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Development of Unmanned Aerial Vehicle for Agrochemical Spraying to Enhance Crop Protection

Kadala F. Shalzim & Ndana'acha Alfred
Adamawa State College of Education Hong, Adamawa State, Nigeria
felixkadala@gmail.com; ndanacha.alfred@gmail.com

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Abstract

The use of autonomous or guided unmanned aerial vehicle (UAV) is beginning to have enormous benefits in Agriculture by modernizing the ways in which farmers work not only to improve the yield and maximize profit but also the need to be healthy by avoiding direct contact with the agrochemicals used in our farmlands. The aim of this paper is to present an on-going research on the local development of agricultural spraying unmanned aerial vehicle for enhancing crop production and protection in small and medium scale maize, rice, and sugar cane plantation farmers in the Nigeria. The objective is to design and develop a practical UAV sprayer based solutions that would enable the adoption of the precision agriculture farming technique by Nigerian farmers. The proposed method involved the development of a 850 mm hexa-rotor UAV platform with an air bone spray system, the UAV uses a pixhawk flight controller, iRotor 5010/360KV motors with a1555 propellers,40A ESC and 5200mAh/ 22.2volts battery. It telemetry operates on a frequency of2.4GHz using flysky transmitter and receiver, with an ultrasonic sensor for capturing the unmanned aerial vehicle height above the ground level. In this research thrust analysis was performed tos determine the lift capacity of four propeller, the 1245, 1447, 1555 and 1655 inches in combination with 360Kv motor. And it was determined that the 1555 inches propeller out performs the other three propellers as shown in their performance plots in Spyder-Python – Anaconda. The UAV Sprayer system was implemented using the best optimal performing components, with the overall intention of developing sustainable methods in crop production and protection that would increase the crop yield that will build a resilient economy and minimize human exposure to the hazardous chemicals while optimizing both crop production and protection.

Keywords: Development, Unmanned Aerial Vehicle, Crop Production, Crop Protection

INTRODUCTION

Over the last decades, there has been a growing shift from traditional agricultural practices to precision agriculture. This is due to the evolution of satellite and manned aircraft technologies to support the more efficient technique of precision agriculture. However, the downside of this is the fact that satellite and manned aircraft technologies are too expensive and therefore unaffordable by many small and medium scale, commercial and subsistence farmers. Within the last decade, there has been increasing shift towards the adoption of unmanned aerial vehicles (UAVs) in precision agriculture due to its lower cost and greater usage flexibility over the satellite and manned aircraft alternatives. But the problem is that the UAV often requires more expensive sensors such as the multi-spectral, ultra-spectral, and thermal infra-red sensors which may be large in size for the UAV payload cavity and too heavy for small UAV to carry in flight for long periods of time. These often results in the development of bigger and more expensive UAVs which may still be outside the available budget of small and medium scale farmers. Therefore, in other to address this problem, we are proposing the development of an 850 mm hexa copter unmanned aerial vehicle that will be locally assembled and fitted with spray system which can also be used for spraying agrochemicals in our farmlands. In this research, a considerably large 850 mm hexa-rotor UAV platform, with a locally constructed spray system, was developed and used to spray liquid fertilizer popularly known as super grow over an hectare of farmland, with the aim of developing standardized agricultural spraying drone for the application of common agricultural herbicides, pesticides and liquid or soluble fertilizer on crops grown in Hong local government of Adamawa State Nigeria, in order to support crop protection and production.

The manual agricultural spraying method is very slow and requires many able hands to cover large farm lands, which exposes these workers to various diseases caused by the sprayed agrochemicals hence the need for unmanned aerial vehicle spray system (Sharma et al,. 2021). The Unmanned aerial vehicle (UAV) also known as the drone is an aircraft that can be remotely controlled or fly autonomously through software controlling the flight plans with the help of auto-pilot (Neelabh et al,. 2020). A manual sprayiny system is depicted against a UAV spraying system in figure:1.1.

(a) (b)

Figure 1.1 (a) manual spray system and (b) UAV Spray system

Labour force shortage in agricultural production has grown and may continue to grow, in the future as youth are looking for white collar jobs (Lee et al,. 2021). Agricultural mechanization development strategy needs to be put in place and in alignment with this; the use of unmanned aerial vehicle for agrochemical application in agriculture will contribute to the advancement of crop protection mechanization providing improved ability to apply the agrochemicals in time sensitive manner with enhanced safety and efficiency (Xiongkui et al., 2017).The UAV based application technology for agrochemicals is considered as a high efficiency alternative to the conventional manual spray, tractor sprayer and even the manned aerial application(Xiongkui et al., 2017).The potential ease of deploying a UAV coupled with the reduction in operator's exposure to chemicals and the improved ability to apply chemicals in a highly timely and highly spatially resolved manner makes UAV spray application an attractive research area (Giles & Billing, 2015).

The use of UAVs to carry out the task of spraying agrochemicals can be beneficial for many reasons among which are:

i. The reduction of human contact with the chemicals, which in turn preserves human health.
ii. To improve the performance of the spraying system operation by avoiding the presence of chemicals outside the desired areas, which helps to preserve neighborhood fields, that can be other crops, preserved natural areas or even water sources.
iii. Precise application of these agrochemicals reduces environmental pollution.

METHODOLOGY

This research work is divided into three phases; the first phase involves design and development of the drone frame by estimating the anticipated load, getting the desired frame and coupling them together. The second phase involves mounting both the mechanical and electrical components of the drone, configuring it and testing it without load and finally the third phase is the design and development of a pesticide and herbicide spraying system to be mounted on the UAV which is expected to carry a 2 kg payload with a 45 - 60 minutes flight time, as an integrated autonomous robotic flying machine to provide solution in aiding farming operation by precisely spraying crop agrochemicals.

UAV Propeller Static Thrust Analysis

In this research work the Mezjlik static thrust calculator (Mejzlik, 2020). was used to simulate the various performances of the 1245 inches, 1447 inches, 1555 inches and the 1655 inches propeller in combination with 360Kv rated motor powered by a 22.2 volts supply. The results obtained from the simulation performed in the Mezjlik static thrust calculators, was then analyzed in Anaconda-Python-Spyder IDE for proper representation of results as shown in Table 1.2 to 1.5 and figure 1.6 to 1.10.

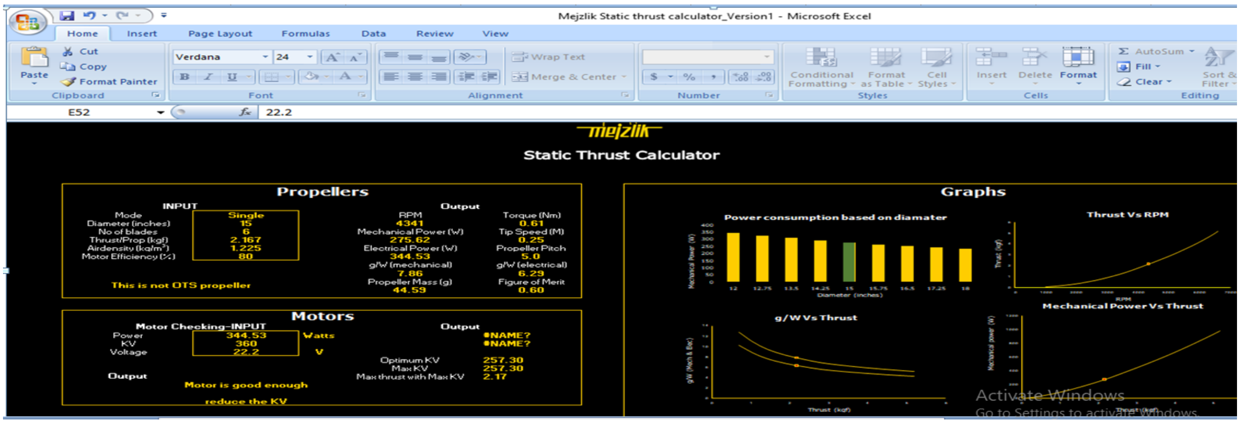

Figure 1.3: Mezjlik Static Thrust Calculator

UAV Dynamic Thrust Analysis

The dynamic thrust equation was used to compute the dynamic change in the velocity of air at the propellers in response to a corresponding change in the dynamic thrust generated by the motor and propeller combination.

$$T = \frac{\pi d^2}{8}\rho(\Delta v)^2$$

(1.1)

Where: T - Thrust (N)

d - Propeller diameter (m)

ρ - Density of air (1.225Kg/m^2)

v - Velocity of air at the propeller (m/s)

Δv - Velocity of air accelerated by propeller (m/s) (Abioye 2015).

The computation was done for the four propellers used in this research and the results are presented in tables 1.2- 1.5 and the obtained was plotted as shown in figures 1.6 - 1.9

UAV platform

The UAV platform developed for this research was the Heritage UAV with the following components as shown in table 1.1.

Table1.1: Hexacopter spraying drone component

S/N	ITEMS	QUANTITY
1	ZD850mm fibreHexacopter frame	1
2	Pixhawk flight controller	1
3	Flycati-Rotor 5010/360KV	6
4	Readytosky Electronic speed controllers	6
5	Propellers	6
6	915 MHz Radio frequency (RF) Transmitter	1
7	915MHz Radio frequency Receiver	1
8	12vdc Sprayer Pump	1
9	Sprayer tank	1
10	Sprayer Nozzle	4

UAV aerial footage capture operation

The UAV was routinely flown over the research area, capturing aerial footages, as shown in figure 1.5.

(a)

(b)

(c)

(d)

(e)

(f)

Figure 1.5: (a) Heritage Agricultural Spraying Drone ready for testing (b) Shows the Pixhawk flight controller displaying blue light it is powered properly connected for usage (c) Shows the battery level of the sprayer pump being tested (d) Shows the locally assembled agrochemical sprayer being tested before mounting on the drone, (e) & (f) shows the UAV sprayer in action.

RESULTS AND DISCUSSION

In this section, the result of the various thrust analysis carried out on the 1245, 1447, 1555 and 1653 inches propellers is presented, to justify the reason for choosing the 1555 inches propeller. Also the practical result of the physical implementation of the UAV sprayer was presented to show the level of success achieved in the research work.

Result of thrust analysis on 1245 inches propeller

Table 1.2: 1245 inches Static Propeller Performance for 12inches diameter, 6 blades and at 1.225 kg/m^3

S/N	RPM	Thrust (kgf)	Torque (Nm)	Mech power (W)
1	3578	0.49	0.11	42.76
2	4283	0.73	0.18	78.57
3	4910	1.00	0.24	124.55
4	5541	1.34	0.33	189.06
5	6169	1.79	0.43	279.47
6	6807	2.20	0.54	381.99
7	7398	2.65	0.65	503.84
8	8008	3.15	0.78	653.11
9	8579	3.64	0.90	812.29
10	9121	4.14	1.03	984.07
11	9355	4.45	1.12	1096.36

Below is the plotted graph of the above data.

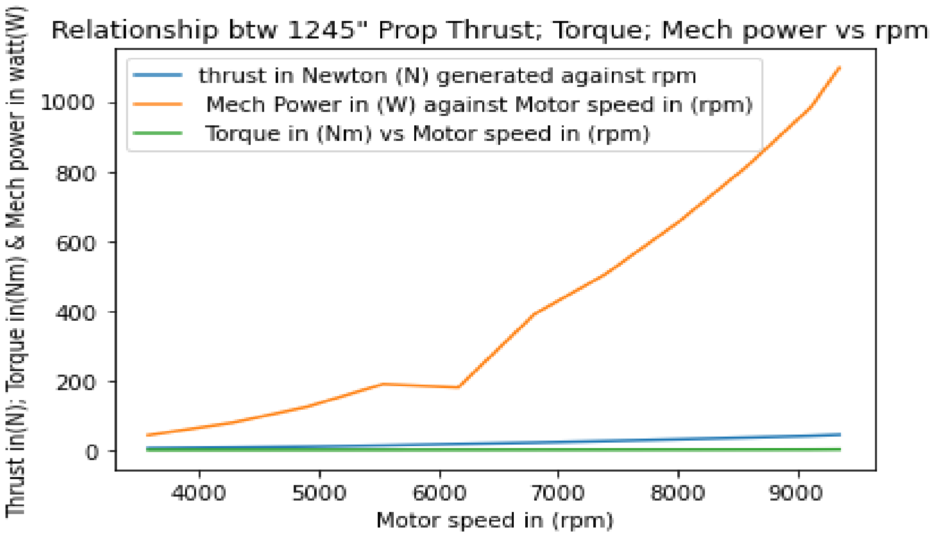

Figure 1.6: Shows the relationship between 1245 inches propeller thrust, torque and mechanical power against the motor speed (rpm).

Result of thrust analysis on 1447 inches propeller

Table 1.3 1447 inches Static Propeller Performance for 14 inches diameter, 6 blades and at 1.225kg/m^3 air density

S/N	RPM	Thrust (kgf)	Torque (Nm)	Mech power (W)
1	1040	0.05	0.02	2.55
2	1635	0.16	0.05	9.32
3	2182	0.29	0.09	20.55
4	2710	0.50	0.14	40.07
5	3234	0.76	0.21	70.31
6	3736	1.06	0.28	110.64
7	4225	1.42	0.37	163.70
8	4700	1.80	0.47	229.42
9	5159	2.26	0.59	320.62
10	5595	2.69	0.70	412.67
11	6040	3.11	0.80	505.65
12	6486	3.52	0.91	617.74
13	6890	4.09	1.05	760.07
14	7050	4.29	1.11	816.51

Bellow is the plotted graph of the above data

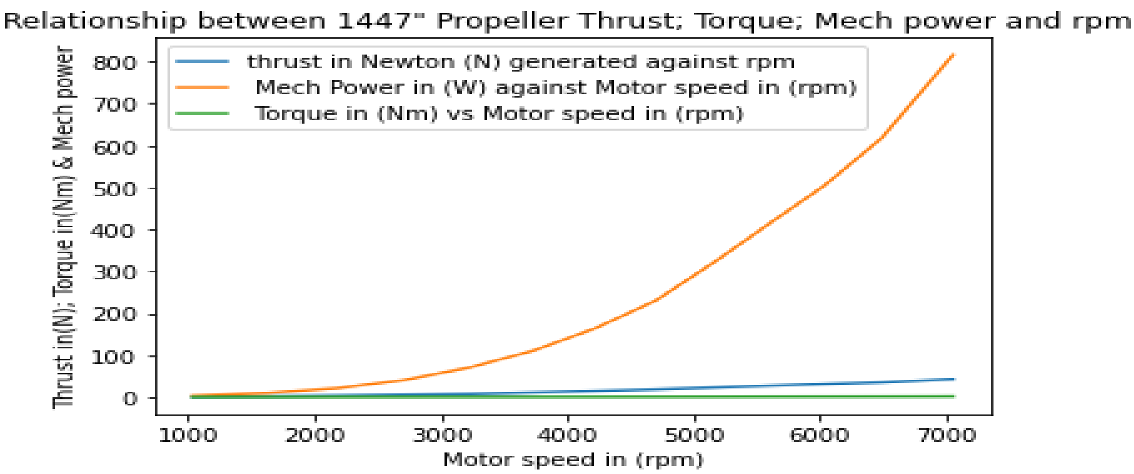

Figure 1.7: Shows the relationship between 1447 inches propeller thrust, torque and mechanical power against the motor speed (rpm).

Result of thrust analysis on 1555 inches propeller

Table 1.4 1555 inches Static Propeller Performance for 15 inches diameter, 6 blades and at 1.225kg/m^3 air density

S/N	RPM	Thrust (kgf)	Torque (Nm)	Mech power (W)
1	1014	0.10	0.03	3.33
2	1579	0.24	0.07	12.20
3	2100	0.42	0.12	27.30
4	2620	0.69	0.20	53.90
5	3141	1.05	0.29	95.42
6	3606	1.42	0.39	149.00
7	4067	1.88	0.53	223.67
8	4505	2.34	0.65	306.67
9	4935	2.81	0.78	405.47
10	5336	3.29	0.91	508.18
11	5735	3.81	1.04	627.32
12	6127	4.37	1.19	765.74
13	6478	4.94	1.35	916.30
14	6612	5.19	1.43	987.80

Below is the plotted graph of the above data.

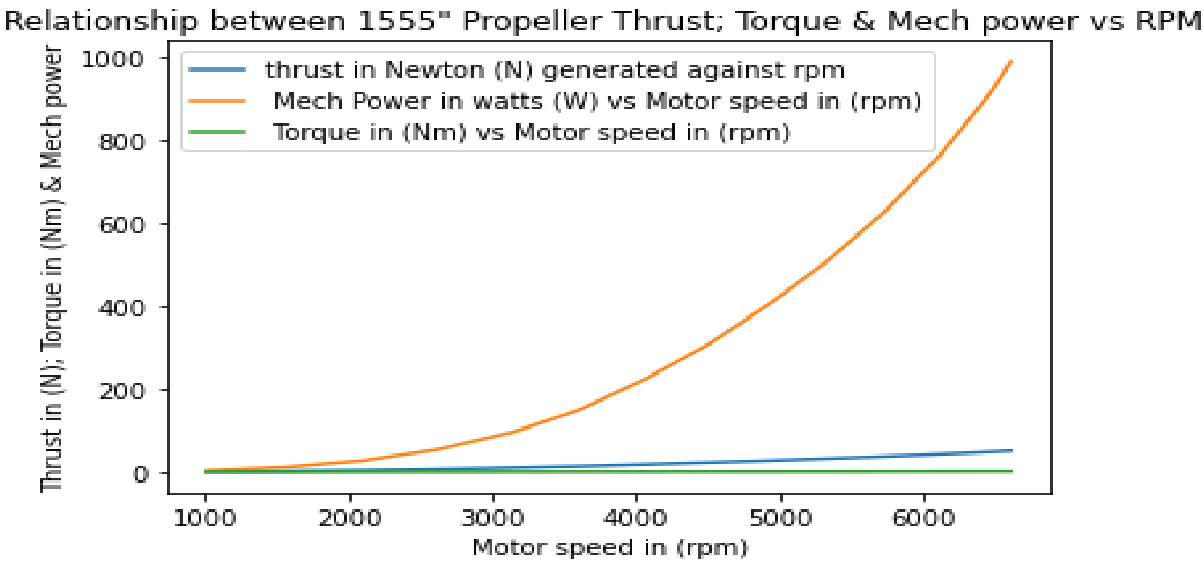

Figure 1.8: Relationship between 1555 inches propeller thrust, torque and mechanical power against the motor speed (rpm).

Result of thrust analysis on 1653 inches propeller

Table 1.5 1653 inches Static Propeller Performance for 16 inches diameter, 6 blades and at 1.225kg/m^3

S/N	RPM	Thrust (kgf)	Torque (Nm)	Mech power (W)
1	991	0.11	0.05	4.97
2	1530	0.29	0.10	16.09
3	2044	0.53	0.17	37.33
4	2546	0.87	0.27	73.10
5	3039	1.09	0.39	125.03
6	3482	1.34	0.53	192.31
7	3915	1.91	0.66	270.11
8	4720	2.25	0.82	370.63
9	4905	3.01	0.97	479.68
10	5078	3.85	1.14	606.26
11	5416	4.45	1.32	745.96
12	5775	5.08	1.49	900.32
13	6079	5.65	1.66	1055.18
14	6182	5.87	1.73	1119.25

Below is the plotted graph of the above data.

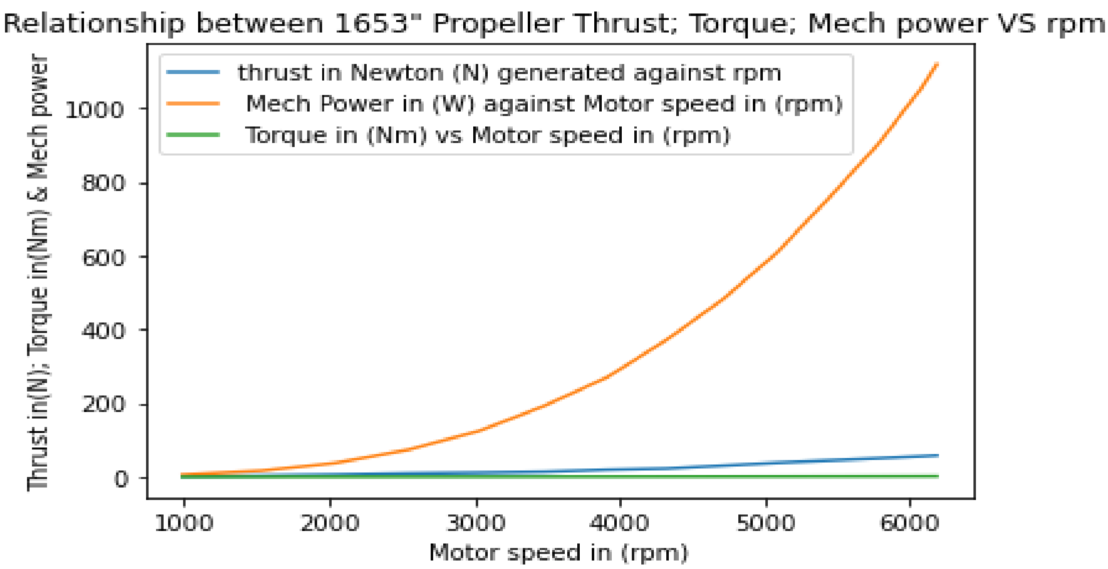

Figure 1.9: Shows the relationship between 1653 propeller thrust, torque and mechanical power against the motor speed (rpm).

Result of Theoretical Dynamic Thrust Analyzed

Table 1.6: Calculated dynamic thrust generated and the corresponding change in velocity of air at the 1245, 1447, 1555 and 1653 inches propellers.

S/N	Dynamic thrust generated in Newton (N)	Change in velocity of air at the 1245 inches propeller in meter per second (m/s)	Change in velocity of air at the 1447 inches propeller in meter per second (m/s)	Change in velocity of air at the 1555 inches propeller in meter per second (m/s)	Change in velocity of air at the 1653 inches propeller in meter per second (m/s)
1	10.00	14.96	12.82	11.97	22.01
2	20.00	21.16	18.13	16.92	31.12
3	30.00	25.91	22.21	20.73	38.12
4	40.00	29.98	25.64	23.93	44.01
5	50.00	33.45	28.67	26.76	49.21
6	63.77	37.38	32.38	30.22	55.57
7	70.00	39.58	33.92	31.66	58.22
8	80.00	42.31	36.27	33.85	62.24
9	90.00	44.88	38.47	35.90	66.02
10	100.00	47.31	40.55	37.84	69.59
11	110.00	49.61	42.53	39.69	72.99
12	127.53	53.42	45.79	42.73	78.57

Below are the plotted graphs of the above data.

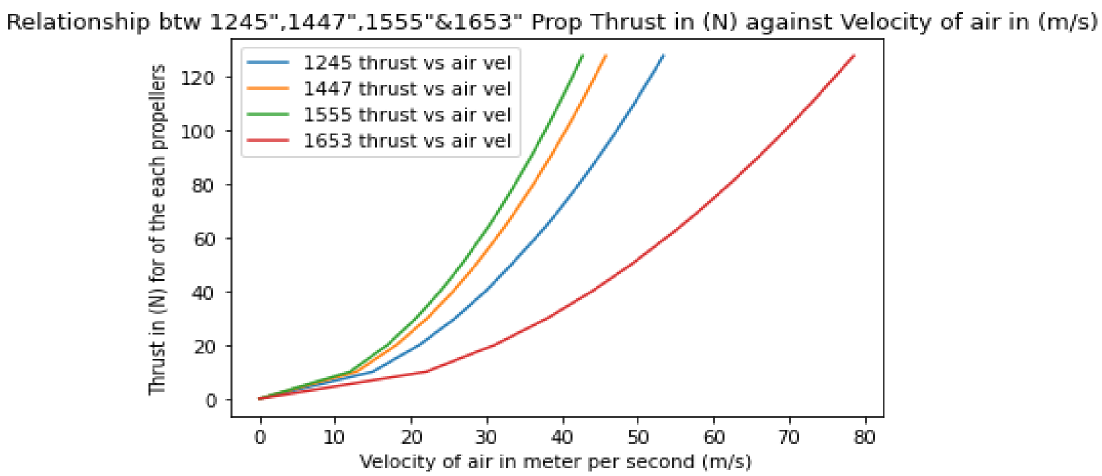

Figure 1.10: Shows the relationship between 1245, 1447,1555 and 1653 inches Propeller thrust generated against their various velocity of air generated (m/s) at the propellers tip.

DISCUSSION

From the static thrust analyzed it can be seen from figure 1.6 that the 1245 inches propeller had some haphazard increment which caused the thrust not to build up until slightly above 5000 rpm which was at a high rpm. While for the 1447 inches propeller in figure 1.7 the thrust generated started building up at about 3300rpm with a steady increment in the mechanical power however it was not optimum as the performance of the 1555 inches propeller showed in figure 1.8 indicates that the lift thrust generated started the build up at about 2900 rpm with more smoothes incremental curve which outperforms the 1245 and 1447 inches propellers. From figure 1.9 we can see that the 1653 inches propeller thrust generated started building up at about 3000 rpm, so based on the static thrust analyzed the 1555 inches propeller out performs the other three propellers when used in combination with the chosen 360Kv that has a maximum speed of 7000 rpm.

Subsequently, figure 1.10 shows the performance relationship between the theoretical dynamic thrust generated for 1245, 1447, 1555 and 1653 inches propeller against their respective change in velocities of generated at the propellers.

From the result and image captured of the spray action performed, it was clear that the Heritage UAV mounted with the spray system flew over the study area and test spraying was carried out as shown in figure 1.5.

CONCLUSION

As part of the need to develop sustainable methods in farming that would increase crop yield, minimize human contact or exposure to the used agrochemicals while optimizing both production and human protection based on the use of an unmanned aerial agricultural spraying vehicle. We propose the integration of a simple spray system-based on the locally assembled aerial robotic platform to be used in farming operation. In this research, an 850 mm hexa-rotor UAV platform was developed and used to carry a locally assembled spray system. The results were presented and discussed. And it was observed that the Heritage agricultural spraying drone has performed the spray action as expected however there was some difficulties due to the failure of the GPRS system but we switch over to the manual flight control for the rest of the operations.

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