Regenerative Braking Systems (RBS)

Pratik Bhandari, Shubham Dubey, Sachin Kandu, Rupesh Deshbhratar

***Abstract*—** Most brakes commonly use friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat, though other methods of energy conversion may be employed as all the energy here is being distributed in the form of heat. Regenerative braking converts much of the energy to electrical energy, which may be stored for later use. Driving an automobile involves many braking events, due to which higher energy losses takes place, with greater potential savings. With buses, taxis, delivery vans and so on there is even more potential for economy. As we know that the regenerative braking, the efficiency is improved as it results in an increase in energy output for a given energy input to a vehicle. The amount of work done by the engine of the vehicle is reduced, in turn reducing the amount of energy required to drive the vehicle. The objective of our project is to study this new type of braking system that can recollect much of the car's kinetic energy and convert it into electrical energy or mechanical energy. We are also going to make a working model of regenerative braking to illustrate the process of conversion of energy from one form to another. Regenerative braking converts a fraction amount of total kinetic energy into mechanical or electrical energy but with further study and research in near future it can play a vital role in saving the non-renewable sources of energy.

***Keywords*:** Regenerative, Braking, Hybrid vehicles, Kinetic energy recovery system (K.E.R.S.), Flywheel, Motor, Hydraulic Power Assist.

I. INTRODUCTION

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction. The term 'Braking' in a moving vehicle means the application of the brakes to reduce its speed or stop its movement, usually by depressing a pedal. The braking distance is the distance between the time the brakes are applied and the time the vehicle comes to a complete stop. In braking systems on conventional vehicles, friction is used to counteract the forward momentum of a moving vehicle. As the brake pads rub against the wheels or a disc that is connected to the axles, excessive heat energy is created. This heat energy dissipates into the air, wasting as much as 30 percent of the vehicle's generated power. Over time, this cycle of friction and wasted heat energy reduces the vehicle's fuel efficiency. More energy from the engine is required to replace the energy that was lost by braking.

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Most of it simply gets released in the form of heat and becomes useless. That energy, which could have been used to do work, is essentially wasted. The solution for this kind of this problem is Regenerative Braking System. This is a new type of braking system that can recollect much of the car & kinetic energy and convert it into electrical energy or mechanical energy. The energy so produced can then be stored as mechanical energy in flywheels, or as, electrical energy in the automobile battery, which can be used again

There are 7 multiple methods of energy conversion in RBSs including spring, flywheel, electromagnetic and hydraulic. More recently, an electromagnetic-flywheel hybrid RBS has emerged as well. Each type of RBS utilizes a different energy conversion or storage method, giving varying efficiency and applications for each type.

The effect of regenerative brakes is less at lower speeds as compared to that at higher speeds of vehicle. So the friction brakes are needed in a situation of regenerative brake failure, to stop the vehicle completely

II. CONVERSION OF KINETIC ENERGY TO ELECTRICAL ENERGY USING MOTOR

The most common form of regenerative brake involves using an electric motor as an electric generator. The working of the regenerative braking system depends upon the working principle of an electric motor, which is the important component of the system. Electric motor gets activated when some electric current is passed through it. But, when some external force is applied to activate the motor (during the braking), then it behaves as a generator and generates electricity. This means that whenever motor runs in one direction, the electric energy gets converted into mechanical energy, which is then used to accelerate the vehicle and whenever the motor runs in opposite direction, it performs functions of a generator, which then converts mechanical energy into electrical energy, which makes it possible to utilize the rotational force of the driving axle to turn the electric motors, which results in regenerating electric energy for storage in the battery and simultaneously reducing the speed of the car with the regenerative resistance of the electric motors. This electricity is then used for recharging the battery

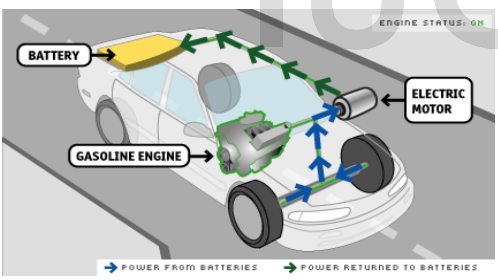

Fig 1: Motor-Generator RBS

III. FLYWHEEL RBS

A flywheel is component which is used to store mechanical energy and then release the stored energy when needed for acceleration. Flywheel is a heavy, high-speed rotating disc that builds up kinetic energy as it spins. The amount of energy stored depends upon how heavier it is and how fast it rotates. Heavier weight and faster rotation results in higher energy storage. We can relate it to a discus thrower in the Olympics. He winds-up, building an increasing store of force and energy as he spins, and then releases the disc and sends it flying through the air. The method of transmission of energy directly to the vehicle is more efficient rather than first storing it in the battery, as it does not consists of the conversion of energies. As, during the recharging of battery, mechanical energy is converted into electrical energy and during discharging vice-versa . So, due to these conversions transmission loses occur and the efficiency reduces. As, in the other case, there are no transmission loses since mechanical energy stored in the flywheel is directly transferred to the vehicle in its original form. As the energy is supplied instantly and efficiency is high, these types of systems are used in F-1 cars.

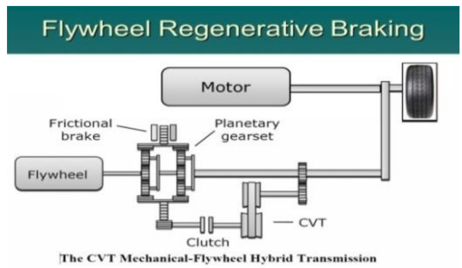

Fig 2: Flywheel RBS

IV. HYDRAULIC ASSISTED RBS

An alternative regenerative braking system is being developed by the Ford Motor Company and the Eaton Corporation. It's called Hydraulic Power Assist or HPA. With HPA, when the driver steps on the brake, the vehicle's kinetic energy is used to power a reversible pump, which sends hydraulic fluid from a low pressure accumulator (a kind of storage tank) inside the vehicle into a high pressure accumulator. The pressure is created by nitrogen gas in the accumulator, which is compressed as the fluid is pumped into the space the gas formerly occupied. This slows the vehicle and helps bring it to a stop.

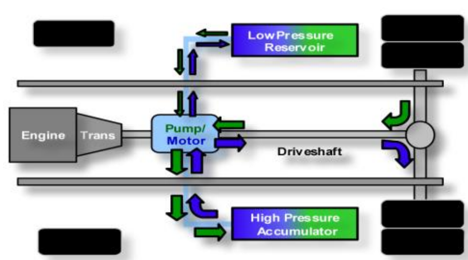

Fig 3: Hydraulic assisted RBS

The fluid remains under pressure in the accumulator until the driver pushes the accelerator again, at which point the pump is reversed and the pressurized fluid is used to accelerate the vehicle, effectively translating the kinetic energy that the car had before braking into the mechanical energy that helps get the vehicle back up to speed. It's predicted that a system like this could store 80 percent of the momentum lost by a vehicle during deceleration and use it to get the vehicle moving again. This percentage represents an even more impressive gain than what is produced by current regenerative braking systems. Like electronic regenerative braking, these kinds of brakes -- HPA systems -- are best used for city driving, where stop-and-go traffic is common

V. REGENERATIVE BRAKING EFFICIENCY

The energy efficiency of a conventional car is only about 20 percent, with the remaining 80 percent of its energy being converted to heat through friction. The miraculous thing about regenerative braking is that it may be able to capture as much as half of that wasted energy and put it back to work. This could reduce fuel consumption by 10 to 25 percent

Hydraulic regenerative braking systems could provide even more impressive gains, potentially reducing fuel use by 25 to 45 percent. In a century that may see the end of the vast fossil fuel reserves that have provided us with energy for automotive and other technologies for many years, and in which fears about carbon emissions are coming to a peak, this added efficiency is becoming increasingly important

VI. EXPECTED OUTCOMES

1. It should store energy while braking which is its primary objective
2. It should return the stored energy whenever required easily
3. It should be compact and easy to install
4. It should provide adequate stopping/braking force to the vehicle
5. When used in conjunction with conventional braking systems , it should easily switch as per requirement
6. Its design should be flexible so that it can cater to the needs of a wide variety of vehicles
7. It should therefore increase the efficiency in terms of fuel consumption and thereby reducing emissions.
8. As it is an add on, its cost should be justifiable in a short time span.

VII. ADVANTAGES OF REGENERATIVE BRAKING

1. Improved Fuel Economy.
2. Reduction in Brake and Engine Wear- Reducing cost of replacement of brake linings, cost of labor to install them, and vehicle down time.
3. Emissions reduction- engine emissions reduced by engine decoupling, reducing total engine revolutions and total time of engine operation.
4. Operating range is comparable with conventional vehicles- a problem not yet overcome by electric vehicles.

Following are the results of a Regenerative Braking setup coupled with ultracapacitors on The Škoda Fabia

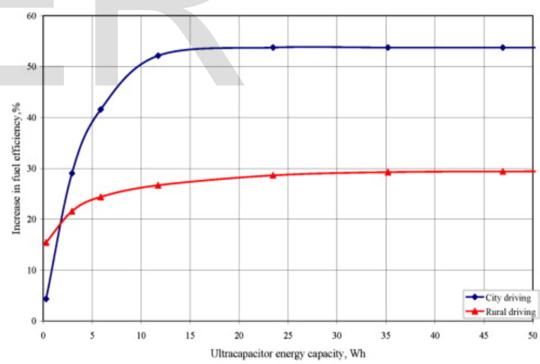

Fig 4: RBS on Škoda Fabia

Parameter	Frequency, %	Avg Power without RBS, kW	Avg Power with RBS, kW
Acceleration	28.3	24.7	15.8
Deceleration	28.2	1.4	0.0
Stationary	3.9	0.0	0.0
Constant Speed	39.5	11.5	10.0

Increase in efficiency	29.4%

Table 1: RBS on Urban model

Parameter	Frequency, %	Avg Power without RBS, kW	Avg Power with RBS, kW
Acceleration	15.8	21.8	19.5
Deceleration	0.0	25.2	0.0
Stationary	0.0	8.0	0.0
Constant Speed	10.0	45.0	2.9
Increase in efficiency	51.7%		

Table 2: RBS on Rural model

In the city model, a 54% increase in fuel efficiency was achieved by this implementation of regenerative braking; in the rural model, a 29% increase in fuel efficiency was found, as described in Figure shown above.

VIII. DISADVANTAGES OF REGENERATIVE BRAKING

1. The main limitation of regenerative brakes when compared with dynamic brakes is the need to closely match the electricity generated with the supply. With DC supplies this requires the voltage to be closely controlled and it is only with the development of power electronics that it has been possible with AC supplies where the supply frequency must also be matched (this mainly applies to locomotives where an AC supply is rectified for DC motors).
2. Regenerative braking is necessarily limited when the batteries are fully charged. Because the additional charge from regenerative braking would cause the voltage of a full battery to rise above a safe level, our motor controller will limit regenerative braking torque in this case.
3. Increases the total weight of vehicle by around 25-30 Kilograms.

IX. SCOPE AND OBJECTIVE

Regenerative braking systems require further research to develop a better system that captures more energy and stops faster. As the time passes, designers and engineers will perfect regenerative braking systems, so these systems will become more and more common. All vehicles in motion can benefit from these systems by recapturing energy that would have been lost during braking process and thereby reducing fuel consumption and increased efficiency. Future technologies in regenerative brakes will include new types of motors which will be more efficient as generators, more powerful battery which can bear more frequent charging and discharging, new drive train designs which will be built with regenerative braking in mind, and electric systems which will be less prone to energy losses.

Of course, problems are expected as any new technology is perfected, but few future technologies have more potential for improving vehicle efficiency than does regenerative braking

X. ACKNOWLEDGEMENT

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