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SOCIETY'S SCIENTIFIC POTENTIAL**

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Stand for research of the electric position drive of ship mechanisms and devices based on a three-phase collector- less motor

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Abstract.

The technical perfection of ship mechanisms and devices is largely determined by the perfection of the corresponding drive and the degree of its automation. At the present time and in the future, the main types of drives of ship mechanisms and devices remain electric drives. Despite the relatively large variety, the majority of marine electric drives as the main components include three-phase asynchronous motors with a short-circuited rotor due to their structural simplicity, manufacturability, and relatively high energy and performance indicators. However, the use of brushless motors with permanent magnets when solving tasks in the field of electric drives of ship mechanisms and devices is becoming more and more noticeable. High power density and efficiency are the main advantages of such motors.

Keywords:

*position electric drive
brushless motors
modeling
transient characteristic
ship mechanism*

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Goal: The purpose of the work is to develop a scheme of the control system and a simulation model of the positional electric drive of ship mechanisms and devices based on a brushless DC motor for studying its dynamics.

To achieve the set goal, the following tasks should be solved:

- analyze design features, principle of operation, mathematical description and control features of brushless motors with permanent magnets;
- to build a scheme of the control system of brushless direct current motors.

Object of study. Transient processes in a positional electric drive based on a brushless motor.

Subject of study. The structure and parameters of the control system of the positional electric drive based on the brushless motor, which affect the control quality.

Research methods. Theoretical studies were carried out with the involvement of modern electric drive theory, methods of automatic control theory and computer modeling in MATLAB Simulink.

Main scientific and practical results, their significance.

1. A simulation model of a positional electric drive based on a brushless motor was developed in MATLAB Simulink. The model is recommended for working out control algorithms, finding optimal parameters of control system elements and a semiconductor converter when designing electric drives based on brushless motors with permanent magnets that have a reduced amplitude of electromagnetic torque pulsations.

2. A laboratory stand has been created for researching the work and working out algorithmic solutions aimed at reducing the range of pulsations of the drive torque on the basis of a brushless motor with permanent magnets.

Introduction

With the development of microprocessor systems, autonomous power supply systems, as well as taking into account the requirements to ensure high reliability of operation, electrical safety and low weight of electric drives, brushless motors are increasingly used in various industries [1].

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Brushless motors with permanent magnets are better known in industries where relatively small dimensions and low power consumption are required. Such motors can have almost any size without any technological limitations. However, large brushless motors are not something completely new.

A comprehensive analysis of the potential application is central to justifying costs and results. The known operational readiness of the drives in combination with such a significant trend as the decrease in the price of drives and magnetic materials suggests that more and more such motors will be operated in the near future.

It should be noted separately that the corrosion resistance, mechanical properties and temperature range of magnetic materials have improved significantly recently. As a result, machines with permanent magnets find a wider distribution in industries with a heavy operating mode, in electric drives of ship mechanisms and devices, in the military field, etc. The cost of permanent magnets from rare earth metals has decreased fivefold over the past two decades, while the corresponding specific magnetizing force has increased threefold, which means a 15-fold improvement in cost-benefit ratio and is essential for affordability at a price.

Brushless motors with permanent magnets are 1–2% more efficient than asynchronous motors and synchronous motors at full load and by 10–15% at partial load. Efficiency is ensured by full excitation of the rotor without current and the absence of corresponding losses at all speeds. At the same time, the cooling of the engine is simplified, since the heat coming from the rotor is insignificant. Simplifying the cooling scheme also results in flexible engine geometry. Permanent magnet machines support a much wider range of aspect ratios than standard motors [2].

The design of the brushless motor allows its operation in water and aggressive environments, and brushless motors practically do not create radio interference [3].

As the volume of production of brushless motors with permanent magnets increases, the design is optimized and their cost is reduced, which additionally contributes to the expansion of their use, while, according to most modern

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researchers, their mechanical and power parts have generally reached a sufficient degree of perfection, therefore one of the promising ways of their further optimization, which can contribute to the expansion of the scope of their application, is the development of new, more advanced technical solutions for control.

At the same time, the analysis of the existing technical solutions for the implementation of brushless motors and their control systems shows that the switching of the windings and the form of the electrical signal applied to them have the greatest influence on the efficiency of their use and the efficiency factor [4]. This feature complicates the use of the electric drive and limits the scope of its use.

Therefore, one of the most relevant directions of research in the field of such electric drive systems is the solution to the issue of minimizing the pulsations of the electromagnetic moment created by the electric motor. Another important direction in the development of this type of electric drive is solving the problem of ensuring the reliability of the operation of the electric drive [5].

Thus, the currently relevant directions of research and development of an electric drive based on a brushless motor indicate the need to create a simulation model of a positional electric drive based on a brushless engine. The work offers one of the possible options for solving the task.

Mathematical description of a brushless direct current motor

Let's consider functional diagram of an electric drive based on a brushless motor (Figure 1) [6, 7]. The speed control system is an adjustable electric drive with the output coordinate – speed h_m and the input coordinate is the speed task signal h_m^* .

The electric drive contains a motor, an inverter, current and angular velocity sensors, and electric drive coordinate controllers.

A three-phase BLDC is connected to the inverter. Supply voltage U_{dc} supplied to the inverter from the DC source.

The functional diagram of the control system in Figure 1 includes a current controller to control the current (and thus the torque). In this case, the signal at the output of

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the PI speed controller is the reference value of the motor current I^* and current sensor is required to measure the actual motor current I .

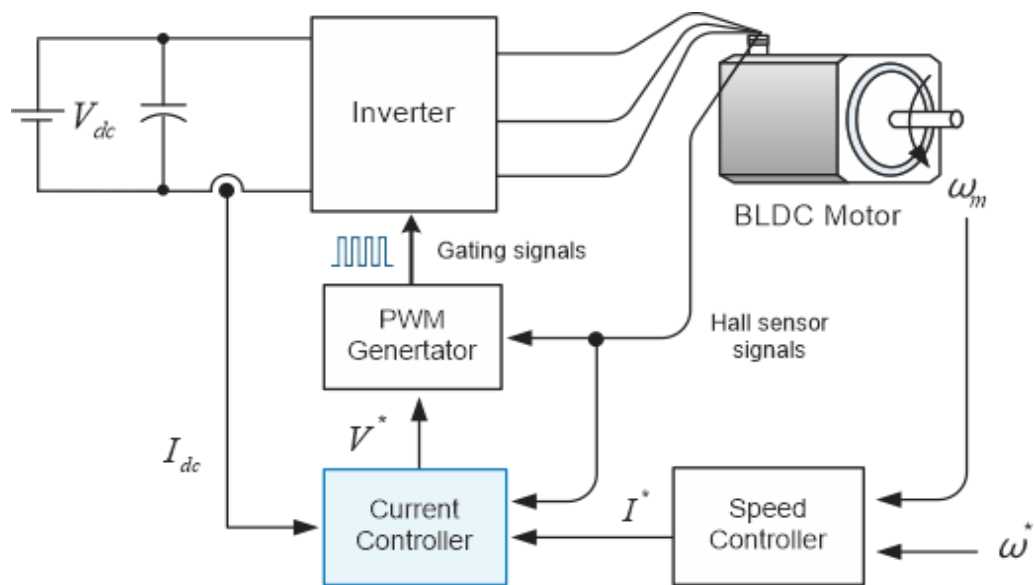


Figure 1
**Speed control system of the electric drive
based on a brushless motor with permanent magnets**

Without a current loop, it is difficult to control the motor current within an acceptable range, because when the speed task changes, the voltage reference value can be changed significantly. In this case, you cannot count on high-quality speed regulation. Moreover, it can cause the drive system to shut down due to a large transient current.

For a drive based on a brushless motor, only the amplitude of the phase currents needs to be monitored. In addition, when measuring the current amplitude, it is possible to control the three-phase currents individually, as when controlling the current of AC motors. However, since the amplitude of the phase current of a brushless electric motor is proportional to the current I_{dc} direct current links, so the amplitude of the phase current can be controlled by measurement I_{dc} . In this case, only one current sensor is required on the DC side of the circuit and is therefore more economical.

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2.3 Study of dynamics

As a result of the simulation of the BLDC control system, transient characteristics of the control system were obtained. In most drives, such a transient process of working out medium/large movements is considered the best, when the motor speed during the working out of a given angle changes according to a trapezoidal graph, because it allows you to fully use the overloading capacity of the motor and excludes the occurrence of overregulation in the transient process.

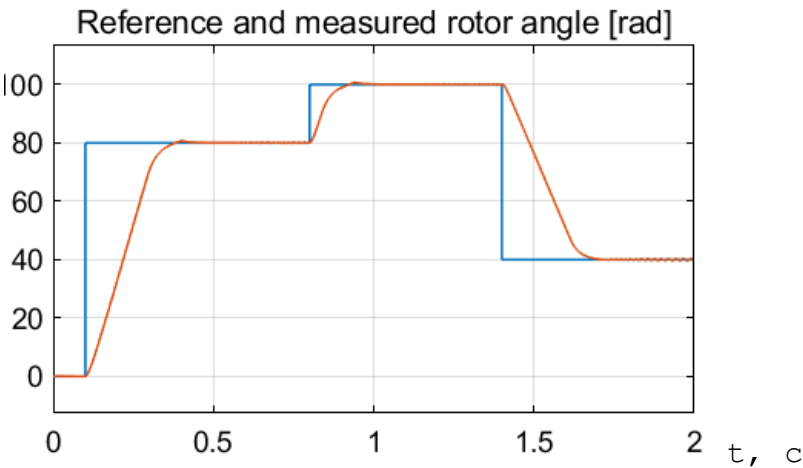


Figure 2
Transient characteristics of the turning angle

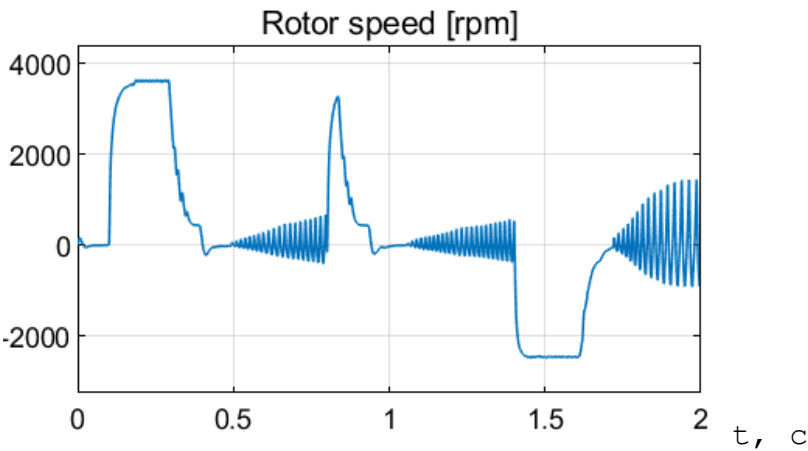


Figure 3
Transient speed characteristic

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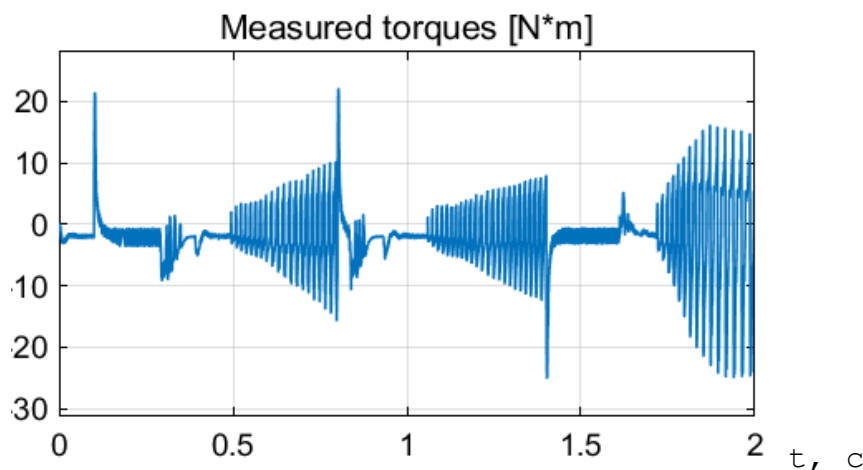


Figure 4
Transient characteristic of the moment

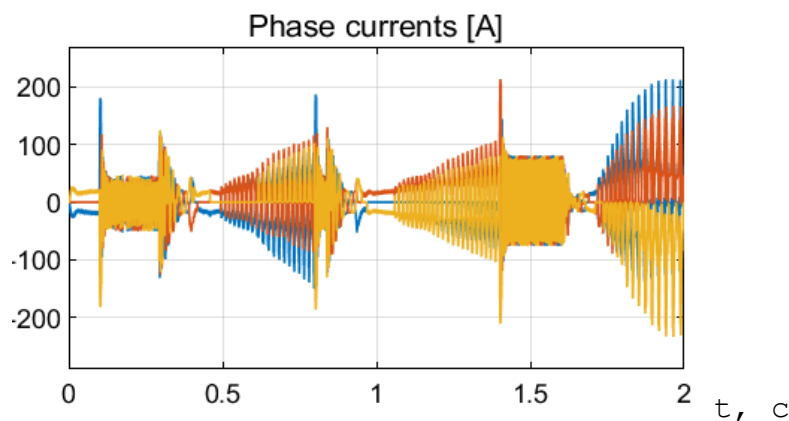


Figure 2.4
Transient characteristics of stator phase currents

The analysis of transient processes showed that the system is operational and has relatively high-quality indicators. It was found that when working out medium/large turning angles, the motor speed changes according to a trapezoidal graph, therefore, the overload capacity of the motor is fully used. Torque ripples are caused by current ripples that occur during phase switching. Due to torque fluctuations, the characteristics of speed regulation deteriorate, especially at low speeds.

There are two main causes of torque ripples caused

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directly by the brushless motor control system. The first is due to current pulsations caused by PWM in the period between phase commutations. The second is the processes that occur when switching the current from one phase of the motor to another.

CONCLUSIONS

The paper presents the results summarizing theoretical studies of the positional electric drive of ship mechanisms and devices based on a brushless motor with permanent magnets.

A functional diagram of a positional electric drive based on a brushless direct current motor was built. The closed loop of position control consists of two parts: the position control system and the control object – the speed subsystem.

A simulation model of a positional electric drive based on a brushless motor has been developed. Modeling of the control system of the electric drive based on the BLDC was carried out in MATLAB and the control quality was investigated. The analysis of transient processes showed that the system is operational and has relatively high-quality indicators. It was found that when working out medium/large turning angles, the motor speed changes according to a trapezoidal graph, therefore, the overloading capacity of the motor is fully used. Torque ripples are caused by current ripples that occur during phase switching. Due to torque fluctuations, the characteristics of speed regulation deteriorate, especially at low speeds.

To verify the proposed simulation model in the future, it is planned to conduct a comparative analysis of the simulation results and experimental data obtained with the help of the stand [8].

In further research, it is planned to use this model to study new topological solutions and control algorithms for a highly efficient positional electric drive of ship mechanisms and devices based on a brushless DC motor.

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