Design and Analysis of Hub-Type Switched Reluctance Motor

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Abstract

At the beginning, the rated technical specifications of the motor are determined by the vehicle parameters of the electric vehicle. The electromagnetic design and structural design of the hub-type switched reluctance motor are completed according to the technical requirements. The designed motor is designed by the Maxwell 2D module of ANSYS software. Perform finite element magnetic field analysis.The nonlinear module is built in Matlab's Simulink module to analyze the starting process and operating characteristics.

Keywords

1. Introduction

Cars provide convenience for people's lives. However, traditional fuel vehicles generate a lot of harmful exhaust gas during use. In the global greenhouse environment, the exhaust emissions of traditional fuel vehicles will be an extremely serious drawback. The demand for electric vehicles is even more urgent.The motor is the core component of the electric vehicle, and its excellent performance significantly affects the dynamic performance of the new energy vehicle.Switched reluctance motors are rugged and suitable for use in high temperature and high speed environments.In addition, it has the advantages of simple structure, less post-maintenance, low manufacturing cost and high efficiency.More critically, the rotor does not require rare earth permanent magnets, which also results in lower costs in raw materials and manufacturing processes.Therefore, the motor is increasingly attracting the interest of researchers.

2. Determination of motor rated performance parameters

The hub-type switched reluctance motor designed in this paper will match the four wheels of the electric vehicle. The power of the four motors is the same, which is one quarter of the total power of the whole vehicle.By integrating the vehicle parameters of the mainstream electric vehicles currently on the market, the models to be driven are Chery eq1, Volkswagen up or Mercedes-Benz smart.The vehicle parameters are shown in Table 1:

Table.1 Vehicle parameters

parameter	Numerical value
Curb quality m_0/kg	1200
Full load quality m_a/kg	1600
Windward area of the whole vehicle A/m^2	2.50
Wind resistance coefficient C_d	0.340
Hub rolling radius r/m	264
Rolling drag f coefficient	0.014

In addition, it is necessary to determine the power performance indicators of electric vehicles, such as the maximum speed, the climbing ability and the acceleration time of 0 to 100km/h. The combination of these three capabilities can determine the rated power of the motor. The dynamic performance of the vehicle is shown in the table. 2 shows:

Table.2 Vehicle dynamic performance indicators

parameter	Numerical value
Maximum speed v_{max} /km/h	150
0-100km/h acceleration time t/s	10
Maximum climb i%	30

When the electric car maintains a constant speed for more than 30 minutes on good road conditions, it can determine a constant total vehicle driving resistance. P_{v1} 。

$$P_{V1} = v_{max} \cdot \left(\frac{C_d \cdot A \cdot v_{max}^2}{21.15} + mgf \right) \cdot \frac{1}{3600 \cdot \eta_t} \tag{1}$$

η_t is the transmission efficiency of the system.

When the car is climbing, the total driving resistance of the vehicle is P_{v2}.

$$P_{v2} = v_l \cdot \left[\frac{C_d \cdot A \cdot v_l^2}{21.15} + mg \sin(\alpha) + mg \cos(\alpha) \right] \cdot \frac{1}{3600 \cdot \eta_t} \tag{2}$$

In view of this, the total power of the motor designed in this paper should be greater than or equal to the total power of any of the above-mentioned driving resistance, that is, the formula (3) shows:

$$P \geq \max\{P_{v1}, P_{v2}\} \tag{3}$$

Regarding the rated speed of the motor, it should be combined with the economic speed of the electric vehicle. v_N To design, usually the car's economic speed range is 75 to 95km / h, in view of the high efficiency of high-speed motors, this paper takes an economic speed of 90km / h.

$$n_N = \frac{v_N \cdot i_g \cdot i_0}{0.377 \cdot r} \tag{4}$$

In the middle i_g For the transmission ratio, i_0 For the gear ratio of the reducer, this paper adopts the method of directly driving the hub motor,so both values are 1.

According to the above calculation results, the rated torque can be calculated from the equation (5).

$$T_N = \frac{9550 \cdot P_N}{n_N} \tag{5}$$

At present, the battery voltage for driving pure electric vehicles has been standardized. Refer to the mainstream electric vehicles in the market in the past two years, such as Nissan Leaf SV 2017 with a battery voltage of 360V, Chevrolet Bolt EV Premier with a battery voltage of 355V, Tesla Model-X The P90D 2016 uses a battery voltage of 345.6V.Combined with the motor power calculated by the above formula (3), the designed rated voltage of the hub-type switched reluctance motor is 360V.

In summary,the rated technical specifications of the hub-type switched reluctance motor designed in this paper are shown in Table 3:

Table.3 Motor rated technical specifications

project	Numerical value
rated power	15kW

Rated voltage	360V
Rated speed	1200rpm
Rated torque	$119\,N\cdot m$

3. Establishment of finite element model

According to the requirements of the above rated technical specifications, the size of the switched reluctance motor is calculated by the relevant formula of the motor structure design.Usually, according to the experience of the designer, the structural parameters obtained by the formula are slightly adjusted.Here, this paper uses the parameter tracking function of Optimize's in ANSYS software to determine the structural design.The structural parameters of the motor are shown in Table 4:

Table.4 Structural parameters of the motor

project	Value	project	Value
Stator pole number	12	Number of rotor poles	8
Stator outer diameter	299mm	Rotor outer diameter	170mm
Stator inner diameter	170.8mm	Rotor inner diameter	68mm
Stator pole arc coefficient	0.38	Rotor pole arc coefficient	0.27
Stator yoke thickness	24mm	Rotor yoke thickness	25mm
Core length	135mm	Winding turns	43
Core stacking coefficient	0.95	Air gap	0.4mm

After determining the motor structure parameters, the finite element model of hub-type switched reluctance motor is established in the Maxwell 2D module in ANSYS software. Firstly, the motor geometry is drawn and the material definition is performed, and then the boundary conditions are set in order, and the excitation source is added. Grid division and solver settings.The two-dimensional finite element model of the hub-type switched reluctance motor is shown in Figure 1.

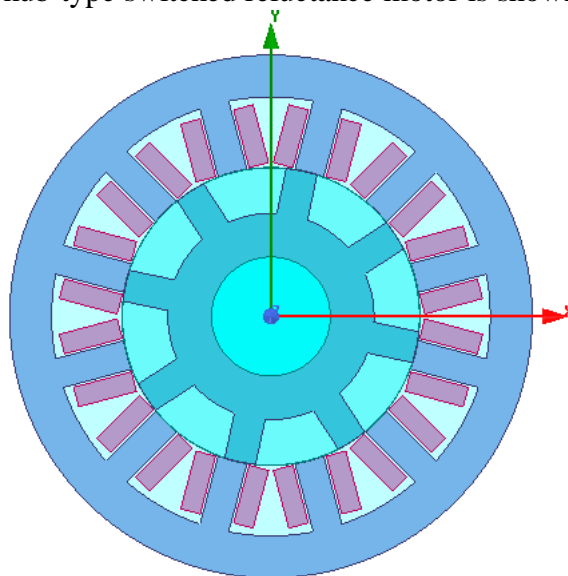

Fig.1 finite element model of 12/8 hub-type switched reluctance motor

4. Speed model simulation of nonlinear model

In order to establish a high-precision motor speed control model, a large number of accurate Ψ-i-θ Data and T-i-θ Data, using the look-up table method to build a nonlinear model of switched reluctance motor in Matlab's Simulink module. Figures 2 through 4 show the nonlinear inductance curves, nonlinear flux linkage curves, and nonlinear torque curves for the designed motor.
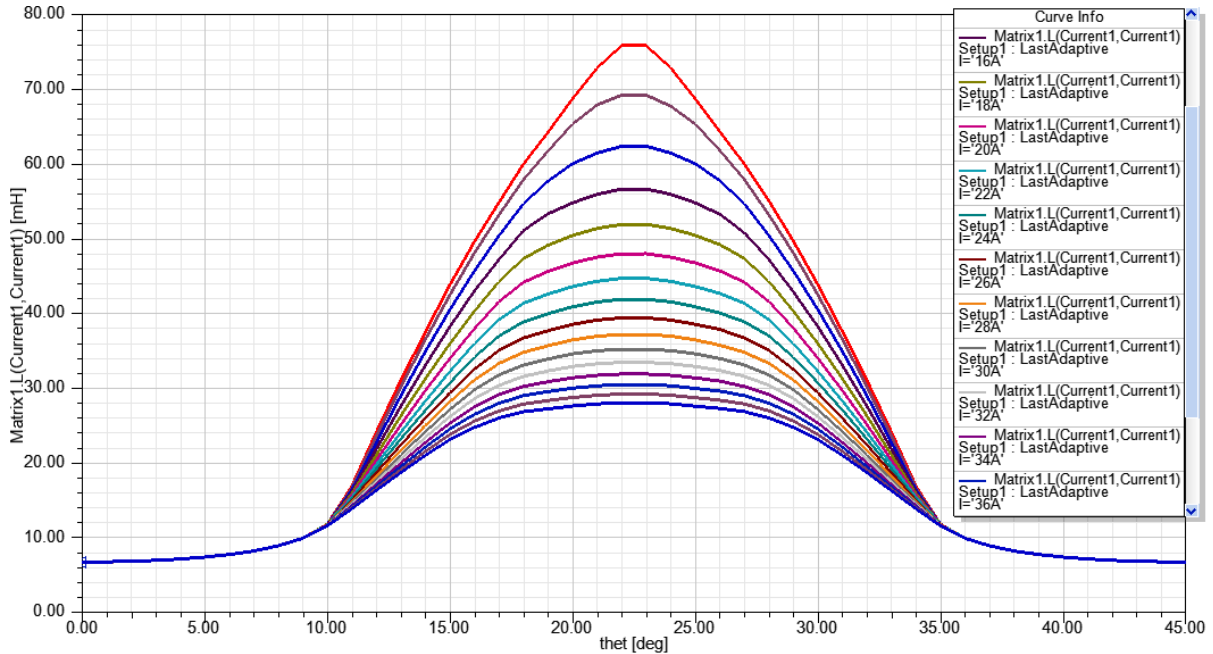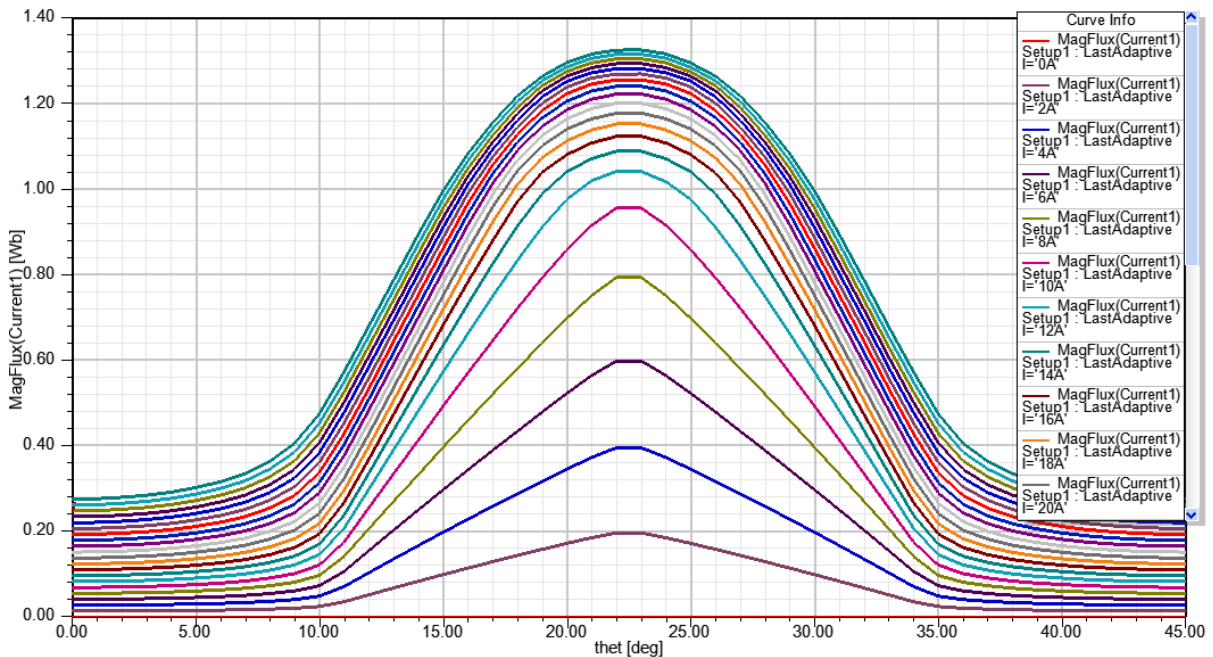

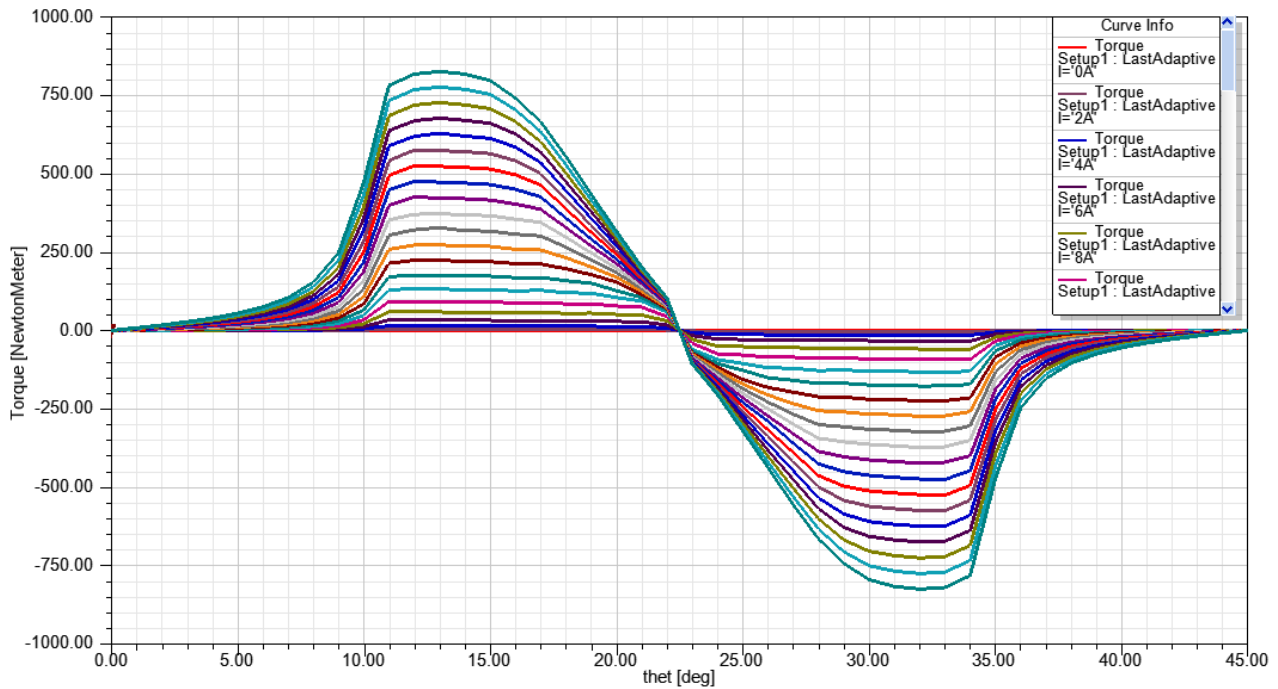Fig.2 Nonlinear inductance curve

Fig.3 Nonlinear flux linkage curve

Fig.4 Nonlinear torque curve

4.1 Constant torque control system for nonlinear models

The motor designed in this paper is used to drive electric vehicles. It needs to obtain a constant large torque during starting to ensure the dynamic performance of the whole vehicle.Therefore, current chopper control is used when the motor is running at low speed, and the current is limited to a certain range.In this way, the constant torque characteristic is obtained to ensure the starting requirement of the motor at low speed.Its Simulink model is shown in Figure 5:
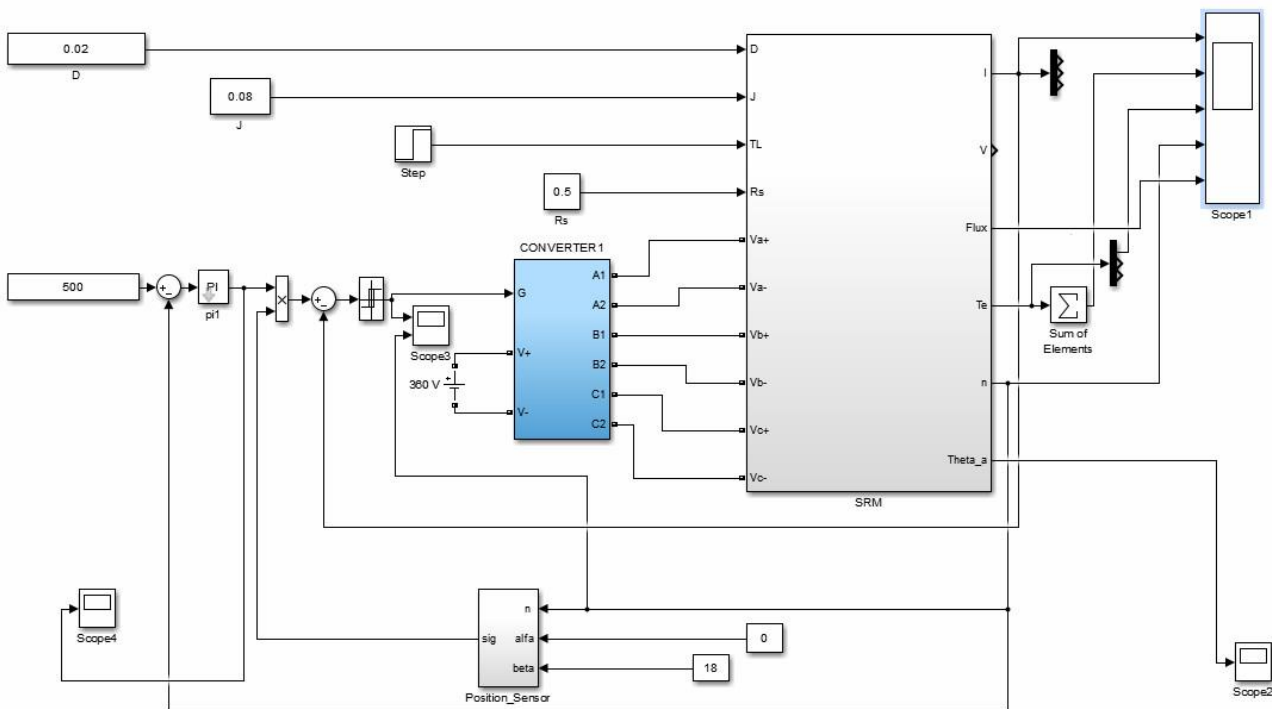

Fig.5 Constant torque control model

Figure 6 is a simulation waveform diagram of the constant torque model of the motor.
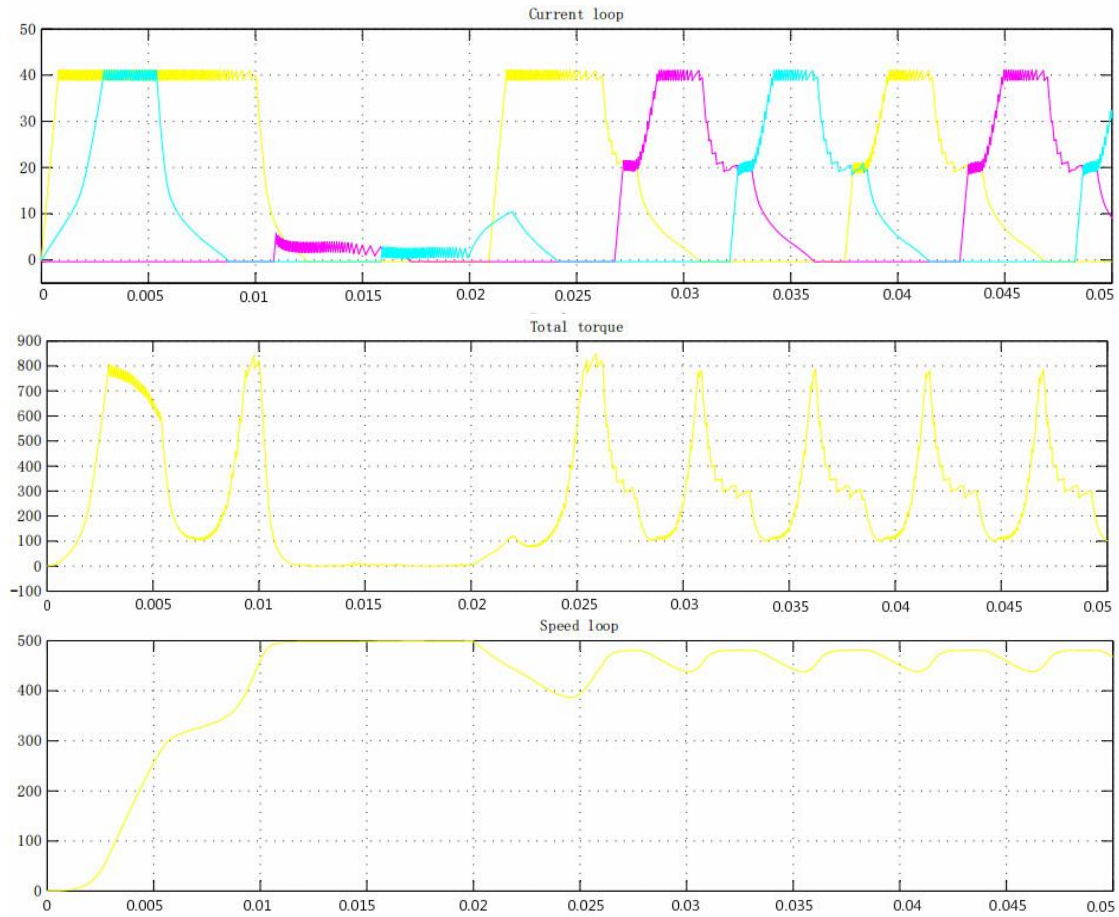
Fig.6 Constant Torque Control Simulation Waveform

4.2 Constant power control system for nonlinear models

When the motor speed is raised to a certain value, the angle position control mode is adopted.Since the motor has a certain speed, the value of the induced electromotive force can suppress the excessive winding current very well. At this time, only the opening angle is controlled. θ_{on} Turn off angle θ_{off} To achieve speed regulation, the motor enters the constant power zone.The constant power control model is shown in Figure 7:
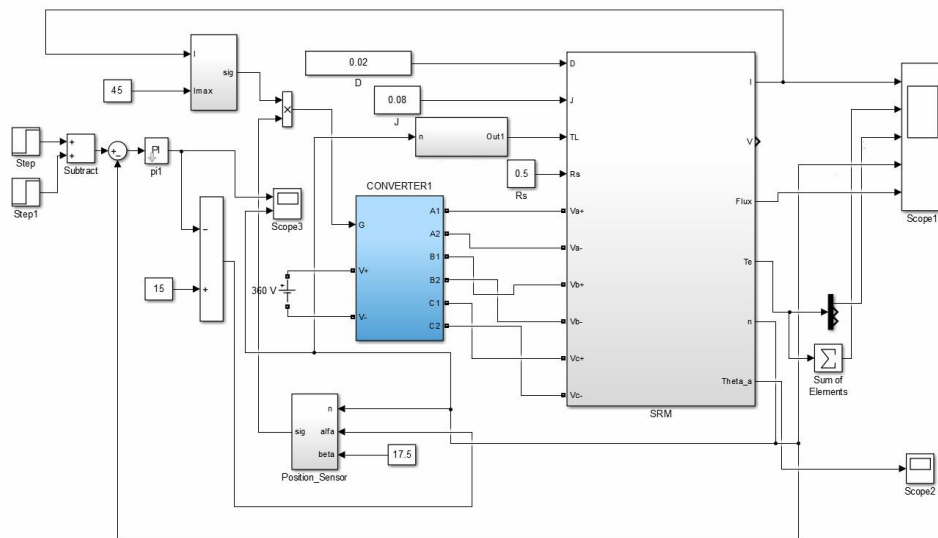

Fig.7 Constant power control model

Figure 8 is a simulation waveform diagram of the motor constant power model.
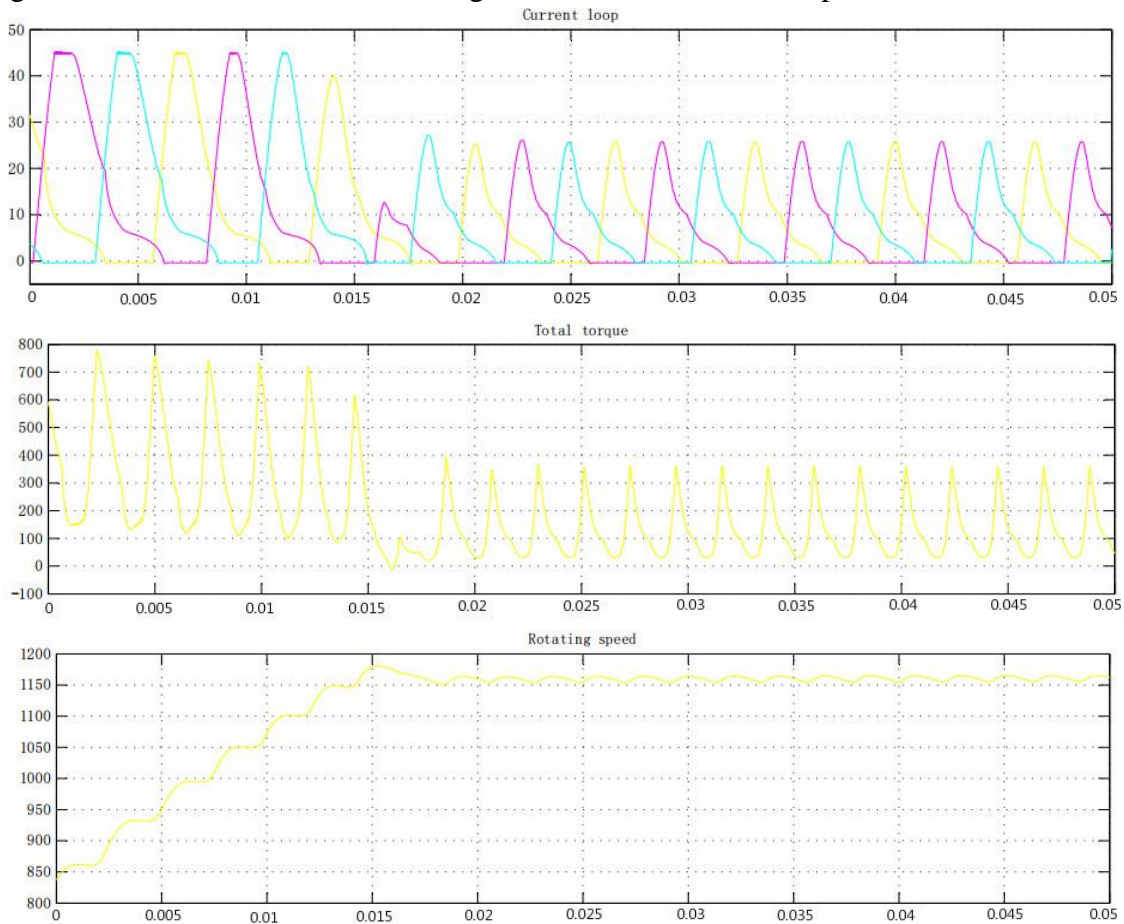

Fig.8 Constant power control simulation waveform

5. Conclusion

In this paper, the structural design of the motor is completed according to the technical index of the motor. Then the finite element model of the designed motor is established in Maxwell 2D module, and the nonlinear data obtained by finite element simulation is used to establish the tuning of the motor in Matlab's Simulink module. Speed control model.It can be seen from the simulation waveform that the designed motor quickly reaches the steady state within 0.02s, and the speed and torque are both up to meet the motor requirements for driving the electric vehicle.When entering the constant torque control zone, it can be seen that the torque value will be steadily reduced while the speed is steadily increasing.When the speed stabilizes at 1200 rpm, the average torque will remain at $120\,N \cdot m$ No longer change.

References

[1]Wang Honghua.Speed control technology of switched reluctance motor [m]. MechanicalIndustry Press, 2014.

[2] Chen Shikun. Motor Design [m]. Mechanical Industry Press, 1997.

[3] Jiang Baojun, Zhou Lin, Zhang Dongsheng, Luo Tengke. Parameter optimization analysis based on external rotor switched reluctance motor[J]. Journal of Chongqing Jiaotong University, 2016.05.33 (Vol. 35, No. 5).

[4]Dai Ting,LI Jun.Application of Ansoft in Simulation Design of External Rotor Switched Reluctance Motor[J].Journal of Taizhou University, 2014(Vol.36, No.3)

[5] Han Shuai, Wang Yan, Yin Tianming.Design and Control System Simulation of External Rotor Switched Reluctance Motor for Electric Vehicles[J].Motor and Control Applications, 2013(Vol.40 No.10).