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Regenerative Braking System-Review

***Vijaykumar S. Ghorade* [1], *Sanchit B. Dhotre*[2], *Pramod R. Dabhade*[3], *Mangesh R. Dhage*[4], *Prasanna B. Gajghane*[5]**

Professor[1, 2,3,4,5]

Department of Mechanical Engineering

STC, SERT, Khamgaon

Corresponding Author's email: *vijayghorade29101992@gmail.com*

Abstract

Regenerative Braking System is the way of slowing vehicle by using the motors as brakes. Instead of the surplus energy of the vehicle being wasted as unwanted heat, the motors act as generators and return some of it to the overhead wires as electricity. The vehicle is primarily powered from the electrical energy generated from the generator, which burns gasoline. This energy is stored in a large battery, and used by an electric motor that provides motive force to the wheels. The regenerative braking taking place on the vehicle is a way to obtain more efficiency; instead of converting kinetic energy to thermal energy through frictional braking, the vehicle can convert a good fraction of its kinetic energy back into charge in the battery, using the same principle as an alternator.

Keywords*— Regeneration, Braking, Battery, Flywheel, Brake, Wear, Fuel*

1. INTRODUCTION

1.1 Brake

A brake is a machine element and its principle object is to absorb energy during deceleration. In vehicle brakes are used to absorb kinetic energy whereas in hoists or elevators brakes are also used to absorb potential energy. By connecting the moving member to stationary frame, normally brake converts kinetic energy to heat energy. This causes wastage of energy and also wearing of frictional lining material.

1.2 Regenerative Braking System

Regenerative Braking System is the way of slowing vehicle by using the motors as brakes. Instead of the surplus energy of the vehicle being wasted as unwanted heat, the motors act as generators and return some of it to the overhead wires as electricity. The vehicle is primarily powered from the electrical energy generated from the generator, which burns gasoline.

This energy is stored in a large battery, and used by an electric motor that provides motive force to the wheels. The regenerative breaking taking place on the vehicle is a way to obtain more efficiency; instead of converting kinetic energy to thermal energy through frictional braking, the vehicle can convert a good fraction of its kinetic energy back into charge in the battery, using the same principle as an alternator. Therefore, if you drive long distance without braking, you'll be powering the vehicle entirely from gasoline. The Regenerative Braking System comes into its own when you're driving in the city, and spending a good deal of your time braking.

You will still use more fuel in the city for each mile you drive than on the highway, though. (Thermodynamics tells us that all inefficiency comes from heat generation. For instance, when you brake, the brake pedals heat up and a quantity of heat, or energy, is lost to the outside world. Friction in the engine produces heat in the same way. Heat energy, also, has higher entropy than, say, electric, meaning that it is less ordered.)

1.3 Definition

Braking method in which the mechanical energy from the load is converted into electric energy and regenerated back into the line is known as Regenerative Braking. The Motor operates as generator.

1.4 Regenerative Braking for Hybrid Vehicle

In most electric and hybrid electric vehicles on the road today, this is accomplished by operating the traction motor as a generator, providing braking torque to the wheels and recharging the traction batteries. The energy provided by regenerative braking can then be used for propulsion or to power vehicle accessories.

2. REGENERATIVE BRAKING

There are three standard layouts used in hybrid electric car power trains—series, parallel and series-parallel—but we are only going to describe the series-parallel power train because of its increasing popularity. The Toyota Prius uses the parallel-series power train, and according to the Toyota

Motor Sales, U.S.A, Inc., “Prii…comprises half of all hybrids on the road in the U.S. with sales totaling 1.2 million units through April 2012”.

The series-parallel power train utilizes the best components of both the series and the parallel drive train, which is why this type is so popular. According to Hybrid center a project of the Union of Concerned Scientists, a series-parallel power train has a power splitting device in its transmission that couples the electric motor with the internal combustion engine. This gives both the engine and the motor access to the driveshaft and allows for a wider variety of power options, and “as a result of this dual drive train, the engine operates at near optimum efficiency more often”. Since the engine and motor are coupled in this way, a smaller engine can be used, which will burn less fuel.

3. REGENERATIVE BRAKING STRATEGY

The layout of internal combustion engine (ICE) vehicle and electric vehicle are shown in Figure 1 and 2 respectively. The platform of this ICE vehicle is front engine, front drive (FF) using manual transmission. Its braking system is cross link circuit or X layout with four wheel disk brakes and anti-lock brake system (ABS).

The modification from engine into electric vehicle is achieved by installing motor-generator (MG) instead of engine and changing the manual transmission into fixed transmission since electric motor does not need complex-ratio transmission so as engine to maintain optimal operation on the fuel economy region.

Thus, this vehicle platform is still the FF, front motor, front drive. Because regenerative torque needs medium to send this brake torque into driven wheel, the vehicle platform is factor defining that only driven wheel, front wheel in this case, can contribute regenerative braking power. Therefore, front wheels are cooperated by regenerative and friction brake force while rear wheels have only friction brake operation.

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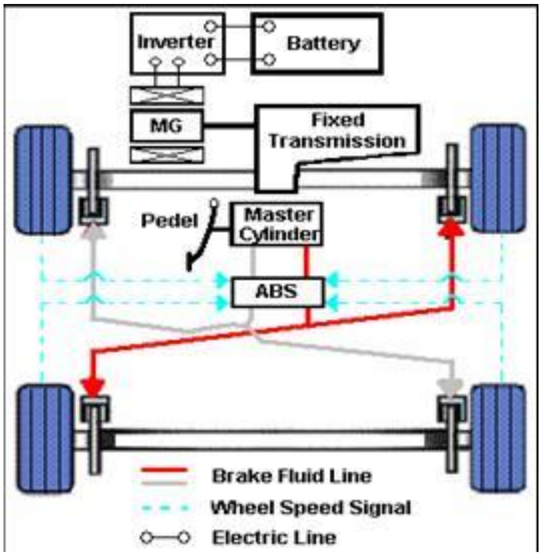

Fig. 1: Layout of the ICE vehicle and braking system

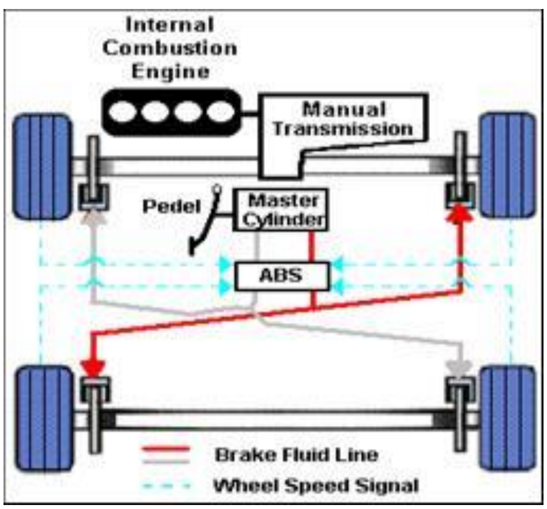

Fig. 2: Layout of the EV and braking system

3.1 Non-modified braking system

Based on this regenerative strategy, shown in figure 2, conventional braking system is applied without modification. During braking, the mechanical braking system is operated independent of regenerative process. In this case, the pressure of brake fluid at front wheel remains as conventional. Thus, while regenerative brake operates at front wheels, the amount of front brake force is higher than normally required brake force. Nevertheless, the concern about front wheel locking is resolved by ABS that automatically reduces brake pressure if wheel locking takes place.

3.2 Modified braking system with emulated ABS signal

The objective of this system is to allow regenerative system can obtain as much energy as possible by reducing friction brake force be equal to a quantity of regenerative brake force. The layout of modified braking system with emulated ABS signal is shown in Figure 3.

The modification is to trap front wheel speed signal to regenerative control unit (RCU) and then send emulated wheel speed signal to ABS control unit to simulate the wheel locking-up situation. Consequently, ABS control unit will automatically reduce brake fluid pressure at front wheel. On one hand, if sum of regenerative and front friction brake force is more than force of front wheel requirement, emulated signal is sent to reduce friction brake force. On the other hand, if friction brake force is not enough, the RCU will suddenly stop sending emulated signal to allow ABS to increase proper friction brake force.

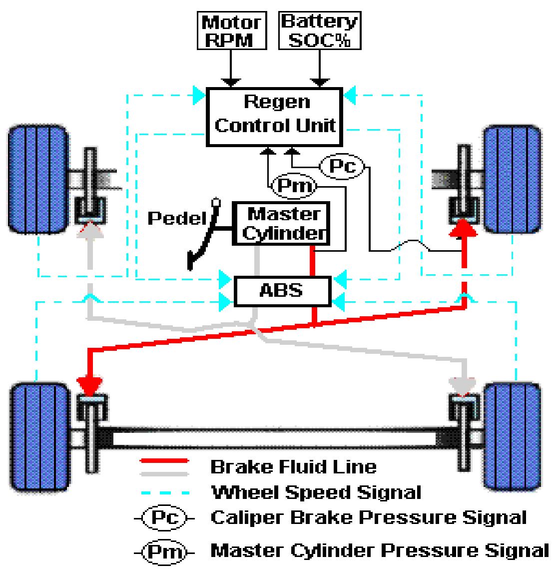

Fig. 3 Layout of regenerative system of modified braking system with emulated ABS signal

4. NECESSITY OF THE SYSTEM

The regenerative braking system delivers a number of significant advantages over a car that only has friction brakes. In low-speed, stop-and-go traffic where little deceleration is required; the regenerative braking system can provide the majority of the total braking force. This vastly improves fuel economy with a vehicle, and further enhances the attractiveness of vehicles using regenerative braking for city driving. At higher speeds, too, regenerative braking has been shown to contribute to improved fuel economy – by as much as 20%.

Consider a heavy loaded truck having very few stops on the road. It is operated near maximum engine efficiency. The 80% of the energy produced is utilized to overcome the rolling and aerodynamic road forces. The energy wasted in applying brake is about 2%. Also its brake specific fuel consumption is 5%.

Now consider a vehicle, which is operated in the main city where traffic is a major problem here one has to apply brake frequently. For such vehicles the wastage of energy by application of brake is about 60% to 65%. And also it is inefficient as its brake specific fuel consumption is high.

4.1 Energy Conservation

The flywheel absorbs energy when braking via a clutch system slowing the car down and speeding up the wheel. To accelerate, another clutch system connects the flywheel to the drive train, speeding up the car and slowing down the flywheel. Energy is therefore conserved rather than wasted as heat and light which is what normally happens in the contemporary shoe/disc system.

4.2 Wear Reduction

An electric drive train also allows for regenerative breaking which increases Efficiency and reduces wear on the vehicle brakes. In regenerative braking, when the motor is not receiving power from the battery pack, it resists the turning of the wheels, capturing some of the energy of motion as if it were a generator and returning that energy to the battery pack.

4.3 Fuel Consumption

The fuel consumption of the conventional vehicles and regenerative braking system vehicles was evaluated over a course of various fixed urban driving schedules. The results are compared as shown in figure. Representing the significant cost saying to its owner, it has been proved the regenerative braking is very fuel-efficient.

Braking is not total loss: Conventional brakes apply friction to convert a vehicle's kinetic energy into heat. In energy terms, therefore, braking is a total loss: once heat is generated, it is very difficult to reuse. The regenerative braking system, however, slows a vehicle down in a different way.

5. ELEMENTS OF THE SYSTEM

There are three basic elements required which are necessary for the working of regenerative braking system, these are:

5.1 Energy Storage Unit (ESU)

The ESU performs two primary functions:

1. TO recover & store braking energy
2. TO absorb excess engine energy during light load operation.

The selection criteria for an effective energy storage includes

1. High specific energy storage density
2. High energy transfer rate
3. Small space requirement

The energy recaptured by regenerative braking might be stored in one of three devices: an electrochemical battery, a flywheel, in a regenerative fuel cell.

5.2 Batteries

With this system, the electric motor of a car becomes a generator when the brake pedal is applied. The kinetic energy of the car is used to generate electricity that is then used to recharge the batteries. With this system, traditional friction brakes must also be used to ensure that the car slows down as much as necessary. Thus, not all of the kinetic energy of the car can be harnessed for the batteries because some of it is "lost" to waste heat. Some energy is also lost to resistance as the energy travels from the wheel and axle, through the drivetrain and electric motor, and into the battery. For example, the Toyota Prius can only recapture about 30% of the vehicles kinetic energy.

The Honda Insight is another vehicle in addition to the Prius that is on the market and currently uses regenerative braking. In the Insight there are two deceleration modes: When the throttle is engaged, but the brake pedal is not, the vehicle slows down gradually, and the battery receives a partial charge. When the brake pedal is depressed, the battery receives a higher charge, which slows the vehicle down faster. The further the brake pedal is depressed, the more the conventional friction brakes are employed. In the Insight, the motor/generator produces AC, which is converted into DC, which is then used to charge the Battery Module. The Insight, as well as all other regenerative systems, must have an electric controller that regulates how much charge the battery receives and how much the friction brakes are used.

5.3 Flywheels

In this system, the translational energy of the vehicle is transferred into rotational energy in the flywheel, which stores the energy until it is needed to accelerate the vehicle. The benefit of using flywheel technology is that more of the forward inertial energy of the car can be captured than in batteries, because the flywheel can be engaged even during relatively short intervals of braking and acceleration.

In the case of batteries, they are not able to accept charge at these rapid intervals, and thus more energy is lost to friction. Another advantage of flywheel technology is that the additional power supplied by the flywheel during acceleration substantially. Accommodate On the market, it should solve many of the problems with hybrid vehicles that manufacturers are facing today when it becomes available.

6. DESCRIPTION & OPERATION

Regenerative (or Dynamic Braking) occurs when the vehicle is in motion, such as coasting, traveling downhill or braking. And the accelerator pedal is not being depressed. During "Regent," the motor becomes a generator and sends energy back to the batteries.It is explained as follows, because the wheels of a decelerating vehicle are still moving forward, they can be made to turn the electric motor, which then feeds energy to the batteries for storage. The system becomes, in effect, a generator, which provides braking force while it converts the vehicle's kinetic energy into a reusable form- electrical energy.

When the accelerator pedal is released, the absence of pressure triggers a response from the Energy Storage Unit (ESU). Regenerative braking begins, and the batteries are re-charged by the motor, which is turned by the wheels. In this case, the friction brakes are not engaged. If more vigorous deceleration is required, and the brake pedal is depressed, this engages both sets of brakes. However, to maximize energy efficiency, it is advantageous to apply the regenerative brake as such as possible – it therefore tends to do more of its total work in the first part of the braking motion.

6.1 There are two deceleration modes:

1. Foot off throttle but not on brake pedal - in this mode, the charge/assist gauge will show partial charge, and the vehicle will slow down gradually.

2. Foot on brake pedal- In this mode, a higher amount of regeneration will be allowed, and the vehicle will slow more rapidly. During light brake pedal application, only the IMA motor//generator is slowing the car. With heavier brake pedal application, the conventional friction brakes also come into play. When decelerating, regeneration will continue u8ntil engine speed falls to about 1000 rpm. At this point, the driver will typically shift into neutral. In this way braking of the vehicle is obtained.

7. EXAMPLE

7.1 Regenerative braking of Toyota Prius

Toyota realized that one way to achieve longer vehicle range was to conserve and reuse some of the energy that a vehicle normally loses as heat caused by braking friction. This idea led engineers to apply the principles of regenerative braking.

In all Toyota vehicles that feature the regenerative braking system, the regenerative brake is only responsible for a part of the deceleration necessary to stop the vehicle. In an EV, this fraction is determined by the vehicle's speed when braking is initiated. The remaining braking force is provided by the vehicle's friction brakes. To maximize fuel economy, of course, the regenerative braking system is made to do as much of the braking work as possible.

7.2 Technology Used in Toyota Prius

Toyota's engineers found were to have the prius' regenerative brake supply a continuously varying amount of braking torque as the vehicle decelerates. A pure EV, with its greater battery capacity, can achieve substantial energy saving without modifying the regenerative brake's contribution throughout the braking action. This was not the case for the prius. So Toyota engineers developed a new type of control value to regulate the interplay between the two systems.

8. RESULT

Regenerative braking technology is one more positive step forward in Toyota's quest to realize the ultimate eco car. By working in concert with previously developed electric motor technologies, its application helps Toyota's electric vehicles and hybrid vehicles (including the recently released prius) to achieve extended ranges and to be friendlier to the environment than ever before. At the same time, this new technology remains unobtrusively in the background; drivers benefit from regenerative braking while enjoying the same firm braking feel found in conventionally equipped vehicles.

9. CONCLUSION

Theoretical investigations of a regenerative braking system show about 25% saving in fuel consumption

The lower operating and environment costs of a vehicle with regenerative braking system should make it more attractive than a conventional one. The traditional cost of the system could be recovered in the few years only. The exhaust emission of vehicle using the regenerative braking concept would be much less than equivalent conventional vehicles as less fuel are used for consumption. These systems are particularly suitable in developing countries such as India where buses are the preferred means of transportation within the cities.

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BIOGRAPHIES

1. Prof. Vijaykumar S. Ghorade, Assistant Professor, Department Of Mechanical Engineering, STC, SERT, Khamgaon

2. Prof. Sanchit B. Dhotre, Lecturer, Department Of Mechanical Engineering, SVCP Ambegaon Bk.

