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DESIGN AND ANALYSIS OF A QUADCOPTER USING CATIA

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Abstract—In this paper or work was to study the static and dynamic parameter of the structure of quadcopter by determining and analyzing the dynamics of the quadcopter.. Though, there are many parameters which affect the performance of the quadcopter, the scope of this paper work is limited to optimization, determination, design and analysis of framework and to integrate them into whole systems for best results.

In this paper we will also come across the following aspects

a. Study the static and dynamic parameters of the framework

b. Workout the parameters by analysis, design, and optimization of structure.

c. Study of existing quadcopters and the parameters affecting its performance.

1. INTRODUCTION

1.1 UAV

An unmanned aerial vehicle (UAV), commonly known as a drone and also referred to as an unpiloted aerial vehicle and a remotely piloted aircraft (RPA) by the International Civil Aviation Organization (ICAO), is an aircraft without a human pilot aboard. ICAO classify unmanned aircraft into two types under Circular 328 AN/190.

- **Autonomous aircraft** – currently considered unsuitable for regulation due to legal and liability issues.

- **Remotely piloted aircraft** – subject to civil regulation under ICAO and under the relevantnational aviation authority.

The typical launch and recovery method of an unmanned aircraft is by the function of an automatic system or an external operator on the ground.

1.2Quadcopter (UAV) structure

A quadcopter, also called a quad rotor helicopter orquad rotor, is a multirotor helicopter that is lifted and propelled by four rotors. Quadcopters are classified as rotorcraft, as opposed to fixed-wing aircraft, because their lift is generated by a set of rotors(vertically oriented propellers).

Unlike most helicopters, quadcopters use two sets of identical fixed pitched propellers; two clockwise (CW) and two counter-clockwise (CCW). These use variation of RPM to control lift and 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.

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 take off 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.

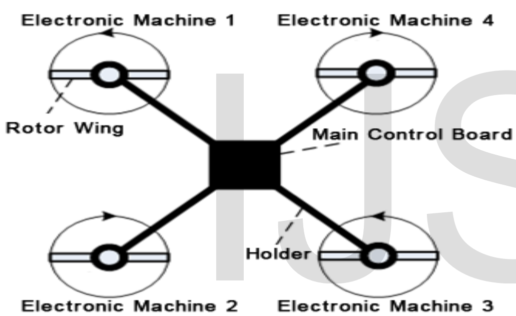


Fig 1.1 Quadcopter Structure

- The three major components of the frame are custom and required manual machining. The main components manufactured are the center frame supports, landing gear cum crash absorber, and the arms. Initially vacuum bag method may be used for making carbon fiber laminates, and CNC milling machine may be used for the further precision fabrication

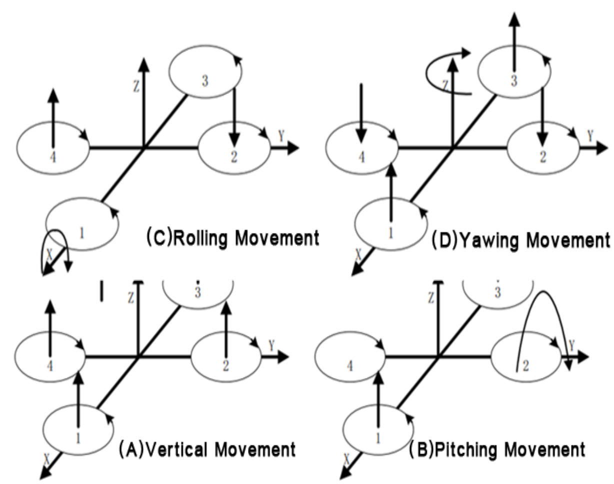
CENTRAL HUB

- The center piece is created from two flat, pieces of carbon fiber laminate milled to the desired specifications and shape. These pieces serve to fasten the four arms of the quad-rotor together and hold the electronics hub off the ground. The carbon fiber rods on the final design of the quad-rotor require two fasting points, where the test version of the quad-rotor only required a single piece. The additional fastening point is due to the possible weaknesses formed during the tricky processing stage. The frame's many constraints required a versatile and simple, for easy adjustments, center piece.

SPARS

- Machining the rectangular carbon fiber rods has proven itself to be very difficult. Preliminary machining is done on test pieces to acclimate to the machine and material. The best tool for cutting carbon fiber rods is a diamond tipped jewelers saw, however this tool is expensive and unavailable. Consequently, other manufacturing machines were used. The band-saw catches the fibers rips the rod on the blade causing it to splinter. There are also problems drilling into carbon fiber rods. Since diamond tipped bits are also unavailable, when the nondiamond drill bit is lowered to the face of the material, the fibers would snag on the bit and split the rods. These issues can be over come by following a few steps:
- Place two thinner, one foot pieces of wood running nailed to the 2x4 length wise, separated by a distance slightly greater than the thickness of the rods.
- Fix the rod in place using tape. The tape is compressive enough to hold the rod firmly to the jig, adding support without crushing it.
- Drilling at high speeds, with a series of 3 bits each increasing in size proved a capable method.
- The carbon fiber splitting when using the band-saw can be overcome in a similar way as with drilling. Tape the rods in the same way as done when drilling the carbon fiber, however the tape should be thicker than before. The contraption is fed through the band-saw using a straight flat piece of wood to brace the back of the rods, preventing it from bending when the blade put pressure on it.

6 Degrees of Freedom Control



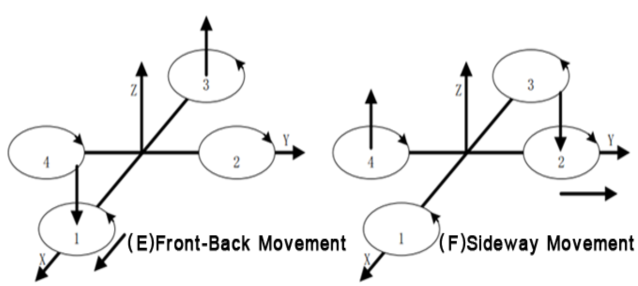


Fig 1.2 6DOF control of quadcopter

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1.3 MATERIALS

1.3.1Carbon Fibre

- Carbon fiber is composed of carbon atoms bonded together to form a long chain. The fibers are extremely stiff, strong, and light, and are used in many processes to create excellent building materials. Carbon fiber material comes in a variety of "raw" building-blocks, including yarns, uni-directional,weaves, braids, and several others, which are in turn used to create composite parts.

1.3.2Properties of Carbon fibre

- **Carbon fibre has High Strength to weight ratio**

  Materials such as Aluminium, titanium, magnesium, Carbon and glass fiber, high strength steel alloys all have good strength to weight ratios. Because of the way the crystals of carbon fibre orient in long flat ribbon or narrow sheets of honeycomb crystals, the strength is higher running lengthwise than across the fibre. The fibre being aligned with the direction of greatest stress.

- **Carbon fibre is very Rigid**

  Carbon fiber reinforced plastic is over 4 times stiffer than Glass reinforced plastic, almost 20 times more than pine, 2.5 times greater than aluminium.

- **Carbon fibre is Electrically Conductive**
- This feature can either be useful or be a nuisance. In Boat building conductivity has to be taken into account just as Aluminium conductivity comes into play. Carbon fiber conductivity can facilitate Galvanic Corrosion in fittings. Careful installation can reduce this problem.
- **Fatigue Resistance is good**

  Resistance to Fatigue in Carbon Fiber Composites is good. Damage in tensile fatigue is seen as reduction in stiffness with larger numbers of stress cycles, (unless the temperature is high)

- **Fire Resistance/Non flammable**

  Depending upon the manufacturing process and the precursor material, carbon fiber can be be made to feel quite soft to the hand and can be made into or more often integrated into protective clothing for firefighting. Nickel coated fiber is an example. Because carbon fiber is also chemically very inert, it can be used where there is fire combined with corrosive agents. Carbon Fiber Blanket used as welding protection.

- **High Thermal Conductivity in some forms**

Because there are many variations on the theme of carbon fiber it is not possible to pinpoint exactly the thermal conductivity. Special types of Carbon Fiber have been specifically designed for high or low thermal conductivity.

- Low coefficient of thermal expansion

  Carbon fiber can have a broad range of CTE's, -1 to 8+, depending on the direction measured, the fabric weave, the precursor material, Pan based (high strength, higher CTE) or Pitch based (high modulus/stiffness, lower CTE). Low Coefficient of Thermal expansion makes carbon fiber suitable for applications where small movements can be critical. Telescope and other optical machinery is one such application.

- **Nonpoisonous, Biologically inert, X-Ray permeable**

  These quality make Carbon fiber useful in Medical applications. Prosthesis use, implants and tendon repair, x-ray accessories surgical instruments, are all in development. Although not poisonous, the carbon fibers can be quite irritating and long term unprotected exposure needs to be limited. The matrix either epoxy or polyester, can however be toxic and proper care needs to be exercised.

- **Carbon fibre is Relatively Expensive**

  Although it offers exceptional advantages of Strength, Rigidity and Weight reduction, **cost is a deterrent**. Unless the weight advantage is exceptionally important, such as in aeronautics applications or racing, it often is not worth the extra cost. The **low maintenance requirement of carbon fiber** is a further advantage.

2. LITERATURE SURVEY

Design Of A Quadcopter Using PID Control Algorithm

D. Deva prakash

The military use of quadcopter has grown because of its ability to operate in dangerous locations while keeping human operators safe. Here, a low-cost hover control mechanism is developed and implemented on a microcontroller. Flight control becomes simpler as the quadcopter hovers at a constant level from ground by itself, at the same time making it too easy to maneuver at heights and perform tasks such as imaging. A PID control method to obtain stability in flying the quadcopter is designed. The model has four input forces which are basically the thrust provided by each propeller connected to each rotor with fixed angle. By varying the speed of rear and front motors, we can obtain the pitch, roll and yaw motions of the quadcopter. Future improvements can be made to improve the design, to prove that it is possible to produce a small scale UAV that can perform functions of interest to the military as well as commercial and industrial applications.

Simple GUI Wireless Controller of Quadcopter

D. Hanafi

The development of remotely operated Quadcopter system. The Quadcopter is controlled through a graphical user interface (GUI) where the communication between GUI and Quadcopter is constructed by using wireless communication system. The Quadcopter balancing condition is sensed by FY90 controller and IMU 5DOF sensor. For smooth landing, Quadcopter is equipped with ultrasonic sensor. All signals from sensors are processed by Arduino Uno microcontroller board and output from the Arduino Uno microcontroller board is implemented to control Quadcopter propellers. The GUI is designed using Visual Basic 2008 Express as interfacing communication between the Proportional, Integral and Derivative (PID) controller and the Quadcopter system. The experiment shows that the Quadcopter system can hover while maintain it balancing and the stability is guaranteed. Moreover, the developed system is able to cope with load disturbance up to 250 gduring the hover position. Maximum operated time of Quadcopter is six minutes using 2200 mAh Lipo battery and operate time can be increased by using largest battery capacity.

Quadcopter Design and Implementation

Goponov. I

The design and implementation of quadrotor helicopter system. The class is intended to provide the students with both theoretical and practical knowledge in the areas of mechanical engineering and design, system integration, hardware programming, and control system design and implementation. The class has the objectives which are very clear for the students, and gaining practical skills in such a blend of several unrelated technical fields at the same time can give the students unique experience of system design and integration, which can prove to be very useful in their future career.

Controller Design for Quadcopter Using Labview

This paper describes the modelling of a four rotor vertical take off and landing (VTOL) unmanned air vehicle known as Quadcopter air craft,which is a new model design method for the flight control of an autonomous Quadcopter.The aim is to develop a model of the vehicle as realistic as possible.The model is used to design a stable and accurate controller to develop a Image controlling method using LabView to obtain stability in flying the Quadcopter flying object.

Convertawings Model A Quadrotor

This unique helicopter was intended to be the prototype for a line of much larger civil and military quadrotor helicopters. The design featured two engines driving four rotors through a system of v belts. No tailrotor was needed and control was obtained by varying the thrust between rotors. Flown successfully many times in the mid-1950s, this helicopter proved the quadrotor design and it was also the first four-rotor helicopter to demonstrate successful forward flight. Due to a lack of orders for commercial or military versions however, the project was terminated. Convertawings proposed a Model E that would have a maximum weight of 42,000 lb (19 t) with a payload of 10,900 lb (4.9 t) over 300 miles and at up to 173 mph (278 km/h). The Hanson Elastic Articulated (EA) bearingless rotor grew out of work done in the early 1960s at Lockheed California by Thomas F. Hanson.

3. DESIGN OF QUADCOPTER

3.1 Design of Quadcopter

The design of quadcopter has been done by using **CATIA V5** software. The design is done in such a way that there should not be any damage to the propellers, motors and electrical equipments.

The central hub, spars and the arms are designed individually and assembled.

CATIA V5

CATIA (Computer Aided Three-Dimensional Interactive Application) started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault, at that time customer of the CAD/CAM CAD software[1] to develop Dassault's Mirage fighter jet. It was later adopted in the aerospace, automotive, shipbuilding, and other industries.

CATIA enables the creation of 3D parts, from 3D sketches, sheetmetal, composites, molded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing & BIW. It provides tools to complete product definition, including functional tolerances as well as kinematics definition. CATIA provides a wide range of applications for tooling design, for both generic tooling and mold & die. CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches. CATIA is able to read and produce STEP format files for reverse engineering and surface reuse.

Length of the arm =215mm

Length of vertical and horizontal sides of center base =50mm

Length of diagonal side of center base =67mm

Length and breadth of rectangle drill =20*6mm

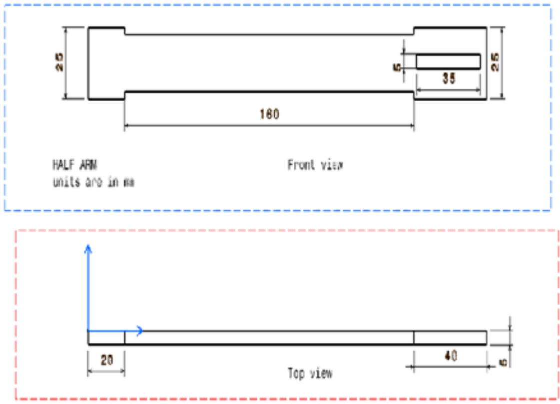

Fig 3.1 2D structural parts of quadcopter

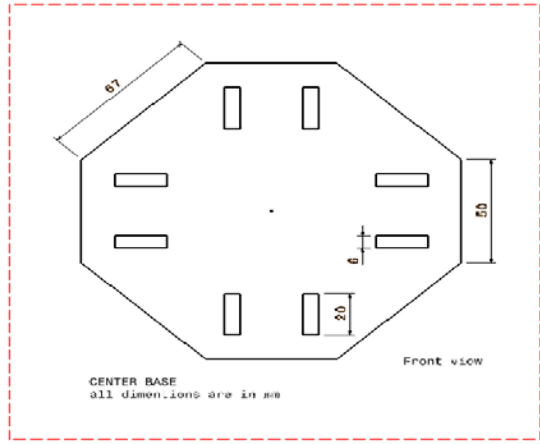

Fig 3.2 central hub

3D Design of the Quadcopter parts

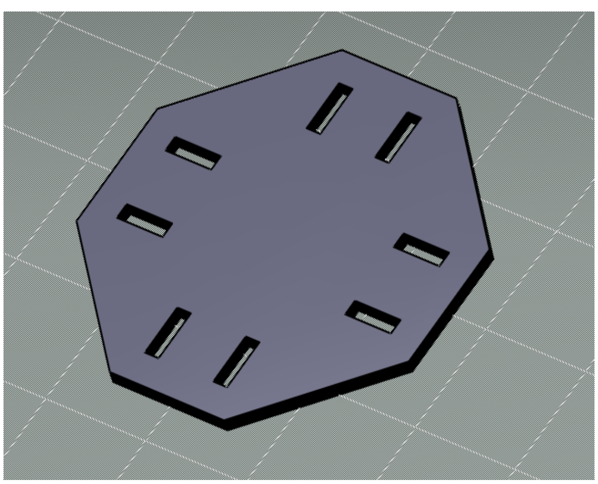

Fig 3.3 3D central hub

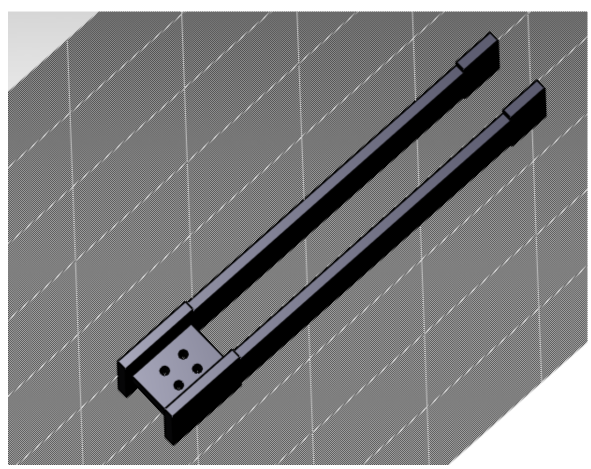

Fig 3.4 Arm

Assembly of the Arm and Central hub

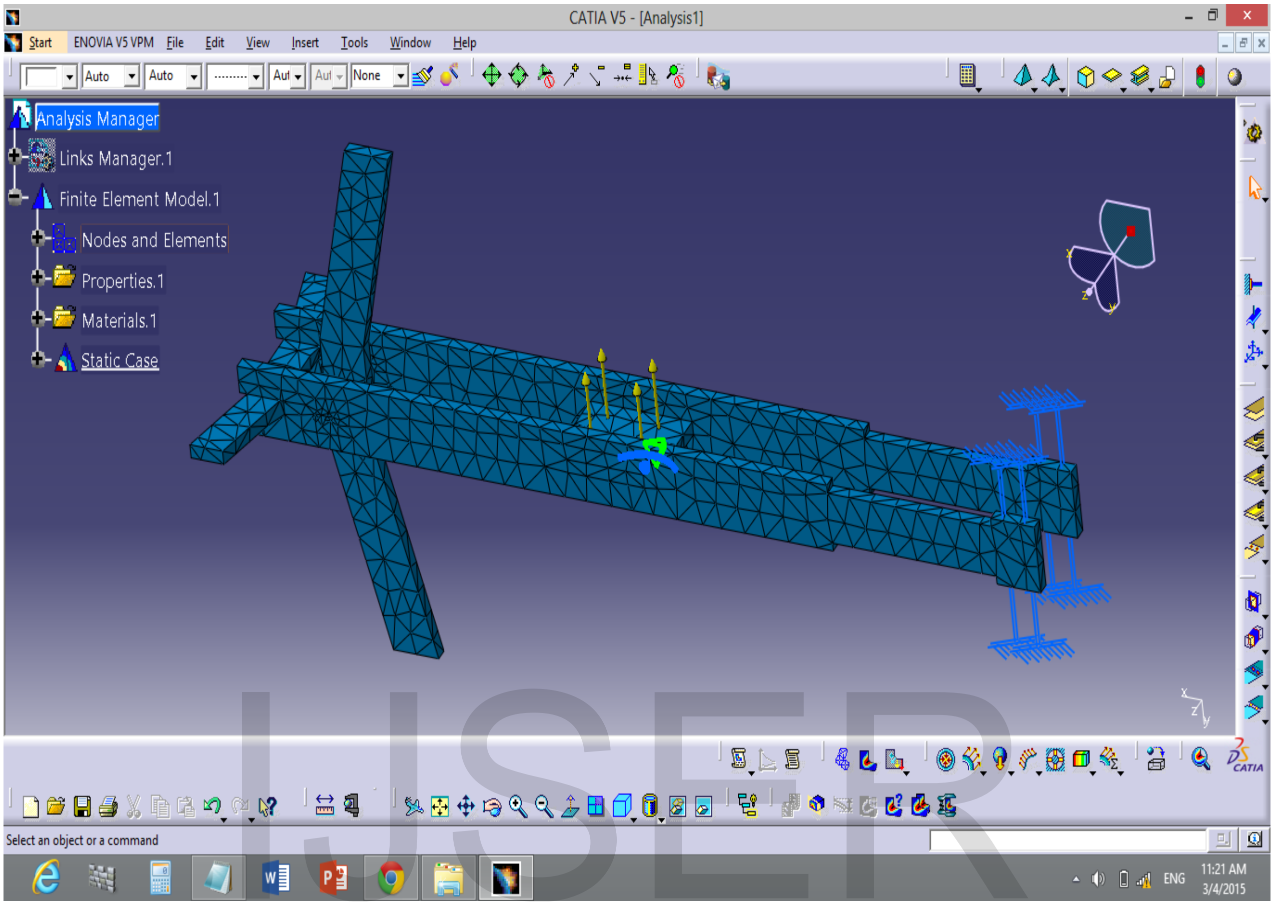

Fig 3.5 complete assembly of the Arm

The 2D view of the arm is ddrawn in the catia v5 software and it is converted in to 3d view by giving thickness of 20mm. like wise the arm stand and the knife edge curvature is designed and converted it in to 3D view. The three parts can be designed individually or at a time by creating another plane on the side wich we need to add the futher design. After sketching that part on the plane and it is converted in to 3D by using 3D tool bar. The holes are drilled by using drill bit in the tool bar. Same as the arm stand the knife edge of the arm is created and converted in to 3D.

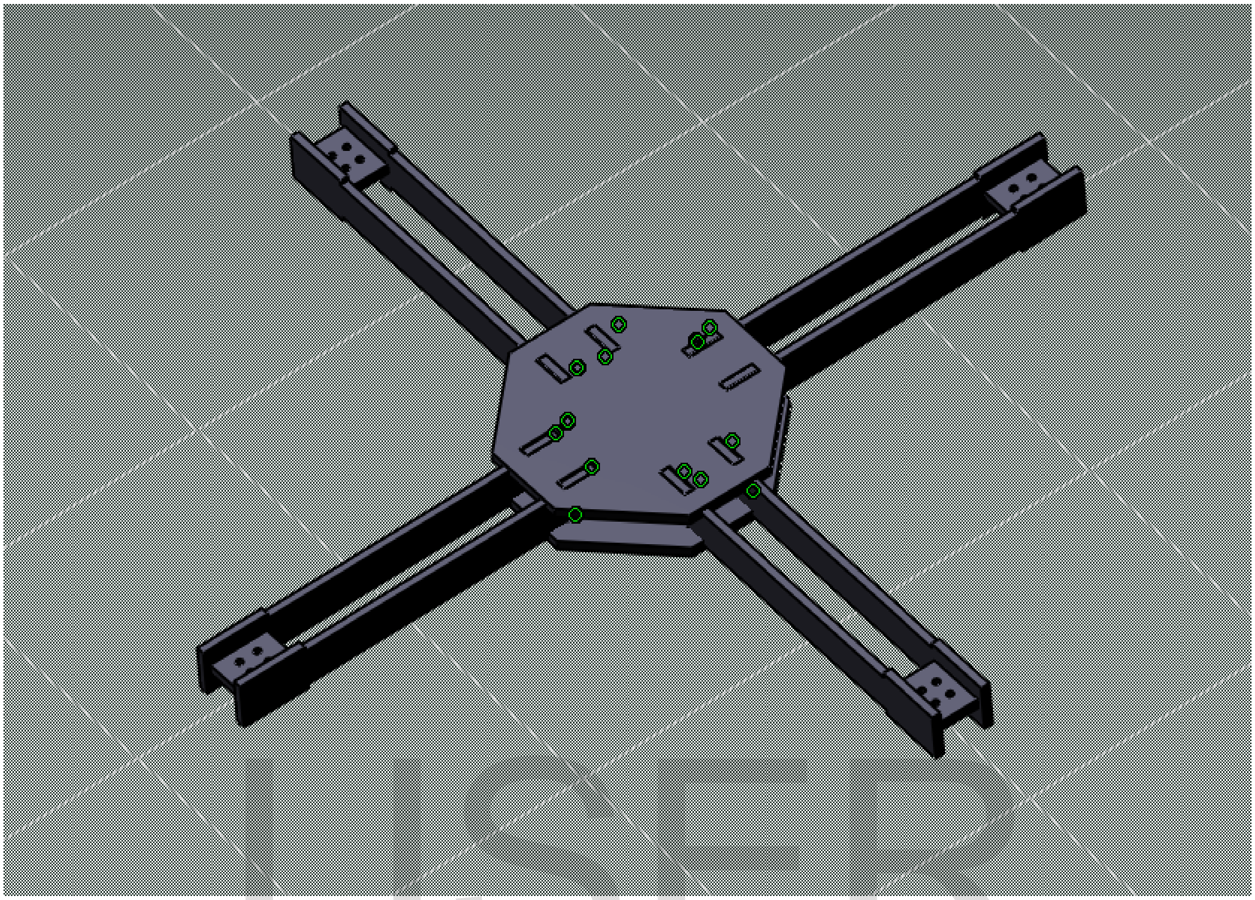

Fig 3.6 assembly of central hub and arm

The figure shows the top view of the assembly of the central hub and the arm. The both parts are sketched and designed individually. So by using catia vs or ProE softwares the assembly ca be done. The figure is assembled with our the arm stand and the knife edge. The central rectangle holes are drilled of light 20mm and thickness 20mm. The flat bouncer edge of the arm is also of 20mm so that the edge of the arm will be clamped correctly in the central hub.

4. ANALYSIS

4.1 Analysis of Quadcopter design

Analsysis of thr parts of the designed quadcopter is done by using **ANSYS**software. Ansys software is the tool of the FEM analysis. Here we are going to make the analysis of the material by using carbon fibre. The parts ae meshed first and then

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analysed with the specific boundary conditions and various loads.

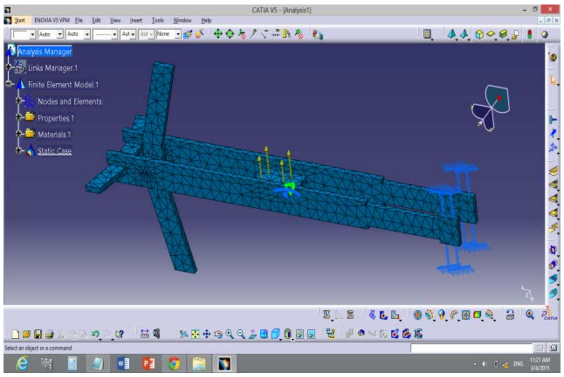
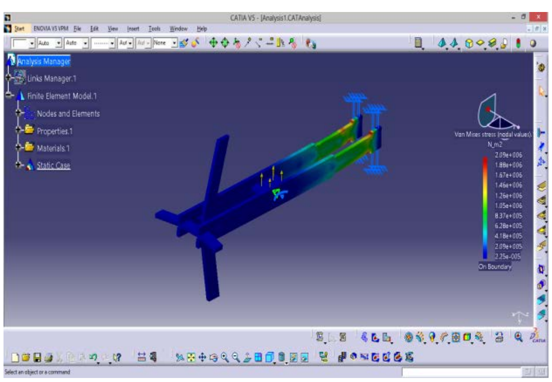


Fig 4.1 Forces based on motor basis

4.2 FEM ANALYSIS

The finite element method obtained its real impetus in the 1960s and 1970s. The method originated from the need to solve complex elasticity and structural analysis problems incivil and aeronautical engineering.The method has since been generalized for the numerical modeling of physical systems in a wide variety



Maximum stress - 2.09mpa

Minimum stress- 2.25 e-005 pa

of engineering disciplines, e.g., electromagnetism, heattransfer, and fluid dynamics.

A variety of specializations under the umbrella of the mechanical engineering discipline (such as aeronautical, biomechanical, and automotive industries) commonly use integrated FEM in design and development of their products. Several modern FEM packages include specific components such as thermal, electromagnetic, fluid, and structural working environments. In a structural simulation, FEM helps tremendously in producing stiffness and strength visualizations and also in minimizing weight, materials, and costs.

FEM allows detailed visualization of where structures bend or twist, and indicates the distribution of stresses and displacements.

Full assembly of one arm, after meshing, applying boundary conditions. One end is fixed and motor base is applied with 10 N of load.

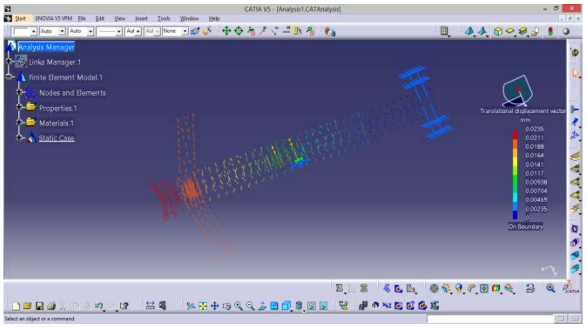


Fig 4.3 Displacement of Arm under applied load

Displacement vector – 0.0235mm

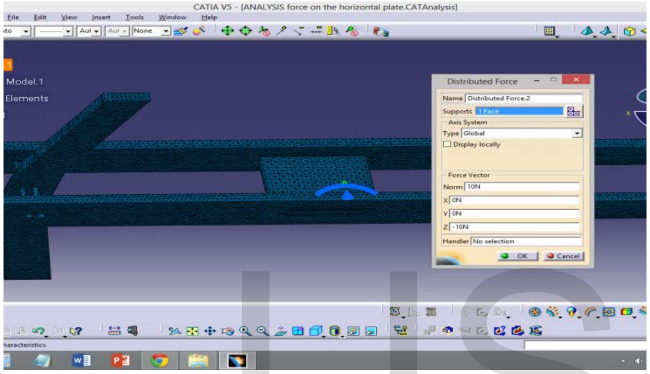


Fig 4.4 Force on horizontal plane

Force applied – 10

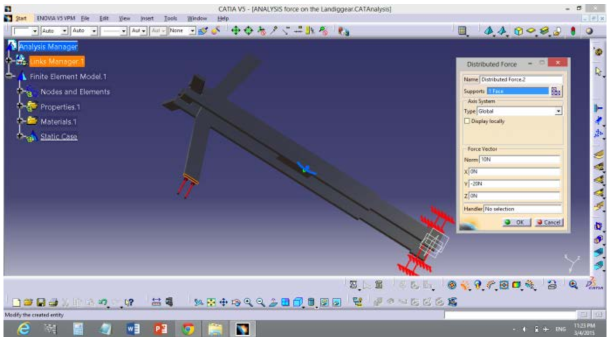


Fig 4.5 Force on landing gear

Force applied – 10N

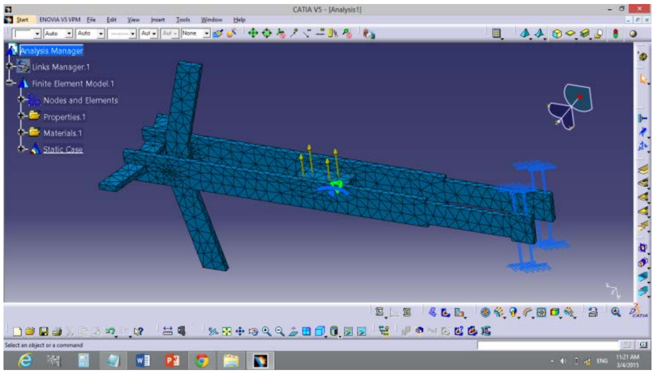


Fig 4.6 force based on motor basis

5. FABRICATION AND ASSEMBLY

5.1 Carbon fibre manufacturing

Carbon fiber–reinforced polymer, carbon fiber–reinforced plastic or carbon fiber–reinforced thermoplastic (CFRP, CRP, CFRTP or often simply carbon fiber, or even carbon), is an extremely strong and light fiber-reinforced polymer which contains carbon fibers.

CFRP's can be expensive to produce but are commonly used wherever high strength to weight ratio and rigidity are required, such as aerospace, automotive and civil engineering, sp orts goods and an increasing number of other consumer and technical applications.

The binding polymer is often a thermoset resin such as epoxy, but other thermoset or thermoplastic polymers, such as polyester, vinyl ester or nylon, are sometimes used. The composite may contain other fibers, Such as aramid e.g. Kevlar, Twaron, aluminium, Ultra-high-molecular-weight polyethylene(UHMWPE) or glass fibers, as well as carbon fiber. The properties of the final CFRP product can also be affected by the type of additives introduced to the binding matrix (the resin). The most frequent additive is silica, but other additives such as rubber and carbon nanotubes can be used. The material is also referred to as graphite-reinforced polymer or graphite fiber-reinforced polymer (GFRP is less common, as it clashes with glass.

Compression molding

A quicker method uses a compression mold. This is a two-piece (male and female) mold usually made out of aluminum or steel that is pressed together with the fabric and resin between the two. The benefit is the speed of the entire process. However, this technique has a very high initial cost since the molds require CNC machining of very high precision.

The above figure shows the carbon fibre after completing the compression moulding process. The process took two days to complete.

5.2 Design Fabrication using CNC machining

Computer numerical control (CNC) is a specialized and versatile form of soft automation and its application cover many kinds, although it was initially developed to control the motion and operation of the machine tools.

Machining process

The sketches are machined with carbon fibre by using CNC machine with the help of Artcam Pro software

Artcam Pro: A complete solution for the design and manufacture of 2D Artwork & 3D Reliefs. This was the software used to give sketch commands and codes to the CNC machine

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Fig 5.6 cutting of carbon fibre using CNC

5.4 DC Motors

Four brushless DC motors and propellers has been used.

Specifications

Diameter – 27.9mm
Length -39.7mm
Weight -53g
KV – 935
Maximum thrust - 860G

5.5 Flight Control Board

Here KK 2.1.5 flight controlboard is used. The original KK gyro system has been updated to the incredibly sensitive 6050 MPU system making this the most stable KK board ever and adds the addition of an auto-level function. At the heart of the KK2.1 is the ATMEL Mega 644PA 8-bit AVR RISC-based microcontroller with 64k of memory. An additional header has been added for voltage detection, so now there is no need for on-board soldering. A handy piezo buzzer is also included with the board for audio warning when activating and deactivating the board, which can be supplemented with an LED for visual signaling. A host of multi-rotor craft types are pre-installed, simply select your craft type, check motor layout/propeller direction, calibrate your ESCs and radio and you're ready to go! All of which is done with easy to follow on screen prompts! If you're new to multi-rotor flight or have been unsure about how to setup a KK board then the KK2.1 was built for you. The 6 Pin USBasp AVR programming interface ensures future software updates will be quick and easy.

5.6 Transmitter

Here we use avionic RCB6i transmitter with receiver. This is one of the advanced transmitter with receiver to control the quadcopters and mini uav's.

5.7 Lipo battery

A lithium polymer battery, or more correctly lithium-ion polymer battery (abbreviated variously as LiPo, LIP, Li-poly and others), is a rechargeable battery of lithium-ion technology in a pouch format.

5.8 ESC (Electronic speed control)

An electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless motors essentially providing an electronically generated three-phase electric power low voltage source of energy for the motor. An ESC can be a stand-alone unit which plugs into the receiver's throttle control channel or incorporated into the receiver itself, as is the case in most toy-grade R/C vehicles. Some R/C manufacturers that install proprietary hobby-grade electronics in their entry-level vehicles, vessels or aircraft use onboard electronics that combine the two on a singlecircuit board. Here for this quadcopter 20amps esc has been used.

5.9 Fabricated model

CONCLUSIONS

The required light airframe feasibility UAV(Quadcopter) design is fabricated using carbon fibre of crash resistability and made it to fly successfully.

This Structural Analysis of the carbon fibre leads to the following conclusions:-

- Vibration got reduced when compared to the plastic uav.
- There is no effet to the rotors propellers and othr electrical components by using this design.
- The strength and resistance capacity is increased.
- **FUTURE WORK**
- Advanced techonology can be used like autopilot system etc.
- By using sensors and cameras can be used for defence and airforces.
- Still more miniature uav can be made by using this design.

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