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Research Article

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Simulink modelling and simulation for self-excited doubly salient retarder system

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ABSTRACT

According to the self-excitation doubly salient retarder's braking torque equation and dynamic equation, its braking torque model and the vehicle's dynamics model can be built using Matlab/Simulink. The simulation results show that the relationship of automobile braking torque, excitation current and retarder speed, and that the variation of vehicle deceleration rate. This method can optimize the control system of retarder, as well as can be used as auxiliary means of verification of doubly salient self-excited retarder design.

Key words: self-excited retarder; braking torque; simulink simulation

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INTRODUCTION

As an auxiliary brake device for automobile, retarder is independent of brake system of automobile friction, and the most extensive application is eddy current retarder. Compared with the traditional hydraulic braking system, the eddy current retarder has obvious advantages: non-contact braking, no mechanical wear, eliminating brake sharp whistle greatly, and share most of the braking load of the vehicle, thus improving driving safety greatly, and reducing traffic accidents. Self-excitation doubly salient liquid cooled retarder is a new vehicle auxiliary braking device, as a kind of eddy current retarder, and there are many advantages, for example, the braking torque, smooth braking, energy saving and environmental protection, and it can real-timely adjust brake gear by adjusting the excitation current, so that the brake is more compliant and comfortable, and will have extensive market prospect.

This paper mainly studies the self-excitation doubly salient retarder and its kinematics model，and establish Self-excitation doubly salient retarder braking model by MATLAB/Simulink. Considering the road grade and vehicle loading conditions, we can optimize the control system of retarder excitation current with PID algorithm, by analysis of the basic law of vehicle deceleration brake.

EXPERIMENTAL SECTION

Doubly salient self-excited retarder sets its brake coil and generator's armature winding to the rotor, and sets eddy current body and the generator`s excitation winding to the stator, (Fig.1) The braking torque is adjusted by the current of generator static excitation windings [1].

During self-excited retarder working, the control module provides current to the exciting winding of the generator, and electromotive force is produced on the rotating armature winding. It provides voltage to retarder coil, resulting in possessing current and magnetic lines of force on retarder electromagnetic iron core. When magnetic line is cut by stator, eddy current are generated on the inner surface of the stator, and the torque which works on the automobile drive shaft hinders the motion of the rotor, thus resulting in the brake torque on the car.

Fig.1: Doubly salient self-excited retarder

To make sure doubly salient self-excited retard under a relatively low temperature, the heat on the stator passes the coolant pipes, circled with the engine cooling fluid. Control module to adjusts the excitation current retarder making different gears and excitation current by PWM, in order to achieve the continuously adjustment of the barking torque. When the retarder braking control module needn't to work, the module will cut off the excitation current loop, and retarder rotor won't possess the magnetic force line. The inner wall of the stator won't have eddy current and the braking torque either.

The total barking power of doubly salient self-excited retarder is comprised by the retarder barking power and the generator barking power, so the total barking power of doubly salient self-excited retarder is:

$$P=\frac{3B^2D^2a^2\omega^2b\Delta h}{(a+b)\rho}+\frac{I^2r+U_1I_1}{\eta} \tag{1}$$

Type:B is the air gap magnetic induction intensity(T);D is the retarder stator inner radius(m);a is the equivalent length of retarder rotor electromagnetic iron core(m); b is the equivalent width of retarder rotor electromagnetic iron core(m); ω is the angular velocity of magnetic field variation(rad/s); ρ is the electrical resistivity of the rotor`s iron core;h is eddy current effective depth; I is the excitation current input retarder power device(A); r is the reluctance constant generator's excitation windings(Ω); η is the rate of the effective use of the generator power;U1 is the value of the retarder generator's rated output voltage value (V); I_1 is the value of the retarder generator's rated output current value (A).

We set that T as the barking torque of the retarder (N·m), ωn as the rotor angular velocity (rad/s), and P=T× ωn , therefore,

$$T=\frac{P}{\omega_n}=\frac{3B^2D^2a^2{N_P}^2{\omega_n}^2b\Delta h}{(a+b)\rho\omega_n}+\frac{I^2r+U_1I_1}{\eta\omega_n} \tag{2}$$

$$B=\frac{8(a+b)\rho\mu_0NI}{16(a+b)\rho l_g+\sqrt{2K_e\mu_0\Delta habD\ \omega}} \tag{3}$$

$$\Delta h=\sqrt{\frac{2}{\omega\mu\sigma}}=\sqrt{\frac{2\rho}{\omega\mu}} \tag{4}$$

Type: NP is the number of the magnetic pole pairs; ωn is the retarder speed(rad/s), $\omega = N_p \omega_n$; σ is the electrical conductivity of rotor(s/m); $\rho = \frac{1}{\sigma}$; μ is the permeability of the rotor, $\mu = \mu_r \mu_0$ (H/m), μ_r is the relative permeability of rotor, μ0 is the vacuum permeability, μ0=4×π×10-7 H/m; K is the conversion coefficient; N is the number of winding of a single excitation coil; lg is the length of the air gap (m).

From the (2), the calculated T is the maximum barking torque of the doubly salient self-excited retarder. Once the barking torque determined, we can calculate the value of I(the excitation current of the excitation winding of retarder power device), and also can determine the self-excitation retarder`s excitation current. So that the relationship among the self-excitation retarder excitation current, rotor speed and barking torque can be established.

Based on (2) to (3), we set the excitation current and the rotor speed as inputs, and the braking torque as output, the module of the air gap magnetic induction intensity B is set up by MATLAB/
Simulink [2], as shown in Fig.2.

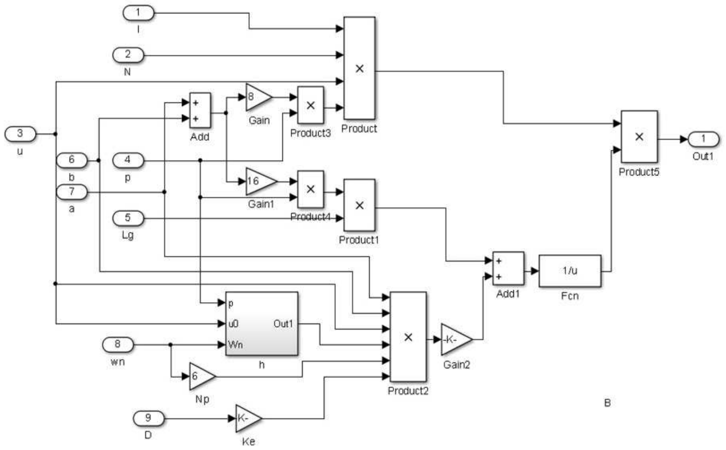

Fig.2: The module of air gap magnetic induction intensity B

After encapsulating the module of air gap magnetic induction intensity B, we can get the module of doubly salient self-excited retarder barking torque according to (2), as shown in Fig.3.

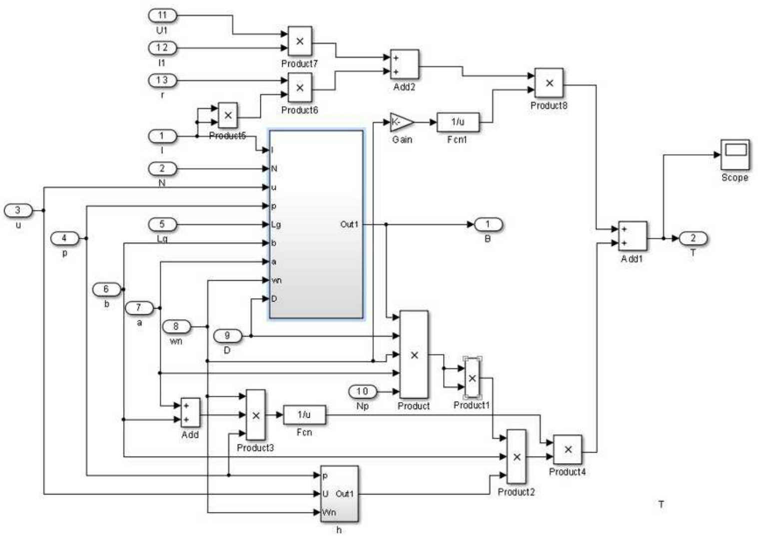

Fig.3: The module of the doubly salient self-excited retarder braking torque

The module of movement

For the module of movement, this paper mainly considers the retarder`s braking performance at the condition that the way is downhill. When the vehicle is on the road of gradient of θ, the driving force of the vehicle acceleration is the force component of the gravity along the slope, usually called the ramp down (F_i).When retarder is working, based on the vehicle's kinematics analysis, we can obtain the kinematics equation of vehicle.

$$F_d = F_i - F_f - F_w - F_R \tag{5}$$

Type: F_d is inertia force when the deceleration of the vehicle (N); F_i is the automobile rolling resistance (N); F_w is the automotive air drag (N); F_R is the retarder instantaneous braking force (N).

$F_w = Cv^2$, that C is the wind resistance constant, v is the car's speed. $F_f = mgf$, that m is the quality of the car, g is the acceleration of gravity, f is the road resistance coefficient, so the braking force retarder is:

$$\begin{cases} F_R = mg\sin\theta - mgf - Cv^2 - m\dfrac{dv}{dt} \\ F_R = \dfrac{T}{R} = \dfrac{3B^2D^2a^2N_P{}^2\omega_n{}^2b\Delta h}{(a+b)\rho\omega_n R} + \dfrac{I^2r + U_1I_1}{\eta\omega_n R} \end{cases} \tag{6}$$

According to (6), we can see the doubly salient self-excited retarder barking torque is not only associated with the performance of retarder itself, but also had a close relationship to the vehicle's quality. Under the effect of the barking torque (T) and the road slope(θ),vehicle can change the speed and we can obtain the module of movement, according to the relationship, as shown in Fig. 4.

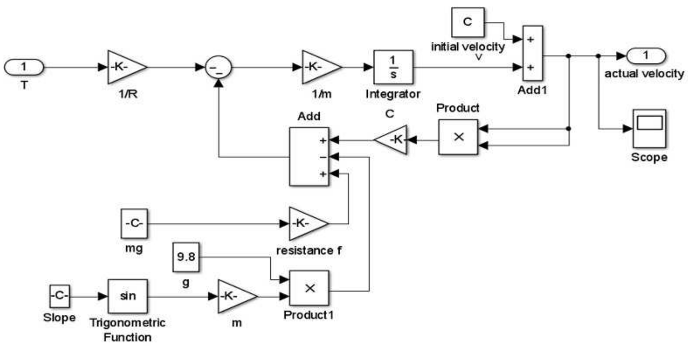

Fig.4: The module of the vehicle movement

Based on the value of current Id excitation coil, doubly salient self-excited retarder's controller divides barking gear. We can control it by the way of controlling of the value of generator stator excitation current. In this paper, using the PID control strategy, we can control the braking torque of retarding through adjusting the value of excitation current of self-excited retarder[3], and regulate the speed of the vehicle, as shown in Fig. 4.

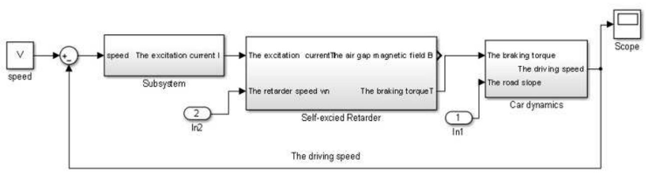

Fig.5: The module of controlled doubly salient self-excited retarder by PID simulation results and analysis

RESULTS AND DISCUSSION

It is obtained that the relationship between speed and barking torque, as shown in figure 6, through simulating the module of the doubly salient self-excited retarder barking torque. The equivalent length of the retarder rotor magnetic core is 100mm,and the equivalent width of the retarder rotor magnetic core is 30mm, and the inner radius of the retarder stator is 442mm,and the magnetic poles is 6,and the air gap length is 1mm,and the permeability of vacuum is 4 π × 10-7,and the conductivity of rotor core is 7×10-6s/m. Because that the gear distribution of retarder barking force is uniform, it can be adjusted that the retarder barking torque through changing the value of 10A, 20A, 30A of excitation current[4].

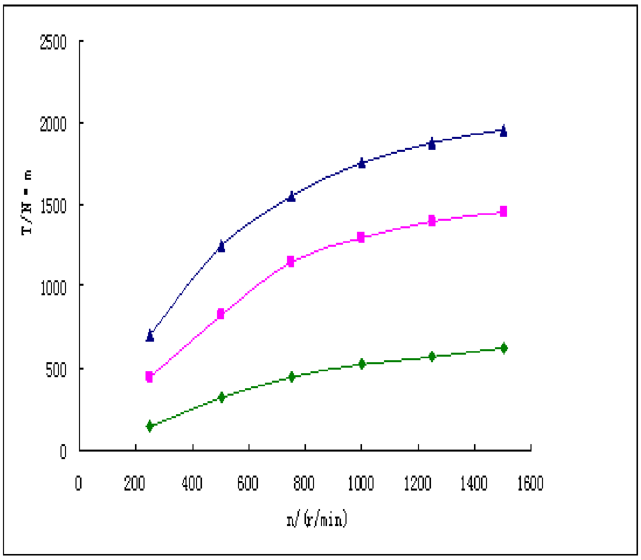

Fig.6: Retarder brake performance under different excitation current

Setting the simulation object is the BT-5313VNCJJ-S truck of Beijing FuTian Motor Limited Company, the vehicle performance test which installs the retarder that this paper introduces is test. The main technical parameters of the vehicle is that the no load weight is 14T, and the tire radius is 0.552m, and the transmission ratio is 4.8.If the vehicle drives on the ramp of average slope of 6% by changing the value of braking torque, we can simulate the module of vehicle movement as the figure 4, and can obtain the simulation results of different gear [5].

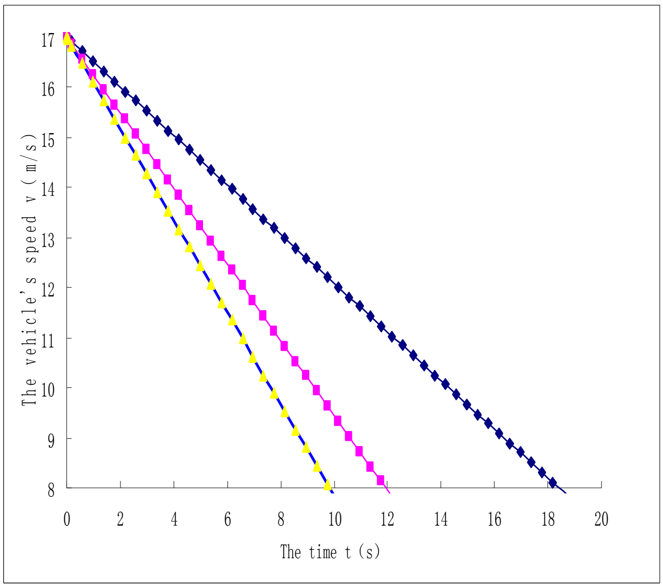

Fig.7: The relation of speed and time under different gear

From the analysis of the simulation results, the higher the speed is, the bigger the barking torque is, and the greater the current is, the bigger the barking torque is. From the velocity-time curve at three gear case, it can be seen that the bigger the gear is, the shorter the braking time is. In other words, if you want to quickly brake, you will increase the braking torque. The simulation results reflect the actual situation of retarder.

CONCLUSION

In this paper, through analysis and processing to the modeling, simulation and data of braking system which install doubly salient self-excited retarder, meanwhile, simulation the retarder dynamic system, it is obtained that the relationship between braking torque and speed under the different excitation currents. The research can be used for design reference of automotive electric eddy current retarder.

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