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REGENERATIVE BRAKING SYSTEMS (RBS)

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***Abstract*— In today's world, braking is the most important system in an Automobile. Brakes are energy conversion devices, which convert kinetic energy of the vehicle into thermal energy. Most brakes commonly use friction between two surfaces to convert the kinetic energy of the moving object into heat. RBS converts much of the energy to electrical energy, which may be stored for later use. Thus in Regenerative Braking the efficiency is improved as it result in an increase in an 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. Since we do not have any reliable alternative source of energy, increasing efficiency and reducing exhaust gas emissions has become the focus which can be bit achieved by RBS.**

Keywords— **Regenerative, Braking, Motor, Flywheel, Hydraulic Power Assist, Hybrid Vehicles.**

I. INTRODUCTION

When we applies the brake of a vehicle, its kinetic energy is converted to heat because of the friction between the braking pads and wheels. This heat energy dissipates into the air, which results to waste a certain percent of the generated energy as energy lost depends on how often, how hard and for how long the brakes are applied.

Regenerative Braking is an energy recovery mechanism which saves energy which would have been otherwise wasted as heat due to friction while braking. That energy is held until required again by the vehicle, whereby it is converted back into kinetic energy and used to accelerate the vehicle. This energy can be stored temporarily or can be used immediately The magnitude of the portion available for energy storage varies according to the type of storage, drive train efficiency, drive cycle and inertia weight. 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 multiple methods of energy conversion in RBS which includes – spring, flywheel, electromagnetic and hydraulic.
Regenerative Braking is used in conjunction with friction brakes. In some cases, at slow speeds, the regenerative braking alone may not be sufficient to bring the vehicle to a complete halt. If the regenerative torque cannot be made high enough to match the braking torque, then the friction brakes make up the difference. Also, if the regenerative brakes fail, then the friction brakes act as a backup braking system. Regenerative braking can be used in both pure electric as well as hybrid electric vehicles. In hybrid vehicles, the gas consumption is reduced because of it. The regenerative braking along with friction brakes can be used in two ways. First, the available braking power from regenerative braking can be calculated and the rest can be supplied by the friction brakes. In such a case, a microcontroller calculates such values in real time using the system parameters. The parameters involved are battery state of charge, vehicle velocity, motor capacity etc. Secondly, without using a controller, both regenerative brakes and the friction brake can be applied in tandem. Regenerative braking is applied to only those wheels which are driven by the motor. Hence, either only front axle or rear axle can have it. The other set of wheels can have frictional brake systems.

II. RBS USING ELECTRIC MOTOR

In an electric system which is driven only by means of electric motor the system consists of an electric motor which acts both as generator and motor. Initially when the when the system is cruising the power is supplied by the motor and when the there is a necessity for braking depending upon driver's applied force on the brake pedal the electronic unit controls the charge flowing through the motor and due to the resistance offered motor rotates back to act as a generator and the energy is energy is stored in a battery or bank of twin layer capacitors for later use.

The main components of this system

- Engine
- Motor/Generator
- Batteries
- Electronic control system

During acceleration, the Motor/generator unit acts as electric motor drawing electrical energy from the batteries to provide extra driving force to move the car as(Shown in fig 1.a). With this help from the motor, the car's internal combustion engine that is smaller and with lower peak power can achieve high efficiency. During braking electric supply from the battery is cut off by the electronic system. As the car is still moving forward, the Motor/ Generator unit is acts as electric generator

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converting ca's kinetic energy into electrical and store in the batteries (shown in fig 1.b) for later use.

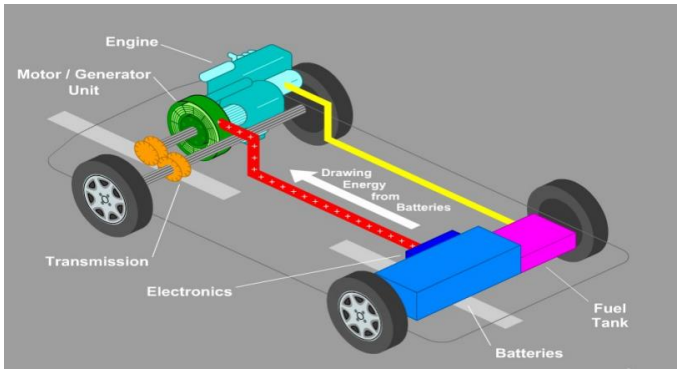

Fig 1.a : Showing energy consumption from battery

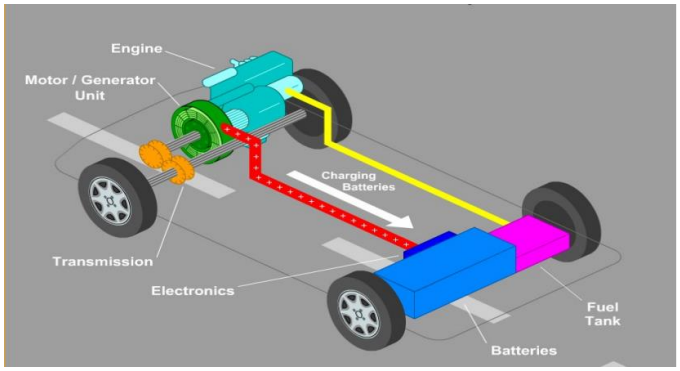

Fig 1.b : Showing charging of the battery when brake applied

III. F-RBS (FLYWHEEL BASED RBS)

Flywheel or inertia wheel used in a machine act as a temporary reservoir of the energy, which stores energy when the energy supply is more than required for an operation and releases the stored energy when the supply power does not adequate with the needs.

Main components:
A typical system consists of a flywheel supported by rolling element bearing connected to a motor-generator. The flywheel and sometimes motor generator may be enclosed in a vacuum chamber to reduce friction and reduce energy loss. First-generation flywheel energy-storage systems use a large steel flywheel rotating on mechanical bearings. Newer system use carbon fibre composite rotors that have a higher tensile strength than steel and can store much more energy for the same mass. To reduce friction, magnetic bearings are used.

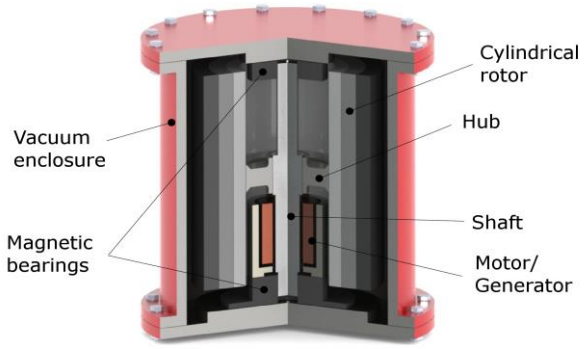

Fig 2 : The main components of a typical flywheel

When the vehicle decelerates, the kinetic energy of the vehicle gets transferred back when the vehicle has to accelerate again. Using flywheels provides the advantage of a high power (storing and releasing both) energy storage system, compared to conventional batteries. Due to which, flywheel energy storage systems are being used to replace electrochemical batteries in the field of power supply for Uninterrupted Power Supply. Heavier the flywheel and faster the rotation, more energy will get stored.

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.

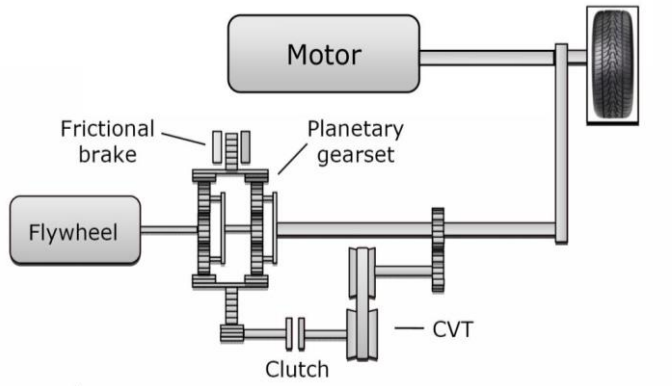

Fig 3: Flywheel regenerative braking system

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IV. HYDRAULID RBS

Hydrostatic Regenerative Braking (HRB) system uses electrical/electronic components as well as hydraulics to improve vehicle fuel economy. 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.**

The basic idea of a Hydraulic regenerative braking system is that when the vehicle slows down or decelerates, it will store the kinetic energy that was originally momentum as potential energy in the form of pressure. This is done by using a displacement pump to pump hydraulic fluid into an accumulator. When the vehicle accelerates, the pressure is released from the accumulator which will spin the drive shaft and accelerate the vehicle. Thus the engine remains idle while the pressure is released and when the accumulator is empty, or the desired speed is achieved, the engine will then engage in order to maintain a constant velocity, or to accelerate the vehicle beyond what the capacity of the accumulator was capable of.

Hydraulic regeneration systems have been considered by the automotive industry for implementation in hybrid vehicles for a number of years. A gas charged hydraulic accumulator is a potential energy storage device in the form of a cylindrical m spherical vessel that can hold relatively large amounts of hydraulic fluid under pressure. The device stores energy by compressing a gas (usually nitrogen), and has proved to be much more practical than the weight or spring loaded type. They are also lighter, cheaper and more compact. The hydraulic system consists of an accumulator, an oil reservoir and a variable displacement pump/motor. The wheel driven hydraulic pump builds up pressure in the accumulator and energy is transferred by the pump motor unit. A variable displacement unit of this type is simple to control. As with electric vehicles, these systems are also less efficient at low power because of their substantial fixed mechanical losses.

Bosch Rexroth has a regenerative braking system that does not require a hybrid vehicle. In fact, it does not involve electrical storage. The Hydrostatic Regenerative Braking (HRB) system is intended for commercial vehicles and mobile equipment. The company says that initial measurements show that the HRB system reduces the fuel consumption in these vehicles by up to 25%.

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. At present, these hydraulic regenerative brakes are noisy and prone to leaks. However, once all of the details are ironed out, such systems will probably be most useful in large trucks.

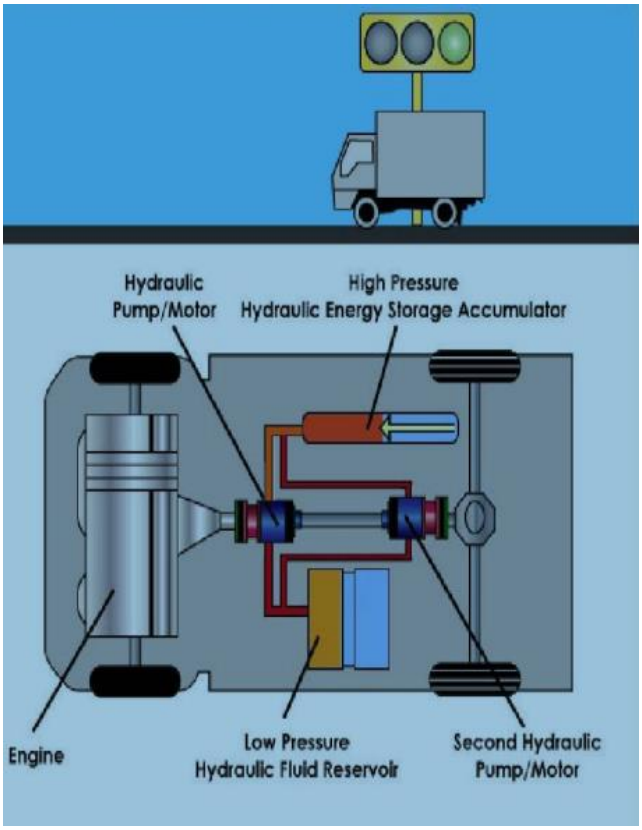

Fig 4: Hydraulic regenerative braking system

V. REGENERATIVE BRAKING SYSTEM 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. ADVANTAGES OF RBS

1. **It improves the fuel economy of the vehicle**

The amount of fuel consumed can be dramatically reduced with this type of braking system. The International Journal of Vehicle Design noted in 2011 that

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fuel consumption covering the NEDC (New European Driving Cycle) was improved by 25%.

2. It allows for traditional friction-based brakes

A friction braking system is included with a regenerative system to ensure a vehicle is able to stop in time.

3. It prolongs the charge of the battery

Once the energy is captured by the regenerative brakes, the energy is used to recharge the batteries of the vehicle. Because this energy would normally be lost, it allows each vehicle to experience a prolonged charge while driving.

4. It reduces the wear and tear on the braking system

The greater efficiency given to the braking allows for a reduced level of wear on the brakes of the vehicle. With standard friction brakes, there is no way to accomplish this benefit.

VII. DISADVANTAGES OF REGENERATIVE BRAKING SYSTEM

1. It offers a sliding scale of benefits

The effects of regenerative braking decrease with the speed a vehicle is traveling. At low speeds, friction brakes are required to bring most vehicles to a complete stop. That means there is still energy being lost.

2. It offers a different feel to the driver

Regenerative braking systems feel different to drivers who are used to traditional systems. The brake pedal on the vehicle often feels soft, described as "mushy" by many drivers. Until you get used to the new system, some may have a lack of confidence in the capabilities of their brakes.

3. 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.

4. Increases the overall weight

RBS increases the total weight of the vehicle by around 25-30 Kilograms.

VIII. FUTURE SCOPE

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.

IX. CONCLUSION

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. The results from some of the test conducted show that around 30% of the energy delivered can be recovered by the system. Regenerative braking system has a wide scope for further development and the energy savings. The use of more efficient systems could lead to huge savings in the economy of any country.

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