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Investigation of the Efficiency of Motor based on Temperature for Agriculture Application

Mohammad Farhan Adli Paiyadh[1], Ahmad Hamdan Ariffin[1*],

[1]Faculty of Mechanical Engineering and Manufacturing,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

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Abstract: Drone is widely used in various industries in the world in line with the era of modernisation especially for medium farmers. This problem gives a challenge for small and medium farmers to adapt new technology in the aspects of drones due to expensive price of drones. The combination of high optimization of efficiency of motor with moderate price are required to decrease the price of drone. The selection of motor is one of the ways to reduce the price of drones. The efficiency of motor is one of the criteria to be considered before selecting the motor for drone. This project outlines a methodology for investigating the efficiency of the motor based on the temperature. This study focuses on how temperature could affect the efficiency and the thrust performance of the motor that could be used in agriculture industry. The experiment was conducted by using 5 kinds of motor to gain each of their RPM, throttle percentage, current load of motor, thrust force, power of motor, ambient temperature and temperature of motor. The lowest reading of RPM at the lowest temperature of motor is 670 rpm for M8 brushless dc motor, 889 rpm for M8 Pro brushless dc motor, 890 rpm for T-motor, 990 rpm for Agras T-10 motor and 1552 rpm for 10015/75kv motor. The highest efficiency of motor at lowest temperature is 19.23 g/W for M8 brushless dc motor. Results were organised by temperature (motor) vs RPM, temperature (motor) vs power, temperature (motor) vs thrust force, ambient temperature vs RPM, ambient temperature vs power and ambient temperature vs thrust force. Based on all conditions, the best motor is M8 Brushless direct-current motor because the lowest reading of RPM at the lowest temperature of motor was 670 rpm, lowest reading of power at the lowest temperature of motor was 13 watts and lowest reading of power at the lowest temperature of motor was 250 gf. The results showed that based on all these conditions, the efficiency of the motor is 19.23 g/W.

Keywords: Efficiency of Motor, Small Farmers, Thrust Performance, Temperature (Motor), Ambient Temperature, Motor Selection

1. Introduction

Nowadays, medium farmers are starting to grow within the country. The farming method has shown great advancement in adapting technologies such as drone into their ways of growing plants and fruits.

**Corresponding author: ahmadh@uthm.edu.my*

The part of the drone that is considered as one of the highest price values is the motor (Mccormick, 2001). The aim of this research is to provide data of motor thrust performance depending on the temperature by finding the efficiency of motor and its thrust performance.

Drone designs come in a variety of shapes, sizes, features, and uses (Vergouw et al., 2016). Each drone type has its own set of benefits and drawback (van der Merwe et al., 2020). Drones are divided into four categories: fixed-wing, single-rotor, multi-rotor, and hybrid. Each sort of drone has its own set of advantages and disadvantages (van der Merwe et al., 2020).

In general, fixed-wing drones are the most efficient, as the lift provided by the aircraft's wings minimises the amount of energy required to keep the drone aloft (van der Merwe et al., 2020). Industrialists and academics have been motivated to design lighter drones with improved flying times and efficiency as a result of increased competition and the quest for new uses (Delbecq et al. 2020). Its light weight and high thrust generating capacity of motors enable it to boost its weight lifting capability, which will be enhanced by the addition of electronic components for operation (Singh et al. 2019).

1.1 Motor of drones

Electric motors are more versatile and adaptive than they've ever been. Motor selection is critical when designing a motion control system. The motor must be compatible with the system's function and overall performance goals. Fortunately, there is a motor design suitable for any application. Some of the commonly used electric motors are AC brushless motors, DC brushed motors, DC brushless motors, direct drive, linear motors, servo motors and stepper motors. However, this study is focusing on brush DC motor and brushless DC motor only (Sato et al. 2020).

Variable speed drives have relied on straight-current (dc) brushed motors, either with an independently excited field or a permanent-magnet rotor. Brushed dc motors are utilised as a standard in many industrial applications due to their simple operating features, flexible performance, and high efficiency. These factors, combined with the long development history, have resulted in brushed dc motors becoming a standard. Despite recent advancements in brushless dc and vector-controlled ac motors, brushed dc motors have a number of advantages that will assure their continued use by system designers (Crowder 2020).

The mechanical commutator (brushes) utilised in many conventional electric motors is replaced by this control method. Brushless dc motor consists of stator, stator windings and permanent magnet rotor or salient soft iron rotor. The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor or an induction (asynchronous) motor. They may also use neodymium magnets and be out-runners (the stator is surrounded by the rotor), in-runners (the rotor is surrounded by the stator), or axial (the rotor and stator are flat and parallel) (Smith 2012).

1.2 Data set used to measure the efficiency of motor

According to European Aviation Safety Agency (EASA) and Joint Authorities for Rulemaking on Unmanned System (JARUS), power or thrust control systems must be designed so no unsafe condition will result during normal operation of the system which means that the systems must be tested in order to achieve zero failure during normal operation. Therefore, this lab experiment is a crucial part in obeying the rules and regulations structed by the law.

All of the data are gained from the experiment conducted in the lab based on standard situation in real world. The data is collected to determine each of the motors' performance based on each category of variable which are rpm of motor (rpm), throttle percentage (%), amps (A), thrust (gf), power (watts), ambient temperature (℃), temperature of motor (℃) and efficiency (g/W). Based on Table 1 for M8 Brushless direct-current motor, it clearly shows that as the value of rotation per minute (rpm) increase, the value of thrust force also increases. However, the efficiency of motor decreases as the temperature of motor increases.

Table 1: Data for M8 Brushless direct-current motor

Rpm of motor (rpm)	Throttle (%)	Amps (A)	Thrust (gf)	Power (watts)	Ambient temperature (℃)	Temperature of motor (℃)	Efficiency (g/W)
670	35	0.4	250	13	26.0	40	19.23
935	40	0.8	500	26	26.1	45	19.23
1126	45	1.3	750	43	26.3	50	17.44
1288	50	1.9	1000	63	26.5	55	15.87
1444	55	2.6	1250	86	26.7	60	14.53
1585	60	3.3	1500	109	26.9	65	13.76
1714	65	4.2	1750	139	28.0	70	12.58
1825	70	5	2000	165	28.1	75	12.12
2036	75	6.8	2500	224	28.3	80	11.16
2200	80	8.8	3000	290	28.5	85	10.34
2405	85	11.2	3500	370	28.7	90	9.46
2545	90	13.6	4000	449	28.9	95	8.91
2710	95	16.2	4500	535	30.0	100	8.41
2864	100	19.7	5000	650	30.1	105	7.69

2. Methodology

The research methodology for the project is represented by the flow diagram in Figure 1.

2.1 Flow Chart of Project

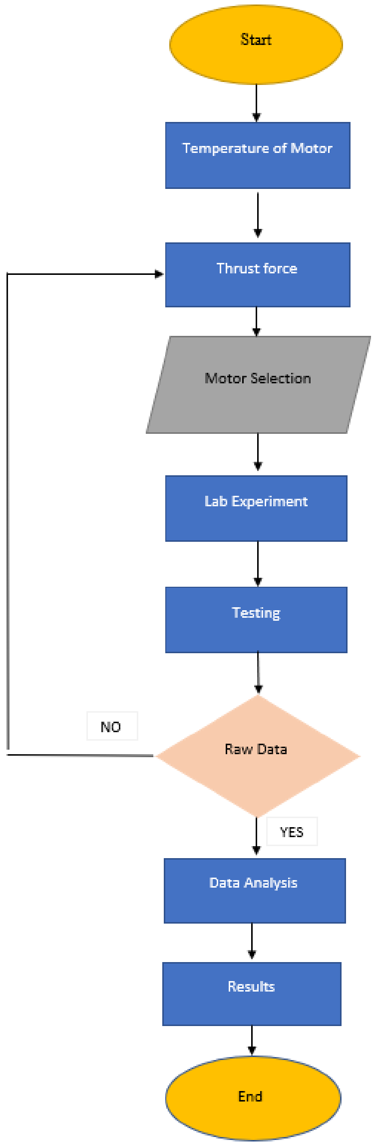

Figure 1: Flow Chart of the project

2.2 Detailed Methodology

Temperature of Motor

Motor is a component that would produce heat over a period of time. As the time increase, the temperature of the motor also increases. This would eventually cause a problem in a long – term if it is being ignored. The temperature will affect the efficiency of the motor which is bad because the higher the efficiency of a motor, the lower the chances of motor failure. The instruction manual and the motor nameplate clearly describe the temperature range of a motor. The most frequent working temperature range for general purpose industrial motors is -20° C to 40° C. This temperature range is suitable for a wide range of industrial applications. Components like as seals, fans, insulation, and bearing grease must be taken into account in applications where ambient temperatures reach 40° C. The temperature of the motor will be considered as a variable that will be measured during the lab experiment. Different temperature will be resulting in different efficiency of the motor.

Thrust force

The time taken in this lab experiment will be one of the key factors in determining the efficiency of motor. The motor will run for about 1 hour and the temperature of the motor will be taken at every ten minutes. It is expected that the temperature will increase as the time continues but the optimum temperature will be obtained through this data so that the motor can maintain its capabilities without fail.

Motor Selection

The motor selection process begins with evaluating the characteristics of the motor and ensuring the motor is available for testing. A few of them were selected and have been evaluated based on each of their characteristics and availability. Besides that, these motors were chosen because of their capabilities to uphold their own job in making sure that the drone will run smoothly without fail. The percentage of these motors to fail is quite low because the motor is capable to uphold twice the all – out weight of their respective drones. This means that even at full weight of payload, the drone would be functioning perfectly without failure. Table 2 shows the comparison between drones and its specification.

Table 2: Comparison between motors

Company	dji	dji	dji	dji	dji
Types	MG - 1	MG – 1P	Agras T30	Agras T10	Agras T20
No. of propeller	8	8	6	4	6
Motor used	M8 brushless 135KV	M8 Pro brushless 135KV	T – motor	Agras T10 motor	10015 / 75kv
Price of motor per unit (RM)	155.99	155.99	1099.80	341.98	617.00
Max thrust (Kg / rotor)	5.1	5.1	18.7	11.2	13.5
Max Power (W)	770	770	3000	2000	2400
KV Value (Rpm/V)	135	135	77	84	75
Weight (g)	280	280	756	527	616

Lab Experiment

For the motor thrust test rig, the component that is needed to set up the rig is 3 half inch of diameter PVC tube, two of them have the length of 24 centimetres while one of them is 25 centimetres and conjunction parts to connect the pipes. All the components are connected with M3 screw with different length. Then, the pulley is connected to component via M3 screw with 20-millimetre length. All the components are joint by a plywood to hold the test rig in place. The motor will be connected to 70 Ampere electronic stability control which already connected to wattmeter. The servo tester will be used to control the throttle of the motor. To identify the thrust force, a spring balance of 50 kg limit is being used. Figure 2 shows the final setup of the motor thrust rig.

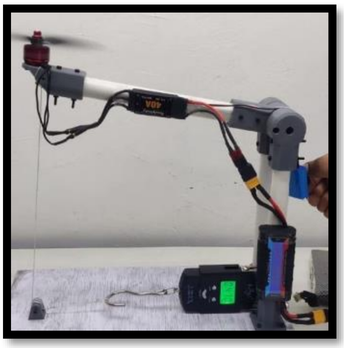

Figure 2: the motor thrust rig

Detailed Analysis

Analysation of data was conducted after the data have been tabulated. The data gained was the data of the motor. The parameter used in the data analysis were rotation per minute, percentage of throttle, current load of motor, thrust force of motor, power of motor, ambient temperature, temperature of motor and efficiency of motor. The efficiency of motor can be obtained through division of the thrust force of motor and the power of motor. Analysation of data was conducted through plotting of graph from the data gained.

Results and Discussion

Figure 3 shows M8 brushless dc motor that was selected as the best motor among the motors. The motor was selected based on all the condition during the experiment.

Figure 3: M8 Brushless DC Motor

Table 1 shows the summary of results for M8 brushless direct-current motor. The results for the motor were categorized into 6 sections which are RPM vs temperature (motor), Power vs temperature(motor), Thrust force vs temperature (motor), RPM vs ambient temperature, Power vs ambient temperature and Thrust force vs ambient temperature.

Table 1: Summary of results for M8 Brushless DC Motor

Parameter	`Lowest Reading in Graph						Efficiency (g/w)
	RPM vs temperature (Motor)	Power (watts) vs temperature (Motor)	Thrust force (gf) vs temperature (Motor)	RPM vs ambient temperature	Power (watts) vs ambient temperature	Thrust force (gf) vs ambient temperature	
Value	670	13	250	670	13	250	19.23

The graph of rotations per minute (RPM) vs temperature (motor) in Table 1 reveals that 670 RPM, which corresponds to a temperature of 40 degrees Celsius, has the lowest value. The following graph, which depicts the relationship between power and temperature (motor), reveals that the M8 brushless dc motor has a minimum power requirement of 13 watts. The value of thrust force that is the lowest on the graph of thrust force vs temperature for the motor is 250 gf. The lowest value of rotation per minute, as shown by the graph of RPM vs ambient temperature, is 670 rpm, which occurs at a temperature of 26 degrees Celsius. The following graph, which depicts power in relation to the surrounding temperature, reveals that the M8 brushless dc motor has a minimum power need of 13 watts. The value of thrust force that is the lowest on the graph of thrust force vs ambient temperature is 250 gf. Aside from that, the overall efficiency of the motor when operating under these conditions was 19.23 g/W.

3. Conclusion

This paper presents the investigation of efficiency of motor based on temperature has been done. This research showed the detailed data of each motor and the analysis of graph based on the data. According to the data and the graph, it can be concluded that the objective to investigate the efficiency of the motor based on the temperature is achieved. It can be seen that the efficiency of the motor can be found based on the power of the motor and the thrust force of the motor. The efficiency of the motor shows that both ambient temperature and temperature of motor have affected the performance of the motor. As the ambient temperature and the temperature of motor increases, the efficiency of motor decreases. This clearly shows that the performance of the motor can be optimized by decreasing the temperature of motor and ambient temperature. The objective to optimize the thrust performance of motor for agriculture purposes are also achieved. The table of data for motor represents the rotation per minute (rpm) of the motor, the throttle percentage, the current of motor, the thrust force of motor, the power of motor and the temperature of motor. Based on these data, the efficiency of motor can be determined. The graph of data for motor shows how temperature of motor and the ambient temperature can affect the rotation per minute, the power of motor and the thrust force of the motor.

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