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Development of Flying Car Model with Quad Rotors

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Abstract—The quad rotor based flying car model with T-tail horizontal stabilizer is presented. This paper discusses the design of the flying car including the definition of Design Requirement and Objective and a preliminary design, analysis of aerodynamics, weight and balance, manufacturing the flying car model, as well as indoor and outdoor flight testing. The dimension of the flying model is 1/5 of the full real car. The initial model configuration has been improved to have better aerodynamic efficiency, propulsive trust and weight reduction. Concerning the manufacturing process, easy and inexpensive method is explored. For the testing purpose, the flying car is equipped with a stabilize device to control its instability motion. In-door and out-door flying test shows that the designed flying car can fly in stable reaching 3 meter high in-door condition, and that be able fly with less stable at out-door condition.

Keywords—flying car, quad rotor, manufacture, flight testing.

I. Introduction

NUMEROUS Numerous flying car concepts have been developed since the 19th century, for example the flying jeep concepts of VZ-6CH, VZ-7AP and VZ-8P designed by Chrysler Corporation. However, in 1959 this project was decided not to proceed because it found many problems and related technology was not mature at that time. Currently, the development of flying car shows much progress in both small flying car and fullscale flying car.

The development of a flying car requires researches in various disciplines that are still many challenges. The design of flying cars has to consider light weight structure, aerodynamics of ground effect, higher propulsive trust, ease manufacture, and flight stability and controllability. This paper presents the fully development of flying car including design, manufacture and in-door and out-door flight testing. This will contribute to the creation of flying car driven by ducted quad rotors. The selection of quad rotors as thrust generation is due to its characteristics for providing good capability of Vertical Take-off and Landing (VTOL), hovering capabilities as well as maneuverability. Researches on quad rotors have been carried out by some researchers [1,2,3,4,5].

The dimension of the flying model is 1/5 of the full real car. The design begins with the initial configuration created using CATIA V5 R19. This configuration is then improved to have better aerodynamic efficiency, propulsive trust and weight reduction. The improvement of fan efficiency is carried out by proposing ducts as fan boundaries. [6,7,8].

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Computational model are generated to analysis aerodynamic loads and flow behavior. The weight analysis is performed by calculating each component of flying car including body, rotors, wheels and control device. Concerning the manufacturing process, easy and inexpensive method is explored. The light materials are used such as composite for the supporting structure, styrofoam for car body by shaping to obtain a curvature of body as the same as the design. For flight testing, to control the instability motion flying car due to propeller rotation, an Inertial measurement unit (IMU) is used. The final design configuration of the flying car is shown in **Figure 1**.

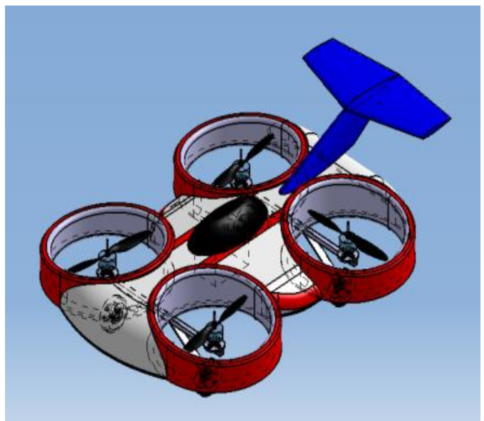

Figure 1 Design configuration

II. Design Requirement and Objective

The quad rotor based flying car is designed to have good road and flight performances [9]. The design requirement of the flying car is:

- Able to move on-road and fly in-air
- The size is about 1:5 actual size of real car.
- Design weight 3 kg
- Maximum weight 4 kg
- Thrust/weight, T/W = 1,6 – 2
- Endurance, 15 – 20 minutes
- Ceiling altitude, 100 meters above the ground.
- Max forward speed, 60 km/hr
- Operates in indoor and outdoor environments

The objectives of the flying car are:

- Low vibration
- Easy manufacturing
- Inexpensive

- All required items for manufacture are easy to get
- Can be controlled well

The First design iteration of the flying car as the initial configuration is developed to have a shape as F-1 design car as depicted in **Figure 2**.

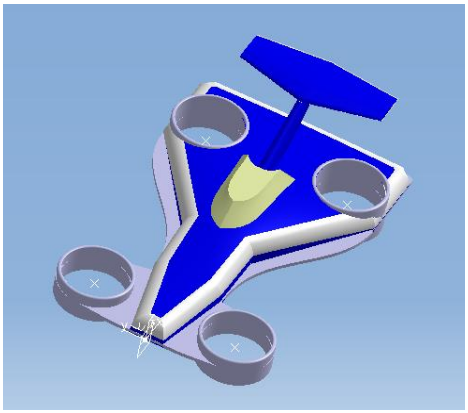

Figure 2 First iteration of flying car design

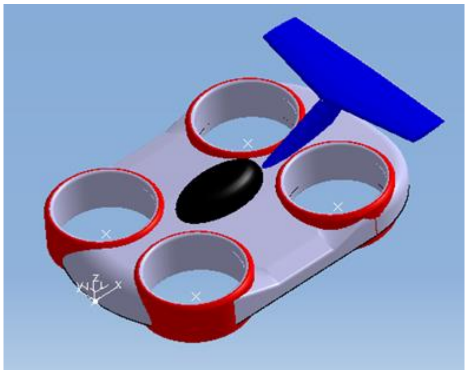

Figure 3 The second iteration of flying car design

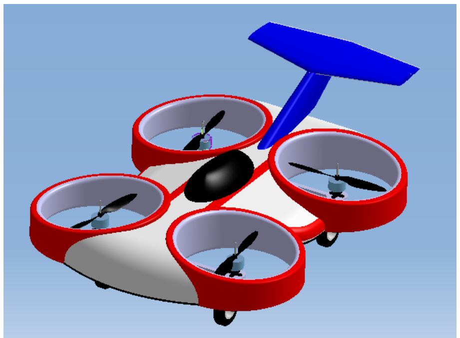

Figure 4 The final result of flying car design

In order to yield good maneuverability of the flying car, the high available thrust is required. The typical trust loading (thrust over weight) for quad rotor configuration is 1.7 – 2.0. In addition, based on the thrust loading, the quad rotor can perform a hover with 50-70% throttle stick. In order to get the thrust loading, there are several ways can be conducted, namely by increasing thrust or reducing weight of the flying car model.

The design improvement is carried out for the first flying car due to the duct diameter size is smaller, the horizontal tail position will disturb incoming flow to rear rotor inlets, the required space allocation for systems is too narrow and more rearward causing the location of center of gravity to be more backward as well as the structure chassis at aft part is too small. The result of design modification is depicted in **Figure 3**.

The second iteration of flying car design is still facing a problem related with overweight. Some weight reductions are carried out by scratching the body surface and reducing area of the horizontal tail. The result of design improvement is shown in **Figure 4** and the detail design drawing in several views is depicted in **Figure 5**.

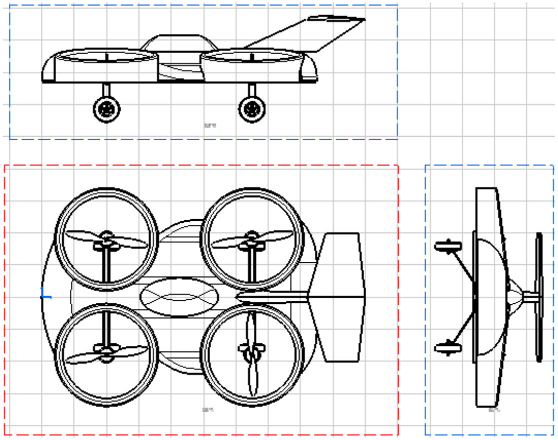

Figure 5 Design drawing in 3 views

The control system for the flying car uses a remote control. The control system installed in the flying car consists of:

- Receiver
- Servo for rudder movement
- Four brushless electric motors
- Four electronic speed control
- Battery LiPo 4000 m Ah
- Controller set

The controller set is used to control incoming current for four motors so that each motor can obtain different thrust. The controller device has been developed by Centrums ITB. The controller consists of three gyro for three axis (X,Y,Z), 3-axis accelerometer, 3-axis magnetometer and software for commands.

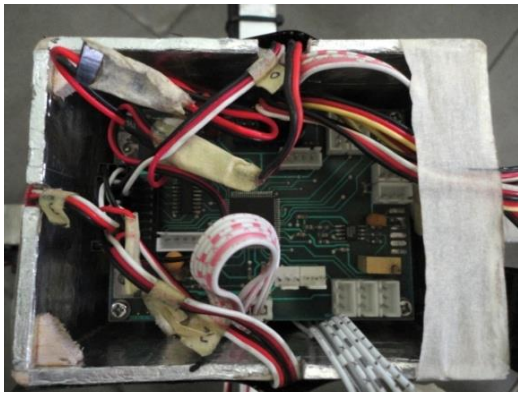

Figure 6 Centrums ITB controller for Flying car

Data specification for the flying car is given in **TABLE I**.

TABLE I GEOMETRY DATA AND SYSTEMS

GENERAL DATA	
Length	1000 mm
Width	640 mm
Height	350 mm
W_{design}	3,240 kg
Runway requirement	1 meter x 1 meter
	VTOL (vertical take off and landing)
Propulsion systems	
Brushless electric engine	Power 300 watt (x4)
Propeller	10 inch
ESC (electronic speed control)	40 A
Controll systems	
Controller	Designed by Centrums ITB
Servo	1
Remote control	7 channel

III. ANALYSIS OF FLYING CAR

A. Weight and Balance

The analysis of weight and balance consists of determination of weight percentage of total and components, center of gravity location, and free body diagram.

TABLE II WEIGHT OF FLYING CAR COMPONENTS

No	Components	Weight (gram)	Percentage (%)
1	Chassis	746	25,98
2	Body	386	11,91
3	Landing Gear	288	8,88
4	Motors	432	13,32
5	Propeller	40	1,24
6	ECS	196	6,04
7	Servo	24	0,74
8	Baterry	349	10,77
9	Controller	235	7,25
10	Cables, etc	448	13,83
	TOTAL	**3240**	**100**

The location of cg is (42.5, 0.0, 0.0) with the reference (0.0,0.0,0.0) located at nose of the flying car.

Free body diagrams at various flight conditions are given as follows:

1) Hovering

$$\Sigma Fx = 0$$
$$\Sigma Fy = 0$$
$$\Sigma Fz = 0$$
$$\Sigma M = 0$$
$$Wto = 4 \times T_{hover}$$
$$3200 \times 9{,}8 = 4 \times T_{hover}$$
$$T_{hover} = 7840 \text{ N}$$

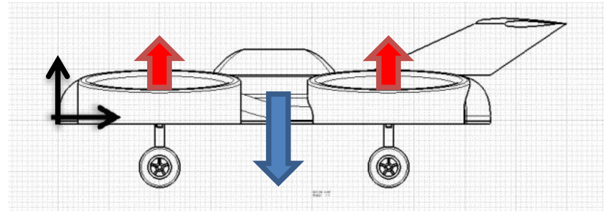

Figure 7 Hovering condition

2) Forward flight

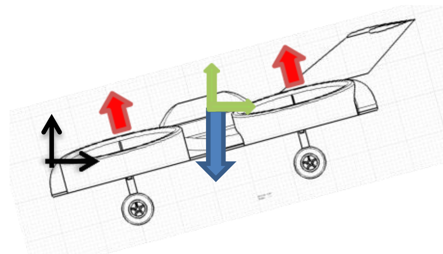

Figure 8. Forward flight condition

B. Aerodynamics

Analysis of Aerodynamic is conducted using computational method. The result of streamline flow around flying car is shown in **Figure 9**.

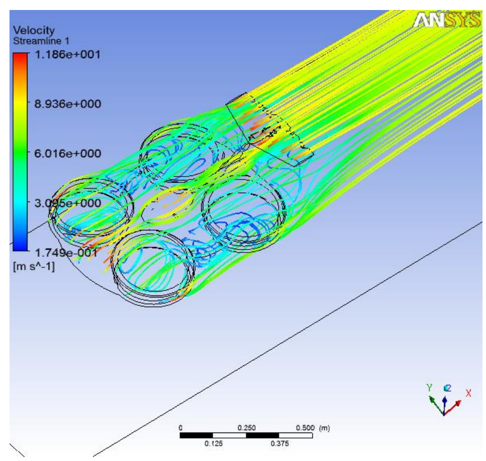

Figure 9 Streamline flow around flying car

IV. MANUFACTURE OF PROTOTYPE FLYING CAR

Manufacturing process begins after final design is fixed. Final design must be in accordance with the DRO. Systematic diagram for design process of flying car is shown in **Figure 10**.

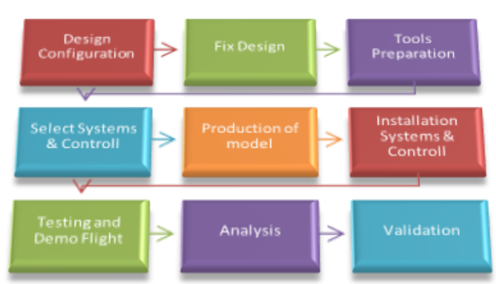

Figure 10 Design process of flying car

The manufacture of flying car begins with making molds. The molding is made of plywood material. The result of the molding for chassis is show in **Figures 11**.

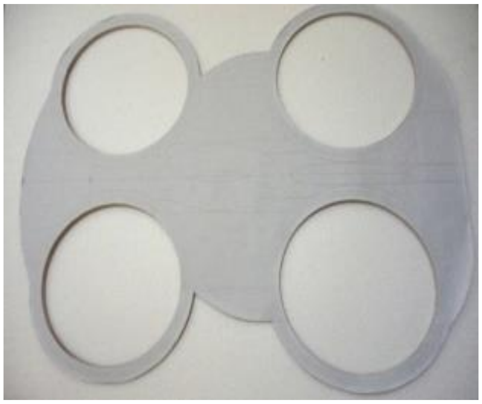

Figure 11 Molding for chassis

The subsequent process makes the curvature of body of flying car using the material of Styrofoam. The Styrofoam is cut using electric wire to yield the curvature based on the design drawing. The result of flying car body is depicted in **Figure 12**.

Figure 12 Body shape

V. Testing

A. Component Testing

In experimental method is out several tests: weight & balance test, rpm test, and thrust test. **Figure 13-15** show component testing activities of weight and balance, rpm and thrust, respectively.

The results of rpm and thrust measurement for two propellers are given in **TABLE II**.

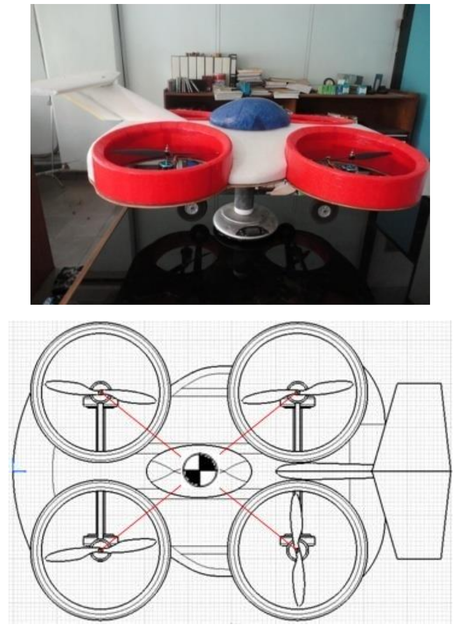

Figure 13 Weight and balance test

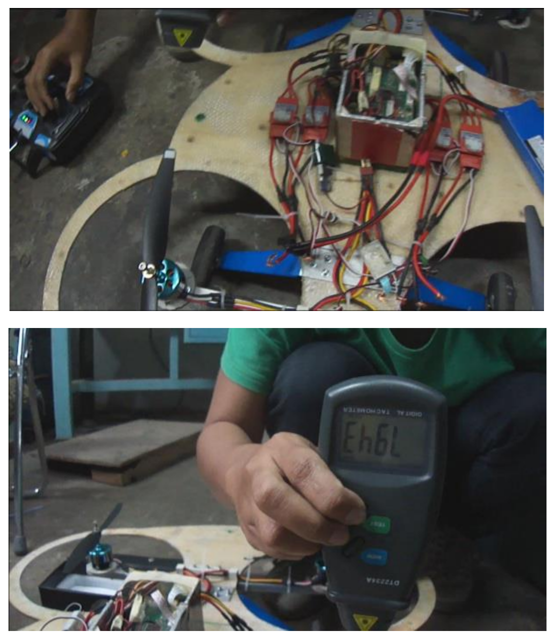

Figure 13 RPM test

TABLE III RESULTED THRUST OF EACH ROTOR WITH TWO DIFFERENT PROPELLER

NO	Motors	Propeller GWS 10x6		Propeller APC 12x3.8	
		Max RPM (rpm)	**Max Thrust (gram)**	**Max RPM (rpm)**	**Max Thrust (gram)**
1	MOTOR 1	7930	906	6773	1470
2	MOTOR 2	7934	907	6735	1452
3	MOTOR 3	7960	914	6760	1464
4	MOTOR 4	7898	899	6690	1432
	Average	**7930,5**	**906,5**	**6739,5**	**1454,5**

Figure 14 Thrust test

B. *Flight Testing*

In order to know the flight behavior of the designed flying car, indoor and outdoor flight test are carried out. For in door test, the effect of wing side may be able to be minimized. For the outdoor test, the disturbance of wind side is natural that we would like to know how best the flying car can be controlled at that condition.

The results of indoor testing as shown in **Figure 15** are that the flying car can fly stable reaching 3 meter high with the flight duration of 5 minutes.

For the outdoor testing, the flying car can fly reaching 1 meter high with considerable effort from pilot to control. The outdoor testing result is depicted in **Figure 16**.

Figure 15 In-door flight testing

Figure 16 Out-door flight testing

CONCLUSION

- Flying car based on quad rotors has been designed successfully to meet the DRO.
- Manufacture process of the flying car requires more careful attention in making high curvature of the body.
- Based the component testing, the use of propeller with size of 10 inch only provide limited available thrust compared to required thrust.
- From the indoor and outdoor flight testing, it shows that the designed flying car has good flight performance at in door, and it is still need the design improvement to obtain better outdoor flight performance

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