Design and Manufacturing of Unmanned Aerial Vehicle

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Abstract: In modern times, the entire world's economy is driven by agricultural sector. Though technological advancement in this sector have been prevalent for long time, it has been developing gradually over the period. This project will aid the community in simplifying the process of spraying pesticides aerially and will also cover a huge chunk of land mass from a single point. A remote-controlled UAV (Unmanned Aerial Vehicle) is used to spray the pesticide to avoid the humans from coming in contact with harmful pesticides and toxic chemicals. The UAV is operated by manual flight plans and the sprayer is manually triggered by RF (radio frequency) controlled Nozzle. Radio Controller controls the movement and speed of the drone. This project describes the development of UAV using additive manufacturing and the sprayer module. This model is used to spray the pesticide content to areas that aren't easily accessible by humans. This drone system mainly works on the principle of thrust. The sprayer module will spray the liquid pesticides over the field aerially. This project mainly concentrates on designing a low weight structure using material which is recyclable, cost effective and less harmful to the environment that sprays pesticides for farming.

Keywords — Agricultural Sector, Unmanned Aerial Vehicle (UAV), Sprayer module, Pesticides, Radio Controller, Thrust.

I. INTRODUCTION

Drone Technology is emerging as a huge invention accounting for the help in various fields. One of them is agriculture. In the agriculture field, drones can be used for numerous advantages such as soil and field analysis, seed planting, spraying of fertilizers and pesticides on crops, surveying and crop mapping, monitoring the fields health and its management, etc. In this new era farmer's productivity and profitability has increased by using this precise technology. Considering these aspects, a drone is developed using an automated system and according to the needs. This project aims to overcome the problems regarding the weight of the frame and its suitability with equipment used in the system. UAV's were initially used in military operations and this practice has made humans develop systems that will be used in various applications. The Indian service sector is the most substantial contributor to the country's GDP. Contributing 18% to the GDP, it is the prime source of livelihood for approximately 58% of the country's population. Agriculture sector along with forestry and fishing, results in a gross added value of around Rs.18.55 lakh crore as of 2019. Regardless of its contribution to the GDP, the country is yet to enhance productivity and efficiency in the sector to reach its highest potential. Unsuitable methods for monitoring crops, irrigation, use of pesticides and many other necessary farming activities are currently adopted. Resources are inadequate, and are needed to be allocated according to weather conditions to gain the return on investment. As the governments and businesses across the world reorganized the significance of food security and consequences of environmental degradation, pollution, climate crises, and water scarcity, the urgency to overcome certain obstacles arose. Drone technology has widespread applications, and unmanned aerial vehicles are widely popular in different industries. Drones encourage farmers to receive plenty of benefits through precision agriculture. And fill the gap of human error and inefficiency by traditional farming methods. The purpose of adopting dinner technology is to exclude any guesswork or ambiguity and focus on accurate and reliable information instead. Agriculture drones empowers farmers to adapt to specific environments and make mindful choices accordingly the data gained related to weather, soil conditions and temperature, helps to regulate crop health, crop scouting, crop irrigation, and crop damage assessments [1]. Drone technology equipped with artificial intelligence AI, machine learning ML, and remote sensing features are rising in demand because of its advantages. Typically, drones include navigation systems, GPS, multiple sensors, programmable controllers, and tools for autonomous drones. Unmanned aerial vehicles UAV s can get more precise data than satellites, which are in use now as introductory goods for farm management, for precision

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agriculture. Drone technology quickly reestablishes traditional agrarian practices. They give effective control on fungus, insects, etc. It will help to increase the quality of crops as well as production. According to this, the exact amounts of chemicals needed to fight the infestations are known, and this helps diminish the costs inflicted by farmers. Additionally, through drone crop spraying human contact with harmful chemicals will be limited. And agri-drones can carry out these tasks much quicker than agri-vehicles. Boost productivity, mitigate input costs and ultimately maintain a good quality crop drones are novel agro-tech tools to assess the crop health and eradicate fungi from the farms [4].

In today's growing world, the agriculture sector is going to become a good income source as well as a good source for foreign exchange and it will help to grow our economy. Agriculture, with its allied sectors, is the largest source of livelihoods in India. 70 percent of its rural households still depend primarily on agriculture for their livelihood, with 82 percent of farmers being small and marginal [7]. Currently, techniques such as photogrammetry, machine learning and vegetation indices are being used in advancing the development of mapping, irrigation and monitoring. [10]

II. BASIC COMPONENTS USED IN DRONE

a) Frame of the Drone - Frame is used for mounting of all the accessories and equipment that will be useful for it. It also ensures the stability of the drone according to its design.
b) Brushless Motors - These motors help to lift off the drone from the ground position and also to maneuver accordingly.
c) Electronic Speed Controller (ESC's) - Electronic speed controller are the ones who get input of the speed from the flight control board. As the name suggests, these ESC's control the speed of the motor.
d) Propellers - Propeller are mounted on the motors to generate thrust and lift the drone.
e) Power Distribution Board- power distribution board is used to source the power from battery to the motors.
f) Flight Controller Board(FCB) - Flight controller board is used for mounting the extra accessories used in drones like telemetry, GPS, etc. It acts as the brain of the drone to give signals to other components.
g) Battery - This is the power source of all the components who require electric supply to ensure working of the drone. [8]
h) Transmitter and Receiver - Transmitter is a remote control which is used for giving commands to the drone and receiver is used to receive the transmitted signals from the remote control and pass it to the flight controller board.

These are some basic components used in drones to ensure the drone function properly.

III. METHODOLOGY

A. Methodology Flowchart

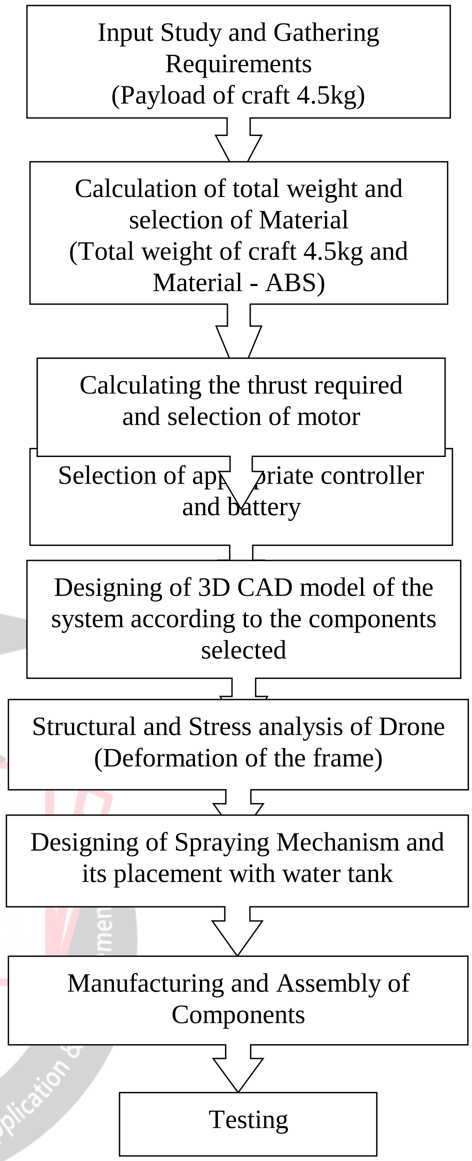

Fig.1 Methodology Flowchart

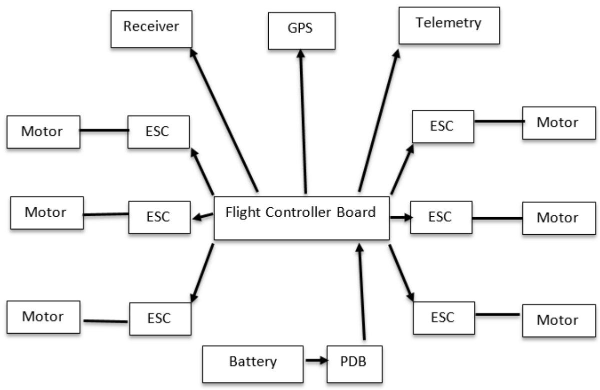

Fig. 2 Block Diagram of Hexacopter

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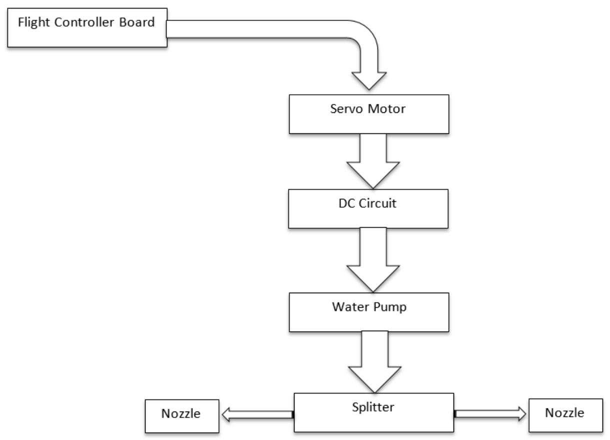

Fig.3. Block Diagram of Spraying Module

B. *Components Description*

Frame Components

i) Frame:

1. It is relatively inexpensive.
2. It is famously durable.
3. The centre plate doubles as a power distribution board which tidies things up quite a bit and allows me to get rid of my ugly DIY wiring harness.

Things to consider here are weight, size, and materials. They're strong, light, and have a sensible configuration including a built-in power distribution board (PDB) that allows for a clean and easy build.

Frames can also be built at home using aluminium or balsa sheet. But results will vary from manufactured frames, both aesthetically and in terms of flight attributes.

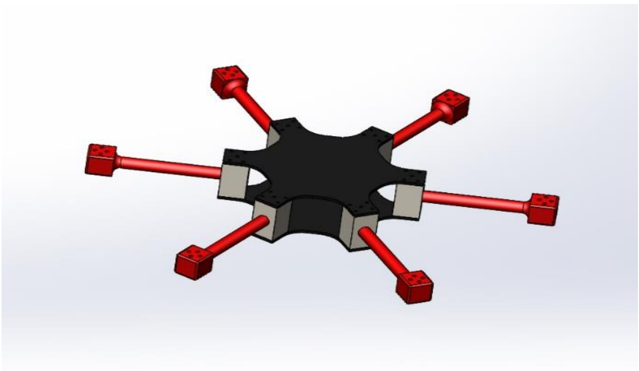

Fig.4. Drone Frame

ii) Motors

Motors used in drones are brushless DC motors. BLDC motors have longer life as compared to others. And also these motors can achieve higher rpm speeds. These motors are rated in KV rating. KV is known as Kilovolt. Platform of the drones also contributes towards payload capacity [5].

The motors also have movement in clockwise and anti-clockwise direction. These motors are placed in configuration as shown in the figure below.

BLDC motor designation

Ex- 1050 750KV

Here, 10 denotes the stator size of the motor and 50 is rotor size. 750 KV is the KV rating of the motor. Lower the KV, Higher is the torque generated.

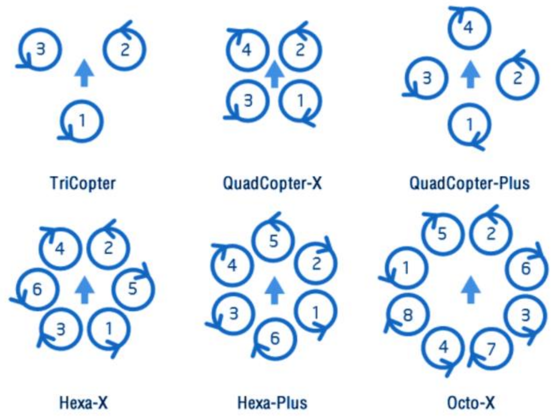

Fig. 5 Configuration of Motors in Drones

iii) ESC's

An ESC is an electronic speed control which regulates and controls the speed of the motor. ESC are rated in amperes. These regulate the current to the motors according to the need. ESC's receives signal from the flight controller board to vary the amount of the current. These ESC's are selected as max. ampere rating of the motor multiplied by 1.5 factor. ESC are an essential component of modern multi-rotors that offer high power, high frequency, high resolution 3-phase AC power to motor in an extremely compact miniature package

Fig.6. Electronic Speed controller

iv) Power Distribution Board

Power distribution board are also known as PDB's. As the name suggests, these are used to distribute the power to motors and other accessories that are used in drone. Some PCB's are integrated in the drone frame which offer a great feasibility in terms of wire connections and complex structure. PDB's are available in different ampere rating and are selected on the basis of total ampere requirement of the drone.

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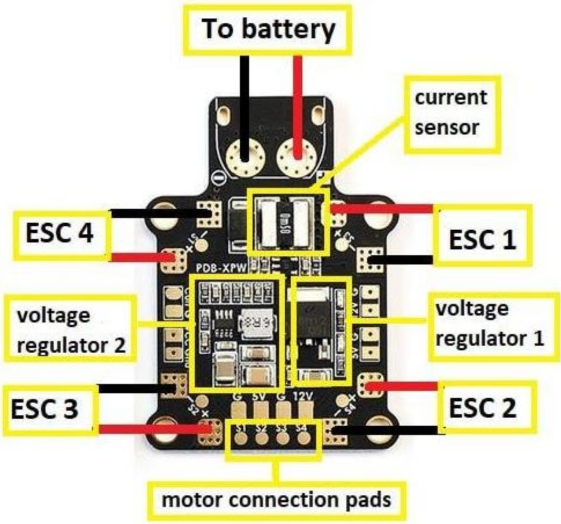

Fig.7. Power Distribution Board

v) Battery

Battery in the drones acts as mitochondria. It supplies power to PDB and PDB distributes the power accordingly. Batteries are denoted in Mah (milli-ampere-hour) rating. Batteries can be used in series and parallel connections as per the requirement of voltage and current. The greater the Mah rating of the battery, greater the flight time of the drone. These batteries are lithium polymer based batteries.

Fig.8. Battery

vi) Flight Controller Board

The Flight Controller Board (Pixhawk) acts as the brain of the drone also known as FCB. FCB sends the signal to all the other components. FCB has inputs of motor ESC's. FCB has attachments of FPV cameras, telemetry, GPS, etc [3]. It is basically the nervous system of the drone which receives the signal from the transmitter. Receiver is mounted on FCB. This should be placed on a shock absorbing plate as the shocks during the flight may affect the stability and malfunction of the components. It supports 8RC channels with 4 serial ports. It has 2mb of flash memory and 512kb of RAM memory.

Fig.9. Pixhawk FCB with 915MHz telemetry, GPS, Shock Absorbing Plate

vii) GPS

GPS is known as Global Positioning System. It improves the stability of drone. It helps to determine the location of the drone. The position provided by the receiver can be used to track the UAV, or, in combination with an automated guidance system, steer the UAV [6].

Fig.10. GPS

viii) Telemetry

Telemetry is used to provide the direction and path to a drone. This can also be remotely activated by a mobile device. Telemetry is available in 433 MHz, 915Mhz, etc. Telemetry is a digital two-way data stream, which can both send data about the flight down to a ground station (in our case, the Mission Planner) and send commands up to the autopilot. There are other ways to get telemetry data, such as embedding it in the video stream of your FPV system (called On-Screen Display) and, confusingly, some RC gear offer a limited telemetry downlink, but by doing it with its own radio link like the 3DR Telemetry kit, it arrives in a full digital form that can be displayed, logged and analyzed by the Mission Planner.

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Fig.11. 433MHz Telemetry

ix) Transmitter and Receiver

A transmitter is a device that uses radio signals to transmit commands via set frequency using a radio receiver which is connected to drone. A transmitter consists of many channels. These channels can be used for purposes like activating components like camera, pumps and other accessories. Basic function of a transmitter is to control the movement of the multirotor. An FPV Drone Radio Transmitter commonly uses the following frequencies: 27MHz, 72MHz, 433MHz, 900MHz, 1.3GHz, and 2.4Ghz, 433Mhz, 900Mhz, and 1.3GHz are typically used in long-range FPV and RC systems.

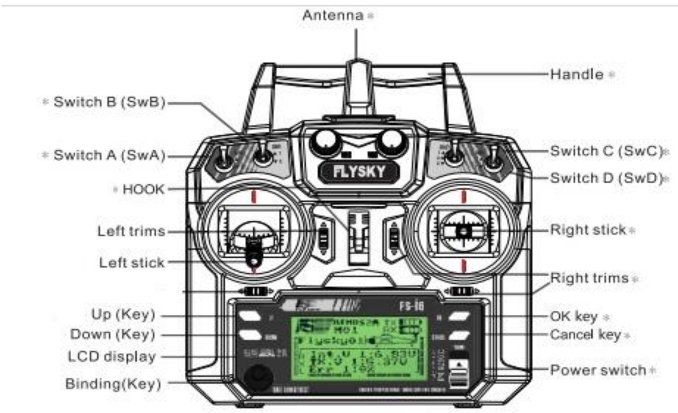

Fig.12. Transmitter Pin Diagram

Fig.13. Flysky FS-i6 2.4Ghz RC Transmitter

Fig.14. 6ch 2.4Ghz Receiver

C. Spraying Module:

i) Servo Motor

Servo motor will be used to regulate and control the flow of water through nozzle. This will be connected to the flight controller board which will receive the signal from the transmitter. The end of the motor will be further attached to the DC motor controller which will give power to the water pump.

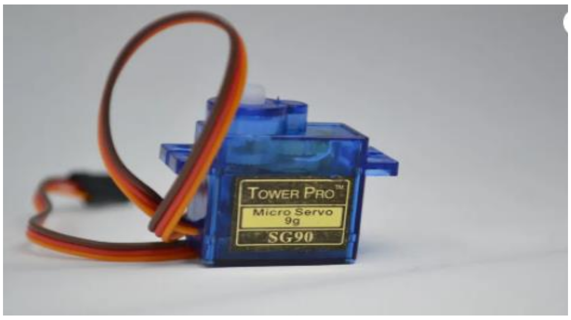

Fig.15. Servo Motor

ii) DC Motor Controller

DC Motor Controller is used to provide power to the water pump. Now, this controller will receive a kinetic energy from the servo motor which will be converted to electric energy. So as the speed of the motor changes, the input current supplied to the pump also changes and hence the flow of water is controlled. This controller is available in various configurations as per the requirement of voltage and current.

Fig.16. DC Motor Controller

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iii) Water Pump

Water pump is used to pump water from the tank attached to the frame of the drone. These are used to move water, they play a fundamental part in agriculture as they move water from its source to field and crops. Water is drawn into the pump through the inlet side when pressure difference is made within pump system. The water wants to move from an area of high pressure to an area of low pressure.

Fig.17. Water Pump

D. Calculations:

Selection of Motor

An electric motor is an electrical machine which converts electrical energy into mechanical energy. There are two types of motors generally used for drones, they are

i. CW and CCW Motors:

Basically the difference between CW and CCW motors is the prop shaft thread rotation. The intention is to use 3 CW motors and 3 CCW motors on a hexacopter, so that when the motors spin, all six prop nuts lock themselves down.

Thrust Calculations:

General required thrust is given by a formula mentioned below it is,

Thrust required = (total weight) × thrust ratio

Here, the thrust ratio will be 2:1 because in most of the agricultural drones speed is not a necessary criteria. Torque is what we needed. In FPV or racing drones the thrust ratio required is greater than 8:1 or 13:1 depending on the requirement. [9]

= 4500 x 2/1

Thrust force required =9000 gf.

As frame is hexacopter,

Thrust force required per motor = 9000/6

= 1500 gf.

Now, we started searching for the motors that will produce 1500gf of force at 50-85% of throttle. Motor is never chosen at 100% throttle because if in case you need an extra amount of thrust then you will be able to use it. It is considered as a factor of safety while searching for motors.

We found an I-rotor 5010 750KV motor which produces 1456gf at 85% throttle.

Prop Test Data	5010-750KV						
Voltage(V)	Propeller (inch)	Throttle	Current (A)	Watts(W)	Thrust(G)	RPM (RPM/Min)	Efficiency (G/W)
11.1	APC 12*3.8	50%	2.6	28.86	421	3567	14.59
		65%	5.4	59.94	567	4333	9.46
		75%	8	88.8	789	4676	8.89
		85%	11.2	124.32	956	5189	7.69
		100	15	166.5	1009	5689	6.06
	APC13*4	50%	2	22.2	338	3890	15.23
		65%	3.5	38.85	458	4789	11.79
		75%	6	66.6	667	5554	10.02
		85%	8	88.8	850	6409	9.57
		100	10.6	117.66	1020	6800	8.67
14.8	APC11*4.7	50%	4	59.2	566	4879	9.56
		65%	7.2	106.56	789	5656	7.40
		75%	11	162.8	1009	6442	6.20
		85%	14.3	211.64	1267	6789	5.99
		100	18.3	270.84	1456	7089	5.38
	APC 12*3.8	50%	4	59.2	621	5089	10.49
		65%	8	118.4	901	5678	7.61
		75%	12.5	185	1200	5789	6.49
		85%	18.5	273.8	1456	6124	5.32
		100	22.4	331.52	1678	6578	5.06

Tab.1. Motor Thrust Test Chart

We have calculated the thrust force in above steps. By considering the value of thrust force, we have checked the table and selected the suitable configuration.

Calculations for an ESC:

ESC = 1.2-1.5 x max amp rating of motor.

= 1.5x22.4

= 33.6A

So, we selected ESC of 40A.

That is Ready to Sky 40A opto ESC.

Opto ESC's are more durable and are highly insulated

Battery Calculations:

As we know from the motor thrust chart that we need only 4S battery i.e. 4 cell battery.

If we consider a 4S 5200mah battery, then it will supply a continuous current of 20.8A for 15 minutes. We need 0nly 18.5A of current to achieve 2:1 thrust ratio. So our flight time will increase to 16-17 minutes. We can also use larger batteries than 5200mah to increase flight time considering the cost of total drone equipment as per the need.

We have to calculate the amount of energy it is consuming; hence we have now calculating the source required by the battery.

Max source = discharge rate*capacity

= 20×5200

= 104000

= 104Amp

Discharge rate**:**

Discharge rate is simply how fast a battery can be discharged safely. In the RC Li-Po battery world it is called the "C" rating. Remember we should never discharge a Li-Po BATTERY BELOW 80% OF ITS CAPACITY.

So, the max source i.e. ESCs should not exceed 104A, since we have selected a 40A ESC there is no problem, it is a perfect battery.

Propeller Calculations for Thrust:

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We have, Payload Capacity + The weight of the craft itself = Thrust * Hover Throttle %

4500 = T×85%

T = 5294 gf

This amount of thrust should be provided by 6motors, so we can calculate individual thrust required by,

T = 5294/6

T = 882.33 gf

Since the thrust required is 882 gf, as we calculated above thrust produced or generated by each motor is 1500 gf. The system will be safe or run without any default.

Finally, we have concluded to select the 6 propellers of size 12×3.8 inch which 3 are supposed to CW and others for CCW as mentioned in the motor thrust chart.

3D CAD Design Parts and Assembly:

The design of Hexacopter has been done by using Solidworks 2020 software. The design is done in such a way that there should not be any damage to the propellers, motors and mechanical equipments. The central hub, spars and the arms are designed individually and assembled.

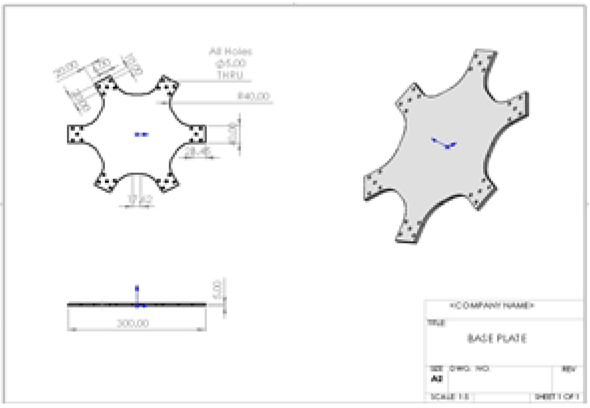

Fig. 18. CAD Model - Base/Top Plate

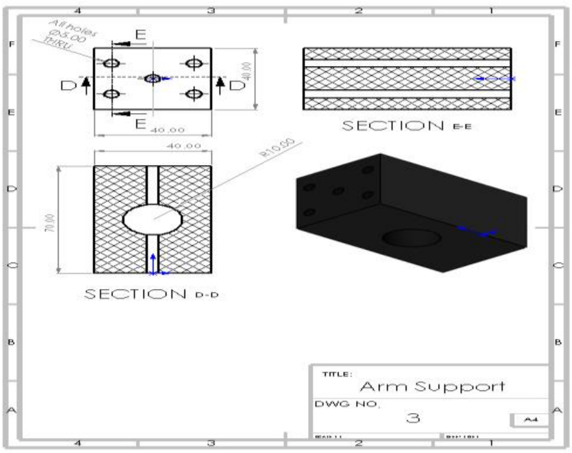

Fig.19. CAD Model – Arm Support

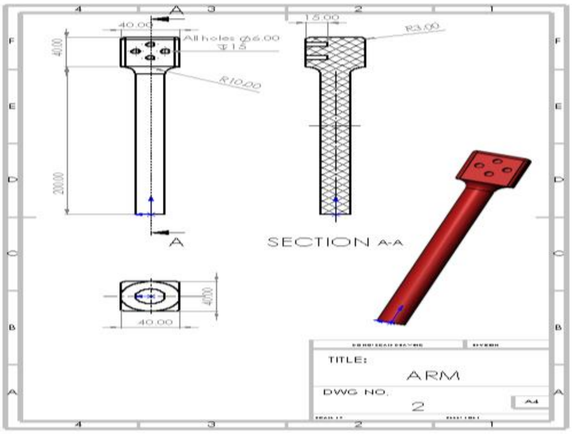

Fig.20. CAD Model - Arm

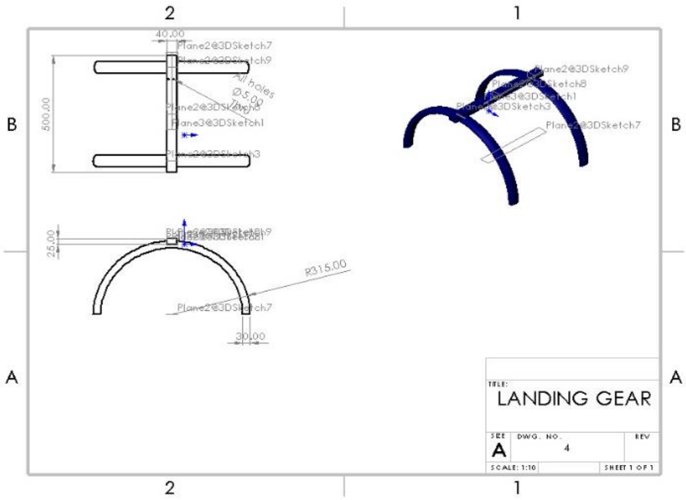

Fig.21. CAD Model – Landing Gear

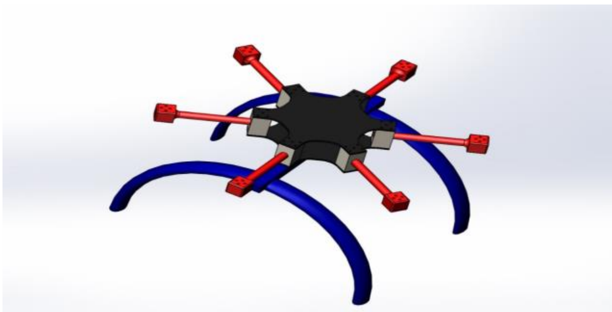

Fig. 22. Assembly

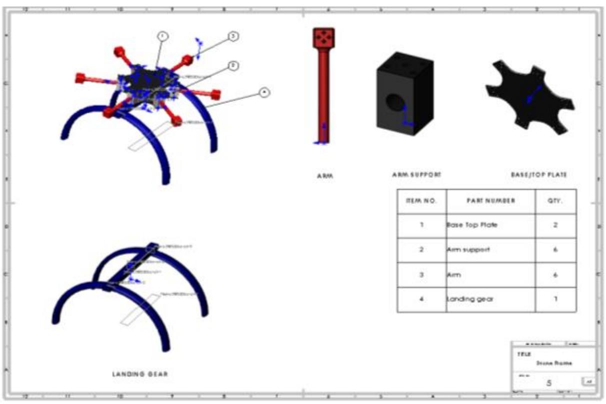

Fig. 23. Bill of Materials

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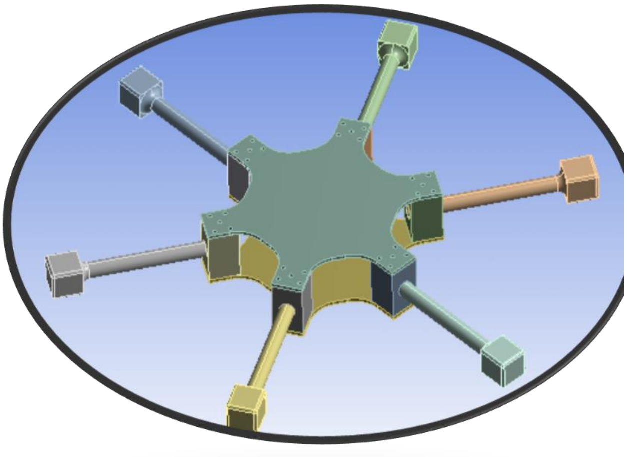
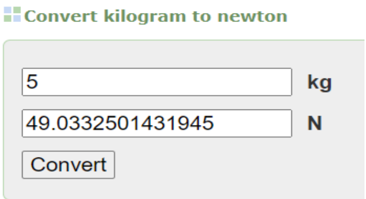
IV. ANALYSIS

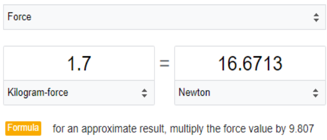
Drone Frame Structural Analysis:



Load Conditions:

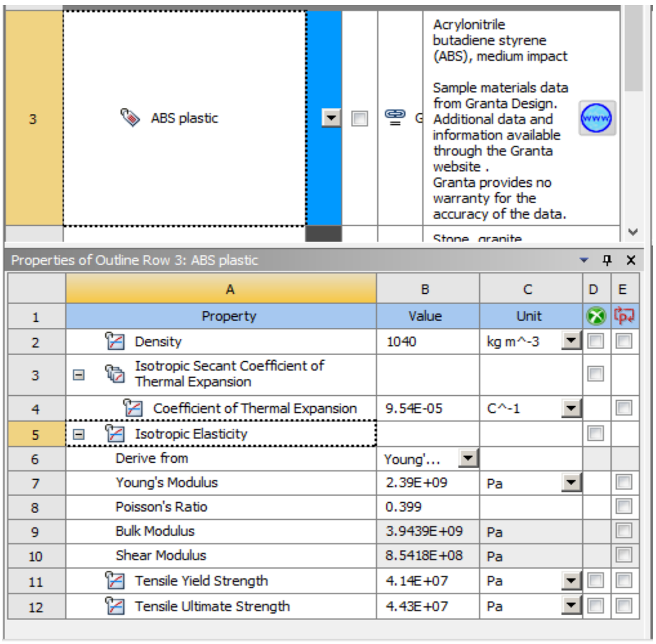


Load at Centre of the Frame



Load at Arm End

Material Properties – ABS Plastic



3	ABS plastic			Acrylonitrile butadiene styrene (ABS), medium impact Sample materials data from Granta Design. Additional data and information available through the Granta website . Granta provides no warranty for the accuracy of the data.

Properties of Outline Row 3: ABS plastic

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	1040	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
4	Coefficient of Thermal Expansion	9.54E-05	C^-1		
5	Isotropic Elasticity				
6	Derive from	Young'...			
7	Young's Modulus	2.39E+09	Pa		
8	Poisson's Ratio	0.399			
9	Bulk Modulus	3.9439E+09	Pa		
10	Shear Modulus	8.5418E+08	Pa		
11	Tensile Yield Strength	4.14E+07	Pa		
12	Tensile Ultimate Strength	4.43E+07	Pa		

Tab.2. ABS Material Properties

Why only ABS?

ABS is 25% lighter than PLA. PLA is string and stiff but ABS is tougher. ABS is more ductile with higher flexural strength and better elongation before breaking. ABS is more suitable for heat resistance as PLA can lose its structural integrity. ABS has glass transition temperature of 105ºC whereas PLA has glass transition temperature of 60ºC. Cost of ABS is also cheaper than PLA and it is readily available everywhere.

Loading Conditions:

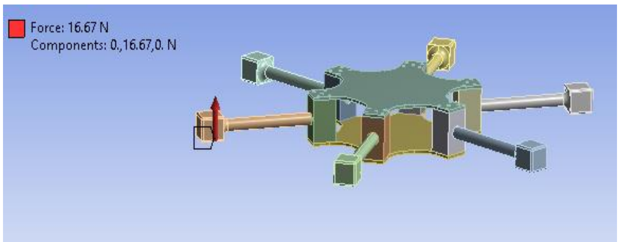


Fig.25. Thrust Force

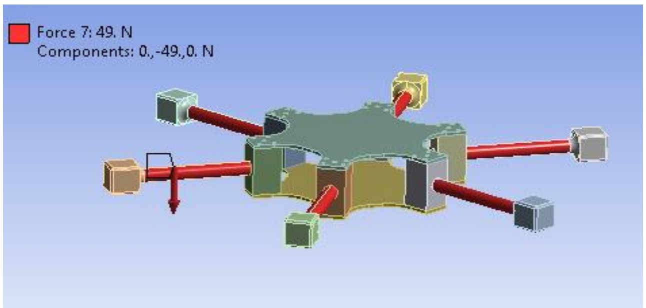


Fig.26. Tank Weight Load and Motor Thrust

Meshing**:**

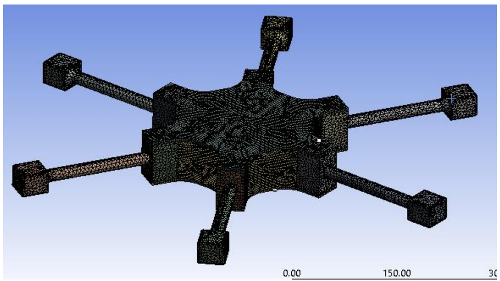


Fig. 27. Meshing

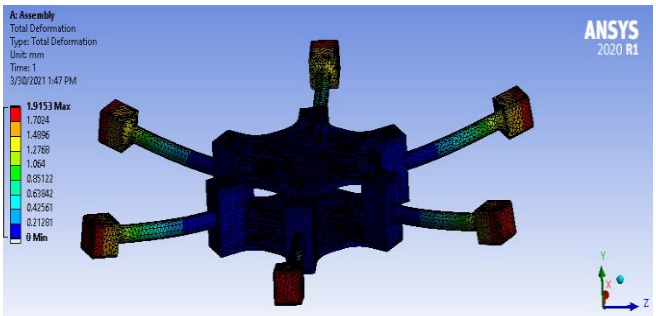


Fig.28. Deformation Before Modification

Total Deformation – 1.92mm

Total Deformation After Modification:

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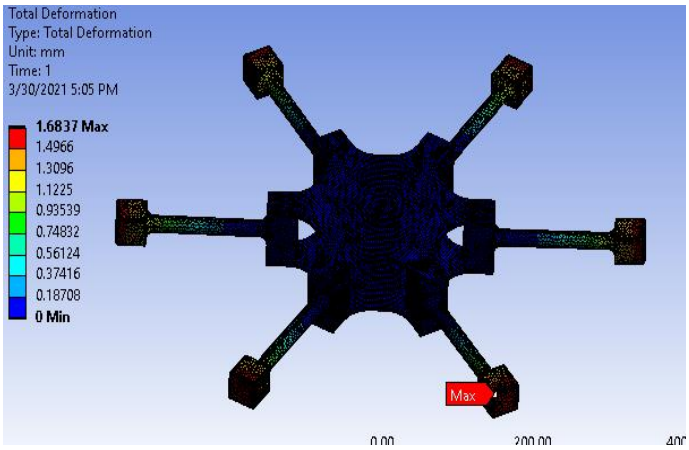

Fig.29. Deformation After Modification

Total Deformation After Modification – 1.68mm

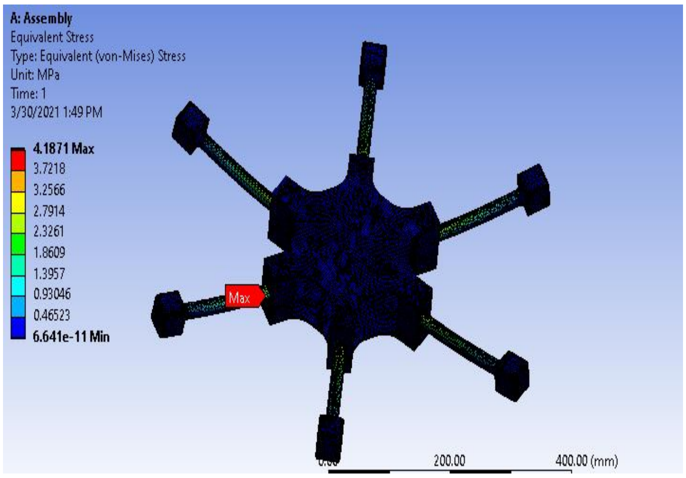

Fig.30. Stress Analysis on Frame Before Modification

Equivalent Stress = 4.18Mpa

Maximum stress value: - 3.1 MPa

Allowable Yield Strength: - 4.14 MPa

Allowable Ultimate Tensile Strength: - 4.43MPa

Equivalent Stress After Modification:

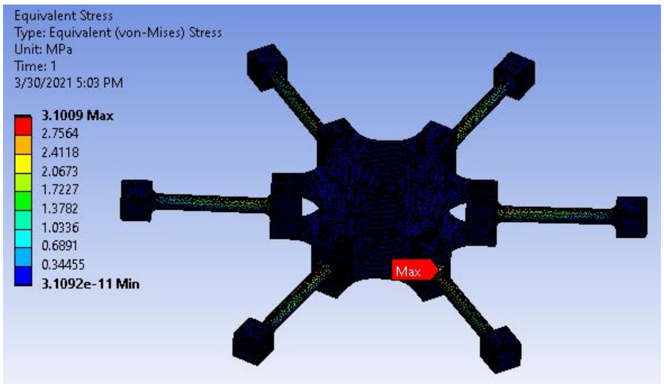

Fig.31. Stress Analysis on Frame After Modification

Equivalent Stress After Modification = 3.1Mpa

Maximum stress value :- 3.1 MPa

Allowable Yield Strength :- 4.14 MPa

Allowable Ultimate Tensile Strength :- 4.43MPa

Maximum induced stress is less than allowable stress for material.

According to the above analysis, we are assured that our design is safe and ready to use. This also concludes that additive manufacturing technique can also be used for manufacturing drones. Additive Manufacturing Technique allows the users to modify the design according to the purpose and help the environment by causing no waste and harm. The cost is also too low compared to other techniques and materials which is a bonus for 3D printing.

Result and Conclusion of Analysis:

1. Total Deformation Value is 1.68 mm at ARM end.
2. Equivalent Stress Value is 3.1 MPa, which is much lower than yield strength & ultimate strength of the deployed material.
3. After drone frame modification, total deformation and equivalent stress have reduced by some amount.

   In conclusion, given drone frame assembly is Safe and Stable for the given loading conditions.

V. Future Scope

1. Weight lifting capacity of the Hexa-Copter can be increased by increasing-

• The number of motors.

• The propeller size.

• Rating of the Motor.

2. Flight time can be increased by increasing the battery capacity.

3. Pesticide carrying capacity can be increased by increasing the size of the tank.

4. Development of Nozzles. (i.e. rotation of nozzles around their axis and different types of nozzles can be used)

5. Stability of the drone can be increased by designing Octacopter Frame.

6. If weatherproofing is done then it can be used in any season.

7. Monitoring of health of the crops can be done by using camera mounted on the drone.

VI. CONCLUSION

In this paper we have described a design of the drone using many other components which will be useful for the flight. This design demonstrates that additive manufacturing

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technique can also be adopted for small scale purpose. This paper also clarifies the doubts regarding platform to be used for own suitable purpose.

NOMENCLATURE

UAV	Unmanned Aerial Vehicle
BLDC	Brushless Direct Current
ESC	Electronic Speed Controller
FCB	Flight Controller Board
PDB	Power Distribution Board
RF	Radio Frequency
PLA	Polylactic Acid
KV	KiloVolt
mAh	Milli Ampere Hour
GPS	Global Positioning System
gf	Grams of Force
kg	Kilogram
CAD	Computer Aided Design/Drawing
DC	Direct Current
AC	Alternating Current
PCB	Printed Circuit Board
RAM	Random Access Memory
FPV	First-Persion View
RC	Remote Controlled
CW	Clockwise
CCW	Counter-Clockwise

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