ISSN 2278-3091
Volume 9, No.1, January – February 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse38912020.pdf
https://doi.org/10.30534/ijatcse/2020/38912020

Development of a 3D Printed Quadcopter Drone through CFD Analysis

Jefferson Clark Chan, Smilleon Chua, Zigmund Ian Tria, Hans Yubontoy; Alvin Chua
Mechanical Engineering Department, De La Salle University, Manila, Philippines
Corresponding author: alvin.chua@dlsu.edu.ph

ABSTRACT

This paper presents a 3D printed quadcopter that is comparable with the DJI F450 frame. The making of the quadcopter for this research involves conceptualization and design, simulation of parts, 3D printing the parts, and then assembly and testing. The design of the drone was achieved through its constraints; i.e. the aesthetic, aerodynamics, ease of assembly, speed of printing, weight and strength of the chassis. The researchers also took into account the layout of various electronic components used including the Pixhawk flight controller, RC receiver, telemetry, ESC, and power distribution board. The researchers simulated the parts in terms of stress, displacement, weight, and flow analysis. Obtaining satisfactory results in the simulation would merit the design to be fabricated using a 3D printer.

Key words: 3d printed, Drone, Quadcopter, CFD

1. INTRODUCTION

With the rise on the use of drones for various applications it is important to find ways of manufacturing the product. Drones in the market typically use injection molded parts[1], but ordering such would cause downtime for the drone when faced with crashes during flights. In order to lessen such inconveniences, and also with the opportunity of producing our own parts through 3D printing, this research will test the performance of the 3D printed drone in comparison to an existing drone in the market, the DJI F450.

The results of this research will redound to the benefit of drone research considering the benefits of applying 3D printing technology with the quadcopter. Additionally, 3D printing allows the user to personalize the frame depending on the user's requirements and needs[2]-[9]. Design iterations can also be conducted for improved functionality. Similar to a software update, the frame can also be replaced not only because it is damaged, but also for increasing efficiency when it is needed. Necessary modifications in the 3D design, printing them and testing the 3D printed parts for obtaining the desired results can be achieved.

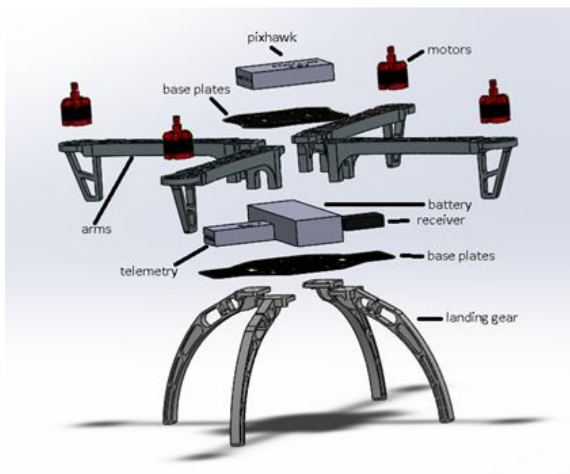

Figure 1: Conceptual Framework of DJI F450 Drone (exploded view)

Figure 1 shows the exploded view of the DJI F450[10].The DJI F450 has a skeletal frame figure and its electronic components are exposed. For the purpose of this research, the 3D conceptual design of the project would be compared to the DJI F450. The parts to be designed are the base plate, arms, and landing gears.

In addition to those parts, a canopy and a battery compartment would be included for added functionality of the drone, something that the DJI F450 does not have. Furthermore, design constraints such as the build volume of the 3D printer and the quadcopter's 450mm diagonal motor to motor length is to be considered because the main components such as the motors, propellers, ESC and other electrical components.

2. METHODOLOGY

The research would consist of four major phases to determine whether or not the 3D printed chassis is comparable to that of the DJI f450 (See Figure 2).

Figure 2: Flowchart of the Methodology

The first step in this research is to brainstorm the designs of the parts of the drone to be fabricated. The researchers would be using the DJI F450 arms and base as the basis of our dimensions and strength. With this in mind, the aim of the designing phase is to be able to produce a 3D printed frame using Tough PLA material that is comparable to the original injection molded DJI f450 frame. The researchers would take into consideration the designs and issues of previously printed quadcopter drones, and the design structure of strong and light entities. It is however to be noted that the design would only be limited to the dimensions of the original DJI f450 frame. The researchers would then use a CAD software to produce different designs for the prototype, but only the frame with the optimal design would move on to the next stage of this research.

Once the designs have been optimized, the researchers would then simulate the frame starting with the arms, in which the parameters would be its volume, mass, stress, and its displacement. Once the optimal arm design is determined from the aforementioned parameters, the researchers would then assemble the arms and its other parts in the same CAD software, in preparation for the static and flow analysis simulation to compare its strength (stress and displacement) and its aerodynamic property (drag force) with that of the DJI f450 frame.

After simulating and comparing both frames in the CAD software, the researchers will correct any design issues or errors to make sure the drone will function properly and the frame will not bend or fail. Once these are all settled, the researchers may now fabricate the drone by using the locally available 3D printer and filament. The researchers would assemble the 3D printed chassis along with it to form the drone completely.

Finally, for the testing of the 3D printed frame, there would be two flight tests that would be conducted – *battery/flight time test* and the *pitch, roll, and yaw characteristics of the drone*. During these times, qualitative analysis of the drone's handling and dynamics are also analyzed. The important aspect in differentiating lies in the desired vs. actual flight characteristic of the two drones.

3. RESULTS

This section includes the results that was done in the four major stages of the research.

3.1 DESIGNED 3D PRINTED DRONE

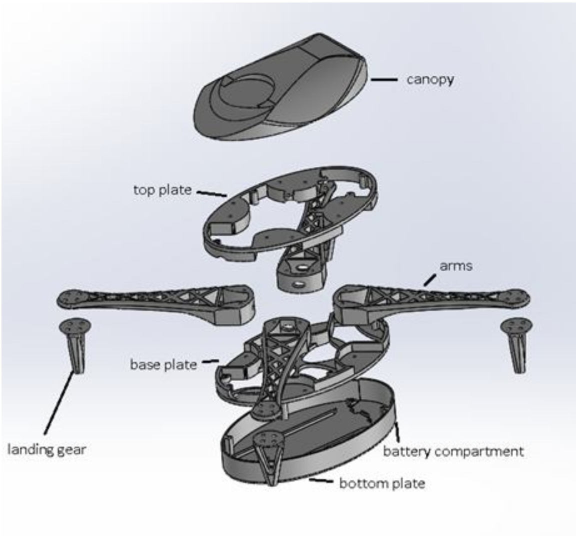

Figure 3: Exploded view of the design of quadcopter "Arrow"

Figures 3 and 4 shows the results of the designed parts assembled together to form the chassis for this research's quadcopter. The drone comprises a total of 13 parts to be 3D printed.

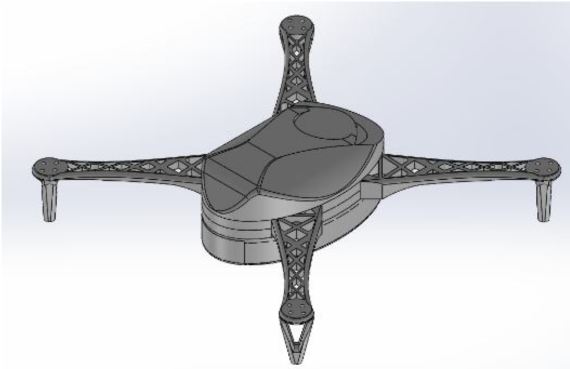

Figure 4: Isometric view of 3D printed drone Arrow

3.2 LOAD SIMULATIONS

After successfully assembling all the designs in the software, the researchers moved on to the next stage of the research - simulation. The 3D printer filament material used for the 3D printed drone is Tough PLA whereas the commercially available DJI f450 uses the injection molded material PA66+PTFE (Nylon). Figures 5 and 6 shows the stress and displacement simulations of DJI f450,respectively.

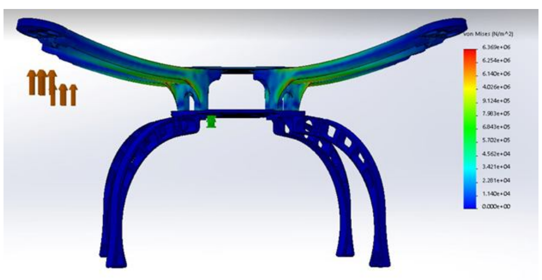

Figure 5: Stress Simulation of DJI f450

Figure 6: Displacement Simulation of DJI f450

On the other hand, Figures 7 and 8 shows the stress and displacement simulations of Arrow, respectively.

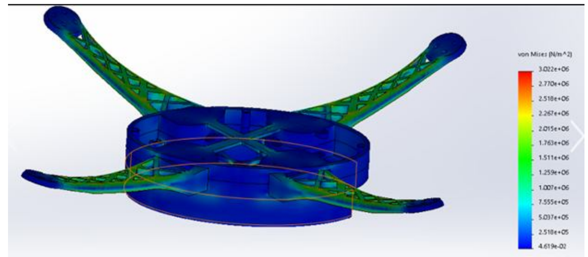

Figure 7: Stress Simulation of Arrow

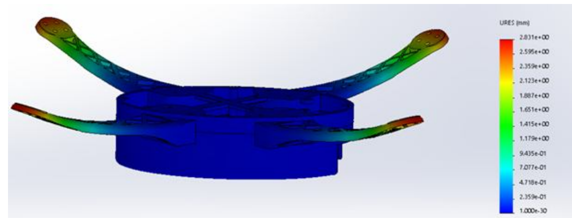

Figure 8: Displacement Simulation of Arrow

Based on the frame simulations, it can be observed that Arrow is significantly stronger in terms of stress analysis, with only 3 million stress value. The F450 frame had a resulting 6 million, showing that this design is only half as strong as Arrow. The displacement of Arrow is also an improvement compared to the F450 4mm displacement, improving it down to 2.8mm, an improvement of 70%. Because of this, it can be concluded that the design of Arrow is superior.

3.3 AERODYNAMIC SIMULATIONS

In this section, the researchers obtained the Reference Area and the Drag force of both drones at different directions and orientations (+x, -x, +y, -y, +z, -z) using the air flow simulation of the CAD software. The fluid velocity and fluid density used is 25 kilometers per hour (kph) in all directions and 1.2 kilograms per square meter, respectively. Figures 9 and 10 shows samples from the drag force simulations of Arrow and DJI F450 on one of its directions. The results are comparable.

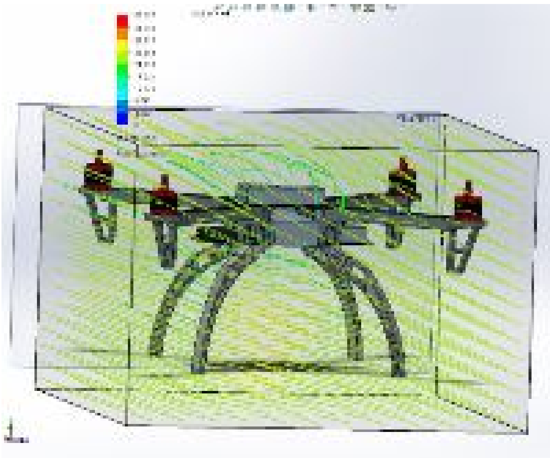

Figure 9 : Drag Force Simulation of DJI f450

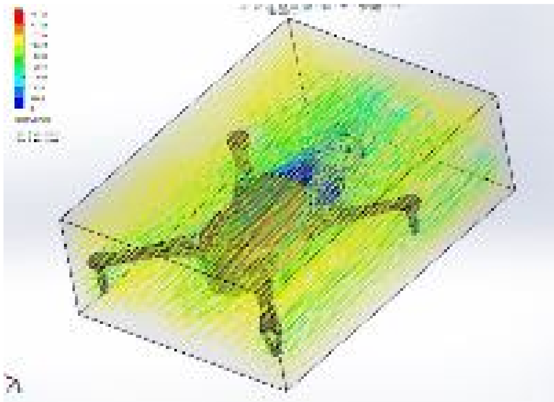

Figure 10 : Drag Force Simulation of Arrow

After simulating the air flow on both drones at different directions, it was observed that Arrow drag coefficient is relatively lower than its counterpart. This means that it has better aerodynamic properties than the DJI F450.

3.4 SET-UP TIME

Figure 11:.3D printed drone Arrow

The designed and simulated frame parts were then 3D printed by the locally available printer. Every electrical components were also then assembled as seen in Figure 11. The drone was calibrated using the software ArduPilot and Mission Planner. Flight tests were conducted on the battery performance of the quadcopter and also the ability of the quadcopter to stabilize itself when hovering. Any other data could be gathered from the log files of the ArduPilot software. Any misbehavior in the quadcopter is calibrated through the flight controller.

Table 1: Set-up time of Arrow vs DJI F450

ASSEMBLY TIME	
DJI F450	30 min
Arrow	35 min

Table 1 shows the set-up time for the fabricated quadcopter chassis *Arrow* in comparison to the DJI F450 quadcopter. The resulting data would show that in comparing the assembly time of the Arrow with the DJI, given the additional features of Arrow, with its enclosed design, the addition of a battery compartment, canopy, and the limitation of 3D printing, the addition of five minutes to the original assembly time is deemed to be comparable and acceptable.

3.5 WEIGHT & BATTERY LIFE

Table 2: Weight and Battery Time of Arrow vs DJI F450

FRAME WEIGHT (g)		BATTERY TIME			
		Trial 1	Trial 2	Trial 3	Average
DJI f450	333	8 minutes 32 seconds	8 minutes 30 seconds	8 minutes 30 seconds	8 minutes 30.67 seconds
Arrow	397	7 minutes 17 seconds	7 minutes 17 seconds	7 minutes 15 seconds	7 minutes 16.33 seconds

On the other hand, Table 2 shows the weight and battery time for the fabricated quadcopter chassis *Arrow* in comparison to the DJI F450 quadcopter. The researchers performed the flight test with three trial runs for each drone and it was observed that *Arrow* consistently has lower battery time than that of DJI F450 at around one minute less. This is due to the fact that *Arrow* is heavier than the DJI F450 drone by 60 grams which lead to more power consumption to thrust the drone.

3.6 FLIGHT TEST

In the flight test, the drone lifted off from the ground 3 meters upward and hovered for 5 seconds at a certain point (A) then the drone moved from point A to point B (3 meters away), hovered again for 5 seconds and then landed on the ground. Figures 12 shows some of the recorded values of the pitch (desired and actual) of DJI F450 and *Arrow* using alt hold mode. All the data obtained here were from the flight log files of the Ardupilot and Mission Planner software. The desired data of the drone was followed accurately by both DJI and Arrow results.

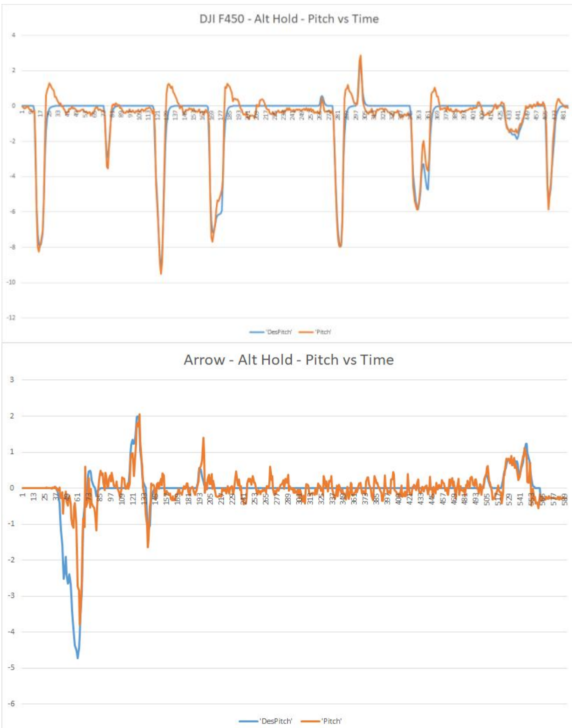

Figure 12:. DJI F450 vs. Arrow flight data log - Pitch (alt hold)

The log files presented hundreds of data points for both the characteristics' actual and desired. In comparing the percentage error of the numerical data set of each of the characteristics of its respective drone, the researchers first took the average values of the respective actual and desired data. From these values the researchers calculated for the percentage errors and compared them to determine if the data shows similar flight characteristics for both drones and to know which of the drone is better.

Table 3: Summary of Percentage Errors - Arrow vs DJI F450

	DJI F450 (Alt Hold , Stabilize)	Arrow (Alt Hold , Stabilize)
Avg Pitch % error	0.652853% , 0.126317%	1.521732% , 0.154913%
Avg Roll % error	4.498816% , 0.575373%	5.365375% , 2.12421%
Avg Yaw % error	0.012151% , 0.103344%	0.178743% , 0.097613%

As observed from the graphical presentations and Table 3, the flight characteristics of DJI f450 and Arrow has similar behavior wherein there is not much discernable difference from the obtained percentage errors despite it being 3D printed. The Yaw of both drones have good results because the desired and the actual evidently overlap each other, as if it was traced from the beginning to the end. The pitch and roll characteristics also have similar characteristics on both ends.

4. CONCLUSION

The research was able to design the parts of the new quadcopter drone using a CAD software for 3D printing. The quadcopter when fabricated would have a total of 13 parts. The designed canopy was streamlined at the back half to be able to lessen the drag force and to have a better wind flow. It achieved a teardrop-like shape and was based on a table for the range of the lift and drag coefficients based on frontal area or shape.

For the simulations, the researchers have analyzed the loads on the quadcopter frame and found out Arrow has better coefficient of drag than the DJI even though Arrow has higher drag force.. The results in the simulations was used as the basis for fabricating. The researchers found that Arrow slightly took more time to assemble than the DJI but Arrow is slightly better in terms of functionality i.e. weather resistant, and a lower coefficient of drag.

ACKNOLEDGEMENT

The authors would like to acknowledge the Department of Science and Technology - Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD) and the Mechanical Engineering Department of De La Salle University for supporting the research project

REFERENCES

1. Joshi, D. (2017). “Commercial Unmanned Aerial Vehicle (UAV) Market Analysis – Industry trends, companies and what you should know.”
2. Cantrell, J., Rohde, S., & E. (n.d.). “Experimental Characterization of the Mechanical Properties of 3D-Printed ABS and Polycarbonate Parts (Tech.).”

Gainesville, Florida: Mechanical and Aerospace Engineering Department.
3. Dai, L. S., Harary, M. A., Pompei, C. T., Shan, S. L., & Tu, M. J. (2016). "3D Printed Quadcopters (Tech.)." New Jersey Governor's School of Engineering and Technology.
4. Garcia Carrillo, Luis Rodolfo &Dzul, Alejandro & Lozano, Rogelio &Pégard, Claude. (2013). "Modeling the Quad-Rotor Mini-Rotorcraft." 10.1007/978-1-4471-4399-4_2. https://doi.org/10.1007/978-1-4471-4399-4_2
5. Gebhardt, A., &Hötter, J. (2016). "Additive manufacturing: 3D printing for prototyping and manufacturing." Munich: Hanser. https://doi.org/10.3139/9781569905838
6. Letcher, T., & Waytashek, M. (2014). "MATERIAL PROPERTY TESTING OF 3D-PRINTED SPECIMEN IN PLA ON AN ENTRY-LEVEL 3D PRINTER" (Conference Paper). Montreal, Canada: ASME IMECE 2014.
7. Radharamanan, R. (2016), "Use of 3-D Printers to Design, Build, and Test a Quadcopter Drone." Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.27111
8. Dim, C. et al (2019) "Novel Experiment Design for Unmanned Aerial Vehicle Controller Performance Testing" IOP Conference Series: Materials Science and Engineering
9. Espinola, J. (2019) "Virtual simulations for drone education of senior high school students" International Journal of Engineering and Advanced Technology
10. Valentak, Z. (2017). "Drone market share analysis & predictions for 2018 - DJI dominates, Parrot and Yuneec slowly catching up."