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REVIEW ON REGENERATIVE HYDRALAUIC BREAKING SYSTEM WITH MEASUREMENT OF PERFORMANCE BY ELECTRONIC VACCUM BOOSTER

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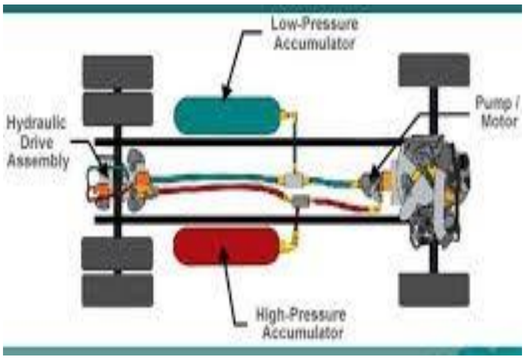
Abstract – *This paper gives brief information about the regerative hydraulic breaking system. The* ***hydraulic brake*** *is an arrangement of braking mechanism which uses brake fluid, typically containing ethylene glycol, to transfer pressure from the controlling mechanism to the braking mechanism. The factors under investigations are the brake pedal stroke velocity, the gaps between the brake pads and the brake disc, and the configuration of the brake system. This paper presents a new configuration of parallel hydraulic regenerative vehicle (PHRBV) to improve the braking energy regenerated potential and engine work efficiency. Based on the analysis of optimal energy distribution for the proposed PHRBV over representative urban driving cycle, a fuzzy torque control strategy based on the vehicle load changes is developed to real-time control the energy distribution for the proposed PHRBV. Simulation results demonstrate that the proposed PHRBV with torque control strategy takes advantage of the high power density and efficiency characteristics of the hydraulic regenerative braking system minimizes the disadvantages of low energy density and effectively improves the fuel economy of PHRBV.*

Key Words: Hydraulic system schematic, parallel hydraulic regenerative braking, hysteresis, hydraulic system, brake system

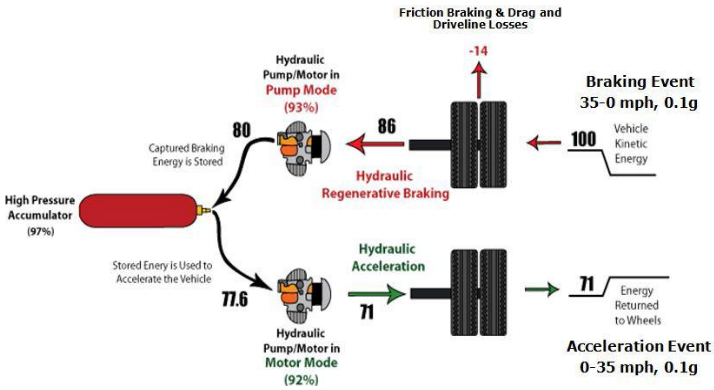
1.INTRODUCTION

In now a day the world facing the problem of energy exhaustion and pollution control. many car-producing countries have been controlling the polluting emissions and fuel economy of their vehicles by setting more standards. Therefore, it brings the new energy vehicle, which can regenerate energy while braking, to public focus. 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 drive shaft and accelerate vehicle. Thus the engine remains idle while the pressure is released and when the accumulator is empty, or the desired speed is the engine will engage to maintain constant velocity.



OBJECTIVE

The primary objective of this topic is to validate that a Hydraulic regenerative braking system can increase the stop and go fuel efficiency of a vehicle by 32%. It is energy recovery mechanism which slows a vehicle or object down by converting kinetic energy into another form which can be either used immediately or stored until needed.



DESIGN

The design is transparent so that the control of this system functions as intuitively as possible. It was designed to be controlled by gas and brake pedals so that any new user will be familiar with its control. The design of the hydraulic system was created so it in no way hinders the performance or integrity of the vehicle. Not only will the system be predictable in use, it will be reliable and consistent.

Hydraulic regenerative braking system

A Hydraulic regenerative braking system schematic waseated for a series hydraulic hybrid vehicle. This schematic was designed to include acceleration and braking control using hydraulic flow control valves, regenerative braking using check valves, and forewords and reverse directions using a directional selector valve. An important safety feature of the hydraulic schematic is the high pressure relief valve, which ensures that the pressure in the system never reaches an unsafe level

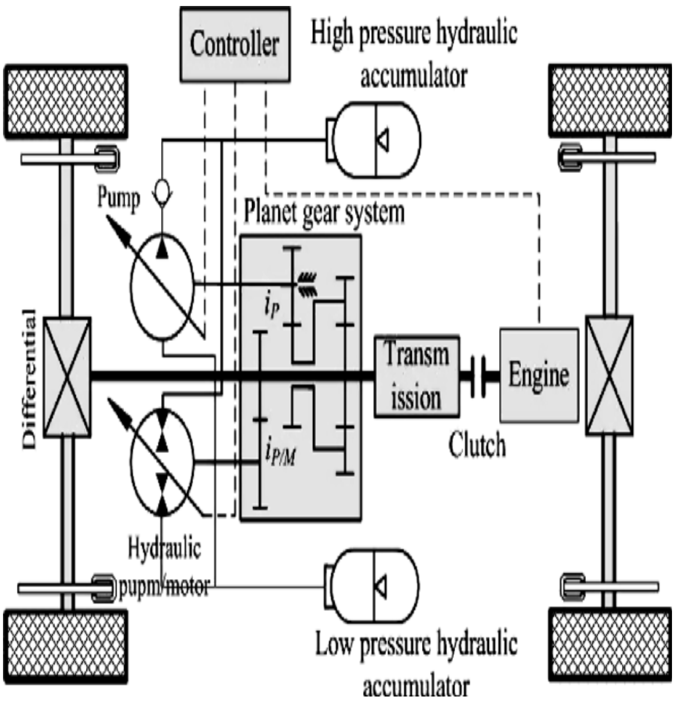


Fig. presents a new type of configuration for hydraulic regenerative braking system which consists primarily of an engine, a high-pressure accumulator, a low pressure reservoir, a variable displacement hydraulic pump, and a variable displacement hydraulic pump/motor unit, clutch, transmission and differential. The hydraulic pump/motor and hydraulic pump are coupled to the propeller shaft via a planetary gear system. During deceleration, the hydraulic pump/motor decelerates the vehicle while operating as a pump to capture the energy normally lost to friction brakes in a conventional vehicle. Also, when the vehicle brake is applied, the hydraulic pump/motor uses the braking energy to charge the hydraulic fluid from a low pressure hydraulic accumulator into a high-pressure accumulator, increasing the pressure of the nitrogen gas in the high-pressure accumulator. The high pressure hydraulic fluid is used by the hydraulic pump/motor unit to generate torque during the next vehicle acceleration. It is designed and sized to capture braking energy from normal, moderate braking events and is supplemented by friction brakes for aggressive braking. Cruise conditions, the hydraulic pump works for charging the hydraulic accumulator, meantime, adjust the engine working point onto the optimal fuel consumption region. When the hydraulic accumulator pressure reaches the highest initiative charging pressure value, the vehicle is driven by the hydraulic accumulator and hydraulic pump/motor. The introduction of hydraulic pump minimizes the lower energy density disadvantage of the accumulator and makes the engine work in high efficiency region through the initiative charging function.

Impact of pump/motor install position on braking energy regeneration

Allocate the hydraulic pump/motor behind the front differential (the front-wheel-drive model) has a greater potential in braking energy regeneration because of the increasing of the front axle load during braking. The front wheel braking force Ff1 and the rear wheel braking force Ff2 are given by [Eq. 1 and 2], respectively.

$$F_{f1} = \varphi\left(Gb + m\frac{du}{dt}h_g\right)\Big/L$$

$$F_{f2} = \varphi\left(Ga - m\frac{du}{dt}h_g\right)\Big/L$$

where u is the friction coefficient between tire and road surface, a is the distance from vehicle center of gravity to front axle center line, b is the distance from vehicle center of gravity to rear axle center line, L is the wheel base and hg is the height of the center of gravity. During the course of braking, the front axle load increases and the rear axle load decreases, therefore, install pump/motor behind the front differential has greater potential in braking energy regeneration. the impact of hydraulic pump/motor install position on braking energy regeneration under different driving cycles.

Operating conditions of PHRBV

Parallel hydraulic hybrid vehicle mainly includes the hydraulic driving condition, cruise condition, accelerating/climbing condition and regenerative braking condition.

MEASUREMENT FOR PERFORMANCE PARAMETER

1 Experiment method

EVB adjusts brake pressure to achieve the desired acceleration. In order to get the desired acceleration, we need to know the relationship between braking intension, the input signal of electronic vacuum booster, and the acceleration of vehicles. In our experiment, different braking intension is sent to the EVB and the actual acceleration will be measured after the braking system adjusts the brake pressure. The relationship between the desired braking intension and the actual acceleration can be obtained. Then calculating the inverse function can get the relationship between the desired acceleration and the actual braking intension, and the inverse function can be used to describe the performance of the EVB. For the purpose of measuring whether speed has an influence on the relationship between the braking intension and the acceleration, the experiment is conducted under different speeds. The method to get performance parameter by experiment is as follows: Let the test car run with the different speeds, then give the different brake intension signals to the CAN bus of test car. The EVB will get the signals and implement automatic control. At the same time GPS measures the speed, and the IMU measures the crosswise and axial acceleration of the car. According to the relationship of the brake intension signal, the acceleration and the speed, the performance parameter of the EVB can be obtained.

2. *Data acquisition*

This experiment is to get the relationship between the vehicle acceleration and the brake intension signal. The actual values of the acceleration and brake intension signal of test car have to be measured. The experimental facilities are as follows: two test cars with electronic vacuum boosters, IMU (Inertial Measurement Unit), GPS and IPC (Industrial Personal Computer). The data acquired by the equipment are as follows: the input brake intension signal (that is the desired braking intension, whose theoretical value is between 0~100, while corresponding with the brake pressure from 0 to 10MPa), the crosswise and axial acceleration of the IMU, and speed of the test car.. The specific steps are as follows:

(1) Conduct the experiment at every desired braking intension 5 times respectively.

(2) Send the brake intension signal to the EVB when the speed achieves to 60km/h and let the signal last for 3~5 seconds. The data are recorded at the same time.

(3) Send the brake intension signal to the EVB again when the test car has slowed down, and repeat the same work until the speed approach to zero.

Data collection is carried out for two cars, getting 16188 and 4579 groups of data respectively.

3. *Data processing*

The installation position between the IMU and the test car's center of gravity has some deviation (shown as Fig.2). The data acquired by the IMU is not the test car's crosswise and axial acceleration. While it is the IMU's (y *a* & *x a)*, we have to calculate the crosswise and axial acceleration of the test car (Y *a* & *X a)*.

The installation deviation angle of IMU, is the deviation angle between the IMU and the test car.

In order to analyze the variation tendency of the acceleration and whether speed has any influence on the acceleration, the time-dependent curve of acceleration and the speed-dependent curve of acceleration have been made. At the same time the relationship of the desired braking intension, the actual acceleration and the speed has been made

3. Results and analysis

The data acquisition and processing give the result that the relationship between the desired braking intension and the acceleration can be separated into 3 parts. For example, for the first car, the first part: when the desired braking intension is less than 7, the braking effect is not obvious. The result almost presents to be a horizontal line. The second part: when the desired braking intension is between 7~40, the relationship of the desired braking intension and the acceleration presents to be linear variation. From the linear equation matched by the two cars, the performance parameter of the EVB can be got by calculating their inverse functions. The third part: when the desired braking intension is greater than 40, the acceleration is constant. It means that the wheels are locked. The results show that the performance parameters of the different cars' EVB are not the same. So the performance parameters of the EVB installed in the different cars have to be measured respectively. At the same time, the relationship between the desired braking intension and the acceleration is not a simple linear relation, but we can use linear model to describe different segments. According to the relationship of the desired braking intension and the acceleration, deducing the inverse function can easily get the relationship of the desired acceleration and the braking intension, and the inverse function can be used to describe the performance of the EVB. When the vehicle is conflicting with other vehicles, the safety acceleration will be sent to the EVB by programming with the performance parameter. The braking system will actively adjust the brake pressure until the speed slow down and avoid the conflict.

CONCLUSION

Hydraulic hybrid technology has the advantage of high power density and the ability to accept the high rates/high frequencies of charging and discharging, therefore, it is well suited for off-road vehicles and heavy-duty trucks. But the lower energy density requires a special energy control strategy for PHRBV. In this study, a new type of configuration for PHRBV is presented. A fuzzy-based torque control strategy is built using the optimization results according to the torque distribution among the engine, hydraulic pump/motor and hydraulic pump, and the vehicle load changes is introduced to the

fuzzy torque control strategy for realizing the fuel economy fullest. The simulation results show that the new configuration of PHRBV effectively improved the braking regenerative potential.
Also This paper introduces a method to measure the performance parameter of automobile braking system with electronic vacuum booster via real vehicle experiment. The conclusions are as follows:
(1) The speed has no influence on the relationship between the desired braking intension and the acceleration.
(2) The performance parameters of the different cars' EVB are not the same, so the performance parameters have to be measured respectively.

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