Exploring Reliability in DC Brush Motors

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Abstract

As drones become more widely used, it is important to study the reliability of their components. Due to size and weight restrictions, each component must have superb reliability to avoid failure of the whole system. My research focused on improving the reliability of DC brush motors that can be used in drones. First, by collecting failure data on motors with pre-manufactured propellers as the test group. Then by studying the reliability of the same motors with 3D printed propellers to determine if it is possible to increase reliability.

Literature Review

This experiment uses brushed motors because they are easily made small which is optimal for drones. A brush motor has three basic components: a stator, a rotor, and brushes with a commutator. A stator generates an electrical field that surrounds the rotor, the main force that powers the motor. The rotor is energized by the electrical field which causes it to turn. The commutator (a segmented copper sleeve) has carbon brushes slid along it as the motor turns to generate a dynamic electrical field inside the motor (Condit, 2004). Figure 1, below, shows a basic diagram of a DC brush motor.

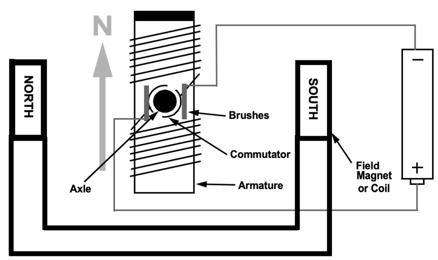

Figure 1: Diagram of Basic DC Brush Motor Circuit (Harrington & Kroninger, 2013)

3D printing has become a cheap alternative to manufacturing, especially for smaller parts that do not need to be mass produced. An assessment of 3D printed drone wings was done at the Wroclaw University of Science and Technology in Poland to determine if 3D printing could be used to successfully create drone parts that allowed for flight. The assessment used a remote control airplane with construction identical to fixed-wing drones and 3D printed wings. Test flights concluded that the aircraft was able to fly, but the weight of the wings was significant (Kujawal, 2017). The successful flight of the airplane proves that flight with 3D printed blades is possible.

Methods and Materials

To test the reliability of drone rotors, a circuit was set up with Arduinos to apply constant stress and data was analyzed with Excel and MATLAB. The complete circuit set up included a INA219 High Side DC Current Sensor, Arduino Uno, Propellers, Brushed DC Motors, 47 microfarad capacitors, 1 megaohm resistors, and various power supplies. Each Arduino Uno had four current sensors and a power supply to power the rotors and apply constant electrical stress until the rotor was deemed to have failed. The rotors were tested at a constant voltage of 5V but the current was varied to create various stress levels as follows:

- Low stress at 1A
- Medium stress at 2.4A
- High stress at 3.1A

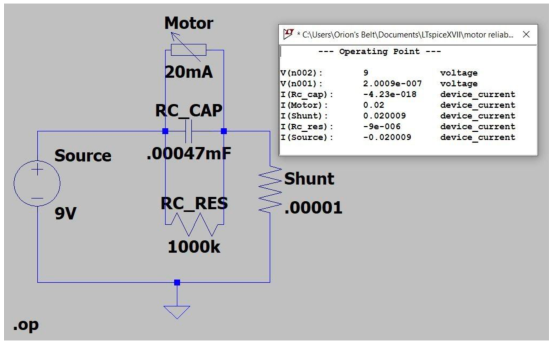

Figure 2: LTSpice Diagram of Testing Circuit

Mechanical stress was applied with a propeller because a drone using rotors would have a propeller, allowing this experiment to be as accurate as possible

A diagram of the circuit set up can be seen in Figure 2, which was created using LTSpice. The Arduino board collected data, which was exported as a csv file and later analyzed using Excel and MATLAB.

In this experiment, the data collected is the failure time of the rotor. Due to this, it is important to define what a failure is. When a rotor stopped spinning completely or slowed significantly, it was deemed to have failed. Even if the rotor would return to full operation if it was adjusted by hand, it would still be deemed a failure. This is because failure is determined based on successful operation on a drone and a significant decrease in speed of the rotor or needed to adjust the rotor manually would result in complete failure midair.

Results

Table 1 is all elapsed time until failure for the 25 motors tested and the mean time to failure (MTTF) for each current. Several data points were removed because their current was measured as higher than normal, which would have skewed the calculations later on.

Table 1: Failure Times for Tested Motors at 5V

Current	Motor ID	Start Time	End Time	Elapsed Time
1A	10	223840	132200	14 hours 43 minutes 20 seconds
	11	205041	182000	21 hours 29 minutes 19 seconds
	14	224130	55700	7 hours 15 minutes 30 seconds
	15	231249	182000	19 hours 7 minutes 11 seconds
	16	232530	55700	6 hours 31 minutes 30 seconds
	17	153632	65300	15 hours 16 minutes 28 seconds
	18	155737	14800	9 hours 50 minutes 23 seconds
	20	114400	4500	13 hours 1 minute
	21	114600	215600	10 hours 10 minutes
	22	114900	45600	17 hours 7 minutes
	23	115300	185400	7 hours 1 minute
MTTF at 1A: 12.868 hr				
2.4A	1	1900	1903	3 minutes
	2	191122	191330	2 minutes 8 seconds
	3	191853	192250	3 minutes 57 seconds
	6	202433	202620	1 minute 47 seconds
	8	204545	204923	3 minutes 38 seconds
	9	213125	214012	8 minutes 49 seconds
MTTF at 2.4A: 3.858 m				
3.1A	12	x	x	40 seconds
	13	x	x	18 seconds
MTTF at 3.1A: 39 s				

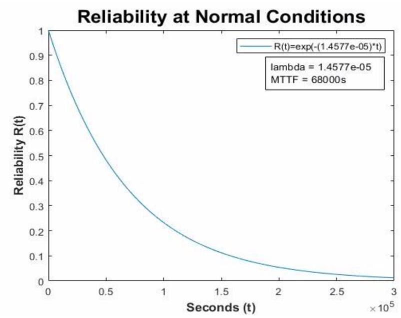

Figure 3: Exponential Distribution of Reliability At Normal Conditions

Extrapolation on the MTTF for each current was done in MATLAB to determine the failure rates under normal conditions. The normal conditions are based off mean time to failure.

The mean time to failure is 18.9 hours, and the failure rate is 1.4577e-05 per second, as seen in figure 3

Future Direction

Due to unforeseen events (a global pandemic), 3D printed propeller blades were not manufactured and tested as hoped. This is the next step in the research of drone blade reliability. The same set up would be used to test drone rotors with 3D printed propellers as was used to test the rotors with already manufactured propellers. If the mechanical stresses of 3D printed propellers is less, then the reliability of the rotors will hopefully increase, allowing for a cheaper and more reliability alternative. If it was found that 3D printed propellers add to the mechanical stress, then experimentation with materials, design, and finish can be done to determine if there is any way to have 3D printing be a viable alternative.

References

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