stored as electric charge in the automobile battery, or as compressed gas/air or in flywheels to be used again by the vehicle.

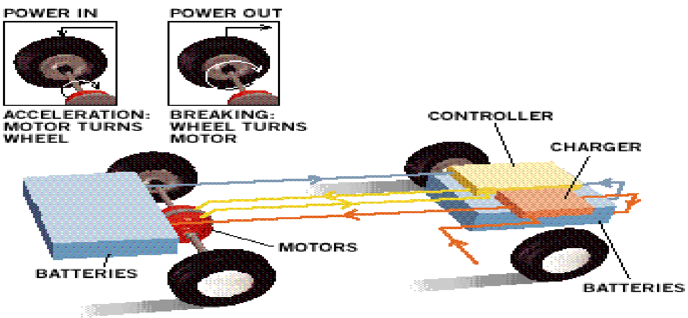

Fig -2: Regenerative braking systems

For instance a KERS using a compressed air system for a vehicle installed with a rotary sliding vane engine, a compressor, a combustion chamber and a motor may work as follows: The braking may be achieved by connecting the rotor of the compressor to a wheel and braking rotation of the rotor. Then the rotary motion of the compressor's rotor is used to generate compressed air, which is then stored in the surge tank to be utilized further. The added efficiency of regenerative braking also means less pain at the pump, since hybrids with electric motors and regenerative brakes can travel considerably farther on a gallon of gas, some achieving more than 50 miles per gallon at this point. And that's something that most drivers can really appreciate.

1.5 Concept Of Regenerative Braking

A regenerative brake[10] is a mechanism that reduces vehicle speed by converting some of its kinetic energy into another useful form of energy - electric current, compressed air. This captured energy is then stored for future use or fed back into a power system for use by other vehicles. For example, electrical regenerative brakes in electric railway vehicles feed the generated electricity back into the supply system. In battery electric and hybrid electric vehicles, the energy is stored in a battery or bank of twin layer capacitors for later use. Other forms of energy storage which may be used include compressed air and flywheels. Regenerative braking utilizes the fact that an electric motor can also act as a generator. The vehicle's electric traction motor is operated as a generator during braking and its output is supplied to an electrical load[Fig]. It is the transfer of energy to the load which provides the braking effect.

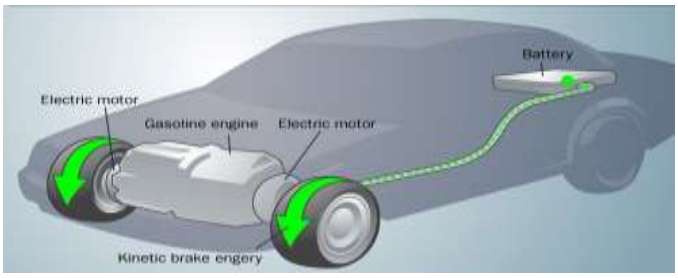

Fig -3 Regenerative braking design

Regenerative braking should not be confused with dynamic braking, which dissipates the electrical energy as heat and thus is less energy efficient.

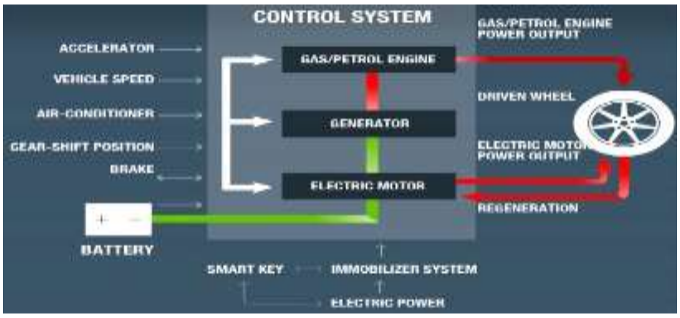

Fig -4: Mechanism conceptual diagrams

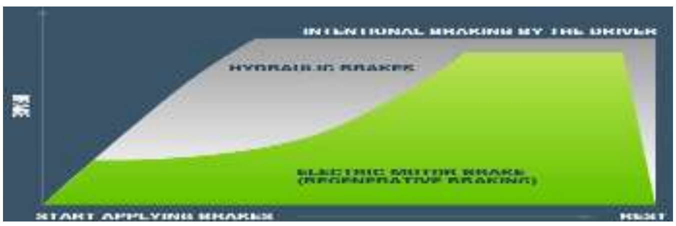

Fig -5: System control battery storage

Conceptual diagram of mechanism shows comparison characteristic curve between hydraulic and regenerative braking, while driver intentionally brakes[Fig.5]. Regenerative braking reuse kinetic energy by using its electric motor to regenerate electricity. Normally, electric motors are turned by passing an electric current through it. However, if some outside force is used to turn the electric motors, it functions as a generator and produces electricity. This makes it possible to employ the rotational force of the driving axle to turn the electric motors, thus regenerating electric energy for storage (in the battery) and simultaneously slowing the car with the regenerative resistance of the electric motors. The system control coordinates regenerative braking and the braking operation of the conventional hydraulic brakes[Fig. 5], so that kinetic energy, which is normally discarded as friction heat when braking, can be collected for later reuse in normal driving mode. Typically, driving in city traffic entails a cycle of acceleration followed by deceleration. The energy recovery ratio under these driving conditions can therefore be quite high. To take advantage of this situation, the system proactively uses regenerative braking when running the car in the low speed range. The regenerative braking effect rapidly reduces at lower speeds; therefore the friction brake is still required in order to bring the vehicle to a complete halt. The friction brake is a necessary back-up in the event of failure of the regenerative brake.

1.6 THE MOTOR AS A GENERATOR

Vehicles driven by electric motors use the motor as a generator when using regenerative braking: it is operated as a generator during braking and its output is supplied to an electrical load; the transfer of energy to the load provides the braking effect. Early examples of this system were the front-wheel drive conversions of horse-drawn cabs by Louis Antoine Krieger (1868-1951). The Krieger electric landaulet had a drive motor in each front wheel with a second set of parallel windings (bifilar coil) for regenerative braking. An Energy Regeneration Brake was developed in 1967 for the AMC Amitron. This was a completely battery powered urban concept car whose batteries were recharged by regenerative braking, thus increasing the range of the automobile. Many modern hybrid and electric vehicles use this technique to extend the range of the battery pack. Examples include the hybrids Toyota Prius, Honda Insight, and the Vectrix electric maxi-scooter.

2. LITERATURE REVIEW

The regenerative braking effect available is limited, and mechanical braking is still necessary for substantial speed reductions, to bring a vehicle to a stop, or to hold a vehicle at a standstill.

Systems use friction to counteract the forward momentum of a moving car. As the brake pads rub against the wheels (or a disc connected to the axle), excessive heat energy is also created.

This heat energy dissipates into the air, wasting up to 30% of the cars generated power[1]. Over time, this cycle of friction and wasted heat energy reduces the car's fuel efficiency. More energy from the engine is required to replace the energy lost by braking.

Hybrid gas/electric automobiles now use a completely different method of braking at slower speeds. While hybrid cars still use conventional brake pads at highway speeds, electric motors help the car brake during stop-and-go driving. As the driver applies the brakes through a conventional pedal, the electric motors reverse direction. The torque created by this reversal counteracts the forward momentum and eventually stops the car.

Khatun P, Mellor P H, Bingham C M; “Application of Fuzzy Control Algorithms for Electric Vehicle Antilock Braking/Traction Control Systems”.

In this paper[1], author P Khatun has described the preliminary research and implementation of an experimental test bench set up for an electric vehicle Antilock Braking System (ABS)/Traction Control System. Here a low cost test bench is used to develop fuzzy control algorithms. In the test bench, a brushless permanent magnet motor is used which is driven by a power inverter and is controlled by a DSP controller. The PM motor is connected to a three phase induction motor which is used to simulate actual road load. Simulation studies are employed to derive an initial rule base that is then tested on an experimental setup representing the dynamics of a braking system. Fuzzy logic membership functions are described for parameters like slip and observed load torque. On basis of the fuzzy rules set, the output torque demand function is derived. By using these fuzzy rules, the slip ratio is limited to 0.1 for dry surfaces. According to the fuzzy rules, the algorithm identifies unstable regions in the graph of torque- slip and reduces the slip. Eventually the slip stabilizes around 0.25 and the control region extends up to 0.35 for a dry road surface. The results indicate that ABS substantially improves performance and has potential for optimal control of wheels under difficult driving conditions.

Dixon J, Ortuzar M; “Regenerative Braking for an Electric Vehicle using Ultra capacitors and Buck-Boost Converter”.

In this paper[2] describes a method to recover energy during braking by using a system of Buck-Boost converter and an Ultra capacitor bank. The buck-boost converter is made using IGBTs and the entire system has been tested on a Chevrolet electric truck. Using a control strategy, the maximum current going to the battery, minimum and maximum voltages of the Ultra capacitor bank are set. The control strategy uses a reference table and has inputs like the state of charge of the battery, vehicle speed, load current etc. A strategy is also given which uses sensors to determine the wheel decelerations so that the converter can be used optimally to recover maximum energy. Results are shown using graphs of battery current, voltage and the capacitor bank voltage. The graphs indicate the proper working of the buck-boost converter. This designed system allows higher acceleration and proper decelerations with minimal loss of energy and minimal degradation of the battery pack.

Xiufang Y, Xin Z; "Study of control logic for Automobile Anti-lock BrakingSystem".

In this paper[3], to find the ideal logic principle for antilock braking, Simulink is used to create the state flow model for the ABS electronic control unit. The state flow diagram for a four channel ABS system is also charted out. The control logic uses logic threshold control method. It uses parameters like reference slip ratio and angular speed threshold to calculate the optimum braking pressure to be applied. The acceleration of the wheel is measured and plotted. When the acceleration is negative, i.e. deceleration is taking place, the logic keeps on monitoring the value till it is of lower value. When it increases, the logic detects when the wheel is about to lock up. This unstable region is detected and the braking pressure is now adjusted so that this unstable region is not encountered again and the wheel is decelerated without the wheel being locked up. A method of alternate boost pressure and decompress is employed so that the vehicle can stay in the stable region for as long as possible and the optimum braking pressure can be applied.

Xu C, Sha L, Cheng K; "Simulation of Integrated Controller of the Anti-Lock Braking System".

In this paper[4], the simulation of a braking system is done by using an integrated controller consisting of a PID controller and a finite state machine. The parameters given to the system are wheel speed, vehicle speed, slip and braking distance. According to these parameters, the braking pressure is controlled. The drawback is that only a single wheel model is used to simulate the braking conditions. The results are compared when the slip ratio is the control parameter and when the integrated controller is used. The use of integrated controller gives a much better control over the slip ratio and the braking pressure can be stabilised to a stable value with much less time than without the controller and the braking distance too reduces significantly.

PiroddiL, Tanelli M; "Real time identification of tire-road frictionconditions".

In his work[5] aims at the real-time estimation of the wheel slip value corresponding to the peak of the tire–road friction curve, in order to provide anti-lock braking systems (ABS) with reliable information on its value upon activation. Different techniques based on recursive least squares and the maximum likelihood approach are used for friction curve fitting and their merits and drawbacks thoroughly examined. Also, optical and pressure sensors are used for measuring the brake pad pressure and working. Their output is then filtered and made sure that there is phase coherence between all signals. The algorithm selects the wheel which has the relatively fastest speed among the four wheels, i.e. the wheel which has the lowest longitudinal slip. The estimated vehicle speed is then found out according to the algorithm. Also a comparison is made between the value of coefficient of friction μ obtained through estimation and its actual value.

Chuanwei Z, Zhifeng B; "Study on Regenerative Braking of ElectricVehicle".

In this paper[6], a control scheme for a constant regenerative current is given based on the analysis of several regenerative braking schemes. The three main control strategies discussed are maximum regenerative efficiency control, maximum regenerative power control and the constant regenerative current control. Analysis is performed for two modes, the continuous current mode and the discrete current mode. Using the above analysis, a formula for regenerative efficiency of a control scheme is derived. The analysis of the braking system is done to find out two aspects, the electric loop efficiency and the regenerative energy efficiency. Using the results of the analysis, the paper concludes that the constant regenerative current control scheme is better than the maximum regenerative power control scheme and the maximum regenerative efficiency control scheme. Also, the paper concludes that the used method gives a higher regenerative braking efficiency and better control performance.

Xue X, Cheng K; "Selection of Electric Motor Drives for ElectricVehicles".

In this paper[7], six types of drive systems for electric motor drives for electric vehicles are discussed. The six types are compared with respect to cost, cooling, fault tolerance, safety, efficiency, weight, maximum speed and reliability. The six systems discussed are- conventional type, transmission-less type, cascade type, in-wheel type with reduction gears, in-wheel direct drive type and four wheel direct drive type. The drives which are compared are the Brushed DC motor drives, Induction motor drives, Permanent Magnet Brushless DC Motor Drives and the switched reluctance motor drives. After analysis of each system and comparison, the paper concludes that the switched reluctance motor drive is the best choice for driving an electric vehicle even though the brushed dc motor drive is most widely used for an electric vehicle.

3. PROBLEM FORMULATION

In the present work Regenerating braking system made of different material and different component has been analyzed for increasing the efficiency of the different vehicle. To produce a RBS model, an e-bike conversion kit has been bought from Hong Kong and an alternator was selected to be installed in the bicycle. The results and calculations show that both devices can function properly, that means both devices can form recovery energy to charge battery during braking. During the recovery energy working, brake effects are formed to decelerate the bike.

4. METHODOLOGY

4.1 Material Procurement Andfabrication

- Electric motor AC/220V 0.5hp.

- Transformer – center tap (24V).
- Dynamo. (0 - 48 V).
- Electromagnetic clutch.
- Two Pole switch.
- Relay - Electromagnetic type.
- Rectifier.
- Bearing.
- Wheel and Tire.
- Sliding Switch.
- Sprocket Chain assembly.
- And many more as per requirement……

4.2 Electromagnetic Clutch

Electromagnetic clutches[13]operate electrically, but transmit torque mechanically. This is why they used to be referred to as electro-mechanical clutches. Over the years EM became known as electromagnetic versus electro mechanical, referring more about their actuation method versus physical operation.

4.3 Construction

A horseshoe magnet (A-1) has a north and South Pole. If a piece of carbon steel contacts both poles, a magnetic circuit is created. In an electromagnetic cultch, the north and South Pole is created by a coil shell and a wound coil. In a clutch, (B1) when powers applied, a magnetic field is created in the coil (A2 blue). This field (flux) overcomes an air gap between the clutch rotor (A2 yellow) and the armature (A2 red). This magnetic attraction pulls the armature in contact with the rotor face. The frictional contact, which is being controlled by the strength of the magnetic field, is what causes the rotational motion to start. The torque comes from the magnetic attraction, of the coil and the friction between the steel of the armature and the steel of the clutch rotor. For many industrial clutches, friction material is used between the poles. The material is mainly used to help decrease the wear rate, but different types of material can also be used to change the coefficient of friction (torque for special applications). For example, if the clutch is required to have an extended time to speed or slip time, a low coefficient friction material can be used and if a clutch is required to have a slightly higher torque (mostly for low rpm applications), a high coefficient friction material can be used.

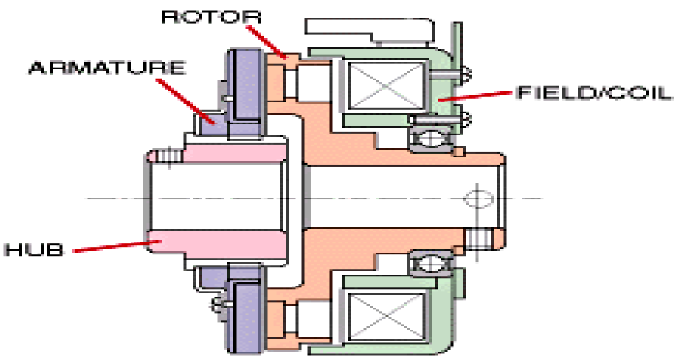

Fig –6: Electromagnetic clutch

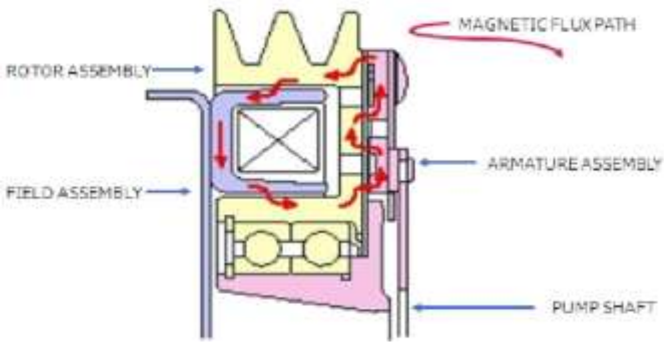

Fig – 7: Cut - off view of electromagnetic clutch

In a clutch, the electromagnetic lines of flux have to pass into the rotor, and in turn, attract and pull the armature in contact with it to complete clutch engagement. Most industrial clutches use what is called a single flux, two pole design (A-2). Mobile clutches of other specialty electromagnetic clutches can use a double or triple flux rotor (A-4). The double or trip flux refers to the number of north/south flux paths (A-6), in the rotor and armature. These slots (banana slots) (A-7) create an air gap which causes the flux path to take the path of least resistance when the faces are engaged. This means that, if the armature is designed properly and has similar banana slots, what occurs is a leaping of the flux path, which goes north south, north south (A-6). By having more points of contact, the torque can be greatly increased. In theory, if there were 2 sets of poles at the same diameter, the torque would double in a clutch. Obviously, that is not possible to do, so the points of contact have to be at a smaller inner diameter. Also, there are magnetic flux losses because of the bridges between the banana slots. But by using a double flux design, a 30%-50% increase in torque, can be achieved, and by using a triple flux design, a 40%-90% in torque can be achieved. This is important in applications where size and weight are critical, such as automotive requirements.

The coil shell is made with carbon steel that has a combination of good strength and good magnetic properties. Copper (sometimes aluminum) magnet wire, is used to create the coil, which is held in shell either by a bobbin or by some type of epoxy/adhesive.

4.4 BASIC OPERATION

The clutch has four main parts: field, rotor, armature, and hub (output) (B1). When voltage is applied the stationary magnetic field generates the lines of flux that pass into the rotor. (The rotor is normally connected to the part that is always moving in the machine.) The flux (magnetic attraction) pulls the armature in contact with the rotor (the armature is connected to the component that requires the acceleration), as the armature and the output start to accelerate. Slipping between the rotor face and the armature face continues until the input and output speed is the same (100% lockup). The actual time for this is quite short, between 1/200th of a second and 1 second.

Disengagement is very simple. Once the field starts to degrade, flux falls rapidly and the armature separates. One or more springs hold the armature away from the rotor at a predetermined air gap.

4.5 VOLTAGE/CURRENT - AND THE MAGNETIC FIELD

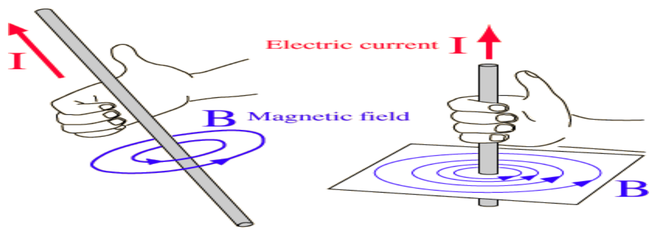

Fig- 8: Fleming's right hand thumb rule

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”. (V-1) The strength of the magnetic field can be changed by changing both wire size and the amount of wire (turns). EM clutches are similar; they use a copper wire coil (sometimes aluminum) to create a magnetic field.

The fields of EM clutch can be made to operate at almost any DC voltage, and the torque produced by the clutch or brake will be the same, as long as the correct operating voltage and current is used with the correct clutch. If a 90 volt clutch, a 48 volt clutch and a 24 volt clutch, all being powered with their respective voltages and current, all would produce the same amount of torque. However, if a 90 volt clutch had 48 volts applied to it, this would get about half of the correct torque output of that clutch. This is because voltage/current is almost linear to torque in DC electromagnetic clutches.

A constant power supply is ideal if accurate or maximum torque is required from a clutch. If a non regulated power supply is used, the magnetic flux will degrade, as the resistance of the coil goes up. Basically, the hotter the coil gets the lower the torque will be, by about an average of 8% for every 20°C. If the temperature is fairly constant, but there may not be enough service factor in your design for minor temperature fluctuation. Over-sizing, the clutch would compensate for minor flux. This will allow the use a rectified power supply which is far less expensive than a constant current supply.

Based on $V = I \times R$, as resistance increases available current falls. An increase in resistance, often results from rising temperature as the coil heats up, according to: $R_f = R_i \times [1 + \alpha_{Cu} \times (T_f - T_i)]$.

Where,

R_f= final resistance, R_i= initial resistance,

α_{Cu} = copper wire’s temperature coefficient of resistance, 0.0039 °C-1, T_f= final temperature, and T_i = initial temperature.

4.6 ENGAGEMENT TIME

There are actually two engagement times to consider in an electromagnetic clutch. 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 rotor. Magnetic lines of flux diminish quickly in the air. The further away the attractive piece is from the coil, the longer it will take for 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 rotor. 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 rotor will create a larger air gap which will change the engagement time of the clutch. 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 get solder.

4.7 TORQUE

Burnishing can affect initial torque of a clutch but there are also factors that affect the torque performance of a clutch in an application. The main one is voltage/current. In the voltage/current section it was shown why a constant current supply is important to get full torque out of a clutch.

When considering torque, is dynamic or static torque more important? For example, if a machine is running at a relatively low rpm (5 – 50 depending upon size) then dynamic torque is not a consideration since the static torque rating of the clutch will come closest to where the application is running. However, if a machine is running at 3,000rpm and the same full torque is required the result will not be the same because of the difference between static and dynamic torques. Almost all manufacturers put the static rated torque for their clutches in their catalog. If a specific response time is needed the dynamic torque rating for a particular clutch at a given speed is required. In many cases, this can be significantly lower. Sometimes 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 clutch.(T-1).

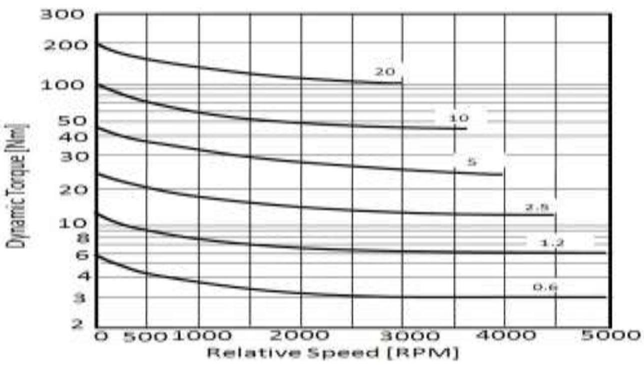

Fig- 9: Dynamic torque versus relative speed graph

4.8 OVER-EXCITATION

Over-excitation is used to achieve a faster response time. It's when a coil momentarily 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 3 times faster response time. For example, a clutch coil that was rated for 6 volts would need to put in 90 volts to achieve the 3 times factor.

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

4.9 DYNAMO

An AC generator or dynamo is a machine which produces AC from mechanical energy. Actually, it is an alternator which converts one form of energy into another[14].

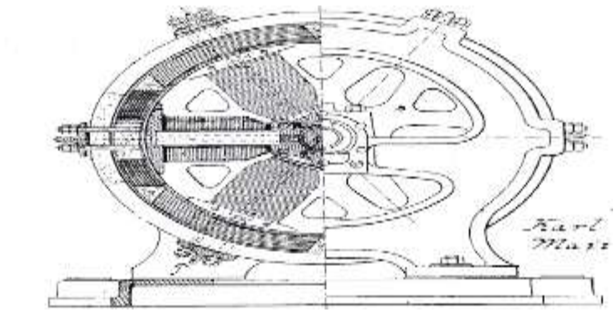

Fig- 10: Dynamo

4.10 Description

The dynamo uses rotating coils of wire and magnetic fields to convert mechanical rotation into a pulsing direct electric current through Faraday's law. A dynamo machine consists of a stationary structure, called the stator, which provides a constant magnetic field, and a set of rotating windings called the armature which turn within that field. On small machines the constant magnetic field may be provided by one or more permanent magnets; larger machines have the constant magnetic field provided by one or more electromagnets, which are usually called field coils.

The commutator was needed to produce direct current. When a loop of wire rotates in a magnetic field, the potential induced in it reverses with each half turn, generating an alternating current. However, in the early days of electric experimentation, alternating current generally had no known use. The few uses for electricity, such as electroplating, used direct current provided by messy liquid batteries. Dynamos were invented as a replacement for batteries. The commentator is a set of contacts mounted on the machine's shaft, which reverses the connection of the windings to the external circuit when the potential reverses, so instead of alternating current, a pulsing direct current is produced.

5. CONCLUSION

In presented model for study and analyzing, It has to be find out that the increase in the efficiency of a vehicle by reducing the fuel consumption and the energy dissipated in overcoming the friction provided by the braking action.

To build a circuit for Anti-Lock Braking System which will prevent the skidding of wheels during hard braking and keep the control of the vehicle at all times with the driver in Electric Vehicles by keeping the slip ratio in the control region. By using a Regenerative Braking sub-system which will recover lost energy in the circuit and give it back to the battery, and also analyses the performance of the entire system to check its utility and confirm that Anti-lock Braking System along with regeneration makes an electric vehicle easier and safer to use as well as makes it more energy efficient. Electrics locomotives use regenerative braking 25- 40% of electric power to be returned to the power system. The required regenerative braking forces can be obtained in a wide range, with possibilities returned energy to energy supply in a high-speed range and stored energy – in a low-speed range. All diesel electric powered locomotives must use hybrid traction technology for fuel economy and environmental aspects. Hybrid traction technology locomotives can use regenerative braking of high-speed and a low speed range. The regenerative braking power can be possibly use in diesel electric locomotives for starting engine, acceleration, and operation mode.

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