Design and Development of Regenerative Braking System

Mr. Kedar Bhanewad
Department of Mechanical Engineering
G H Raisoni Institute of Engineering and Technology, Nagpur, Maharashtra, India

Mr. Rahul Pandhurnekar
Department of Mechanical Engineering
G H Raisoni Institute of Engineering and Technology, Nagpur, Maharashtra, India

Mr. Saurabh B. Khandekar
Department of Mechanical Engineering
G H Raisoni Institute of Engineering and Technology, Nagpur, Maharashtra, India

Mr. Tejpal C. Parshiwanikar
Department of Mechanical Engineering
G H Raisoni Institute of Engineering and Technology, Nagpur, Maharashtra, India

Abstract- Hybrid electric vehicle technology has become a preferred method for the automotive industry to reduce environmental impact and fuel consumption of their vehicles. Hybrid electric vehicles accomplish these reductions through the use of multiple propulsion systems, namely an electric motor and internal combustion engine, which allow the elimination of idling, operation of the internal combustion engine in a more efficient manner and the use of regenerative braking. However, the added cost of the hybrid electric system has hindered the sales of these vehicles. A more cost effective design of an electro-hydraulic braking system is presented. The system electro-mechanically controlled the boost force created by the brake booster independently of the driver braking force and with adequate time response. The system allowed for the blending of the mechanical and regenerative braking torques in a manner transparent to the driver and allowed for regenerative braking to be conducted efficiently.

Keywords – Regenerative Braking System, Electrical Energy, Hybrid Vehicle

I. INTRODUCTION

Brakes are employed to stop or retard the motion of any moving body. Thus, in automobiles the brakes are having the most important function to perform. In conventional braking system the motion is retarded or stopped by absorbing kinetic energy by friction, by making the contact of the moving body with frictional rubber pad (called brake liner) which causes the absorption of kinetic energy, and this is wasted in form of heat in surroundings. The electric motor, normally used for propulsion, can be used as a generator to convert kinetic energy of the vehicle back into electrical energy during braking, rather than wasting energy as heat. This electrical energy can then be stored in an ESS (e.g. *batteries or ultra capacitors*) and later released to propel the vehicle using the electric motor. This process becomes even more important when considering the energy density of batteries compared to gasoline or diesel fuel. Energy density is defined as the amount of energy stored in a system per unit volume or mass. Regenerative braking refers to a process in which a portion of the kinetic energy of the vehicle is stored by a short term storage system. Energy normally dissipated in the brakes is directed by a power transmission system to the energy store during deceleration. That energy is held until required again by the vehicle, whereby it is converted back into kinetic energy and used to accelerate the vehicle.

II. WORKING OF REGENERATIVE BRAKING SYSTEM

Regenerative braking is a braking method that provides charge to the battery by converting the mechanical energy of the motor and kinetic energy into electrical energy. In regenerative braking mode, the car's engine slows down on an incline. When force is applied to the brake pedal, the vehicle slows down and the motor runs in the opposite direction. When operating in the opposite direction, the engine acts as a generator and converts torque energy into electrical energy. In this way, fuel consumption and emissions are reduced. In high-speed vehicles, the braking force is lower, and therefore does not adversely affect the traffic flow. The new electric-hydraulic power train is a parallel hybrid system that includes a traction motor, battery pack, hydraulic pump / motor (secondary component), hydraulic accumulator, reservoir, and a set of hydraulic valves. The hydraulic circuit includes the drive circuit and the drain circuit. The drive circuit consists of a cartridge valve, a one way valve, and a two-position four-way valve. When the vehicle is braking, the valve is shifted to the left; this directs the oil from the reservoir to flow towards the accumulator using the secondary component pump / motor. The secondary component operates in pump mode, using the kinetic energy of the vehicle to pressurize the oil in the reservoir to flow into the accumulator. The energy is stored in the accumulator and the vehicle slows down. The hydraulic system works in the regenerative braking mode. These brakes work very effectively in urban braking situations. The brake system and control sensors are programmed to control all of the vehicle motors. The brake control sensor calculates the electricity to be generated and the rotational force to be fed to the batteries by monitoring the speed and torque of the wheel. During braking, the brake control sensor controls the electrical energy generated by the motor and directs it to the batteries.

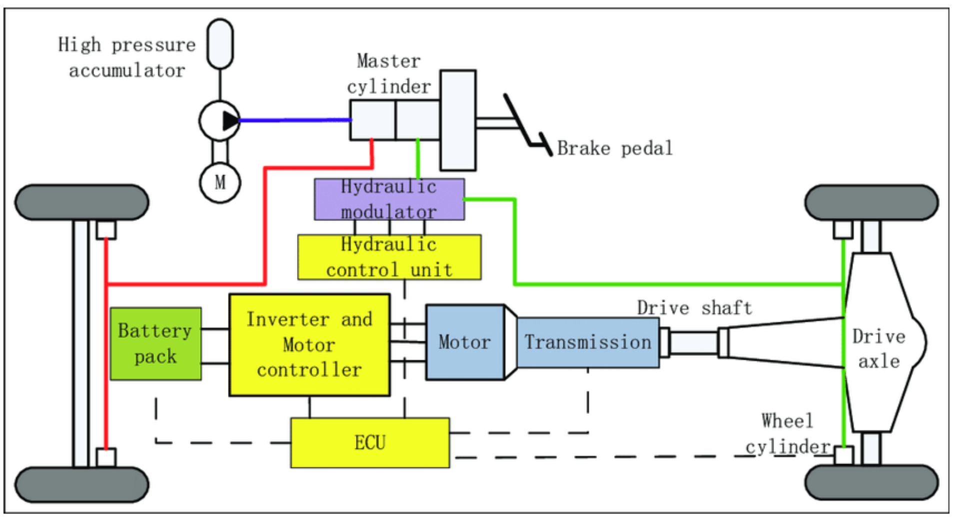

Fig 2.1 Regenerative Braking System

2.1 Types of Regenerative Braking System

2.1.1 Serial regenerative braking

Serial regenerative braking is based on a combination of friction-based adjustable braking system with a regenerative braking system that transfers energy to the electric motors and batteries under an integrated control strategy . The overall design is to estimate the deceleration required by the driver and distribute the required braking force between the regenerative braking system and the mechanical braking system . Serial regenerative braking could give an increase of 15-30% in fuel efficiency. It requires a brake-by-wire system and has more consistent pedal feel due to good torque blending capabil

2.1.2 Parallel regenerative braking

Parallel braking system is based on a combination of friction-based system and the regenerative braking system, operated in tandem without an integrated control. The regenerative braking force is added to the mechanical braking force which cannot be adjusted. The re generative braking force is increasing with the mechanical braking force. The beginning pedal travel is used to control the regenerative braking force only, the normal mechanical braking force is not changed. The regenerative torque is determined by considering the motor capacity, battery state of charge SOC, and vehicle velocity. The regenerative braking force is calculated from the brake control unit by comparing the demanded brake torque and the motor torque available. The wheel pressure is reduced by the amount of the regenerative braking force and that supplied from the hydraulic brake module . Parallel regenerative braking could give an increase of 9-18% in fuel efficiency. It can be added onto a conventional braking systems. However it could compromise the pedal feel and hence requires more work in achieving good torque blending.

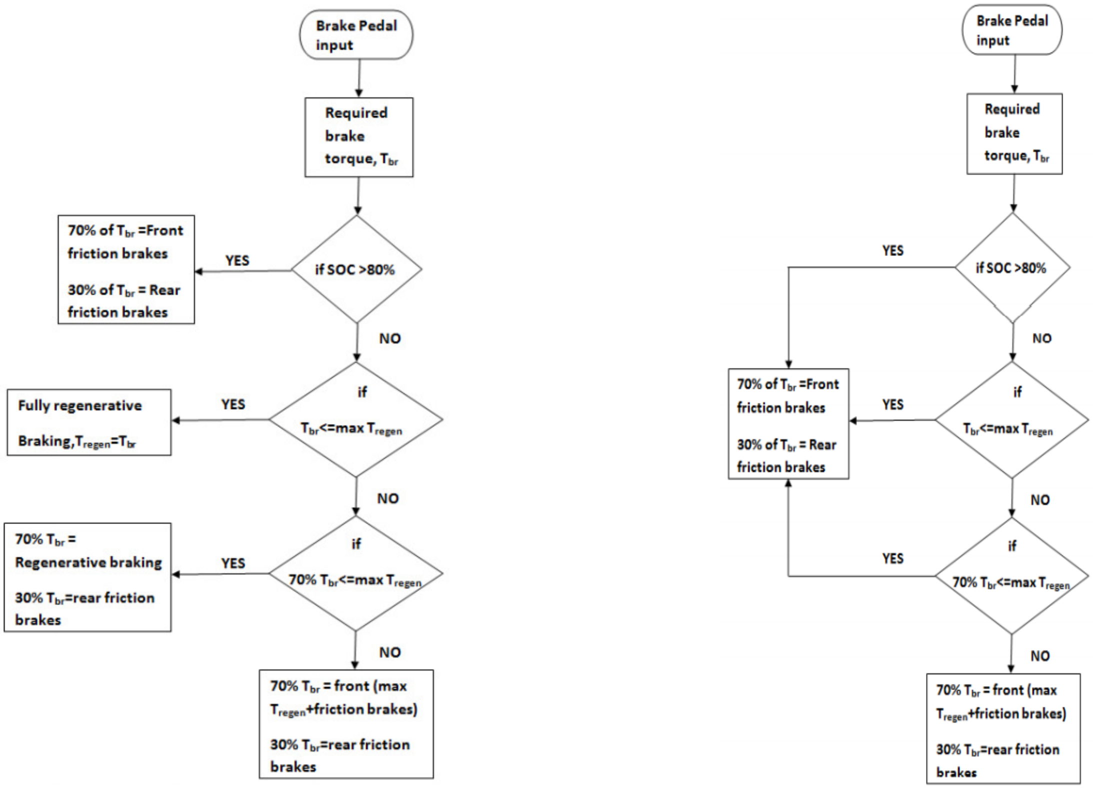

Fig 2.2 Flow Chart for Series and Parallel Regenerative Braking System

2.2 Application

- 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.

2.3 Advantages

- 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 Brake Wear– Cutting down the replacement brake linings cost, the cost of labor for installation, and machine downtime.

2.4 Disadvantages

- 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.

III. Design Calculation

3.1 Formulae

The calculations are done on the basis of regenerating capacity of the vehicle with the regenerative braking installed. The formulae require performing these calculations are given below:-

- To calculate the breaking force is (F_b)= $(mv/\Delta t)$
  Where, m is mass of object, v = velocity of object , Δt = time required to stop the object.
- To calculate electrical energy stored we have E= (V * I / T *2)
  Where V is voltage, I is current, T is time in sec
- To calculate Rotational Kinetic energy = $\frac{1}{2} I \omega^2$
  Where I = moment of inertia of wheel, ω = angular velocity
- To calculate Braking Energy = $\frac{1}{2} m (v_i^2 - v_f^2)$
  Where m = mass of object, v_i = initial velocity, v_f = final velocity

3.2 Calculation

1. Braking Force

   F_b = lets take delta (t) = 5 sec

   Let m = 850 kg ; v = 60 kmph converted to m/s = 16.66 m/s

   850kg * 60000m/3600s = 5* F_k

   F_k = 2832.2 kg m/s^2 or N (Newton)

   It is the total force to stop the car lets say 4 disk brakes engages at the same time each brake needs to provide 708.05 kgm/s^2 brake force.

   $F_k = k * F_b$

   F_k=friction force
   k= friction coefficient
   Ac = contact area
   F_b= braking force (normal force 90 degree)

If the pad area is 10 cm^2 ; Ac= 0.0001m^2

If the disc is cast graphite flake grey iron friction coefficient k = 0.4

Then

$708.05 = 0.4 * F_b$

Thus Braking force should be F_b = 1770.12 kgm/s^2

Hydraulic pad pressure should be

$F_b = P * Ac$
1770.12kgm/s2 = P *0.001m^2

P= 1770.120 = kg/ms (Pascal)

2. Electrical Energy

Output voltage =7.4 volt

Output current range = 14mA

Time required to stop the vehicle = t = 5s

Speed of the wheel= N= 895 RPM

Electrical energy stored (E) = V * I / 2 * T = $(7.4*14*(10^{-3}))/(2*5)$ = 0.0103 J

3. Rotational Kinetic Energy

Let N = 895 RPM

Tyre weight = 6.7 kg

Radius of Wheel = 0.1778 m

Angular velocity (ω) = 2πN/ 60= 93.72 rad/s^2

Moment of inertia of two wheel (I) = 2* MR^2= 0.423 Kgm^2

Rotational kinetic energy (K) =½ I ω^2 = 1857.69.J

4. Braking Energy

m = 850 kg

$v_f = 0$

v_i = 60 kmph = 16.667 m/s

$E_b = 0.5 * m * (v_i – v_f) = 0.5*850*(16.667^2 – 0^2) = 118060.277$ J

For a vehicle coming to complete rest the braking energy is equal to kinetic energy. If the vehicle is not coming to complete rest then the braking energy would not be equal to kinetic energy.

IV RESULT

In this Paper we have discussed about types and working of Regenerative Braking System. This system is helpful to restore energy in hybrid and electric vehicles. This System has maximum efficiency of about 60-70%.This system will be playing a vital role in energy conversion. In race cars the Regenerative braking system has been more effective if used with anti-lock braking system.

V.CONCLUSION

Regenerative braking is one of the effective and emerging technologies which can serve the purpose of capturing and reusing energy lost while braking. The above discussed storage system proves flywheel as a better energy storage system. There is always scope for improvement in terms of technology. Thus, the effort should be made to layout an appropriate design of flywheel which can bear a large amount of the stress developed in flywheel. Also, the research should be made to incorporate such a material for the flywheel which have good strength and comparatively less weight so that they can be feasible for the practical aspects of vehicle. The theoretical investigation shows vehicle that makes frequent stops it can significantly help improve fuel economy of vehicle driven primarily in city about 25%savings in fuel consumption. So also meaning less pollutants emissions and increase in engine life. Regenerative braking is an effective method of improving vehicle efficiency and longevity Is in EVs. It is clear that when the torque driven by the vehicles is measured. Electrical power generated by motor, generator and battery is very useful and hence it should be used in electric vehicles

REFERENCES

[1] S.J.Clegg, “A Review of Regenerative Braking System”, Institute of Transport Studies, University of Leeds, Working paper of 471, 1996.

[2] Chibulka.J, “Kinetic Energy Recovery System by means of Flywheel Energy Storage”, Advanced Engineering, Vol. 3, No. 1, 2009, pp. 27-38.

[3] "Cutting vehicle emission with regenerative braking "P. Clarke, T. Muneer, and K. Cullinane. Transp. Res. Part D Transp. Environ., vol. 15, no. 3

[4] "Flywheel energy and power storage systems" B. Bound, H. Bernhoff, and M. Leijon. Renew. Sustain. Energy Rev., vol. 11, no, 2, pp. 235-258

[5] “Regenerative Braking System” Deepak Vishwakarma, , Sayuja Chaurasia. Imperial International Journal of Eco-friendly Technologies Vol.- 1, Issue-1(2016), pp.27-30

[6] Auto.howstuffworks.com/auto-parts/brakes/brake-types/regenerative-braking.

[7] Research on Regenerative Braking Systems: A Review Bekir Guney , Halil Kilic, International Journal of Science and Research (IJSR) ISSN: 2319-706

[8] “Design and fabrication of regenerative breaking system”. Jerome Nithin Gladson, Suriya B, Ashok Kumar, A Kalyan, International research journal of engineering and technology,Vol 08,Issue No.5

[9] “Regenerative Braking System in Automobiles” Santosh Bawage, Prashant Ranjan, Omar Chaudhari , Sasmit Rai, International Research Journal of Engineering and Technology ,Vol4,Issue 4

[10] “Design, Analysis & Performance Testing of regenerative Braking system” Rohan S Kulkarni, Kshitij Dwivedi, Aditya R Kulkarni, Rajlaxmi B Kolur, Atharv S Kirad, International research journal of engineering and technology,Vol 07,Issue 8

[11] “Research on Electric Vehicle Regenerative Braking System and Energy Recovery” GouYanan, International Journal of Hybrid Information Technology Vol.9, No.1 (2016), pp. 81-9

[12]Dixon J, Ortuzar M; “Regenerative Braking for an Electric Vehicle using Ultracapacitors and Buck-Boost Converter”.

[13] Chuanwei Z, Zhifeng B; “Study on Regenerative Braking of Electric Vehicle”.

[14] Zhang Z, Li W, Zheng L; “Regenerative Braking for Electric Vehicle based on Fuzzy Logic Control Strategy”.

[15] Lv Hongping” Research and Implementation on Control Strategy of “Regenerative Braking for Pure Electric Vehicle”.

[16] Yi Zhang”The Application of Regenerative Braking System to the Commercial Hybrid Vehicles with All-Wheel Drive System”

[17] Deepak Vishwakarma, Sayujya Chaurasia “Regenerative Braking System”

[18] GouYanan "Research on Electric Vehicle Regenerative Braking System and Energy Recovery"
[19] Santosh Bawage, Prashant Ranjan, Omar Chaudhari,Sasmit Rai,"Regenerative Braking System in Automobiles"
[20] Pratik Bhandari, Shubham Dubey, Sachin Kandu, Rupesh Deshbhratar "Regenerative Braking Systems (RBS)"
[21] Bekir Guney , Halil Kilic, "Research on Regenerative Braking Systems: A Review"
[22] Sayed Nashit, Sufiyan Adhikari, Shaikh Farhan, Srivastava Avinash and Amruta Gambhire, "Design, Fabrication and Testing of Regenerative Braking Test Rig for BLDC Motor".
[23] Khushboo Rahim, and Mohd. Tanveer, "Regenerative Braking System: Review Paper", International Journal on Recent and Innovation Trends in Computing and Communication.