Development and Research of Coreless Micro Electric Drive Model of RC Drone

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***Abstract* — The using of coreless micromotor in various fields of technology, in particular in unmanned RC drones and the expansion of their scope of application, are considered. The requirements for RC drones during the design process which determines the using of coreless micromotor were considered. On the basis of the algorithm developed by the authors, experimental studies of the 816 series coreless micromotor, which is most widely used in unmanned RC drones are carried out. These studies made it possible to obtain all the parameters for the development of a high-precision model of the coreless micromotor and the micro-drive of an unmanned RC drone in MATLAB Simulink. On the basis of the obtained experimental results, a high-precision model of the coreless micromotor was created in MATLAB Simulink, and transition processes of speed and current on the model were obtained. The error of the determined current on the model is 4.3 % compared to the experiment. The error of the specified speed on the model is 16% compared to the technical characteristics given in the micromotor datasheet. Experimental studies of the coreless micromotor with an 65 mm RC drone propeller were carried out. Its high-precision model was developed in MATLAB Simulink. The error of the determined current on the developed model is 12.8%, and the speed is 12.2% compared to the experiment.**

Keywords— model, coreless micromotor, RC drone, identification

I. INTRODUCTION

With the development of microprocessor technology and modern micromotors, unmanned RC drones are becoming more and more popular [1] and their fields of application are expanding: from entertainment purposes to special industrial purposes [2,3]. Recently, RC drones have been widely used in rescue operations and military purposes. Such RC drones are subject to a number of special requirements during the design of their design, dimensions, weight, executive mechanisms, autonomous power supply elements, controllability, etc. [3, 4].

Recent studies [5-7] have shown that coreless micromotors (CM) are widely used in drives of small radio-controlled models. A feature of the design of the thin-walled armature of the motor is the absence of iron in the magnetic conductor [8]. The magnetic field created by a fixed cylindrical neodymium magnet in the middle of the hollow cup of the armature interacts with the copper windings of the armature and closes on the outer fixed thin-walled iron cup - the engine body.

Coreless DC motors are a distinct type of small DC motor that have a slightly different design that gives them significant advantages over traditional iron core DC motors. A CM is not a large electric motor that does not have the usual charged iron core in the rotor and charged stator poles. In this micromotor, the rotor windings are wound slightly obliquely to form a self-supporting hollow cylinder that resembles a cup. The stator is located in the middle of the rotor and is made of rare earth magnets. The stator actually has no core. Brushes and a collector, as in a classic motor, are used to ensure a certain direction of current in the rotor windings, ensure a constant direction of rotation.

A CM is driven by the same physical principle as a conventional DC motor - current flows in a coil in a magnetic field, which is acted upon by a force that causes it to rotate. However, since there is actually no iron core in the outer rotor, such a motor has certain advantages over a motor with an iron core.

The first advantage is compactness - CMs are much smaller than traditional iron core DC motors. This property makes them ideal for devices where space (volume) is limited. A second advantage is lightness - CMs are much lighter than traditional iron core DC motors. This makes such motors ideal for devices where weight is important, such as in drones and robots. A third benefit is low noise - CMs are quieter than traditional iron core DC motors. This makes such motors ideal for applications where noise is important, such as in medical devices, military drones, etc. The fourth advantage is higher energy efficiency - the absence of iron on the stator and rotor ensures the absence of losses in iron at high speeds, which are traditionally caused by the action of eddy currents and the action of hysteresis in a rotor with an iron core. These losses at high speeds significantly reduce the efficiency motor with an iron core and create additional heat (additional overheating of the engine). Therefore, a CM has significantly lower losses and a higher efficiency (up to 90%) than a traditional electric motor with an iron core, even if we are talking about micromotors. The fifth advantage is reliability - CMs are more reliable and can last longer with proper maintenance. The sixth advantage is less sparking - the original design without a core reduces the inductance of the rotor winding, which significantly reduces sparking between the brushes and the collector. Sparking causes more wear on engine components, especially during hard starts, creates electromagnetic interference and increases noise.

Therefore, CMs are ideal for applications that require high dynamics, low weight, precision and efficiency. In particular, such motors can provide a fairly high power-to-weight ratio and high speed for small aircraft such as drones and model airplanes. This is due to the fact that they can operate efficiently from a battery with a fairly simple power supply voltage regulation scheme and have low maintenance requirements [7, 8].

CM is a specific type of DC motor [8]. There for manufacturers of series CMs provide only the values of rated values of voltage, armature resistance, and angular speed of the rotor. Therefore, in order to develop and mathematically model the electric drive of an RC drone propeller based on CM, it is necessary to determine other main parameters of the motor.

The analysis of modern literary sources showed a lot of information regarding the design of the RC drone structure, the development and improvement of the user interface, and the conduct of tests. In particular, in [9], the trends of operation of drones with artificial intelligence and IoT are considered. In [7], the basic designs of drones, the principles of electronic speed controllers, the principles of operation and the expediency of using brushless direct current motors in drones are given. In [10], Design, manufacturing and test small turbojet motor for UAV "Drones" is given. In [11], examples of microcontroller control of small direct current motors are given, which can be used to build a system of automatic control and electric drive of an RC drone. In [12], different types of DC motors for robot application, for example in drones, are given. There are also design features, the main characteristics of a CM. This confirms the relevance of our research. But in all these articles and books there is no mathematical modeling and project design definition of the parameters: k_e, k_t, R_a, L_a, J, T_a of the executive motor and its electric drive.

It is of scientific interest with the practical result of determining the parameters of a CM and the parameterization of the mathematical model of such a motor and the electric drive as a whole.

In [13-16], the method of determining the main parameters of various types of electric motors using special software is given. In [16] was researched and developed using a specialized software JMAG Designer for the purpose of designing and simulating electromechanical systems. In order to develop a mathematical model of an electric drive with an RC drone propeller, it is necessary to obtain a complete set of CM parameters. Taking into account the experience of identifying parameters of electric motors [13-16] experimental studies must be carried out. In this case, it will be possible to obtain indicators of the transient process of the executive electric drive. In particular, there is a need to obtain the electromechanical function of the electric drive of the RC drone propeller in the form of a graphic dependence. This will make it possible to improve the process of creating, debugging and testing such devices without expensive field tests and the possibility of equipment damage. And also for creating control systems for RC drones.

The main goal of this study is to develop a model of the electromechanical microdrive system of the RC drone based on the CM. In order to develop a model of such a micro electric drive, a high-precision model of the CM is required, for which all the necessary parameters must be determined.

The main tasks of the research are:

- consider the theoretical foundations of building a CM model and the problems of building its exact mathematical model;
- conduct experimental studies of the CM 816 series of the RC drone in order to obtain all the necessary parameters for the further development of its high-precision model;
- on the basis of the obtained experimental results, create a high-precision model of the CM in MATLAB and obtain the transient process of speed and current on the model;
- conduct experimental studies of the CM with a propeller from an RC drone in order to obtain all the necessary parameters for the further development of its high-precision drive model, and create a high-precision model of such an electric drive of an RC drone in MATLAB based on the CM.

II. Coreless Micromotor For RC Drone Model

CM described by electrical equivalent circuit (Fig.1), where: u – CM DC supply voltage, $e(t)$ – CM back EMF, $\omega(t)$ – CM rotor speed, $i(t)$ – CM current, $T_l(t)$ – CM load torque, $T_e(t)$ – CM electromagnetic torque, J – CM rotor inertia moment.

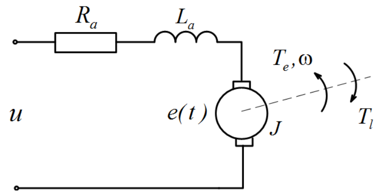

Fig. 1. Coreless micromotor model electrical equivalent circuit

At the next stage, we will make a transition from the description of the motor based on the equivalent electrical circuit to the CM model, implemented due to the description based on transfer functions. Although the design of the CM is significantly different from the classic DC motor with excitation from the excitation winding or permanent magnets, their structural scheme is quite similar. The structural diagram of the CM was investigated and the resulting model was analyzed and shown as a block diagram in Fig. 2.

In the figure, the following abbreviations and designations are used: R_a − CM armature resistance, L_a − CM armature inductance, k_e − CM back EMF constant, k_t − CM torque constant, $e = k_e\omega$ − CM back EMF, $T_e = k_t I_a$ − CM electromagnetic torque.

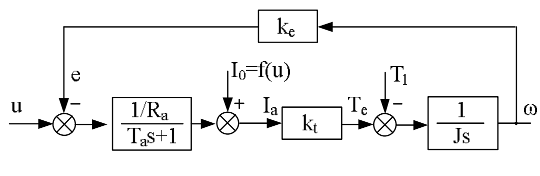

Fig. 2. CM micromotor block diagram