Design of a Quadrotor UAV Aluminum Casting Frame

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Abstract:
This paper describes design of quadrotor frame using aluminum casting type A356.0-T6.0-T6. Although many paper already publish about quadrotor Unmanned Aerial Vehicles (UAVs), design quadrotor using aluminum casting still rarely. Frame that available in the market have lack in the price and assembly. Casting aluminum have component less compare with existing frame. Home industry base and small aluminum casting shop can produce the same frame. This cause small and home base business grow without have lack in quality. Design and measurement of the frame base from standard design of frame in the market. The variable bases from wings length of quadrotor. An overview of Force, Safety Factor, and Deformation test use SolidWorks analysis. The result of the best design based from the highest safety factor and smallest von mises stress compare with propeller available in market. Using the best result, design of quadrotor frame use aluminum casting materials is successfully.

***Keywords**: Design, Casting Aluminum A356.0-T6, Quadrotor Frame, SolidWorks Analysis*

1. Introduction

Unmanned Aerial Vehicles (UAV) are aerial vehicles that flight without human pilot inside. Because of the original type of UAV is human-less, UAV have many advantages and use in many missions, such as emergency mission during a disaster [1], civilian mapping area [2], a survey in the field of agriculture [3], and military missions [4]. UAV have many type i.e. Fixed-wing UAV, Single rotor that can be divided into two types; Axial and Coaxial Rotor UAV, Tandem Rotor UAV, Quadrotor UAV, Blimp UAV, Hybrid UAV, Bird-like UAV, Insect-like UAV, and Fish-like UAV [5].

This paper focuses on the quadrotor UAV because quadrotor UAV already used for aerial application combine with external instrument embedded in quadrotor especially in the aerial photography and aerial observation. For aerial photography application, a camera embedded in the quadrotor and using external sensor, ground station and remote control people control the quadrotor combined with camera co capture and record video about situation in the ground from elevation. With this usefulness of quadrotor UAV, many manufactories already build and sell various design of quadrotor UAVs. The design, material, and assembly instruction included in the box and usually people buy the standard frame from mass produce. This situation has advantages for easy to buy and the manufactories already calculate the force that can be handling by the frame. The disadvantages for mass production frame are the price is expensive compare with the price of the raw material of frame, the production based from big manufactories where the home and small industries cannot produce the same quality because they cannot buy the infrastructure and equipment for mass production.

This paper suggest and purpose to decrease that gap by introducing the new way to produce quadrotor frame using aluminum casting type A356.0-T6. We design, measure, and analyze by static force using SolidWorks software drawing to gain the best value and size of quadrotor frame. We choose Aluminum A356.0-T6 because this material is commonly used for casting many tools and have better mechanical properties compare with another material [6,7]. Aluminum A356.0-T6 also cheaper compare with frame that can be found in the market. Mechanical properties of an Aluminum A356.0-T6 can be improved by combine with other materials and also can be coated [8]. Last, aluminum A356.0-T6 casting frame can produced not only by big manufactories but also it can produce by home and small industries without big different of the quality and performance.

From various journals, there are already explain how to design the quadrotor using SolidWorks drawing software [9], testing the design using design analysis software, meshing character and the type of testing [10], after testing using analysis software there are already gain the result each variable size and from that result will be produce the most efficient and the best size of the quadrotor frame [11]. The design of quadrotor frame based from two brands of quadrotor frame that can be found in the hobby shop locally, DJI450 and Xaircraft X650V. The step by step to design and gain the best size start from measure the existing frame and collect the raw data. Second, gain the external equipment weight data that will be embedded to quadrotor as sensors, motor, ESC, Battery and camera (optional). The result of the external sensor will combine with the weight of quadrotor frame as mass total.

This study will gain the measurement of quadrotor UAV with Aluminum A356.0-T6 as materials use. The result will give the analysis output with safety factor and von mises stress. Form the price comparison between casting quadrotor frame with market frame, there will give the better effectiveness.

2. Aluminum Casted UAV Design

Aluminum casing UAV as shown in the figure 1 have different design with others quadrotor frame. we compares Aluminum frame with 2 others frame i.e. DJI 450 and XAirCraft X650V. the different came from the amount of part and total weight. DJI have less part compare with XAirCraft and have parts more than Aluminum frame. The total weight also influence the payload of quadrotor and Aluminum have less weight compare with others frame.

From table 1 we can measure the existing quadrotor frame as basic references to design quadrotor UAV frame. Basic design also influence from external instruments weight properties as shown in table 2. The target design is found the highest safety factor with the lowest von mises stress. The minimum safety factor is 2 due to safety flight and the longest wing length is 234 mm to accommodate long propeller.

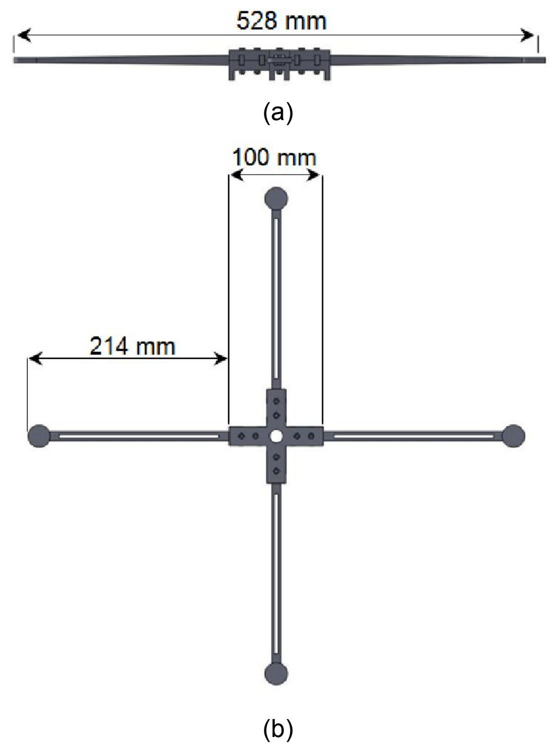

Figure 1 Side view and Upper view of Aluminum casting UAV

Table 1 Comparison of the quadrotor frame

	Quadrotor Frame		
	DJI 450	XAirCraft X650V	Aluminum Casting
Weight (Gram)	327.76	404.07	117.87
Material	PCB for the Board and PA66+30GF	Carbon Fiber	Aluminum A356.0 -T6

In the newton law, there are equations to gain, convert and establish the force from the mass and the gravitation accelerometer.

$$F = m * g \quad (1)$$

$$F_T = F_1 + F_2 + F_3 + F_4 \quad (2)$$

$$Safety\ Factor = \frac{Material\ Strength}{Design\ Load} \quad (3)$$

Where F = force and F_T = Total force from all propeller. F_1 is force in wing 1 for motor 1, F_2 is force in wing 2 for motor 2, F_3 is force in wing 3 for motor 3, and F_4 is force in wing 4 for motor 4. The design concept based from frame size of DJI

Frame and Xaircraft Frame. The frame length based from the length of the diameter of propeller in the market. The exact value of the size of propellers from the market made as references to drawing the wings quadrotor frame. the force place in each ends of the wind as shown in the figure 1 and forced using variable force with the length of forces 0 N, 5N, 10N, 15N, 20N, 25N, and 30N. There are two parameters to analyze the result, safety factor and von mises stress.

The material frame use Aluminum A356.0-T6 and have mechanical properties as shown in the table 2.

Table 2 Mechanical Properties of Aluminum A356.0-T6

Property	Value	Units
Elastic Modulus	7.24E+10	N/m²
Poisson's Ratio	0.33	N/A
Shear Modulus	2.72E+10	N/m²
Mass Density	2680	Kg/m³
Tensile Strength	228000000	N/m²
Compressive Strength	185000000	N/m²
Yield Strength	152000000	N/m²
Thermal Expansion Coefficient	2.10E-05	/K
Thermal Conductivity	151	W/(m.K)
Specific Heat	963	J/(kg.K

3. Frame Testing

Figure 2. Shows the experimental testing setup used in designing the aluminum casting frame. SolidWorks 2010 was used to model the frame.

Figure 2. Simulation Testing

Frame strength testing uses force test with the force being placed at the end of each wing. This placement models the motor when placed at this point. Fixed geometry is placed at the bottom of frame in the end of the leg frame. from variable tests, the wing length and force are changed as shown in the table 3.

Table 3 Parameter of Testing

Parameter	Value
Length of Wing (mm)	(34, 54, 74, 94, 114, 134, 154, 174, 194, 214, 234)
Force (N)	(0, 5, 10, 15, 20, 25, 30)

4. Static Analysis using SolidWorks and Optimization

Using SolidWorks to gain the best result with the longest wings accomplish in the 234 mm wings length (figure 3) and force for each wings 30 N (figure 4). This parameter give quadrotor frame can handle load until 12.24 kg. Force result data give the highest von mises stress where the stress given 30 N each wing with result the highest von mises stress for each wing gives from 9.139 MPa until 74.433 MPa as shown in the figure 4. Quadrotor frame test start from 34 mm until 234 mm wings length.

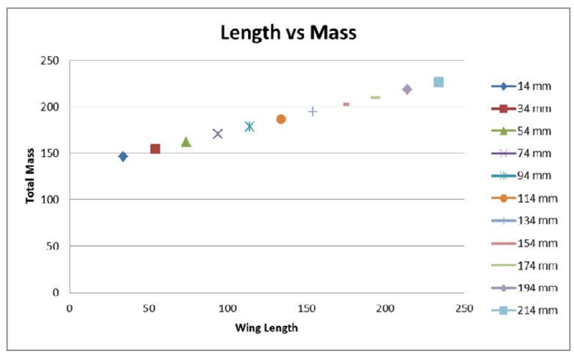

Figure 3. Experimental result Length vs Mass

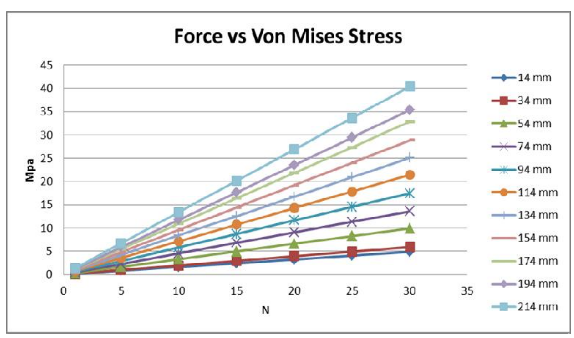

Figure 4. Figure 2 Experimental result Force vs Von Mises Stress

From figure 5, the result of safety factor minimum from each wing of quadrotor variety from 16.63 for 34 mm wing and 2.04 for 234 mm wing. The best result gives Aluminum A356.0-T6 for quadrotor frame with measurement: maximum length of wings 234 mm, force max 30N each wing, minimum safety factor 2, with 117.87 gram of mass.

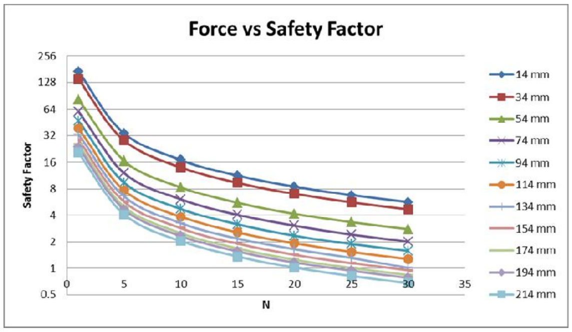

Figure 5. Experimental result Force vs Safety Factor

5. Conclusion

This paper give data of measurement of quadrotor frame design using Aluminum A356.0-T6 as material and the result gives value that this design can be implemented with satisfaction data. the result give information with Aluminum A356.0-T6 quadrotor frame can be build cheaper compare with DJI 450 and XAirCraft X650V due to cheaper the materials and fabrication process. Aluminum casting also weightless compare with two others frame with better strength analysis and safety factor.

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7. References

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