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Parameter Optimization Design Model of Permanent Magnet Retarder Based on Artificial Neural Network Algorithm

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Permanent magnet retarder wins high favor of large cars with easy installation, low power consumption and small size. But this retarder is easily affected by outside conditions or road conditions, so that the temperature field, the magnetic field, the relationship between design parameters will be changed, and the brake torque will further be affected. Through research we found that the parameter design of permanent magnet retarder is the most important point. An optimized parameter enables the brake torque to come into full play and to adjust its external environment. The paper presents the parameter optimization design model of permanent magnet type retarder based on neural network algorithm. In the model, the design parameters of permanent magnet retarder is taken as input values, all influencing factors as the hidden layer of neural network, and the weight coefficient and threshold values of various scene parameters are constantly adjusted to conform to meet practical needs. In addition, according to the results of the output layer, the values of the design parameters are constantly adjusted to reach the ultimate goal of optimizing the design parameters. The comparison of experimental analysis shows that with practicability and reliability, the model can provide a more intelligent, simpler method for the design of permanent magnet retarder.

1. Research background

The large automobile of brake apparatus is an important guarantee for safe driving. In the case of constant speed downhill or high speed slow braking, the large automobile needs to keep the speed below 30 km/h. In general, the automobile needs to use the brake system to slow down the speed. There is a marked defect in the brake: frequent or prolonged use of easy to cause brake drum and friction plate heat, leading to a sharp drop in brake torque, brake failure, thus causing traffic accidents. This phenomenon is more prominent in the long running on the slope of the large motor vehicles in the road. If we want to fundamentally solve these problems, the economic practical approach is to install auxiliary brake device for reducing the speed of the vehicle, so that it can reach the standard of safe driving.
Generally speaking, the design parameters of permanent magnet retarder are empirical method, trial method, and physical structure analysis method. Although the optimized design parameters can be found when under certain conditions, but it takes a long time or the efficiency is slow. And if the condition changes, there is a process of re searching for the optimization parameters. Therefore, a lot of studies tend to establish the model for the design of structure parameters of permanent magnet retarder. These models can be more comprehensive, more specific and more optimized. For example: three dimensional model of brake torque, the temperature field of the motor brush and so on. This article is the use of artificial intelligence algorithm in the neural network, combined with the permanent magnet retarder of various factors, and then put forward the parameter optimization design model. The feature of the model is that it has the function of intelligent analysis, and it can have a feedback mechanism. Through the mechanism to adjust the design parameters in order to achieve the purpose of fast find the optimization value.

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2. Structure influence factor analysis and parameter

2.1 The principle of application and the structure for permanent magnet retarder

Permanent magnet retarder has the advantages of small volume, low energy consumption, convenient installation, so that the structure is different from other kinds of retarder. It mainly consists of three parts: the mechanical device, the control device and the auxiliary device. They are the basic parts: rotor drum, stator, permanent magnet, magnet, magnetic holder, movable iron bracket and so on. As actual picture shown in Figure 1 below:

Figure 1: The permanent magnet retarder

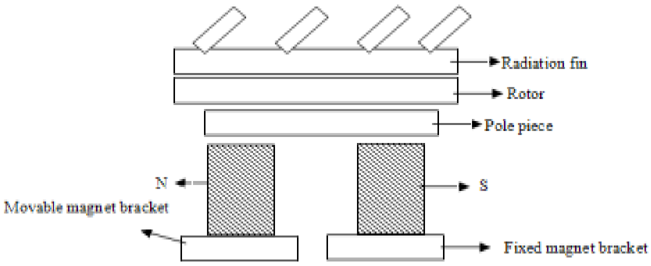

Figure 2: Structure diagram of permanent magnet retarder

The application principle of permanent magnet retarder is to enter the working state through a braking device. After entering the state, the two column poles are alternating with each other, and the magnetic force of the permanent magnet is generated by the reverse. After the magnetic pole piece of the stator in the rotor drum to form a loop, the rotor drums cutting lines to form a vortex. The kinetic energy of the car is converted into eddy current loss, which is dissipated by heat. And thus it generates the brake or slow speed on the drive shaft. The whole process is the converting kinetic energy into heat energy. The concrete structure is shown in Figure 2.

2.2 The parameters and influence factors of the brake torque

The key design of permanent magnet retarder is the selection of the parameters. The traditional design idea is to set up the objective function or model, and study the relationship between the design parameters and the objective function or model. In actually, permanent magnet retarder under the influence of many factors, objective function or model generally do not have self-learning or modulate the function that the design parameters can only meet the needs of a situation, but for a condition may is not suitable. In other words, there is no effect on the actual operating conditions. This section is analysis of permanent magnet retarder with the various influencing factors, in order to get the relationship between influence factors and parameters. Brake torque is an important index to measure the parameters of the design parameters. All parameters are designed with the aim of maximizing brake torque. Permanent magnet retarder can optimize the design parameters mainly have the following several kinds: the radius rotor r , circumference width w , the air gap δ , axial length L , permanent magnet height h_{pm} and so on. The effects of these parameters on the brake torque are both positive and negative, some of the impact of large, and some of the impact of small. So it is necessary to analyze these factors separately.

1) The relationship of electromagnetic field and structural parameters

The expression of the brake torque is derived by the equivalent magnetic circuit method, as shown in the formula (1), W representation method as formula (2):

$$T=\frac{\pi\sigma L r^{3}\Delta h w}{2}(\frac{2\mu_{0}H_{c}h_{pm}}{3\delta+K_{d}\sigma\omega w r\Delta h})^{2} \tag{1}$$

$$w=2\pi n/60 \tag{2}$$

$$y_{n}=\omega_{ni}x_{n}+\theta_{i} \tag{3}$$

The influence of the design parameters of the rotor drum radius, circumference width, the air gap, axial length and permanent magnet height on the brake torque is derived by the above formula. According to many experiments and analysis, the relationship between these parameters and brake torque is approximately linear. Thus, the formula (3) can be used to express the relationship between them.

So that r , w, δ , L , h_{pm} can be set to a set of input values (x_1,x_2,x_3,x_4,x_5) , ω_i is the corresponding weight adjustment factor. The formula of the five input array are related to the weight coefficient, can be expressed as $(\omega_1,\omega_2,\omega_3,\omega_4,\omega_5)$. The weight value coefficient of the radius rotor is positive. The weight value coefficient of circumference width is negative. The weight value coefficient of air gap width is negative. The weight value coefficient of axial length is positive. The weight value coefficient of the permanent magnet height is positive. Through the learning process of neural network is to adjust ω_i and value θ_i . So these two values can be infinitely similar to the practical application.

2) The relationship of temperature field and structural parameters

Permanent magnet retarder with the increase of temperature, its performance tends to decline. When the kinetic energy of the retarder is converted to heat dissipating. If retarder temperature rising, brake torque decreased. Therefore, the rotor temperature influence on the performance of permanent magnet retarder greatly. Through the research and the experiment, we find that the heat dissipation structure of the rotor can effectively improve the heat flux of the rotor; reduction of rotor temperature rise and temperature rise rate; reduce the temperature effect on the permanent magnet demagnetization; to improve the permanent magnet retarder braking stability and service life influence. The heat capacity expression of the rotor is shown in the formula (4):

$$Q=mC\delta=\rho 2\pi r L h c\delta \tag{4}$$

$$B_{g}=\frac{A_{m}/A_{g}}{1+(\frac{R_{g}}{R_{m}})(1+2Z+4\lambda)}B_{r} \tag{5}$$

From the formula, the main parameters influenced by the temperature of the permanent magnet retarder are: the radius rotor r, the air gap δ , axial length L. The relationship of the parameters can be represented by the formula (3). The array of hidden layers is $(\omega_6,\omega_7,\omega_8,)$, According to the formula (4) and the effect of brake torque to derive corresponding weights and threshold.

3) The relationship of magnetic flux leakage and structural parameters

When the permanent magnet retarder work, it produced the magnetic lines of force that can not be completely closed the magnet holding frame, there are still a small amount of magnetic flux through the rotor drum, caused by brake can not be completely removed, thereby affecting the brake torque and braking effect. The magnetic flux leakage effect is mainly related to the magnetic induction intensity of the air gap. A formula (5) is the magnetic induction intensity of air gap. It can be known that the magnetic leakage phenomenon is mainly related to the rotor and air gap. Hidden layer array is (ω_9,ω_{10}) . Similarly, according to the formula (5) derived weights and threshold.

4) Other factors

Other factors influencing the performance of permanent magnet retarder are analysis of coupling effect of multi physical field, control mode, reasonable distribution of joint brake torque and so on. All of them have a certain effect on the design of structure parameters. They can be represented by a hidden array of neurons.

3. Parameters optimization model and establishment process

3.1 Artificial neural network algorithm

Artificial neural network is a kind of intelligent arithmetic model which imitates the brain neurons of animals. It has self - learning, self - training, fuzzy processing, can consider many factors and conditions. The neural network, which is formed by the hierarchical form, is divided into at least three layers, which are input layer, hidden layer and output layer. BP neural network and RBF neural network are typical application. BP artificial neural network is selected in this paper.

3.2 Design principle based on neural network algorithm

According the section 2.1 and 2.2, we can get the brake torque of permanent magnet retarder is affected by many factors. These factors also affect each other. Therefore, the permanent magnet retarder design is a multi-parameter optimization design process. The ultimate goal is to improve the overall performance of permanent magnet retarder, which is to find the global optimal solution. The figure as shown below:

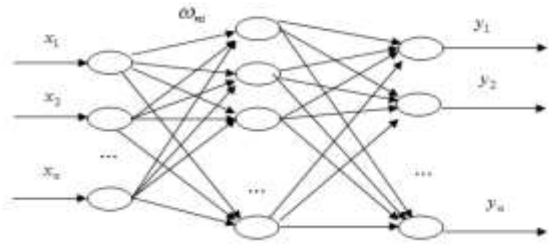

Figure 3: Permanent magnet retarder optimization design process

The model is divided into four parts. Its specific process as following:
(1) The first part is the design of the input layer. In this paper, we design five parameters, and give the range of the selected parameters. The requirement of this part is that the number of neurons in the input layer is consistent with the number of the designed parameters.
(2) The second part is the design of the hidden layer. We select a single hidden layer. The hidden layer of this part is designed that relationship between specific parameters and weights. The relationship between the weight and the corresponding threshold continuously adjusted to the height of linear fitting, according the section 2.2. And left some place for expansion, so as to avoid other of the factors not considered.
(3) The third part is the design of the output layer. The parameters of each input layer correspond to the result of an output layer, the output layer is in the range of [-1, 1]. The value of the output layer is close to 0, proving that the design value is in accordance with the requirements. If the value of the output layer is [-1, 0], proving that the design value is too small, vice versa.
(4) The fourth part is the learning process of neural network, continuing to build a new array of input layers to repeatedly test. A set of parameters, which is calculated as a set of 0 parameters, is used as the optimal value for the input layer. This can be determined by the optimization results of the model.

4. Experiment and simulation

The experiment of this paper is to verify the effect of the model, which is used to explain the practicability of the algorithm. Through the actual test value and the simulation of ANSYS software, it is proved that the design of the model is feasible. We use formula calculation to determine the hidden layer neuron's threshold and weights, and then define the input layer of five design parameters range. The range as follow: Radius rotor (170-240 mm), Circumference with (40-60 mm), Air gap (0.5-2.0 mm), Axial length (60-100 mm), Permanent magnet height (5-20 mm).
In the first experiment, the minimum value of each parameter is selected, and the next experiment, they results are fed back to the input layer, to determine whether the input value should be increased or reduced. After the weight and range adjustment or selection, then the neural network model is calculated, so that the optimal value has been obtained. In this paper, the experimental iteration numbers are about 90, and the experimental evaluation performance index is the maximum brake torque. In addition, we choose the optimal design method based on genetic algorithm (the algorithm is also to maximize the retarder braking torque as the goal). Comparison of the two algorithms can highlight the superiority. The experimental graph obtained by the simulation software is shown in Figure 4:

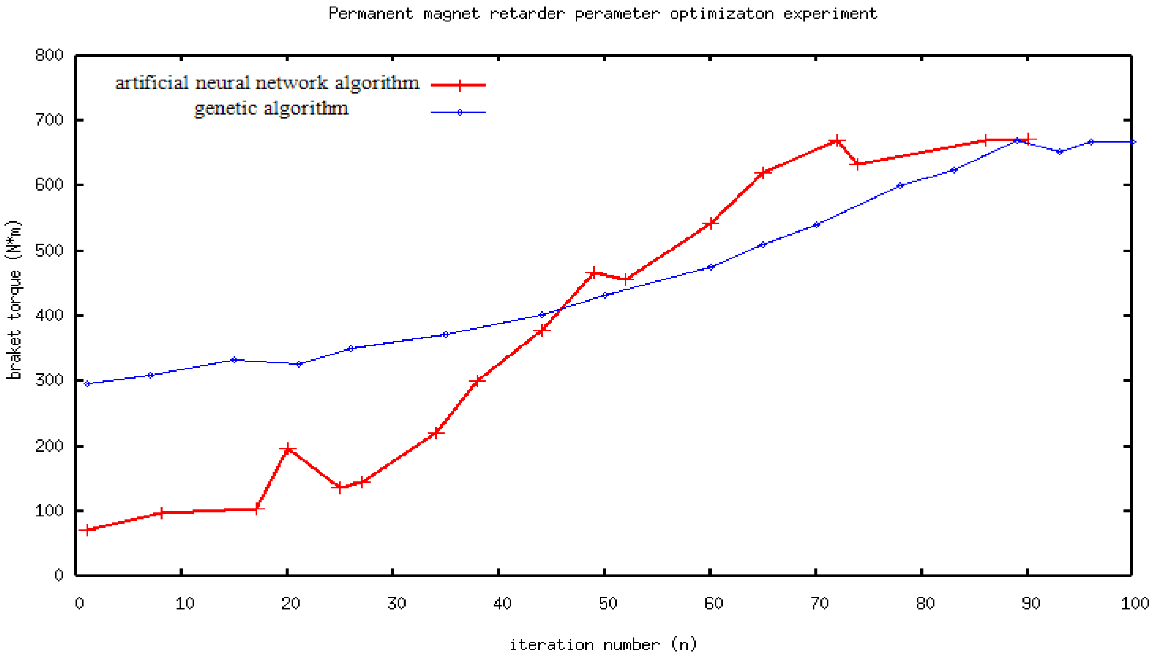

Figure 4: Permanent magnet retader parameter optimization experiment

In this diagram, we can see artificial neural network algorithm at about 70 times to reach the maximum, we get the maximum brake torque, genetic algorithm at about 90 times to reach the maximum. In this place, the design parameters of permanent magnet retarder are the best optimal value. The optimal design parameters from two algorithms are compared with the expected values of the physics experiment as shown in Table 1:

Table 1: Optimized results and comparison

Content	x_1 mm	x_2 mm	x_3 mm	x_4 mm	x_5 mm	Brake torque (N•m)
Expected value	206	44	0.9	91	18	689
Optimized value-1 (blue)	204	45	0.8	86	17	672
Optimized value-2 (red)	205	45	0.8	87	18	674

The results in Table 1, we conclusion that artificial neural network algorithm retarder optimization model can quickly find and expected value approximation to a set of design parameters. Their brake torque is almost similar. This shows that the model is more practical and the structural parameters are optimized. Further to verify the scientific nature of the model, the influence of various permanent magnet retarder design factors can provide a reliable fuzzy algorithm model.

5. Conclusions and prospect

In this paper, analysis of the structural principle of permanent magnet type of retarder, Artificial neural network algorithm is selected, all effects of permanent magnet retarder factors as hidden layer regulating function, practical formulas for the ultimate goal constructed based on artificial neural network algorithm of permanent magnet type of retarder structural parameters optimization design model. In this model, the experimental results are obtained by using the simulation software and the actual physical calculation formula. The end of the experiment shows that the value of the simulation experiment is similar to the expected value, and the brake torque is small, which proves that the model is practical, scientific and reliable.

There is still a gap between the optimal value and the expected value of the actual calculation. This shows that the design parameters of permanent magnet retarder are also affected by other factors. Therefore, in the next step of research experiments and need to more carefully and accurately research and analysis of permanent magnet type of retarder design factors. When we find these factors and give the corresponding weights and thresholds, it makes the design factors to consider more comprehensive, more expectations.

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