DESIGN AND DEVELOPMENT OF AMPHIBIOUS QUADCOPTER

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Abstract—The multirotor is an emerging Unmanned Air Vehicle (UAV) that may have limitless applications. Evolving from a century old design, modern multirotors are turning into small and agile vehicles. A number of multirotor configurations were reviewed for this purpose and finally quadrotor configuration was selected. Our present focus is on developing a suitable design configuration for an amphibious quadcopter with the help of CAD and CAE tools. The design was initiated by the approximate payload the quadcopter should carry and weight of individual components. Based on the approximate weight of the quadcopter, the appropriate motors and corresponding electronic components were selected. The selection of materials for the structure was based on weight, forces acting on them, mechanical properties and cost. First person view (FPV) was incorporated into the system to carry to surveillance with the help from GPS tracking system. Since this quadcopter is amphibious we specially designed an unconventional landing gear so that it could float, take-off and land on water.

I. INTRODUCTION

A multirotor or multicopter is a rotorcraft with more than two rotors. Multirotors often use fixed-pitch blades, whose rotor pitch does not vary as the blades rotate; control of vehicle motion is achieved by varying the relative speed of each rotor to change the thrust and torque produced by each. Due to their ease of both construction and control, multirotor aircraft can be built in various configurations namely quadcopter, hexacopter and octocopter. Early in the history of flight, quadcopter (referred to as 'quadrotor') configurations
were seen as possible solutions to some of the persistent problems in vertical flight; torque-induced control issues (as well as efficiency issues originating from the tail rotor, which generates no useful lift) can be eliminated by counter-rotation and the relatively short blades are much easier to construct. A number of manned designs appeared in the 1920s and 1930s. These vehicles were among the first successful heavier-than-air vertical takeoff and landing (VTOL) vehicles. However, early prototypes suffered from poor performance, and latter prototypes required too much pilot work load, due to poor stability augmentation and limited control authority. More recently quadcopter designs have become popular in unmanned aerial vehicle (UAV) research. These vehicles use an electronic control system and electronic sensors to stabilize the aircraft. With their small size and agile maneuverability, these quadcopters can be flown indoors as well as outdoors. Unlike most helicopters, quadcopters use 2 sets of identical fixed pitched propellers; 2 clockwise (CW) and 2 counter-clockwise (CCW). These use variation of RPM to control lift/torque. Control of vehicle motion is achieved by altering the rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics.

II. METHODOLOGY

The following steps are followed:

1. Background Research
2. Conceptual drawings
3. Part & components selection
4. 3D modeling using CAD
5. Analysis using CAE tool
6. Machining of parts
7. Assembly
8. Flight testing

A conceptual design of quadcopter was done with the help of designs based on past literature. 2D sketches were done to gain appreciation of each component and their positions. A comparative analysis of different materials was done for arms and aluminum was selected for its high strength, light weight, availability and cost. Since the central body houses the electronic components, aluminum could not be used because it is a good conductor hence polycarbonate was selected because of its insulating properties and other mechanical properties like high impact resistance low scratch resistance and durability. Based on initial weight estimation and the thrust required, motors, propellers and other electronic components were selected. 3D modeling of the quadcopter was done using CREO 2.0.The structural components of the Quadcopter were imported to ANSYS in order to analyze them by determine the stresses and deflections and failure criteria. Once the Analysis is done final dimensions are obtained for machining of structural parts using CNC machines. The machined parts and electronic components were assembled. Finally the flight test was done to determine the performance arameters.

III. QUADCOPTER DESIGN PROCESS

A .*Approximate total weight estimation:*

Approximate payload (500g)	Approximate weight of the frame (500g)
Approximate weight of electronic components(800g)	Approximate Weight of landing gear (500g)

Therefore total weight = 2300g

B. *Selection of Electronic components:*

Estimated weight of the quadcopter was around 2300g, keeping a factor of safty(FOS) as 1.75 . The total thrust required to lift the quadcopter is 4025g, therefore the thrust that should be provided by each motor is 1/4th of the total thrust.

COMPONENTS	WEIGHT(g)	TOTAL(g)
Motor (DT 750)	78x4	312
ESC (30A hobbyking)	32x4	128
Battery (5000mAh)	424	424
Board (KK 2.1)	21	21
		885

- Motor (each) :

Required Voltage: 11.1v
Max current drawn:18A (11x4.7 prop)
Max thrust: 1000g+

- ESC(Electronic speed controller):

The motor we selected draws maximum 18Amp so your ESC rating should be higher than 18Amp

ESC = 1.5(FOS) X max amp rating of motor
= 1.5 X 18 = 27A

- Battery :

Our motor draws max 18amp. We are working on quadcopter and it has 4 motors, so all 4 motor will draw 4 x 18amp = 72A
Now as we know we need at least 72A

For 5000mAh 40C,

5Ah x 40= 200A which is greater than 72A hence the battery is sufficient.

Expected duration of the flight

$$= \frac{\text{capacity of battery in "Ah"}}{\text{Max current drawn by motors}}$$
= 5Ah / (18*4)
= 0.069 hr
= 4.1 min (for max throttle)

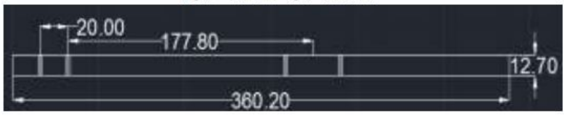
- Flight Control Board :

The original KK gyro system has been updated to an incredibly sensitive 6050 MPU system making this the most stable KK board ever and allowing for the addition of an auto-level function. At the heart of the KK2.1 is an Atmel Mega644PA 8-bit AVR RISC-based microcontroller with 64k of memory.

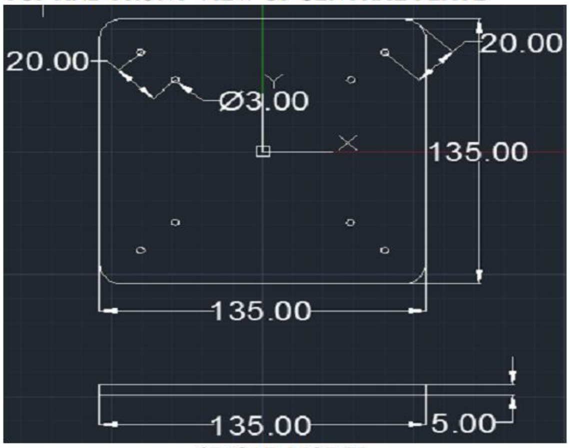
C. *Modeling of Frame:*

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. A detailed design process was started in which a number of 2D sketches were prepared using AUTOCAD. These models were created to assess the size of various components. Then 3D geometric model was designed using CREO (all dimensions in mm).

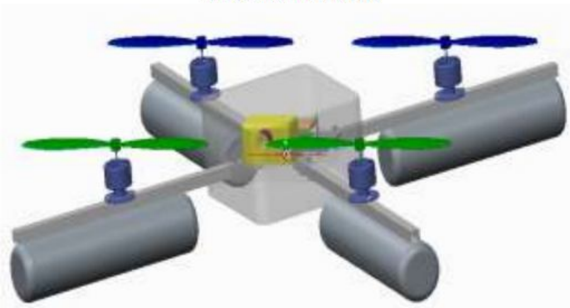
TOP VIEW OF ARM



TOP AND FRONT VIEW OF CENTRAL PLATE

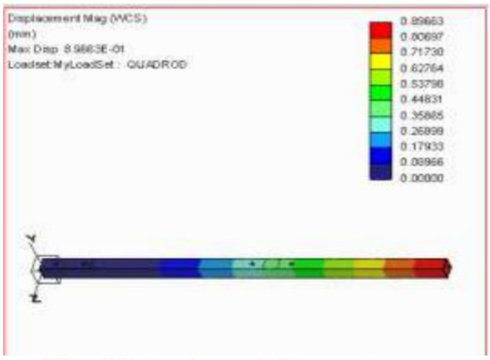


3D CAD MODEL

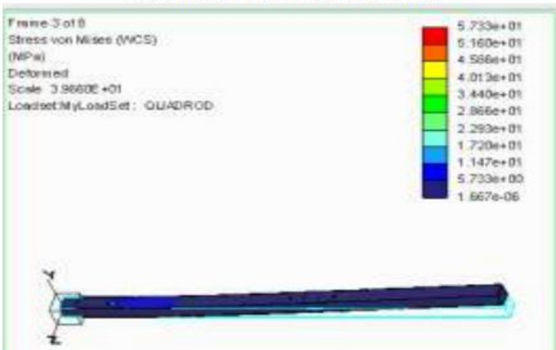


D. *Analysis of Frame:*

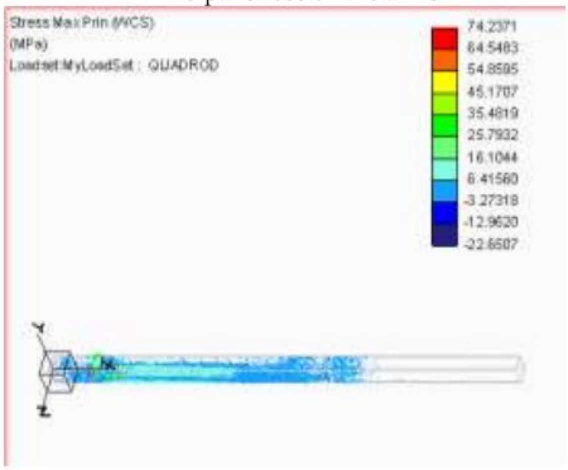
Arm deformation

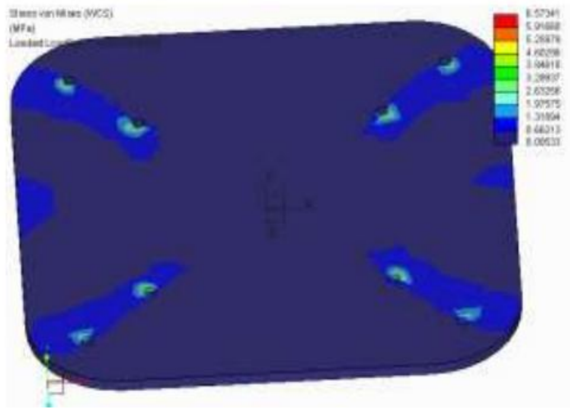


Von Mises stress on the arms



Principal stress on the arms





The following observations could be made from the above results:

(1) Maximum displacement of 0.89663mm approximately was observed near the edge of arm which will not have a significant influence on the stability of quad copter.

(2) Maximum Von Mises stress value was observed as 39.6MPa at a location which was to be attached with the Centre Plate. It was therefore expected that Centre plate support could give required strength and rigidity at this location hence prevent failure.

(3) Maximum principal stress was observed to be 74.235 Mpa at the inner bolt hole attaching the arm to centre plate

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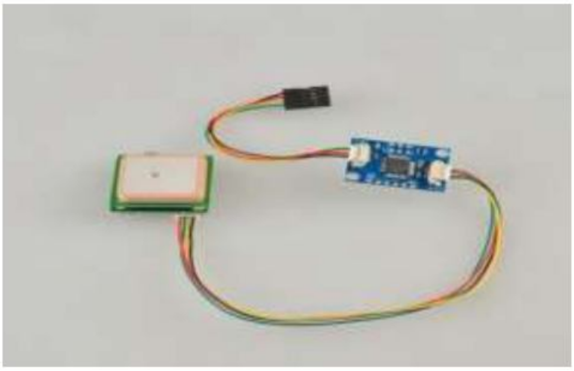
(4)Maximum Von mises stress on the centre plate was found to be 1.975 Mpa around the bolt holes which is much less than the allowable tensile and compression stresses for the polycarbonate material.

E. *Assembly:*

After completing the design and FEM analysis, parts were machined using CNC to get the final required dimensions and assembled along with all the electronic components. The final assembly consisted of the following components:

Component	Number
Motors	4
Propellers	4
Arms	4
Centre plate	2
Bolts and nuts	16
Landing gear	1
Battery	1
FPV	1
FC board	1
ESCs	4
Central housing	1

IV. INCORPARATING GPS SYSTEM



GPS devices need to be connected to a computer in order to work. This computer can be a home computer, laptop, PDA, digital camera, or Smartphones. Depending on the type of computer and available connectors, connections can be made through a serial or USB cable, as well as Bluetooth, Compact Flash, SD, PCMCIA and the newer Express Card. Some PCMCIA/Express Card GPS units also include a wireless modem. Devices usually do not come with pre-installed GPS navigation software, thus, once purchased; the user must install or write their own software. The software may include maps only for a particular region, or the entire world.

V. INCORPARATING FIRST PERSON VIEW

First-person view (FPV), also known as remote-person view (RPV), or simply video piloting, is a method used to control a radio controlled model vehicle from the driver or pilot's view point. Most commonly it is used to pilot an unmanned aerial vehicle (UAV) or a radio-controlled aircraft. The vehicle is either driven or piloted remotely from a first person perspective via an onboard camera, fed wirelessly to virtual reality goggles or a video monitor. More sophisticated setups include a pan-and-tilt gimbaled camera controlled by a gyroscope sensor in the pilot's goggles and with dual onboard cameras, enabling a true stereoscopic view.

There are two primary components of an FPV setup—the airborne component and the ground component (typically called a ground station). A basic FPV system consists of a camera and video transmitter on the aircraft and a video receiver and a display on the ground. More advanced setups commonly add in specialized hardware, including on-screen displays with GPS navigation and flight data, stabilization systems, and autopilot devices with "return to home" capability—allowing the aircraft to fly back to its starting point on its own in the event of a signal loss. On-board cameras can be equipped with a pan and tilt mount, which when coupled with video goggles and "head tracking" devices creates a truly immersive, first-person experience, as if the pilot was actually sitting in the cockpit of the RC aircraft. Ground stations can be equipped with high gain antennas and automatic antenna tracking systems to provide for maximum range on the video link. Both helicopters and fixed-wing RC aircraft are used for FPV flight. The most commonly chosen airframes for FPV planes are medium-sized models with sufficient payload space for the video equipment and large wings capable of supporting the extra weight. Pusher-propeller planes are preferred so that the propeller is not in view of the camera. "Flying wing" designs are also popular for FPV, as many pilots believe they provide the best combination of large wing surface area, speed, maneuverability, and gliding ability. FPV aircraft are frequently used for aerial photography and videography.

VI. RADIO SYSTEM

Radio control (often abbreviated to R/C or simply RC) is the use of radio signals to remotely control a device. The term is used frequently to refer to the control of model vehicles from a hand-held radio transmitter. Industrial, military, and scientific research organizations make use of radio-controlled vehicles as well.

A radio transmitter is an electronic circuit which transforms electric power from a battery or electrical mains into a radio frequency alternating current, which reverses direction millions to billions of times per second. The energy in such a rapidly-reversing current can radiate off a conductor (the antenna) as electromagnetic waves (radio waves). The transmitter also "piggybacks" information, such as an audio or video signal, onto the radio frequency current to be carried by the radio waves. When they strike the antenna of a radio frequency currents in it. The radio receiver extracts the information from the received waves. A practical radio transmitter usually consists of these parts:

- A power supply circuit
- An electronic oscillator circuit to generate the radio frequency signal.
- A modulator circuit to add the information to be transmitted to the carrier wave produced by the oscillator.

VII. FLIGHT TESTING

The quadcopter was put to test flight to see its performance on takeoff, landing, image capture and transmission to ground station, time of flight on fully charged batteries and following results were obtained:

1. A maximum controllable height of approximately 25 meters was achieved.
2. Maximum flight time was 15 minutes under normal operating conditions.
3. Six degrees of freedom was achieved. Rolling motion was partially achieved.
4. The vehicle was able to transmit video successfully within its range of its controllable height of 25 meters.
5. The quadcopter was able to successfully land and takeoff from water, it’s stability on water surface was satisfactory.

CONCLUSION

Extensive design process was carried out and ultimately a quad copter configuration was designed and assembled. It had a capability of carrying out surveillance from 25 meters height for a duration of 15 minutes. Its primary application was to provide real time aerial surveillance, video transmission for ground forces. CAD and CAE tools were extensively used to arrive at an Optimized design of this vehicle.

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