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Regenerative Braking System

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ABSTRACT:

When riding a vehicle, a great amount of kinetic energy is lost when braking, making start up fairly strenuous. The goal of our project was to develop a product that stores the energy which is normally lost during braking, and reuses it to help propel the rider when starting. This was accomplished with a Generator fitted with rubber wheel whose parameters were optimized based on engineering, consumer preference, and manufacturing models. The resulting product is one which is practical and potentially very profitable in the market place. In this paper we study how to use the heat energy by lightening the LED which is lost by applying brakes. After applying brake on the wheel the kinetic energy of wheel is transferred to the rubber wheel attached to the generator which is then transformed in the electrical energy. This electrical energy is used to lightening the LED. We can also use this energy for other purpose by storing in the battery. Our objective is to save the energy lost during brake application in the vehicles with regenerative braking model and to convert kinetic energy of flywheel in DC current with the help of Dynamo.

INTRODUCTION

A regenerative brake is an apparatus, a device or a system which allows a vehicle to recapture part of the kinetic energy that would otherwise be lost in the form of heat during brake and make use of that power either by storing it for future use or feeding it back into a power system for other vehicle uses.

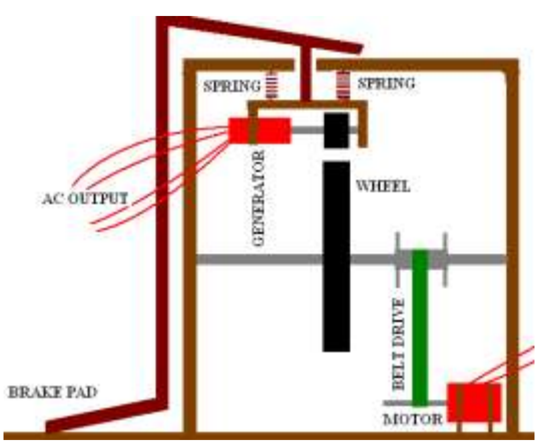


Figure.1
Schematic diagram of regenerative system

Regenerative braking should not be confused with dynamic braking, which dissipates the recaptured electrical energy as heat. In that respect, dynamic braking behaves much like an electromagnetic brake, which employs eddy current losses to produce the braking effect. None of these methods of braking are capable of completely stopping a vehicle, and therefore are not a substitute for friction brakes.

Regenerative braking is used on hybrid gas/electric automobiles to recoup some of the energy lost during stopping. This energy is saved in a storage battery and used later to power the motor whenever the vehicle is in electric mode.

Regenerative braking does more than simply stop the vehicle. 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 vehicle rotates in reverse direction, it becomes an electric generator or dynamo. This generated electricity is fed into a chemical storage battery and used later to power the vehicle at city speeds.

Regenerative brakes are a form of dynamo or generator, during brake the dynamo's rotor slows as the kinetic energy is converted to electrical energy through electro-magnetic induction.

It is estimated that regenerative braking systems in vehicles currently reach 25%-35% electric generation efficiency, with most of the remaining energy being released as heat; the actual efficiency depends on numerous factors, such as the state of charge of the battery, how many wheels are equipped to use the regenerative braking system.

The system is no more efficient than conventional friction brakes, but reduces the use of contact elements like brake pads, which eventually wear out. Traditional friction-based brakes must also be provided to be used when rapid, powerful braking is required, as well as to hold the vehicle stationary.

Since the crisis of the price of fossil oil on the world market rising higher almost every time directly affects to Thailand, making most vehicle users turning the behavior to utilize low-priced alternative energy such as Gasohol, Biodiesel, Liquid Petroleum Gas (LPG) or Compressed Natural Gas (CNG). Especially, LPG and CNG are mostly popular because of their cheap prices per unit and the inexpensive budget of installation. However, the concerns about emission problem like carbon dioxide quantity or greenhouse effect still continuously take place. One of the measures of reducing traffic emission is to propel to use natural friendly vehicles for instance Battery electric vehicle (BEV). Since EV is still expensive and not widespread, the expected tendency of using the EV in Thailand should be alike the utilization LPG or CNG being alternative energy in that the conventional internal combustion engine used cars are modified to be EV.

Regenerative braking system is a significant part of EV, which is responsible for recovering potential and kinetic energy during vehicle braking and storing it into energy storage device instead of dissipating in heat form by fiction brake. The stored energy is utilized to propel vehicle [1] or to supply vehicle’s electrical Application. Regenerative braking system is an effective means to prolong the driving range of EV and also to improve fuel consumption rate of Hybrid Electric Vehicle (HEV), particularly for the vehicle that mainly runs in high frequent stop and go condition such as city traffic [2]. The past researches have suggested that an HEV’s driving range in urban can be extended between 14% to 40% by using regenerative brake [3].

The idea behind the concept to capture and store the mechanical or rotational kinetic energy of the wheels in the same form, in a heavy rotating mass or the “flywheel” [4].This way, if a mechanical variator is used for transmission there won’t be any losses associated with the energy transformations as energy is being transmitted in mechanical form throughout. But in many cases with flywheels for energy storage, and a non-mechanical transmission, energy transformations and consequently the associated losses exist, e.g., an electrical transmission is used in the flywheel battery (FWB) designed by University of Texas at Austin, Centre of Electro-Mechanics (UT CEM).[5]

The Delhi Metro reduced the amount of carbon dioxide (CO2) released into the atmosphere by around 90,000 tons by regenerating 112,500 megawatt hours of electricity through the use of regenerative braking systems between 2004 and 2007. It was expected that the Delhi Metro would reduce its emissions by over 100,000 tons of CO2 per year once its phase II was complete, through the use of regenerative braking. [6]

DMRC on its various lines have employed Automatic Train Protection System (ATP). Over and above ATP System, DMRC has employed Automatic Train Operation (ATO) System on its Line-2, where trains automatically flip flops between powering and braking. In line-3 operation, DMRC has employed automatic control of train braking by way of using a Train Interface Computer (TIC) Control, whereby braking requirements of train are automatically controlled. On its line-1 operation, DMRC employed a system where train operators are trained to effect optimal performance of train on regenerative braking front. [6]

Sr. No.	Line	Inter-station Distance (Km)	Cumulative Energy Consumption (KWHr/train/km)	Regenerated Energy (KWHr/train/km)	Percentage of Regenerations
1	Line 1	1.19(25.09/21)	14.5	4.9	33.7
2	Line 2	1.10(10/11)	16	4.6	28.8
3	Line 3	1.06(33/31)	16.2	5.5	34

Figure.2

Percentage of regeneration in D.M.R.C. for line 1, line 2 and line3. [6]

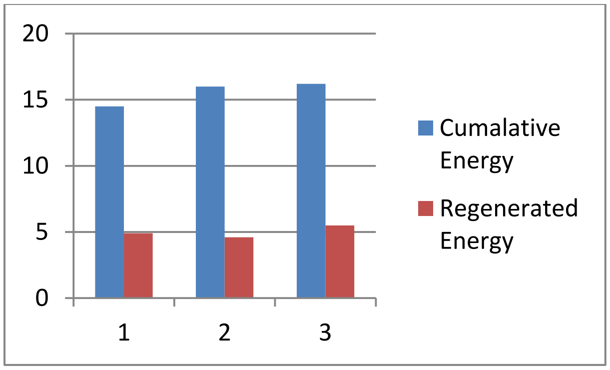


Figure.3

Total energy consumption and regenerated energy in D.M.R.C.

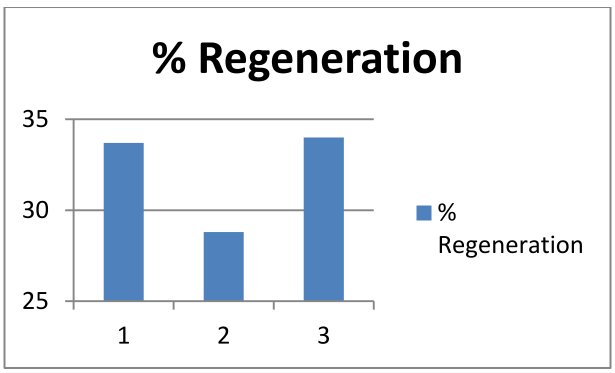


Figure.4

Percentage of regeneration in D.M.R.C. for line1, line2 and line3

Bosch Motorsport Service is developing a KERS for use in motor racing. These electricity storage systems for hybrid and engine functions include a lithium-ion battery with scalable 8 capacity or a flywheel, a four to eight kilogram electric motor (with a maximum power level of 60 kW or 80 hp), as well as the KERS controller for power and battery management. Bosch also offers a range of electric hybrid systems for commercial and light-duty applications. [7]

Construction & Operation:

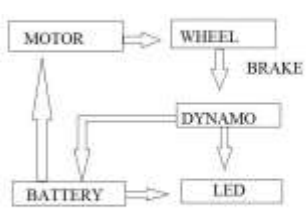


Figure.5

BLOCK DIAGRAM OF REGENERATIVE BRAKING MODEL

Mechanism

Friction

The force that opposes the relative motion or tendency toward such motion of two surfaces in contact. When contacting surfaces move relative to each other, the friction between the two objects converts kinetic energy into thermal energy, or heat. Friction between solid objects and fluids (gases or liquids) is called drag.

The classical approximation of the force of friction between two solid surfaces is known as Coulomb friction, named after Charles-Augustin de Coulomb. The relationship is:

$$F_f = \mu N$$

Where

μ is the coefficient of friction, which is an empirical property of the contacting materials,

N is the normal force exerted between the surfaces, and

Ff is the force exerted by friction.

Types of friction

Static friction-

It occurs when the two objects are not moving relative to each other. The coefficient of static friction is typically denoted as μ_s. Rolling friction occurs when one object "rolls" on another. This is classified under static friction because the patch of the tire in contact with the ground, at any point while the tire spins, is stationary relative to the ground. The coefficient of rolling friction is typically denoted as μ_r.

Kinetic (or dynamic) friction-

It occurs when two objects are moving relative to each other and rub together (like a sled on the ground). The coefficient of kinetic friction is typically denoted as μk , and is usually less than the coefficient of static friction.

Energy loss due to friction

According to the law of conservation of energy, no energy is destroyed due to friction though it may be lost to the system of concern. Energy is transformed from other forms into heat. A sliding hockey puck comes to rest due to friction as its kinetic energy changes into heat. When an object is pushed along a surface, the energy converted to heat is given by:

$$E = \mu_k \int N(x)\ dx$$

Where:
N is the normal force,
$\mu_k$is the coefficient of kinetic friction,
$x$is the coordinate along which the object transverses.

Energy storage in to flywheel
For regenerative braking system an assumption is made that during braking there is no change in the potential energy, enthalpy of the flywheel, pressure or volume of the flywheel, so only kinetic energy will be considered. As the car is braking, no energy is dispersed by the flywheel, and the only energy into the flywheel is the initial kinetic energy of the car. The equation can be simplified to:

$$\frac{mv^2}{2} = \Delta E_{fly}$$

Where:
M is the mass of the car.
v is the initial velocity of the car just before braking.
The flywheel collects a percentage of the initial kinetic energy of the car, and this percentage can be represented byΔE_{fly}. The flywheel stores the energy as rotational kinetic energy. Because the energy is kept as kinetic energy and not transformed into another type of energy this process is efficient. The flywheel can only store so much energy, however, and this is limited by its maximum amount of rotational kinetic energy. This is determined based upon the inertia of the flywheel and its angular velocity. As the car sits idle, little rotational kinetic energy is lost over time so the initial amount of energy in the flywheel can be assumed to equal the final amount of energy distributed by the flywheel. The amount of kinetic energy distributed by the flywheel is therefore:

$$KE_{fly} = \frac{\eta_{fly} m\, v^2}{2}$$

Regenerative braking has a similar energy equation to the equation for the mechanical flywheel. Regenerative braking is a two-step process involving the motor/generator and the battery. The initial kinetic energy is transformed into electrical energy by the generator and is then converted into chemical energy by the battery. This process is less efficient than the flywheel. The efficiency of the generator can be represented by

$$\eta_{gen} = \frac{w_{out}}{w_{in}}$$

Where:
W_{in} is the work into the generator.
W_{out} is the work produced by the generator
The only work into the generator is the initial kinetic energy of the car and the only work produced by the generator is the electrical energy. Rearranging this equation to solve for the power produced by the generator gives this equation:

$$P_{gen} = \frac{\eta_{gen}\, mv^2}{2\Delta t}$$

Where:
Δt is the amount of time the car brakes.
m is the mass of the car.
v is the initial velocity of the car just before braking.
The efficiency of the battery can be described as:

$$\eta_{batt} = \frac{P_{out}}{P_{in}}$$

Magnetic Field
The magnetic field component of an alternator, generator, dynamo or motor**.** The field can be on either the rotor or the stator and can be either an electromagnet or a permanent magnet.

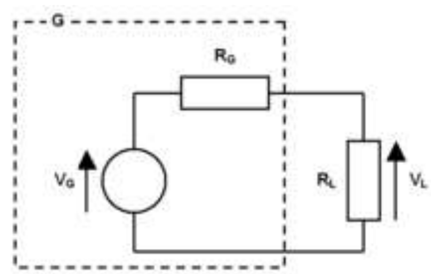


Figure.6
Equivalent circuit of generator and load.

Where
G = generator
V_G = generator open-circuit voltage
R_G = generator internal resistance
V_L = generator on-load voltage

R_L = load resistance

Maximum Power

This theorem states that the maximum power can be obtained from the generator by making the resistance of the load equal to that of the generator.

Electromagnetic Induction

The production of an electrical potential difference (or voltage) across a conductor situated in a changing magnetic flux. Faraday found that the electromotive force (EMF) produced around a closed path is proportional to the rate of change of the magnetic flux through any surface bounded by that path.

In practice, this means that an electrical current will be induced in any closed circuit when the magnetic flux through a surface bounded by the conductor changes. This applies whether the field itself changes in strength or the conductor is moved through it.

Electromagnetic induction underlies the operation of generators, induction motors, transformers, and most other electrical machines. Faraday's law of electromagnetic induction states that:

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

Where:

ε is the electromotive force (emf) in volts

Φ_B is the magnetic flux in Webbers

For the common but special case of a coil of wire, comprised of N loops with the same area, Faraday's law of electromagnetic induction states that

$$\varepsilon = -N\frac{d\Phi_B}{dt}$$

Where:

ε is the electromotive force (emf) in volts.

N is the number of turns of wire (per meter).

Φ_B is the magnetic flux in Webbers through a single loop.

Further, Lenz's law gives the direction of the induced emf, thus, the emf induced in an electric circuit always acts in such a direction that the current it drives around the circuit opposes the change in magnetic flux which produces the emf. Lenz's law is therefore responsible for the minus sign in the above equation. [8]

AutoCAD Software

Deliver better design more quickly and make grate product with AutoCAD simulation software, part of the Autodesk solution for digital prototyping. Predict product behavior, test innovative concepts and optimize design early in the design and engineering process. Validate product to better understand the implication of our design before manufacturing.

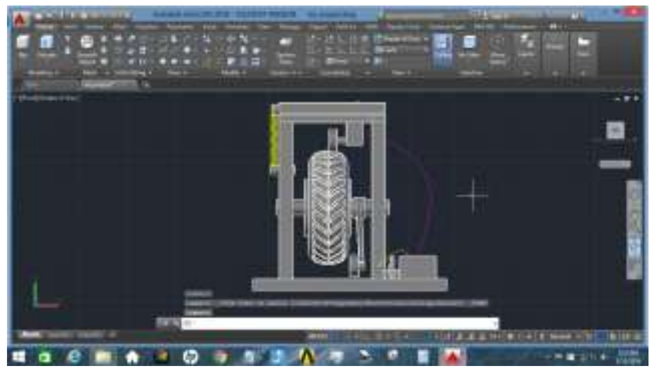


Figure.7
Front View

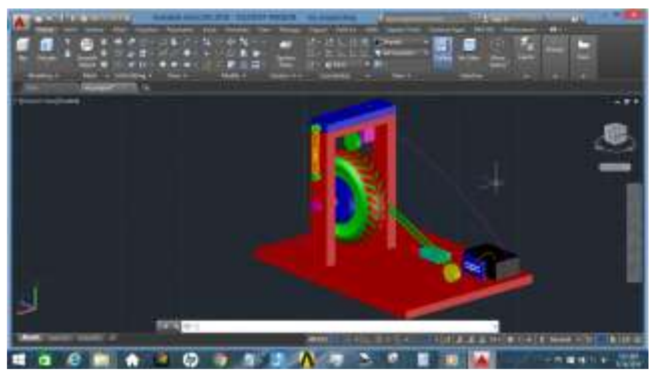


Figure.8
Side View

Result and Discussion

Time taken to stop the wheel

t_1=5.3 sec

t_2=5.1 sec

t_3=4.7 sec

Average time taken to stop the vehicle

$=\frac{t_1+t_2+t_3}{3}$

= 5.3+5.1+4.73

= 5.03

= 5(approx.)

1. Power output after at t_0 = 0 watt
2. Power output after 1 second = 0.41 watt
3. Power output after 2 second = 0.33 watt
4. Power output after 3 second = 0.27 watt
5. Power output after 4 second = 0.23 watt
6. Power output after 5 second = 0 watt

Total work output = Power output × time
= Area of power v/s time Graph

Mass of flywheel m = 1.2 kg
Radius of Flywheel r = 0.15 meter
Angular velocity of flywheel N = 155 RPM
Angular velocity in radian $\omega = \frac{2\pi N}{60}$

$$= \frac{2 \text{ X } 3.14 \text{ X } 155}{60}$$

= 16.22 Radian

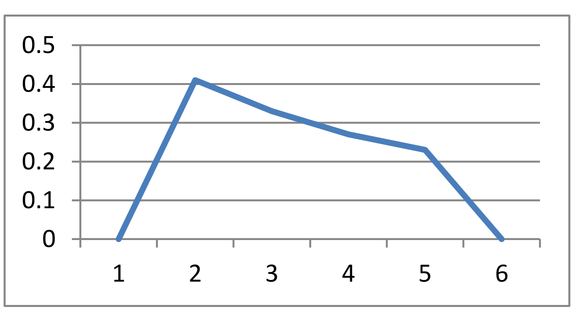
Inertia of Wheel $I = mr^2$
= 1.2 x 0.15 x 0.15
= 0.027 kg-m^2

Energy Input in Regenerative Brake $E_{in} = \frac{1}{2} I\omega^2$

Energy Output in Regenerative Brake
E_{out} = Power Output x time
= Area under the curve
= 1.24 Joule

Efficiency of Regenerative Brake = $\frac{\text{Output Power}}{\text{Input Power}}$

$= \frac{1.24}{3.55}$
= 0.349
=34.9%



Time in second

Figure.9
Power vs. Temperature Graph

In our model the efficiency of regenerative brake is 34.9%. This is near about our range (28%-35%) of regenerative efficiency in DMRC data provided to us [6]. Thus our model is efficiently working for regeneration of energy.
Future work would consist of a redesign of this model to see exactly how much data we may be missing with the assumption that we made with low price, weight and capacity. Despite all the assumptions, we still have realized that this product can be very marketable and that the demand is extremely large which means this is a viable design that will yield a high return on an investment.

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