DESIGN AND FABRICATION OF REGENRATIVE BRAKING SYSTEM

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ABSTRACT

As in today's world, where there are energy crises and therefore the resources are depleting at a better rate, there's a requirement of specific technology that recoversthe energy, which gets usually wasted. So, just in case of automobiles one among these useful technologies is that the regenerative braking system. Regenerative braking is an energy recovery mechanism that slows a vehicle or object by converting its Kinetic Energy (K.E) into a form which will be either used immediately or stored until needed. Using regenerative braking system in automobiles enables us to recover the K.E. of the vehicle to some extent that's lost during the braking process. The converted K.E. is stored for future use or is fed back to the facility system of the vehicle. This energy is often stored during a battery or bank of capacitors for later use. Energy also can be stored with the assistance of a rotating flywheel which is one among the foremost inexpensive and effective method of storing and regenerating power. The present invention provides energy-storing regenerative braking system by transmitting the flywheel force as a torque tending to oppose the forward rotation of a wheel on applying the brakes. A brake-pad assembly, mounted concentrically with the hub of a ground-engaging wheel, is actuated upon braking to supply frictional engagement between the hub and clutch mechanism, while applying a decelerating torque to the wheel. The special braking mechanism is selectively held in position by a rider-controlled clutch mechanism, to accumulate energy over several braking events. Vehicles driven by electric motors use the motor as a generator when using regenerative braking and its output is supplied to an electrical load. The transfer of energy to the load provides the braking effect and regenerate's power.

Keywords: Regenerative Braking, Generator, Brake pad, Energy Recovery, Flywheel

CHAPTER 1
INTRODUCTION

In recent years, there is the lack of reliable alternative energy sources, increasing efficiencyand reducing exhaust gas emissions has become the focus of the modern automotive research. Commercial vehicles such as refuse trucks and delivery vehicles lose a tremendous amount of kinetic energy during frequent braking and constant drive at low speeds on designated city routes, which results in higher fuel consumption and Green House Emission Gas (GHG) emission than other on-road vehicles. Numerous attempts have been made to improve type of vehicles. The technological combination of Exhaust Gas Recirculation (EGR) and Diesel Particulate Filter (DPF) after treatment is one of the effective ways to solve the vehicle emission,especially for NOx and soot. However, this method is not able to reduce the GHG emission since the low temperature combustion of this technology results in increasing the fuel penalty. Sacrificing engine efficiency in exchange for reduced pollutants cannot fundamentally solve the energy crisis. In order to achieve overall GHG reduction targets, a strong reduction is needed particularly for commercial vehicles.

Regenerative energy technology is one of the key features of electrified vehicles. It allows the vehicle to capture a tremendous amount of the kinetic energy lost during braking or decelerating for reuse. That is saying, energy recovery technology can significantly bring down the energy consumption of electrified vehicle, particularly in urban operated route. Generally, there are two regenerative energy approaches which have been applied to commercial vehicles: Regenerative Braking System and Boost Recuperation System. The former is usually applied in series hybrid System. The former is usually applied in series hybrid architecture; the latter in the parallel architecture. The **regenerative braking system** is equipped in the driven axle to recuperate the braking energy loss. The **boost recuperation system** is parallelly coupled with the mechanical propulsion system to recuperate kinetic energy during the deceleration process. Both technologies allow commercial vehicles to have a significant improvement of reducing fuel consumption as well as emissions. However, few researchers have addressed the regenerative energy rate of hybrid commercial vehicles. The more energy the regenerative braking recuperates; the less fuel is consumed. Typical hybrid commercial vehicles are generally designed as rear drive and the regenerative braking system is equipped in rear driven axle(s) to recuperate the braking energy loss. Due to the change of the center gravity in the vehicle under different load conditions, braking energy loss may vary in both front and rear axles.

WORKING PRINCIPLE

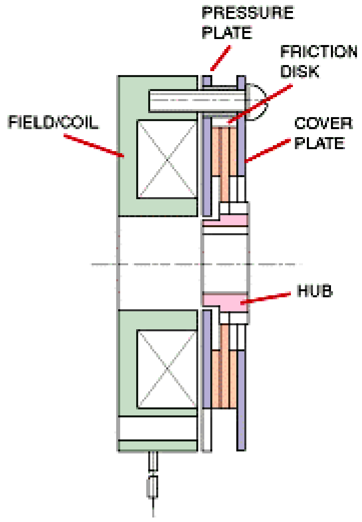
Regenerative braking is an energy recovery mechanism that slows down a moving vehicle or object by converting its kinetic energy into a form that can be either used immediately or stored until needed. In this mechanism, the electric traction motor uses the vehicle's momentum to recover energy that would otherwise be lost to the brake discs as heat. This method contrasts with conventional braking systems. In those systems, the excess kinetic energy is converted to unwanted and wasted heat due to friction in the brakes, or with rheostatic brakes, where the energy is recovered by using electric motors as generators but is immediately dissipated as heat in resistors. In addition to improving the overall efficiency of the vehicle, regeneration can significantly extend the life of the braking system as the mechanical parts will not wear out quickly.

Types of Regenerative Braking System

There are multiple methods of energy conversion in Regenerative Braking System including spring, flywheel, electromagnetic and hydraulic. More recently, an electromagnetic-flywheel hybrid Regenerative Braking System has emerged as well. Each type of Regenerative Braking System utilizes a different energy conversion or storage method, giving varying efficiency and applications for each type. The Types are as follows:

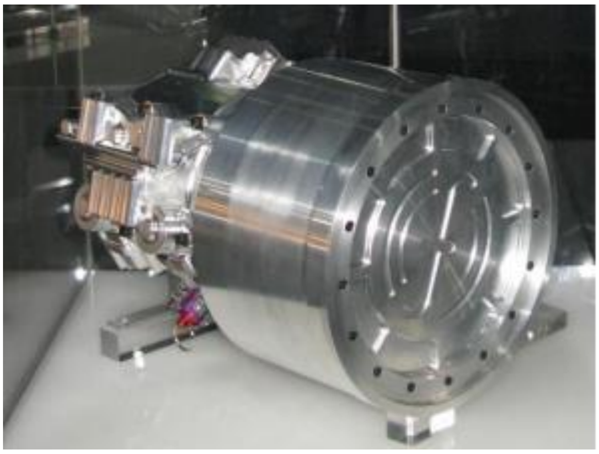
Electromagnetic

In Electromagnetic system, the drive shaft of the vehicles is connected to an electric generator, which uses magnetic fields to restrict the rotation of the drive shaft, slowing the vehicle and generating electricity. In the case of electric and hybrid vehicles, the electricity generated is sent to the batteries, giving them a recharge. In gas powered vehicles, the electricity can be used to power the cars electronics or sent to a battery where it can later use to give the vehicle an extra boost of power. This technique is currently used in some Le Mans Prototype racing cars.



Flywheel

In Flywheel Regenerative Braking System, the system collects the kinetic energy of the vehicle to spin a flywheel that is connected to the drive shaft through a transmission and gear box. The spinning flywheel can then provide torque to the drive shaft, giving the vehicle a power boost.



A KERS flywheel used in Formula car

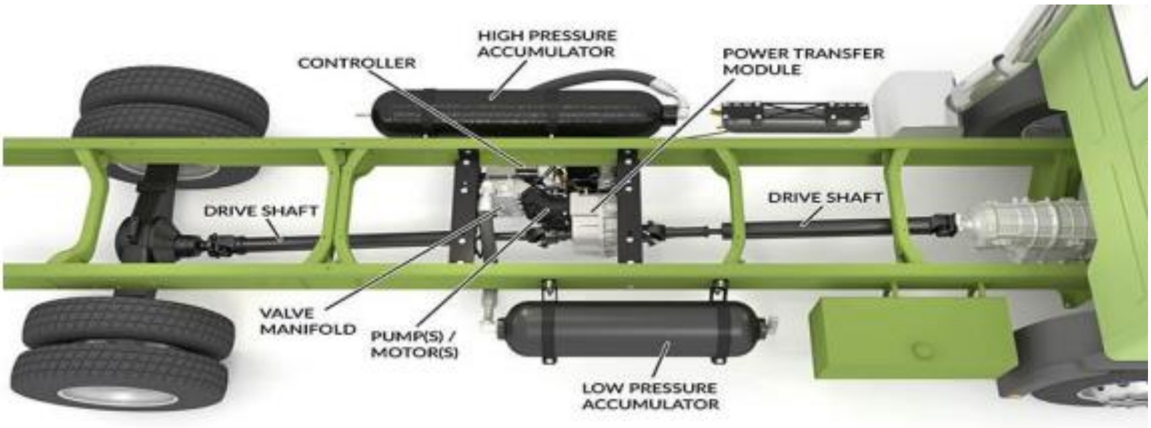
Spring

The spring-loaded regenerative braking system is typically used on human powered vehicles, such as bicycles or wheelchairs. In spring Regenerative Braking System, a coil or spring is winded around a cone during braking to store energy in the form of elastic potential. The potential can then be returned to assist the driver while going uphill or over rough terrain.

: A bike equipped with torsional spring for RBS

Hydraulic

The Hydraulic Regenerative Braking System slows the vehicle by generating electricity which is then used to compress a fluid. Nitrogen gas is often chosen as the working fluid. Hydraulic Regenerative Braking Systems have the longest energy storage capability of any system, as compressed fluid does not dissipate energy over time. However, compressing gas with a pump is a slow process and severely limits the power of the hydraulic Regenerative Braking System.



A hydraulic storage system used in trucks

Applications

- Kinetic energy recovery mechanism.
- Regenerative braking systems are used in electric elevators and crane lifting motors.
- Also used in electric and hybrid cars, electric railway vehicles, electric bicycles, etc.
- Could be used in an industry that uses a conveyor system to move material from one workstation to another and halts at a certain distance after a prescribed interval.

Advnatages

- Better Performance.
- Cuts down on pollution related to supply generation.
- Efficient Fuel Economy–The fuel consumption is reduced, dependent on the machine cycles, vehicle design, automation control plan, and the individual component's efficiency. Reduced wear and tear of Engines.
- Reduced Brake Wear– Cutting down the replacement brake linings cost, the cost of labor for installation, and machine downtime.
- Reduced emissions–Cuts down on pollution related to power generation, engine decoupling reduces the total number of revolutions and thus engine emissions.
- Smaller accessories – reducing fuel tank size and thus the weight of the vehicle.

Dis-advanatages

In practice, the regenerative brakes take the time to slowdown a vehicle, hence most of the vehicles that use them, also have friction brakes working alongside. This is one reason why regenerative brakes don't save 100 percent of braking energy.

- High cost of components, engineering, and installation.
- As compared to dynamic brakes, regenerative brakes are needed to match the power produced by the input supply (D.C. and A.C. supplies), and it is achieved only with the help of development of power electronics.
- A Regenerative braking safety is limited when the batteries storing the recovered energy are 100 % charged. The excessive charge would cause the voltage of the battery to rise above a safe level.
- Added maintenance – Dependent on the complexity of the design.

CHAPTER 02

LITERATURE SURVEY

J.A.A. Hartley, R.G. McLellan, J. Richmond, A.J. Day, I.F. Campean

Regenerative braking systems for electric vehicles enable the range of the vehicle to be extended, but experience has indicated that the benefits are not always as great as might be expected because of inefficiencies in the power conversion processes. Extra mass and cost can often combine to limit the financial viability of a regenerative braking system.

To measure the efficiency of a regenerative braking system, the Tata Ace Electric Vehicle has been tested on a hub-mounted chassis dynamometer, and instrumented to enable calculations for plug-to-wheel efficiency and total range (compared to the same vehicle with little or no regenerative braking).

Previously the Tata Ace EV has been tested on the road to optimise the regenerative braking settings for energy recovery. The vehicle's motor controller allows the field map of the motor to be adjusted, giving full control over the deceleration of the vehicle when the accelerator pedal is released (and subsequent levels of recovered energy). By mounting the vehicle to a calibrated dynamometer, these settings can be validated by monitoring range and efficiency under controlled conditions. The vehicle has been driven at constant speeds and also on the urban section of the New European Drive Cycle, with results presented here.

M.T. Von Srbik, R.F. Martinez-Botas, 2012

Regenerative (REGEN) braking is an effective method to increase the driving range of Hybrid Electric Vehicles (HEV) by minimising vehicle fuel consumption (1). The brake energy generated in a deceleration event can be stored by ways of numerous technologies. Those have thus far been developed to different degrees. Many major vehicle manufacturers have been focusing on energy recovery by operating an electric machine as a generator, storing the recaptured energy in batteries. The reason for this is a combination of the state of technology, experience in component control and integration and established collaborations between companies supplying these components.

The concept of REGEN braking to extend driving range has been widely analysed in the literature, but not as a concept also heavily determined by vehicle design. Regenerative braking efficiency is a measure of how effective the individual components are in recapturing (otherwise lost) braking energy. Hence, it is the percentage of how much energy is recaptured from the energy consumption caused by a specific driving style at any point in time.

The aim is to regenerate as much energy as possible while preserving vehicle stability and allowing effective operation of control systems. In this paper the notion of regenerative braking efficiency is defined as the ratio of regenerated energy to required brake energy, according to Equation

The way the vehicle responds to the load profile depends on vehicle configuration, component capabilities and environmental conditions. Since road and weather conditions cannot be influenced, vehicle designers can only aim to optimise the vehicle configuration and components to suit particular driving styles in an optimal way.

When evaluating how efficiently the vehicle design is in meeting driver requests, dynamic modelling of the subcomponents is necessary. This work focusses on REGEN *system level* performance unlike various other models which assess *individual* component behaviour within *specific* vehicle configurations.

This paper presents and compares simulation with measurement results of REGEN efficiency and energy economy. The capabilities of the simulation environment are demonstrated by defining base- vehicle comprising of a power-split powertrain configuration, an internal combustion engine (ICE), a permanent magnet AC Motor and Generator (M/G), a Nickel Metal Hydride (NiMH) battery and a Continuously Variable Transmission (CVT).

The simulation flow follows energy conversion from the wheel to the storage device. As shown in Figure 1.1, the energy flux to the REGEN component chain stems from a deceleration request from the driver. Losses associated with the energy conversions in the system occur to different degrees at each stage. These include: speed level, load magnitude, temperature, etc

Jefferson and Ackerman (1996)

The paper describes a flywheel based energy storage system designed as a standalone propulsion unit or the main propulsion unit in a hybrid setup, for a railcar application. The system comprised of a steel flywheel and a mechanical variator (i.e., CVT) for matching the speeds of output drivetrain and the flywheel and also in order to affect power transfer from/to the flywheel by the variation of the CVT ratio. The Flywheel of flywheel energy storage (FES) could be charged by an onboard or external power source (battery, engine etc.) en-route or at stops, and by regenerative braking and the charged FES was used to propel the railcar. The system was tested on a laboratory test rig and successfully demonstrated on a minitram. The test rig setup used a composite flywheel, a KOPP CVT and an induction motor as power source (simulating vehicle). Open and closed loop tests were used to understand CVT control and gauge system performance. The minitram system used a steel flywheel of 4 MJ storage capacity. The results from the Minitram system showed that on using 'flywheel only' propulsion, the energy savings were around 24%. It was concluded that having a hybrid powertrain with a flywheel-variator system and a compact constant power source like an Internal Combustion Engine (ICE) or Fuel Cell would result in a fuel efficient vehicle of large range.

Sayed Nashit, Sufiyan Adhikari, Shaikh Farhan, Srivastava Avinash and Amruta Gambhire, 'Design, Fabrication and Testing of Regenerative Braking Test Rig for BLDC Motor', 2016, 1881-84.

In this paper a test bench for testing of regenerative braking capability of a Brushless DC Motor is design and then fabricated. The project creates awareness to engineers towards energy efficiency and energy conservation. It concludes that the regenerative braking systems are more efficient at higher speed and it cannot be used as the only brakes in a vehicle. The definite use of this technology described as in the project in the future automobiles can help us to a certain level to sustainable and bright future of energy efficient world as a part of power that is lost can be regained by using the regenerative braking system.

Tushar L. Patil, Rohit S. Yadav, Abhishek D. are, Mahesh Saggam, Ankul Pratap, 'Performance Improvement of Regenerative braking system', International Journal of Scientific & Engineering Research Volume 9, Issue 5, (2018). 2229-5518.

In this paper the techniques to increase the efficiency of the regenerative braking system is mentioned. The technique mentioned was to reduce the weight of the automobile which increase performance, using super capacitor also improves the conversion rate of energy in regenerative braking system, making the automobile compact also tends to increase the efficiency of the system.

C. Jagadeesh Vikram, D. Mohan Kumar, Dr. P. Naveen Chandra, 'Fabrication of Regenerative Braking System', International Journal of Pure and Applied Mathematics Volume 119, (2018). 9973-9982.

In this paper the Fabrication process on the Regenerative Braking System had been implemented as per the prescribed measures has been taken and the future enhancements should be processed on basis of the need of the study. The Implementation of the regenerative braking system be quite essential in automotive transportation with maximized performance in braking.

A. Eswaran, S Ajith, V Karthikeyan, P Kavin, S Loganandh, 'Design and Fabrication of Regenerative Braking System', International Journal of Advance Research and Innovative Ideas in Education-Vol-4 Issue-3 (2018). 2395-4396.

In this paper the regenerative braking system used in the vehicles satisfies the purpose of saving a part of the energy lost during braking. Also, it can be operated at high temperature range and are efficient as compared to conventional braking system. Regenerative braking systems require further research to develop a better system that captures more energy and stops faster. All vehicles in motion can benefit from these systems by recapturing energy that would have been lost during braking process. The use of more efficient systems could lead to huge savings in the economy of any country**.**

Ketan Warake, Dr. S. R. Bhahulikar, Dr. N. V. Satpute, 'Design & Development of Regenerative Braking System at Rear Axle', International Journal of Advanced Mechanical Engineering. Volume 8, Number 2 (2018), 2250-3234. In this paper the regenerative braking system used in the vehicles satisfies the purpose of saving a part of the energy lost during braking. The regenerative braking system is designed to partially recover the battery charge wasted in braking of the vehicle. The energy is converted into heat by friction brake which is dissipated to the environment. This Energy is utilized to rotate the rotor of generator converting mechanical energy of wheels into useful charge of battery. The regenerative braking system cannot be used as main braking system of vehicle as it cannot bring the vehicle to rest. Experimentation shows that minimum 11% battery energy can be recovered using the regenerative braking system which would otherwise be wasted to heat in friction brakes. Hence the distance travelled between two successive charging requirements can be increase to 10 to 15 % using this regenerative braking, when installed in actual vehicles.

Siddharth K Sheladia, Karan K Patel, V raj D Savalia, Rutvik G Savaliya, 'A Review on Regenerative Braking Methodology in Electric Vehicle', International Journal of Creative Research Thoughts, Volume 6, Issue 1 (2018). 2320-2882.

In this paper it is mentioned that Regenerative braking can save up to 25% to 28% of waste energy. The systems have been enhanced with advanced power electronic components such as ultra-capacitors, DC-DC converters (Buck-Boost) and flywheels. Ultra-capacitors, which help improve the transient state of the car 13 during start up, provide a smoother charging characteristic of the battery and improve the overall performance of the electric vehicle system. Buck-boost converters help maintain power management in regenerative braking systems, such as boosting acceleration. Finally, flywheels are used to improve the power recovery process through automotive wheels. We have learnt the recommendation and conclusion from the previous researcher and then we have utilized in our experiment. We have also changed the components and methods as the researcher suggested to make the experiment more practical and efficient.

Khushboo Rahim, and Mohd. Tanveer, 'Regenerative Braking System: Review Paper', International Journal on Recent and Innovation Trends in Computing and Communication, 5.5 (2018), 736-39.

In this paper the advantages of regenerative braking system over conventional braking system has been mentioned. Regenerative braking systems can work at the high temperature ranges and are highly efficient when compared to the conventional brakes. They are more effective at higher momentum. The more frequently a vehicle stops, the more it can benefit from this braking system. Large and heavy vehicles that movies at high speeds builds up lots of kinetic energy, so they conserve energy more efficiently. It has broad scope for further advancements and the energy conservation. Yimin Gao and Mehrdad Ehsani. SAE Transactions. Vol. 110, Section 7

JOURNAL OF PASSENGER CARS: ELECTRONIC AND ELECTRICAL SYSTEMS (2001), pp. 576-582 (7 pages). Published By: SAE International.

In paper proposed electronic braking system for EV and HEV integrates the regenerative braking, automatically controlled mechanical braking together. This braking system can recover most of braking energy. Therefore, the energy efficiency of the vehicle can be significantly improved. Meanwhile, the braking system can realize wheel antilock function by controlling the electric motor and/or the electrically powered braking actuators