ANALYSIS OF THE RELIABILITY OF DC BRUSHLESS ELECTRIC MOTORS WITH POWER UP TO 200W USED IN MAVs

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Abstract: *This report analyzes the reliability of DC brushless electric motors up to 200W. Reliability is calculated in accordance with the MIL-HDBK-217F Notice2 standard and NSWC-10 standard.*
KEYWORDS: *DC, BRUSHLESS, ELECTRIC MOTORS, RELIABILITY, 200W*

1. Introduction

Today's micro air vehicle (MAV), with the development of technology and automatic control systems, are increasingly being used for both military and civilian purposes. Nowadays, MAVs are used for fun as well as important tasks such as:

- looking for injured in a distressed area;
- search and assessment in areas of disasters, accidents and environmental catastrophes;
- monitoring of forests, agricultural crops, agricultural activities;
- a flying platform for conducting experiments;
- different types of security, control and monitoring;
- mapping and geodetic measurements;
- performing various military operations.

Modern MAVs are a complex set of information sensors [3], automatic control systems [2], and powertrain assembled in the corresponding aerodynamic circuit. In order for the tasks to be performed, all elements of the MAVs must be highly reliable.

In MAVs are used brushless electric motors of up to 200W. This type of DC motors has the following advantages:

- wide range of speed adjustment;
- lack of nodes that require frequent maintenance (collector);
- can be used in explosive environments (no irritation);
- high overload capacity for a short time;
- high energy efficiency (over 90%)
- long life and high reliability due to the lack of brushes.

One of the main disadvantages is the higher price due to the more expensive materials.

2. Experimental part

Reliability of an electric motor means the property of the object to perform the assigned functions, preserving for a certain period of time the values of the established operating parameters within defined limits, corresponding to set modes and conditions of use, maintenance, repairs, storage and servicing.

The function of the reliability P (t), expressing the probability that the accidental processing of the motor to the failure τ will be no less than the set work (0, t), at the failure intensity λ (t) = const is calculated by [1]:

$$P(t) = e^{-\lambda t} \tag{1}$$

The probability of faultless operation of a small brushless electric motor up to 200W can be calculated using the following formula:

$$P(t) = P_b(t) P_w(t) \tag{2}$$

Where P_b is the probability of faultless operation of the bearings, and P_w is the probability of faultless operation of the coils.

Under normal operating conditions (temperature, revolutions, load and vibration), the bearing mounted in a small brushless motor must operate on average 77 000h or MTBF (number of hours that pass before a component, assembly, or system fails) = 77 000/(365×24) = 8.8 years. The probability of failure is $\lambda = 1/77\,000 = 1.3\times10^{-5}$ 1/h. [4, 6]

The probability of faultless operation of the windings is determined by (1), $\lambda = \lambda_w$. To find the failure rate, the average time of service expectation

$$t' = T'_w \exp[-\alpha_t(\vartheta - \vartheta_{max})] \tag{3}$$

which, in principle, depends on the time of service expectation of the winding. In eqn (3) α_t is the temperature coefficient of time of service expectation, ϑ is the temperature of the winding under operation and T'_w is the mean time of service expectation for the winding at the permissible temperature ϑ_{max} for a given class of insulation and relative humidity from 40 to 60%,. The higher the service temperature for the given class of insulation the longer the time T'_w.

Failures resulting from damaged soldered connections – due to breakage or aging - are also possible. Failure rate of winding including soldered connections is [4, 5]

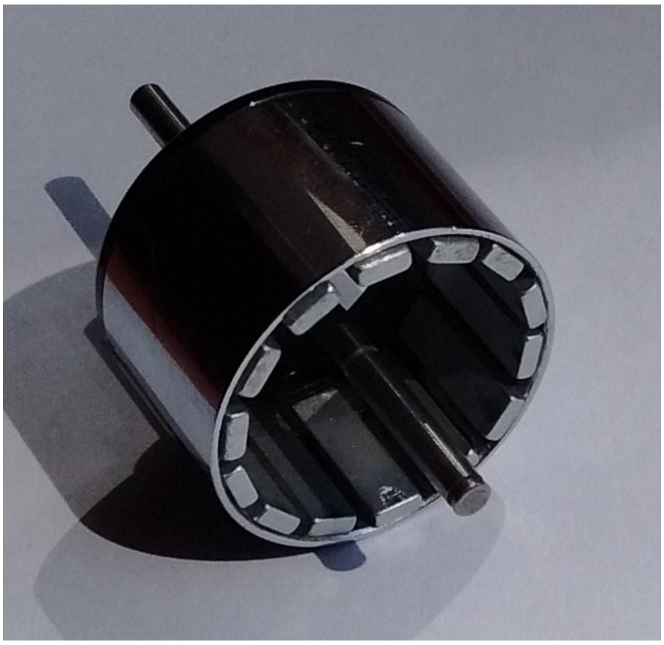

Fig. 1 Brushless DC motor rotor

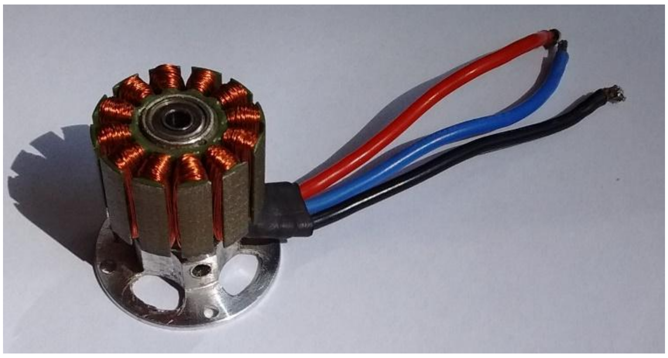

Fig. 2 Brushless DC motor stator

Figures 1 and 2 show a rotor and stator of a 200W brushless DC motor.

The thickness of the conductor from which the winding is made is 0.25 mm. The maximum current for this engine is 16.7A. Probability of failure-free operation of the motor within the time period of 5000 h is P(t)=0.9467, i.e. if 100 such motors operate within the time period t = 5000 h, 6 motors out of these 100 will probably not survive.

The maximum current consumption of brushless electric motors up to 200W is in the range of 1.8A to 27A.

Probability of failure-free operation of the motors within the time period of 5000 h is from P(t)=0.9214 to P(t)=0.95117.

3 Conclusions

From the calculations it can be deduced that the brushless DC motors placed in normal operating conditions have very high reliability. The bearings and windings used have a very long service life. If a suitable engine is selected when designing MAVs, its technical condition will mainly depend on the vibrations and mechanical loads that will affect it in flight.

With proper operation and timely prophylaxis, including regular bearing lubrication and dirt clearance, a high level of reliability can be maintained for a very long time.

4. Literature

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