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Production of Brushless DC Motor for Unmanned Aerial Vehicles and Investigation of Their Electrical Characteristics

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Abstract

High-performance electric Motors are in high demand due to the increasing need for production in all sectors. The brushless direct current motor is a promising future in most dynamic applications, such as the automotive, drone, rolling industries, and home appliances. The objective of this study was to design and manufacture a lightweight, high-thrust brushless DC motor that can reach high speeds suitable for drones and perform the necessary electrical analysis. The structure of the motor was designed using Solid Works software. Then, the designed motor was manufactured and tested. During the test, the current drawn by the motor was tested without load and using a three-blade propeller 18 x 8 inches. The number of revolutions per minute (RPM)was tested compared to the current drawn. It has been observed that the RPM increases rapidly with increasing motor current. As the motor's performance testing continued, the motor's thrust was checked based on the current drawn. As expected, the thrust increases gradually with the increase in the current drawn. Tests have been completed and the results have confirmed that the manufactured motor possesses all the expected features.

Keywords: BLDC Motor, DC Motor, Aerial Vehicles, Drones

1. Introduction

The development of high-performance motors is crucial in industrial applications such as electric trains, robots, and drones. Various electric motors have been proposed for such applications. Among these types, there are traditional direct current motors known for their advantageous features. Direct current (DC) motors are machines that convert electrical energy into mechanical energy. Although DC motors are used in many applications, they have disadvantages such as routine maintenance of commutators, frequent replacement of brushes, and high initial cost. Additionally, conventional DC motors cannot be used in clean or explosive environments due to sparks from the brushes. Brushless DC motors (BLDC) have been invented as an alternative to traditional DC motors [1].

BLDC motors are a special type of electric motors and are one of the types of synchronous motors. The main difference between brushless DC motors and permanent magnet synchronous motors (SMSM) is the back emf waveform .In permanent magnet synchronous motors, the back EMF waveform is sinusoidal, while in brushless motors the waveform is trapezoidal. However, since there are no collectors and brushes in BLDC motors, commutation is done electronically [2].

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The use of BLDC motors is expanding rapidly due to their numerous benefits, such as high efficiency, quiet operation, low maintenance requirements, constant torque delivery, wide speed, and torque control range. Since there are no brushes in this motor, there are no defects caused by brushes such as sparks [3]. Although BLDC motors offer numerous advantages for various applications, they also have some disadvantages that can negatively affect performance Such as the high cost and use of electronic drive circuits, limited high speed and torque, sensor dependency, and heat dissipation [4].

Most studies related to the brushless dc motor have focused on improving the motor design and increasing efficiency, in addition to developing control methods. Kayabaşı and Topçu presented a study examining structural changes in the stator and rotor of a BLDC motor and their effects on the output power and efficiency of the motor within a specific speed range. Changes in motor parameters were made using ANSYS Maxwell software. Analyses related to the magnet material, type of slot, magnet arrangement, and rotor structure were performed. Evaluation of the analysis results revealed that the slot type with a narrower air gap provided higher output power and efficiency compared to other types. Furthermore, the surface magnet motor showed better suitability in terms of power and efficiency at all speeds compared to other channel and embedded types. It was also observed that the inner rotor motor operated more efficiently at all speeds, while the outer rotor design provided higher power output in the region close to the maximum speed (2750 rpm). Motors designed with neodymium and samarium magnets exhibited better performance at low speeds, while XG196/96 magnets performed better at high speeds [5]. Jang and Lee presented a new winding method and inverter circuit to drive the BLDC motor to high speed with large torque. The proposed windings consist of double coils, that is, main and auxiliary coils, and the proposed inverter circuit has nine switches. Both the main and auxiliary windings were energized by parallel connection to produce large starting torque in the starting period [6]. Özgenel conducted a study to increase the performance of a brushless DC motor. The aim of this study is to produce a 12-stage inverter that controls phase currents with the pulse width modulation (PWM) technique. Experimental results show that the 12-stage inverter produces a higher phase voltage, torque, and speed than the 6-stage inverter [7].

This study aims to design and manufacture a lightweight, low-cost BLDC motor that can be used in drones, as well as to conduct tests to monitor the performance of the manufactured motor.

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2. Proposed BLDC motor

Initially, the Proposed motor was designed in the Solid Works program, where the stator, rotor, and shift dimensions were carefully chosen. During the design process, many matters were considered related to reducing the temperature of the coils and reducing the overall weight of the motor, which makes it suitable for unmanned aerial vehicles. Figure.1 shows the proposed motor's design.

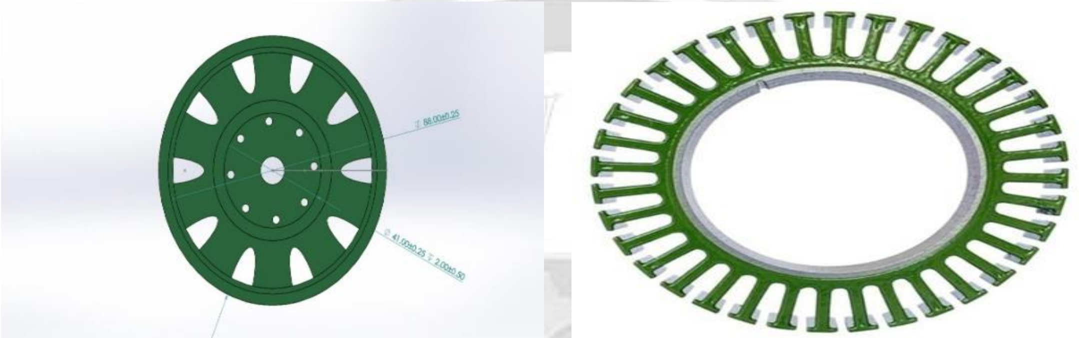

Figure 1 Design Model of The Stator and Rotor of The Motor

After completing the design, the proposed motor was manufactured. The inner part of the motor is made of aluminum, while the outer body uses light and durable plastic, which gives durability and reduces the overall weight of the motor. As shown in Figure 2, The motor's stator is wound bidirectionally with 0.7mm copper wire on 36 poles for improved efficiency.

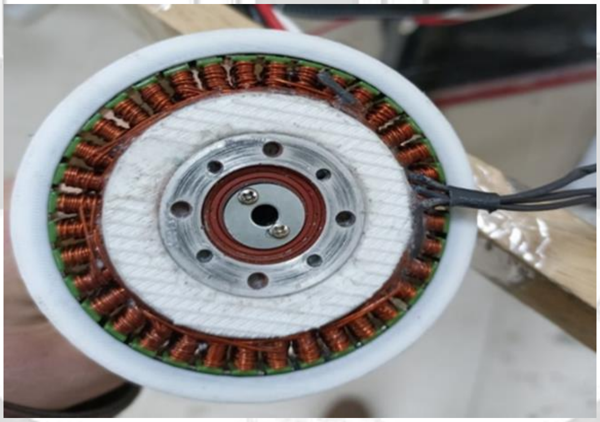

Figure 2. Internal Coils of The Motor

The motor's external view, shown in Figure 3, reveals a durable plastic outer part with a motor designed to withstand high speeds.

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Figure 3. The external view of the motor

Castle PHOENIX ICE2 HV 120 Brushless ESC was used as the motor driver. In the experiments, a 6-cell lithium polymer battery with a voltage of 22.2V and a capacity of 5000mAh was utilized. The driving circuit and battery used are shown in Figures 4 and 5.

Figure 4. The driving circuit used.

Figure 5. The battery used to power the motor.

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3.Results and discussion

The experimental setup for testing the designed and manufactured motor is presented in Figure 6.

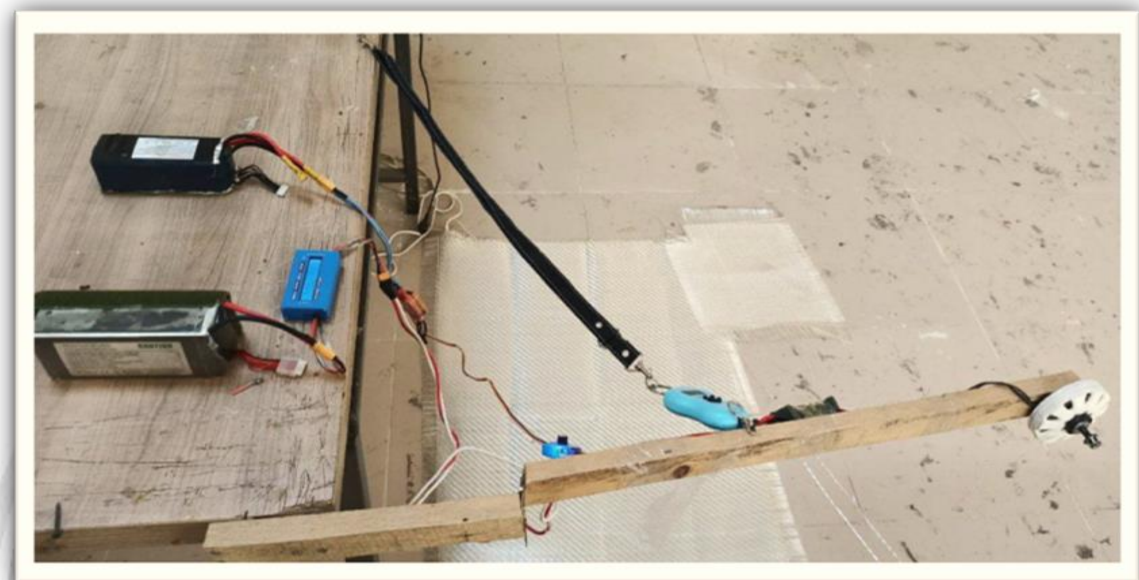

Figure 6. Motor test Setup

Table 1. Current and speed values of the motor without load

Current (A)	Number of revolutions (RPM)
0,1	1789
0,2	2522
0,3	3120
0,45	3875
0,55	4320
0,65	4830
0,72	5120
0,8	5543
0,9	5977

Table 2. Current, thrust and speed values of the motor with 18*8-inch propeller.

Current (A)	Number of revolutions (RPM)	Thrust (g)
30,0	850	180
60,0	1162	530
20,1	1556	1100
80.1	1870	1600
40,2	2190	2300
60,3	2500	3350
20,4	2630	3700
20,4	2780	4025

Initially, the current drawn by the motor was examined at a no-load condition while varying its speed. Figure 7 shows that the current drawn by the motor increases in direct proportion to the number of revolutions.

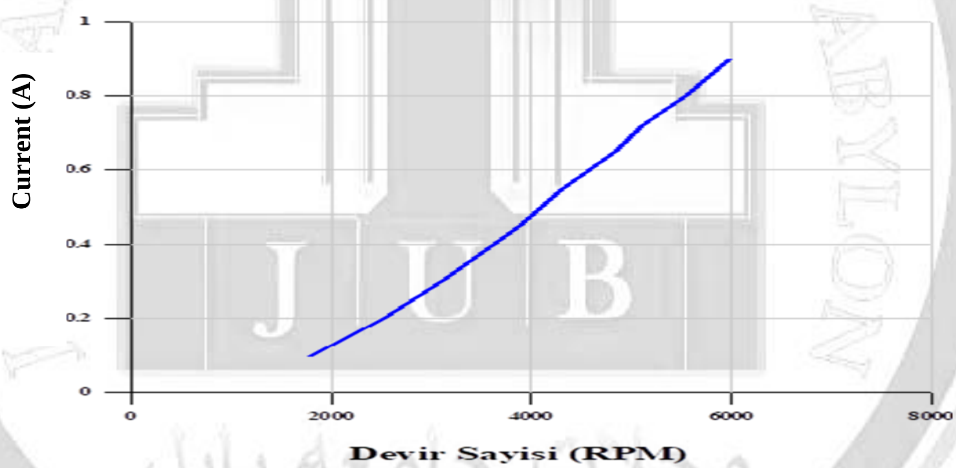

Figure 7. Current and Speed of the motor in no Load Condition

After the no-load condition, the motor designed and produced using a 3-blade 18*8 propeller was tested. Propellers made of beech wood were used to achieve high efficiency and durability. the relationship between the motor speed and the current drawn was examined as shown in figure 8. As expected, the corresponding current drawn also increases as the number of revolutions increases.

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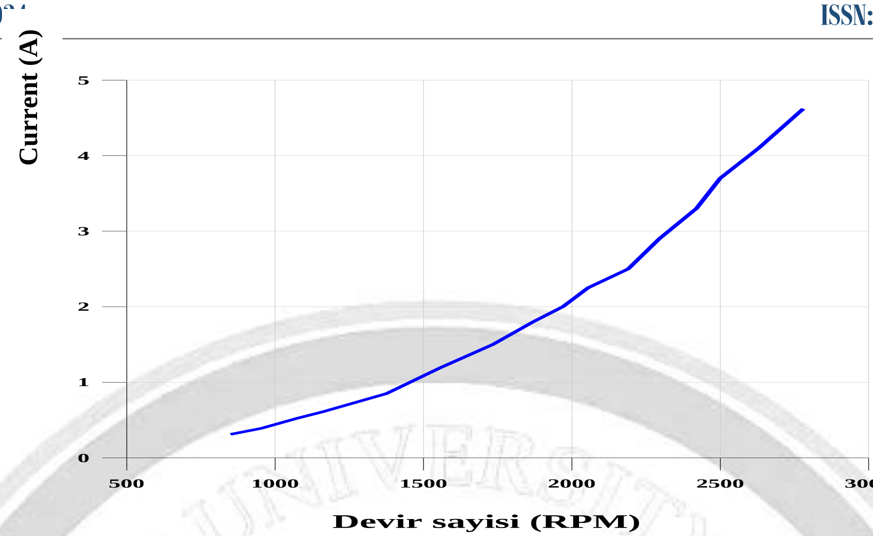

RPM)(Revolutions per minute

Figure 8. Current and Speed of the motor with a three-blade 18x8 Propeller.

While continuing to test the motor's performance, the relationship between the lift force and the current drawn was examined in Figure 9. As can be seen here, the drawn current increases directly with increasing the thrust of the propeller.

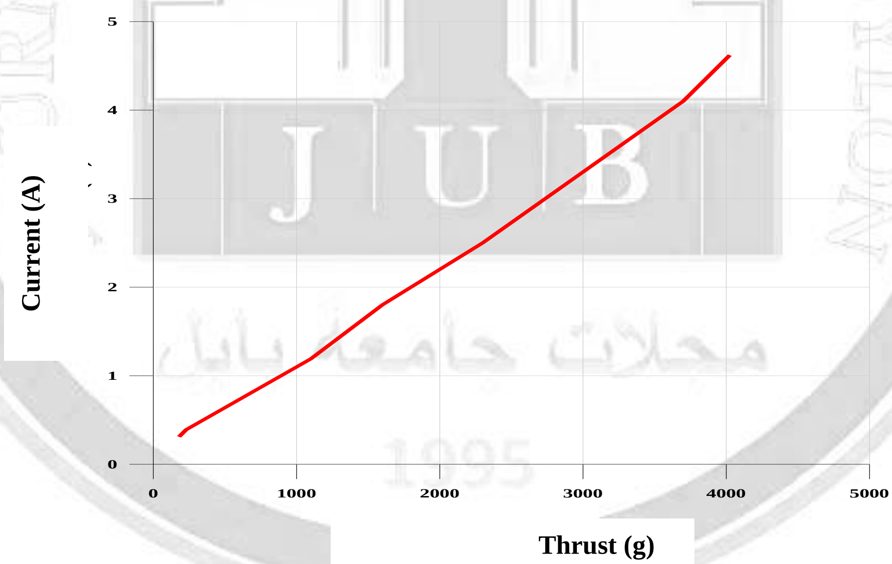

Figure 9. Current and Thrust of the motor with a three-blade 18x8 Propeller.

Finally, the relationship between the number of revolutions and the thrust of the motor was determined, as shown in figure 10.

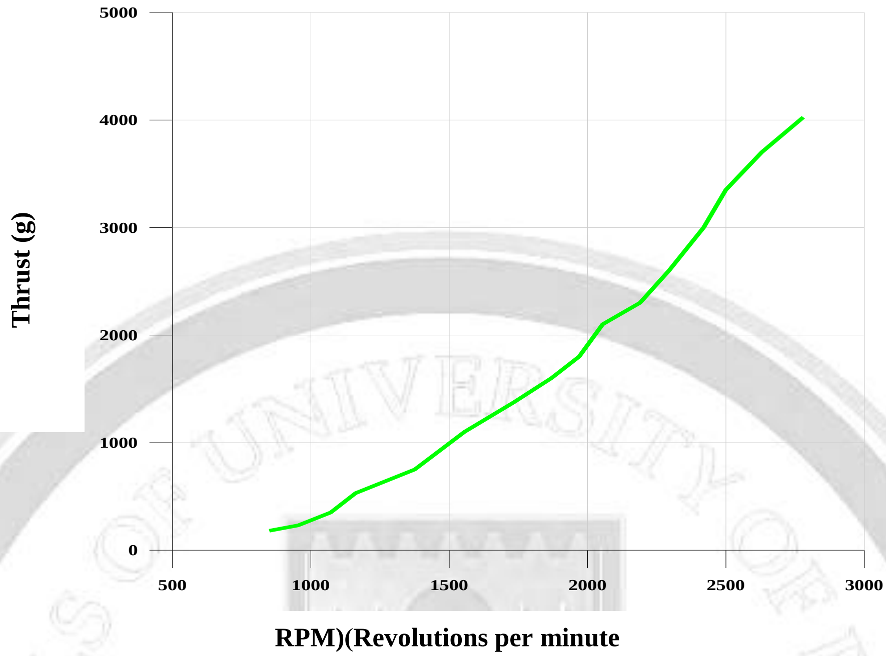

Figure 10. Thrust and Speed of the motor with a three-blade 18x8 Propeller.

Conclusion

This study carried out motor design, production, and performance analyses for UAVs. The designed motor is brushless and can reach high speeds. In addition, the motor, which is produced from very light and durable materials, also becomes advantageous with the selection of economically suitable materials. Performance tests of the produced engine are of great importance. For this purpose, tests were carried out using two different sizes of propellers, 3-blade propellers, and two-bladed propellers. All results show that the motor presented can be used in UAVs, considering the performances of the motors available on the market.

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إنتاج محرك DC بدون فرش للمركبات الجوية بدون طيار ودراسة خصائصها الكهربائية

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الخلاصة

يزداد الطلب على المحركات الكهربائية عالية الأداء بسبب الحاجة المتزايدة للإنتاج في جميع القطاعات. يعد محرك التيار المباشر بدون فرش مستقبلًا واعدًا في معظم التطبيقات الديناميكية، مثل صناعة السيارات والطائرات بدون طيار وصناعات الدرفلة والأجهزة المنزلية. كان الهدف من هذه الدراسة هو تصميم وتصنيع محرك DC خفيف الوزن وعالي الدفع بدون فرش يمكنه الوصول إلى سرعات عالية مناسبة للطائرات بدون طيار وإجراء التحليل الكهربائي اللازم. تم تصميم هيكل المحرك باستخدام برنامج Solid Works. ومن ثم، تم تصنيع المحرك المصمم واختباره. أثناء الاختبار، تم اختبار التيار الذي يسحبه المحرك بدون حمل وباستخدام مروحة ثلاثية الشفرات مقاس 18 × 8 بوصة. تم اختبار عدد الدورات في الدقيقة (RPM)مقارنة بالتيار المسحوب. وقد لوحظ أن عدد الدورات في الدقيقة يزداد بسرعة مع زيادة تيار المحرك. مع استمرار اختبار أداء المحرك، تم فحص دفع المحرك بناءً على التيار المسحوب. وكما هو متوقع، فإن الدفع يزداد تدريجياً مع زيادة التيار المسحوب. تم الانتهاء من الاختبارات وأكدت النتائج أن المحرك المصنع يتمتع بجميع الميزات المتوقعة.

الكلمات الدالة: محركBLDC ، محركDC ، المركبات الجوية، الطائرات بدون طيار .