Modeling and Simulation of Permanent Magnet Synchronous Motor Control System for Electric Hydraulic Excavator

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Abstract

Permanent magnet synchronous motor is the key power system of electric hydraulic excavator. It has the characteristics of simple structure, light weight, low loss, high efficiency and so on. According to the permanent magnet synchronous motor vector control of field oriented control and space vector synthesis of multiple modules are established and simulation, set up the permanent magnet synchronous motor vector control system model, by adjusting the parameters, current, speed and torque waveform stable operation has been verified, the rationality of the permanent magnet synchronous motor the superiority and vector control.

Keywords

Permanent magnet synchronous motor; Electric hydraulic excavator; Vector control.

1. Introduction

Excavator is a kind of machinery used in earthwork, which has two functions of loading and digging. It is widely used in mining, pipeline construction and real estate industry [1]. The permanent magnet synchronous motor is used as a power system of electric hydraulic excavator is a good choice, has the advantages of simple structure, light weight, low loss, high efficiency and power factor, at the same time, it is because there is no DC motor commutator and brush, without excitation current and torque, has the advantages of simple control and easy maintenance etc [2,3]. According to the working condition, considering the electric excavator battery matching and energy recovery, the modeling and Simulation of permanent magnet synchronous motor, and then build the permanent magnet synchronous motor vector control system model, by adjusting the parameters, the current, speed and torque data smooth operation, verify the rationality and feasibility of the electric power system of hydraulic excavator vector control [4].

2. Mathematical model of permanent magnet synchronous motor

In this paper, the permanent magnet synchronous motor was simplified theoretical analysis and control, establish the mathematical model of permanent magnet synchronous motor is clear, the error in the control range, was basically consistent with the actual situation of the results, now make the following assumptions on the permanent magnet synchronous motor:

(1). The permanent magnet and the rotor have no damping effect;

(2). The three-phase windings of the stator are completely symmetrical in space, and the phase difference is 120 degrees [5];

(3). The magnetic circuit of the default motor is linear, ignoring the influence of saturation, hysteresis and eddy current, the superposition principle is applied to the electromagnetic parameters of the motor circuit [6];

(4). The electric potential of the motor stator is changed according to the sine law, and the high harmonic magnetic potential in the magnetic field does not affect the magnetic field [7].

3. Mathematical model of permanent magnet synchronous motor

3.1 Mathematical model of permanent magnet synchronous motor in A,B and C three phase coordinate system

In the operation of permanent magnet synchronous motor, there are three kinds of differential forms, which are in the A,B,C three-phase coordinate system, under the three-phase coordinate system, in the α, β, ocoordinate system of the mathematical model of permanent magnet synchronous motor.

$$u_s = Ri_s + L\frac{di_s}{dt} + \frac{d}{dt}\Psi_s = Ri_s + \frac{d\Psi}{dt}$$

In the A, B, C coordinates of the permanent magnet synchronous motor stator and rotor in the magnetic and electrical structure and asymmetry, synchronous motor mathematical model is a set of nonlinear time varying equations with the rotor instantaneous position. So using A, B, C coordinate system mathematical model for analysis and control of permanent magnet synchronous motor is too complex is not the best mathematical model.

3.2 The mathematical model of permanent magnet synchronous motor in the three-phase coordinate system

The motor can be directly measured in the static state, and the coordinate system can be directly measured. The mathematical model can be used in the study of the characteristics and control of the motor .For ,the coordinate system of the permanent magnet synchronous motor, the motor model can be simplified by the transformation, but because of the asymmetric effect of salient pole rotor direct axis and q-axis inductance show, Dand q-axis are not equal, so the interior permanent magnet synchronous motor voltage and flux linkage equations, and coordinates in a set of nonlinear equations, the mathematical model and the A,B,C coordinates of the model are as complex, and the analysis of the difficult control of permanent magnet synchronous motor is also great, so it is not usually used a mathematical model of the coordinates[8].

3.3 Mathematical model of permanent magnet synchronous motor in d, p and o coordinate system

The surface permanent magnet synchronous motor has the symmetrical rotor structure, the straight axis and the cross axis inductance are equal, the motor model is relatively simple, and the motor can be analyzed and controlled. The flux and voltage equations of d, p and o are respectively:

$$\begin{cases} \Psi_d = L_d i_d + \Psi_f \\ \Psi_q = L_q i_q \end{cases}$$

$$\begin{cases} u_d = R_s i_d + \dfrac{d\Psi_d}{dt} - \omega\Psi_q \\ u_q = R_s i_q + \dfrac{d\Psi_q}{dt} - \omega\Psi_d \end{cases}$$

4. Model establishment and simulation analysis of permanent magnet synchronous motor control system.

4.1 Permanent magnet synchronous motor control system

Permanent magnet synchronous motor vector control is completed by the control of the stator current, especially for the torque control, and ultimately evolved into the control of the current on the D and Q axes. As the output torque has a number of D, q axis current control combination, resulting in a variety of permanent magnet synchronous motor current control strategy.

When the rotor flux with ψf constant, Te and iq the electromagnetic torque is proportional to the control performance of DC motor. In this paper, the most torque control method is used to control the permanent magnet synchronous motor.

4.2 Modeling and Simulation of permanent magnet synchronous motor control system

According to the parameter adjustment, the input angular ω=1000rad/s, Kp=20, Ki=0.4, IGBT three-phase inverter, Inverter DC power supply and space vector pulse width modulation is 320V.PWM inverter for R=2.88Ω, permanent magnet synchronous motor, the d-axis and q-axis stator inductance Ld=Lq=0.0085, J=0.0008kgm2,motor inertia motor, pole number P=4.

5. Simulation result analysis

The model of three-phase current waveform oscilloscope module output of permanent magnet synchronous motor is connected to each output port as shown in Figure 1,the speed waveform Figure 2 and torque characteristic curve as shown in Figure 3,observed that the output waveform is stable without the strong changes of electric hydraulic excavator with permanent magnet synchronous motor control system modeling to meet the requirements at the same time, to verify the rationality and feasibility of the electric power system of hydraulic excavator vector control.

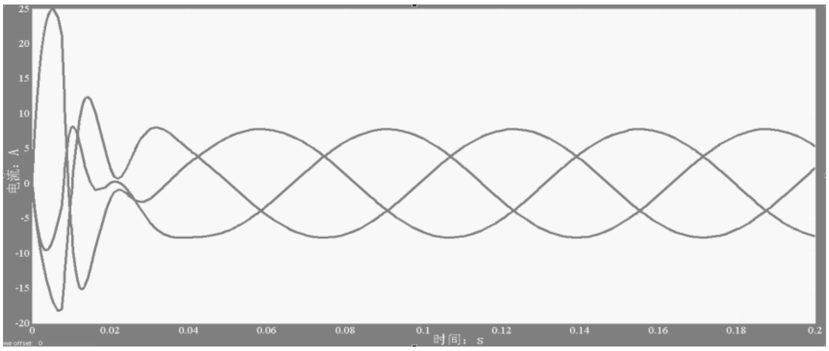

Fig. 1 waveform of three-phase current of permanent magnet synchronous motor

Fig 2 speed output curve of permanent magnet synchronous motor

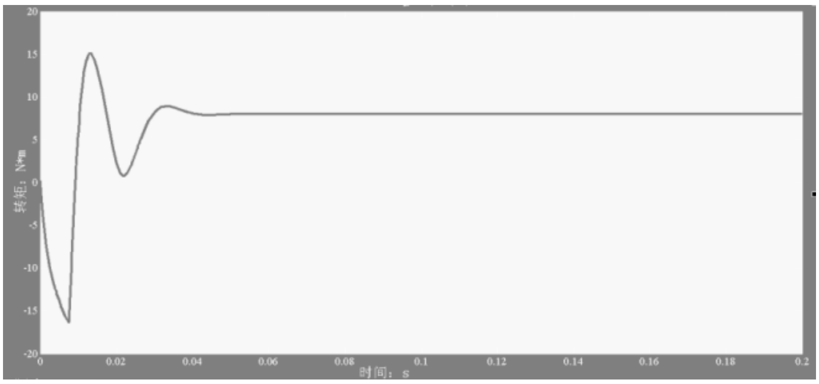

Fig. 4 torque output curve of permanent magnet synchronous motor

6. Conclusion

With the modeling and Simulation of PMSM in electric hydraulic excavator by Matlab/simulink software, the simulation results meet the expected effect, a field oriented control and space vector synthesis modules and simulation analysis, through parameter adjustment, the current, speed and torque data smooth operation, verify the rationality and feasibility of power the vector control system of electric hydraulic excavator. The results of simulation can provide theoretical and experimental data base for modeling and Simulation of permanent magnet synchronous motor control system for electric hydraulic excavator in the future, which is of great significance.

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