CALCULATION OF REGENERATIVE ENERGY WHEN BRAKING OF HYBRID VEHICLES

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GENERAL INFORMATION

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Process Parameters;

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ABSTRACT

Currently, many countries in the world are facing the risk of fossil fuel depletion, in addition to environmental pollution and greenhouse effect caused by the automobile industry. To solve this problem, major automobile manufacturers in the world have implemented the conversion of the automobile industrial revolution to electric cars with the aim of using electric energy to serve the automobile industry, solving the problem of environmental resource depletion and emissions from cars into the environment. In the face of the current serious environmental pollution situation and the threat to human health and life. In this article, the author proposes a solution to replace fossil energy sources by equipping the car engine with two main energy sources: internal combustion engine and electric motor, also known as Hybrid engine, recovering renewable energy during engine braking through a kinetic energy converter into electricity that can charge the battery or provide load for the car. Regenerative braking energy recovery is calculated based on regenerative braking theory combined with simulink simulation, and tested to calculate regenerative braking or deceleration energy on a Toyota Prius II. The results show that with a vehicle mass of 1379kg, the initial speed is 72km/h, after using regenerative braking, the speed is reduced to 32km/h and the energy collected during braking is 221.3 KJ. From the results of theoretical calculations and experimental simulations, we can manufacture a regenerative braking system applicable to popular cars in circulation in our country.

1. INTRODUCTION

In conventional vehicles, there is only one source of energy, which is the power and torque generated by the internal combustion engine to drive the wheels. However, vehicles with two or more energy sources and converters are called Hybrid vehicles. Hybrid vehicles are fully equipped with traction control systems (ASR), ABS brake control systems, and during braking or deceleration, the Hybrid vehicle will recover part of the vehicle's kinetic energy during braking or deceleration of the vehicle's engine. When the kinetic energy source is recovered during braking, when the vehicle is operating on the road to generate electricity to supply the loads and charge the battery, this helps the vehicle save fuel and limit environmental pollution. With the outstanding features of Hybrid cars, fully equipped with safe braking systems that other cars on the market do not have, Hybrid cars are the priority choice for the current automobile industry, meeting the needs and tastes of people when using cars on the road while also meeting emission standards set by the EU or EEA members.

2. RESEARCH METHOD OF HYBRID BRAKE THEORY

In the calculation of brake mechanisms, many authors have written about the braking process and maximum braking force in brake types such as disc brakes, pneumatic brakes, hydraulic-pneumatic brakes. However, no author has mentioned the braking force during the braking process reaching the maximum and recovering energy during the braking process into a useful energy source. In this article, the author builds the theory of regenerative braking and energy recovery during the braking process, combining simulink simulation to produce results close to the actual calculation of the braking theory and recovering kinetic energy from the braking mechanism, converting kinetic energy into electrical energy to charge the battery or accumulator and supplying the loads during vehicle operation. Therefore, the theory of building a braking mechanism on the Hybrid Prius II car was born. To better understand this issue, we will calculate to get practical results: A car with a mass of 1379 kg is moving at a speed of 72 km/h, using regenerative braking to reduce the speed of the car to 32 km/h, the value of energy consumed is calculated according to the formula.

Ek = ½ mv2 will be 47.8 KJ.

$E_k = E_{k1} - E_{k2} = ½ mV_1^2 - ½ mV_2^2 = ½ 1379.20^2 - ½ 1379.8.89^2 = 221308J$.

So $E_k = ½ mv^2$ would be 221,3 KJ.

Where Ek is the kinetic energy of the vehicle; m is the mass of the car and V is the speed of the car. Therefore, if this energy is captured and stored, it can be reused for vehicle acceleration instead of dissipating heat and noise in the brake mechanism. Assuming we recover 25% of that energy (ie 25% of 221.3KJ = 55.3KJ), using this recovered energy will save fuel.

2.1 Theoretical basis of regenerative braking

The task of the brake system is to eliminate the kinetic energy of the vehicle: $E= ½.mV^2$. On a hybrid vehicle, the braking system is a combination of mechanical and electric brakes to suppress the vehicle's kinetic energy. Mechanical Brake: Generates braking force at the wheel. The braking force Fp is generated by the brake mechanism. When the brake force value reaches the maximum value, Then $F_{pmax} = F_{pmax1} + F_{pmax2} = G.\varphi$ then the car skidded completely (this time slip $\delta_p=1$). With slip $\delta_p = V - (R\omega/V)$ In there V: Realistic car speed(m/s); Rω: Theoretical speed (m/s) R: Wheelradius (m); ω: Wheel angular speed (rad/s)

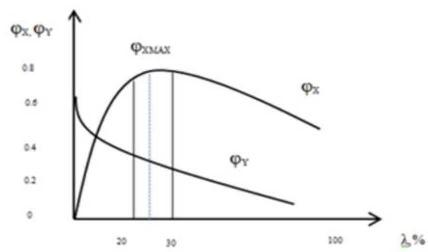

Figure 1. Graph depicting the relationship between adhesion coefficients φ_x, φ_y and slippage δ_p and dark working area

To avoid slippage, on Hybrid vehicles, ABS brakes are used to reduce Fp to maintain slippage δp= (0.2-0.3) to avoid complete skidding.

Advantages of ABS (Nguyen, 2005)

The regenerative braking system on the Hybrid is electronically controlled ABS

Electric brake: Use Motor MG2 in generator mode to create the internal magnetic field of the generator to suppress the moment of inertia at the driving wheel:

We analyze the following diagram:

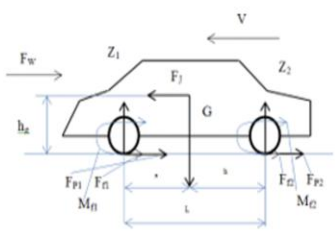

Figure 2. Forces and moments acting on the vehicle during braking (Hsu, 2013)

When the vehicle is traveling on a level road, the equation of motion when braking can be written as follows:

$M*a= -(F_f + F_p +F_\omega)$

$M*(dv/dt) = -(F_f + F_p + F_\omega)$

Where M: is the mass of the vehicle (kg); a: Acceleration of the vehicle (m/s); F_p: Braking force (N); F_ω: Wind resistance (N); F_ω = 0.625*Cx*S*V2; C_x: Air drag coefficient (Ns2/N); S: Area of front bumper of the car; V: Relative speed between car and air. If we reduce the kinetic energy of the entire car to the wheels, we have the following simplified diagram:

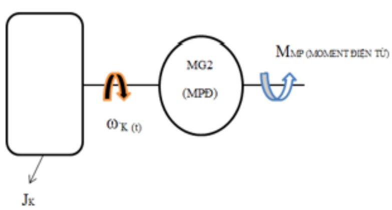

Figure 3. The diagram of the reduction of the kinetic energy of the whole car to the wheels

$\omega_{.k}(t)$: The speed of the wheel changes with time

Mmp:Electromagnetic moment generated by MG2 motor.

Jk: Moment of inertia of the vehicle mass relative to the wheel.

M_f: Rolling resistance moment.

From the reduced diagram, we have the moment equilibrium equationas follows:

$J_k*\omega_k^{\cdot} =M_{qt}=M_p= M_{mp} + M_f$

When the car brakes we have $F_{qt}=F_p$ and

$F_{qt}= m_{tg}*\delta j*j$

We have

$M_p= r*F_p= r*m *\delta j*j= r*m *\delta j*(dv/dt)$

We have $\omega_k= v$ deduce v $=\omega_k*r$ infer (dv/dt)=(dω.k.r)dt

Therefore :

$M_p=M_{qt}= r*m*\delta j*\omega_k^{\cdot}*r=m*r^2*\delta j* \omega_k^{\cdot}$

Where J_k the reduced moment of inertia of the car to the wheel

M_f: Rolling resistance moment (N.m) ;

Mmp: electromagnetic moment of generator (N.m);

r: wheel wheel (m) ;

δ_j: Factor taking into account the mass influence of rotating parts of the car.

We have the generator torque as a function of the time-dependent current I

$M_{mp}= f (I)$

$M_{mp}= M_{đt} + M_0$

In there M_0: The no-load moment is braking. $M_o= (Po/\omega)$

$P_0= \Delta P_{cơ} + \Delta P_{Fe}$: No - load loss power.

$\Delta P_{cơ} = (2 - 4\%)*P_{đm}$: Mechanical power loss.

$\Delta P_{Fe} = K*P.(1/50)*(f/50)^{\beta}*B^2*G_c$:

Magnetic conserved power.

Where: f current frequency

M_{mp}: Mechanical torque applied to the generator shaft.

$M_{đt} = C_M * \Phi_g * I_ư$

Electromagnetic moment emitted by the generator. C_M: Structural coefficient of the generator. Φ_g: Magnetic flux under each magnetic pole in the air gap ;I_u: Armature current (A) ω: Angular speed of the rotor. Because the MG2 motor is connected to the active bridge. So when braking, the motor controller MG2 acts as a generator. The moment generated in the generator will cancel the moment of inertia of the driving wheel.

$M_{mp} = (p_0/\omega) + C_M * \Phi_g * I_ư$

We have the equation of torque balance when braking with electric brake as follows:

$M_p = M_{mp} + 0.625 C_x * S * V^2$

$$\leftrightarrow m * r^2 * \delta j * \omega_k = \frac{P0}{\omega} + C_M * \Phi_g * I_ư + 0.625 C_x * S * V^2$$

$$\rightarrow I_ư = (m * r^2 * \delta j * \omega_k - \frac{P0}{\omega} - 0.625 C_x * S * V^2). \frac{1}{CM * \Phi g}$$

So we have exploited and taken advantage of the electromagnetic torque of the Mmp generator to eliminate M_{qt} (moment of inertia of the vehicle). At the same time, we get the generator's power with the corresponding current Iu. In case the required braking torque is larger than the electromagnetic torque generated by the machine, then the control unit will control the mechanical brake assist.

3. CALCULATION RESULTS OF HYBRID BRAKING

Parameters of the Hybrid Prius II:

M =1379 kg: vehicle weight; r=0.295m: wheel radius; C_x=0.35: coefficient of air resistance; S=2.1 m2: frontal wind resistance area; CM=1.1: structural coefficient of generator; ϕ_g=0.45: magnetic flux through each pair of poles; V: vehicle speed (m/s); ω = 4.113. ω_k. ω_k. (35.5 ÷ 13.5) rad/s ω = (146 ÷ 55.7) rad/s; P_0= 200 W: No-load loss power of motor.; HTTL gear ratio: 4.113.

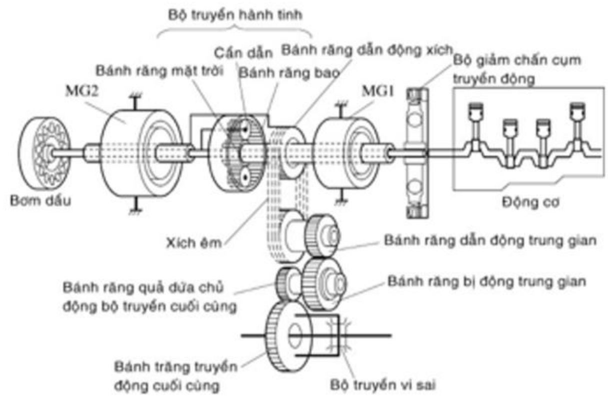

Figure 4. Transmission on Toyota Prius II (Straubel, 2008)

I= (m*r²*δj*ω· – P0 /ω – 0.625*C *S V²) *1/(C *ϕ) using Matlab software

4. DISCUSS THE PROCESS OF HYBRID BRAKING

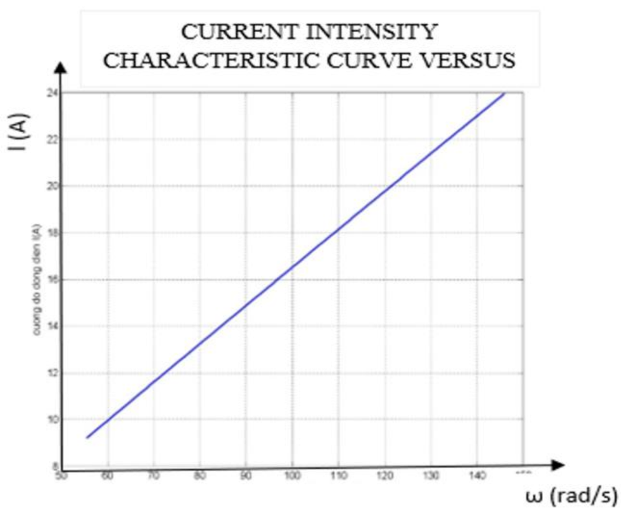

Figure 5. Graph of curent intensity characteristic curverus angular velocity

Through the graph in Figure 5, we can see that the torque supplied to the generator gradually decreases over time. The current intensity (I) of the MG2 engine in generator mode is proportional to the angular speed ω of the engine. To obtain a large enough voltage and store it for the battery, the system needs a converter and corresponding sensors to determine the battery status and the braking speed of the vehicle.

5. CONCLUSION

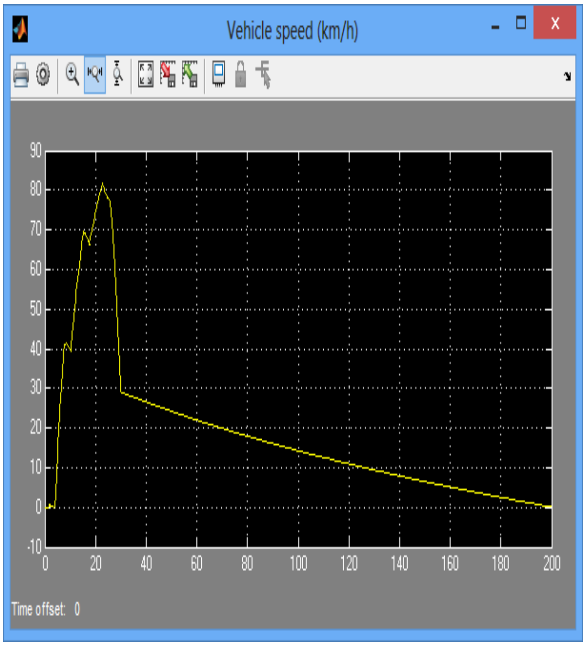

Figure 6. regenerative braking simulation results

From the graphs in Figure 5 and Figure 6, we get the results obtained when using Matlab simulation software, calculating specific parameters on the Hybrid Prius II vehicle, helping us to understand more deeply about the regenerative braking system, clearly seeing the advantages of regenerative braking when used. From the theoretical basis and calculations to give practical results, we can go to the design and manufacture of a regenerative braking system that can be applied to conventional cars currently in circulation in our country. Thus, Hybrid vehicles are the top optimal choice for customers and are widely and safely experienced on the roads of our country.

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TÍNH TOÁN NĂNG LƯỢNG TÁI TẠO KHI PHANH XE HYBRID

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TỪ KHOÁ

Polyethylene tỷ trọng cao (HDPE);
Ép phun;
Thông số quá trình;
Độ co ngót;
Phương pháp Taguchi.

TÓM TẮT

Hiện nay, nhiều quốc gia trên thế giới đang phải đối mặt với nguy cơ cạn kiệt nhiên liệu hóa thạch, bên cạnh đó là ô nhiễm môi trường và hiệu ứng nhà kính do ngành công nghiệp ô tô gây ra. Để giải quyết vấn đề này, các nhà sản xuất ô tô lớn trên thế giới đã thực hiện chuyển đổi cuộc cách mạng công nghiệp ô tô sang ô tô điện với mục tiêu sử dụng năng lượng điện phục vụ ngành công nghiệp ô tô, giải quyết vấn đề cạn kiệt tài nguyên môi trường và lượng khí thải từ ô tô ra môi trường. Trước tình hình ô nhiễm môi trường nghiêm trọng hiện nay, gây ra mối đe dọa đến sức khỏe và tính mạng con người. Trong bài viết này, tác giả đề xuất giải pháp thay thế nguồn năng lượng hóa thạch bằng cách trang bị cho động cơ ô tô hai nguồn năng lượng chính: động cơ đốt trong và động cơ điện, hay còn gọi là động cơ Hybrid, thu hồi năng lượng tái tạo trong quá trình phanh động cơ thông qua bộ chuyển đổi động năng thành điện năng có thể sạc pin hoặc cung cấp tải cho ô tô. Năng lượng thu hồi từ phanh tái tạo được tính toán dựa trên lý thuyết phanh tái tạo kết hợp với mô phỏng simulink, và được thử nghiệm để tính toán năng lượng phanh tái tạo hoặc năng lượng giảm tốc trên xe Toyota Prius II. Kết quả cho thấy, với khối lượng xe 1379kg, tốc độ ban đầu là 72km/h, sau khi sử dụng phanh tái tạo, tốc độ giảm xuống còn 32km/h và năng lượng thu được trong quá trình phanh là 221,3 KJ. Từ kết quả tính toán lý thuyết và mô phỏng thực nghiệm, chúng tôi có thể chế tạo được hệ thống phanh tái tạo áp dụng cho các loại ô tô lưu thông phổ biến ở nước ta.