

Modelling of Commonly Equipping UAV Based Cutting tool/ Payload Mount for Hexacopter

Submitted in partial fulfillment of the requirements for the
award of Bachelor of Engineering Degree in Mechatronics

by

Kaushik R (39090017)

Pugazh Sivakumar (39090039)



**DEPARTMENT OF MECHATRONICS
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

MAY - 2023

Modelling of Commonly Equipping UAV Based Cutting tool/ Payload Mount for Hexacopter

Submitted in partial fulfillment of the requirements for the
award of Bachelor of Engineering Degree in Mechatronics

by

Kaushik R (39090017)

Pugazh Sivakumar (39090039)



**DEPARTMENT OF MECHATRONICS
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

MAY - 2023



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with “A” grade by NAAC | 12B Status by UGC | Approved by AICTE
Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600 119
www.sathyabama.ac.in

DEPARTMENT OF MECHATRONICS

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Kaushik R (39090017)**, **Pugazh Sivakumar (39090039)** who have done the project work entitled “**Modelling of Commonly Equipping UAV Based Cutting tool/ Payload Mount for Hexacopter**” under oursupervision from June 2022 to May 2023.

Internal Guide

Dr. M. Sangeetha M.E., Ph.D.

Head of the Department

Dr. S. Prakash M.E., Ph.D.

Submitted for Viva Voce examination held on May 2023

Internal Examiner

External Examiner

DECLARATION

We, **Kaushik R (39090017)** and **Pugazh Sivakumar (39090039)**, hereby declare that the Project Report entitled “**Modelling of Commonly Equipping UAV Based Cutting tool/ Payload Mount for Hexacopter**” done by us under the guidance of **Dr. M. Sangeetha, M.E., Ph.D.** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.

1. 

2. 

DATE: May 2023

PLACE: Chennai, Tamil Nadu

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of SATHYABAMA for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to Dr. S. Prakash M.E., Ph.D., Dean and Head of Department of Mechatronics, School of Mechanical Engineering for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide Dr. M. Sangeetha M.E., Ph.D., Associate Professor, Department of Mechatronics, School of Mechanical Engineering for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Mechatronics who were helpful in many ways for the completion of the project.

I would also wish to thank my parents for all the tireless efforts they made for making me able to do what I do today.

ABSTRACT

Drones have become extremely prevalent in several different sectors, including agriculture, forestry, and landscaping. Drones limited capacity for performing precise cutting duties, however, is one of their limitations. A novel payload mount for hexacopter drones is being developed to enhance their payload capacity and adaptability in order to overcome this limitation. A variety of payloads, including cameras, sensors, or even tiny packages, can be mounted on a drone's underside using the standard payload mount. The mount can be adjusted and set up to support payloads of different sizes and shapes, making it perfect for a wide range of uses. A two-blade cutting equipment that can be attached to the drone has been developed, allowing it to make precise cuts in challenging places. The cutting tool has two keen, premium blades that are made to last and are intended to cut a variety of materials, including plastic and wood, with clear, accurate cuts by cutting inward. The instrument is compact, lightweight, and simple to attach to a drone's underside. The tool has adjustable design enables it to be set up to perform cutting jobs at various lengths and speed. The drone can carry out precise cutting jobs in difficult-to-reach places, such as on tree branches and in vegetation, with the help of the cutting tool and the developed payload mount. The system is designed to lower initial costs, is simple to install, and can be adjusted to suit different drone models within that segment.

TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	v
	LIST OF FIGURES	ix
	LIST OF TABLES	xi
	LIST OF ABBREVIATIONS	xii
1	INTRODUCTION	1
2	LITERATURE SURVEY	11
	2.1 APPLE HARVESTING DRONES BY TEVEL AEROBOTICS TECHNOLOGIES	11
	2.2 FLY - COCOBOT FOR HARVESTING COCONUT BY ICAR - CCARI & GOA UNIVERSITY 2022	11
	2.3 SMART COCONUT AND PALM CUTTING DRONE 2021	12
3	AIM AND SCOPE	13
	3.1 AIM	13
	3.2 OBJECTIVE	13
	3.3 PROBLEM DEFINITION	13
4	MATERIALS AND METHODS	15
	4.1 DRONE FRAME	15
	4.2 DIRECT CURRENT BRUSHLESS (BLDC) MOTORS	16
	4.2.1 KV Rating Voltage KV Connection	17
	4.3 ANTENNA	18

4.3.1 Front person view (FPV) flying antenna	18
4.3.2 Linear Antenna	18
4.3.3 Radiation Plots/Charts	19
4.4 ELECTRONIC SPEED CONTROLLERS (ESCS)	19
4.5 FLIGHT CONTROLLER BOARDS	20
4.6 PROPELLERS	21
4.7 RADIO TRANSMITTER	22
4.8 RADIO RECEIVER	23
4.9 FPV CAMERA	24
4.10 GROUND STATION	24
4.11 LANDING GEAR	25
4.12 CUTTING TOOL FRAME	25
4.13 RS-555 MOTOR	26
4.14 DIFFERENTIAL GEARBOX	27
4.14.1 Bevel gear	27
4.15 Common Payload Mount	28
4.15.1 Material Selection: ABS Plastic	29
5 RESULTS AND DISCUSSION	30
5.1 INITIAL TOOL FRAME PROTOTYPE	30
5.2 COMMON PAYLOAD MOUNT	31
5.2.1 Mesh Information - Details	32
5.2.2 Analysis of Loads and Fixtures for Common Payload Mount	33
5.2.3 Study Results of Common Payload Mount	34
5.3 SECONDARY TOOL FRAME DESIGN	36

5.3.1 Mesh Information - Details	37
5.3.2 Analysis of Loads and Fixtures for Secondary Cutting Tool Frame design	37
5.3.3 Study Results of Secondary Cutting Tool Frame design	39
5.4 CUTTING TOOL FRAME	40
5.4.1 Mesh Information - Details	41
5.4.2 Analysis of Loads and Fixtures for Cutting Tool Frame	41
5.5 Study Results of Cutting Tool Frame	43
6 SUMMARY AND CONCLUSION	46
REFERENCES	47
ANNEXURE	52

LIST OF FIGURES

FIGURE No	TITLE	PAGE No.
4.1	S550 Hexacopter Frame	16
4.2	Radiation Charts	19
4.3	Electronic Speed Controller	20
4.4	Block diagram of Flight controller for UAV	21
4.5	Propellers	22
4.6	Radio Transmitter for UAV	23
4.7	Radio Receiver for UAV	23
4.8	FPV Camera for UAV	24
4.9	Designed Cutting Tool	26
4.10	RS-555 Motor for Cutting Tool	26
4.11	Differential Gear Box for Cutting tool	27
4.12	Bevel Gear used Differential gear box of Cutting tool	28
4.13	Designed Common Payload Mount	29
5.1	Fabricated Cutting Tool for UAV	30
5.2	Meshed model of Common payload mount	31
5.3	Loads and Fixtures of Common Payload Mount	33
5.4	(a) Stress Plot of Common Payload Mount	34
	(b) Displacement Plot of Common Payload Mount	35
	(c) Strain Plot of Common Payload Mount	35
5.5	Model of Secondary cutting tool frame design	36
5.6	Loads and Fixtures of Secondary Cutting Tool Frame design	37
5.7	(a) Stress Plot of Secondary Cutting Tool Frame	39
	(b) Displacement Plot of Secondary Cutting Tool Frame	39
	(c) Strain Plot of Secondary Cutting Tool	39

	Frame	
5.8	Meshed model of Cutting tool frame	40
5.9	Loads and Fixtures of Cutting Tool Frame	41
5.10	(a) Stress Plot of Cutting Tool Frame	43
	(b) Displacement Plot of Cutting Tool Frame	43
	(c) Strain Plot of Cutting Tool Frame	43
5.11	CAD Model of Improvised Cutting Tool using SOLIDWORKS Tool Frame design	44
5.12	(a) Top view of Cutting tool	44
	(b) Bottom view of Cutting tool	
5.13	Side view of Cutting Tool	45
5.14	Final Cutting Tool Design	45

LIST OF TABLES

TABLE No	TITLE	PAGE No.
4.1	Analogue Signals of Radio Transmitter for UAV	22
4.2	Properties of ABS Plastic	29
5.1	Mesh details for Common Payload Mount	32
5.2	Weight estimation of the designed models	33
5.3	Resultant Forces for Fixtures of Common Payload Mount	33
5.4	Resultant Forces and Moment for Fixtures of Common Payload Mount	34
5.5	Stress analysis, Displacement and Strain of Common Payload Mount	35
5.6	Mesh details for secondary tool frame design	37
5.7	Resultant Forces for Fixtures of Cutting Tool Frame	37
5.8	Resultant Forces and Moment for Loads of Cutting Tool Frame	38
5.9	Stress analysis, Displacement and Strain of Secondary Cutting Tool Frame design	40
5.10	Mesh details for Cutting Tool Frame	41
5.11	Resultant Forces for Fixtures of Cutting Tool Frame	42
5.12	Resultant Forces and Moment for Fixtures of Cutting Tool Frame	42
5.13	Stress analysis, Displacement and Strain of cutting tool frame	44

LIST OF ABBREVIATIONS

UAV	Unmanned Aerial Vehicle
FPV	First Person View
ESC	Electronic Speed Controller
BLDC	BrushLess Direct Current motor
ABS	Acrylonitrile Butadiene Styrene

CHAPTER – 1

INTRODUCTION

Agriculture, India's primary industry, serves as the country's primary economic base. Over the past few decades, there has been a rapid advancement in robotics technology. The use of a variety of intelligent machines and tools that can streamline a variety of tasks in an industrial environment is becoming increasingly common. Coconuts are grown extensively in India, making the nation the third-largest producer of coconuts in the world. Every one of the old approaches to gathering coconuts involved some level of physical exertion; even when a tool was developed for the purpose, the task still required the participation of a person. The protection of the worker, and therefore a rise in the cost of labor as a result of that protection, is currently the primary concern of the owners of coconut and palm farms.

Tethered unmanned aerial vehicles (UAVs) provide several advantages over untethered UAVs, including the ability to do vertical takeoffs and flexible flight control, as well as the elimination of the energy limits that are imposed by the limited A cable system has the benefit of nearly infinite flight duration, which enables vehicles to complete longer missions or carry greater payloads. This is one of the many reasons why a cable system is desirable. Because of these features, tethered unmanned aerial vehicles (UAVs) are beneficial for applications in which endurance is an essential component. Some examples of these applications include continual surveillance, ad hoc networks that are transitory, traffic and crowd control, and monitoring. In recent years, wire systems that are used to supply drones have garnered an increasing amount of interest. In the process of analyzing the air quality or developing monitoring systems, such buildings are frequently utilized. The most fundamental dissimilarity between this system and traditional battery solutions is that, with the former, power to the drone is delivered through the use of a cable that is physically attached to the Ground Power Unit GPU; with the latter, the wire is simply connected to the GPU. [Montanya, J., Lopez, J.A, et.al, 2018]. A structure of this kind can either be positioned directly on the ground or on the board of a transport vehicle, which will then function as the primary unit. In this scenario, the systems of

AC/DC converters (placed on the ground) and DC/DC converters (on board of the drone) are applied in the supply path of the flying system [Xu, Z.W., Zhang, Z., et.al, Q 2019]. This is done in order to supply the drone from the ground station. After that, electrical power is sent to the drone, and the distribution and management of the power that is used by the local electronics that are installed on board the drone are carried out. During the process of summarizing this publication, [Amrita Vishwa Vidyapeetham 2021] asserts that a system is built for a drone aircraft machine that can chop an object without scaling the tree. The system consists of a machine unit, an outboard motor, propellers, a propeller controller, a battery, or an electricity regulating unit, a remote camera equipped with a global positioning system, a transceiver, and a laser cutting module consisting of a laser gun and a laser controller. a wireless communication module that allows for effective transmission and receiving of control signals between the ground station and the machine unit. a processing unit for the purpose of programming the essential features of the machine unit to enhance operation more quickly and efficiently, as well as a processing unit for the purpose of regulating the actuators of the robotic arm unit to support the operator.

Tethered unmanned aerial vehicles (UAVs) have made it feasible to set up temporary communication towers, conduct low-altitude satellite monitoring, conduct border patrols, live stream events, and a great deal of other things. In addition to the flexibility to cut the tether in case additional range is needed, there is a necessity for an unrestricted amount of flying duration and reliability. This is a requirement for the system. [Maurizio Di Paolo Emilio, January 15, 2021] The corporation has been able to increase payloads, flight times, and safety by optimising their most recent tethered drone systems thanks to the most recent advancements in the field of power electronics [Maurizio Di Paolo Emilio, January 15, 2021]. [Maurizio Di Paolo Emilio] [Maurizio Di Paolo Emilio, January 15, 2021]. During operations that last for an extended period of time, tethered quadcopters are used because the necessary power to the gadget is supplied through the tether by an external power source that is located on the ground. [Karan P. Jain, Prasanth Kotaru, et.al 2022]

Tethered drones offer a variety of benefits that untethered models do not, including a higher data transmission rate, the possibility that their batteries can be

continuously charged, better levels of control, and increased levels of safety. Tethered drones also offer a number of other advantages. Tethered drones face a number of challenges, one of the most critical of which being the physical configuration of the tether wire itself. It must be able to deliver power to the rotor drive motors, control electronics, and on-board batteries, in addition to being powerful enough to hold the drone and lightweight enough to prevent it from becoming a safety hazard when the tether is withdrawn to allow for free flight. Because the drone is subjected to a lighter burden as a result of the use of a lightweight cable, the operating efficiency of the drone is able to improve, and it will be able to fly for longer periods of time.

When the aerial vehicle needs additional length of free transmission line to move to its desired target or when there is an excessive amount of cable length that needs to be retracted, the foundation of the Power-over-Tether system is designed to function on its own, independently determining when there is a need to retract an excessive amount of cable length, and then carrying out the appropriate actions in response to those situations. [Anthony Tzes and Christos Papachristos, along with other researchers, 2015]

The application of remotely operated cutting is increasing in sectors like agriculture and manufacturing, with the requirement of efficient tools for the mentioned task. However, the current drone-based cutting tools available on the market have limitations in terms of precision and efficiency. Therefore, this proposes a novel dual-blade cutting tool for drones that offers a new approach to precision cutting. This cutting tool utilizes two blades that operate in a synchronized manner of inward rotational direction, providing a more efficient and precise cutting action compared to existing single-blade cutting tools. The proposed dual-blade cutting tool has the potential to significantly improve the accuracy and efficiency of drone-based cutting tasks, providing a new level of precision and flexibility for agricultural and industrial applications. The tool frame of the cutting tool attaches with the drone or UAVs (Unmanned Aerial Vehicles) at the bottom side as a payload. The proposed common payload mount and the dual-blade cutting tool will not only increase the efficiency and functionality of drone systems but also have potential for significant economic and social impact.

Ground stations for unmanned aerial vehicles (UAVs) are land-based communications and command systems that are largely utilized for directly piloting and communicating with a UAV and its crew. Ground stations for UAVs are also known as UAV control stations. Another name for ground stations is ground control stations for unmanned aerial vehicles (UAVs). These ground-based control systems typically make it feasible to pilot the aircraft while simultaneously transmitting live video and data to and from the drone. Ground Operate Stations, also known as GCS, are hardware and software setups that are based on the ground and allow operators of unmanned aerial vehicles (UAVs) to communicate with and control an UAV and its payloads. Ground Control Stations are also abbreviated as GCS. This can be achieved by configuring the parameters for remote monitoring or by permitting direct control of the UAV. Both of these options are available. GCS subsystems comprise everything from the flight controls console for an unmanned aerial vehicle (UAV) through the operating sticks, the payload monitoring and control panel, and the communication systems with other operators and commanders. Components of the supply system include an electric wire, a system of voltage converters that are connected to a portable generator, and a battery system that acts as a local energy storage facility. All of these elements are connected to one another by an electric wire. [Karan P. Jain, Prasanth Kotaru, et.al 2022]

The flight controller is sometimes referred to as the "brain" of the drone because of its role in managing the Electronic Speed Controllers (ESCs) and motors that are integrated inside it. A board is a piece of electrical circuitry that may house components such as sensors, CPUs, communication protocols, and transmitter pins. This piece of electrical circuitry is known as a board. A flight controller has control over every aspect of the drone that it is attached to. The revolutions per minute (RPM) of the motors are changed as a result of this adjustment. The open-source flight controller hardware project includes all of the sensors that are required for flight control out of the box. It possesses a gyroscope, a compass, a magnetometer, a three-axis accelerometer, and a three-axis accelerometer in addition to a central processor unit and random-access memory. The flight controller, with the assistance of the data collected by the sensors, is responsible for determining the desired rotations per minute (rpm) for each of the quadrotor's

rotors. The flight controller relays this planned speed to the Electronic Speed Controllers (ESCs), which in turn translate it into a signal that the motors are able to understand. The Paparazzi flight controller holds the distinction of being the earliest and oldest open-source drone hardware and software project. Development of this controller began in 2003 at the Ecole Nationale de l'Aviation Civil (ENAC) UAV Lab. The Paparazzi Chimera autopilot was made available to the general public by ENAC Lab in March of 2017. Ebeid and his colleagues have only lately made public a study that is exhaustive in its coverage of open-source flight controllers. Drones gain the capacity to fly autonomously thanks to a programme called an autopilot that is loaded onto the device. On the other hand, unmanned aerial vehicles, sometimes known as drones, are controlled remotely with the use of a controller. [VememaKangunde, Rodrigo S. Jamisola Jr., et.al 2021]

As a result of their capacity to cut and etch onto flat materials, laser cutters find most of their applications in the hands of engineers, designers, and artists. Tools for prototyping and manufacturing, laser cutters are becoming increasingly popular. Laser cutters make use of a focused, narrow laser beam to pierce and cut through materials in order to carve out patterns and geometries that have been determined by the designers. These patterns and geometries can be anything from intricate to simple. The cutting process is a thermal, non-contact, and heavily automated procedure. Because of its non-contact nature, the cutting process is suitable for creating components in large quantities with outstanding dimensional precision and surface polish in a range of industrial industries. According to the research of M. Madic et al. (2012), it is possible to cause material to instantly melt and evaporate by focusing a laser beam with a high-power density on a particular location. [M. Madic, et.al 2012]

The slider-crank mechanism is a specific design of a four-bar linkage that can transform linear motion into rotational motion or vice versa. It does this by sliding a crank along a linear track. A concentric slider-crank mechanism is the fundamental layout that is frequently applied in internal combustion engines. This layout is typically the most common one. The capabilities of this system are restricted due to the fact that there is only one degree of freedom available. The action of cutting is carried out by a fixed pair of parallel blades in front of the slider in the dynamic

analysis of the slider-crank system [Mahmoud W. A., Elkaoud N. S., et.al 2021]. [Mahmoud W. A., Elkaoud N. S., et.al 2021]. [Mahmoud W. A., Elkaoud N. S., et.al 2021] The use of tiny scale slider crank mechanisms can be found in a wide variety of different sophisticated applications. In many different contexts, the key measure of success in terms of performance is determined by how accurately and precisely these systems carry out their respective roles. The input and output of the mechanism are the primary factors that are used to describe its features, and as a result, its capacities to meet certain application needs, according to "Mohamed Damir, Engy Rashed, and Ahmad Elkhatib 2018," which states that the input and output of the mechanism are the primary factors that are used to describe its features.

First-person view, often known as FPV, is essential for piloting a quadcopter through the use of a live video downlink, which is typically displayed on a portable monitor. In order to achieve FPV, the device in question must be outfitted with a compact video camera and an analogue video transmitter. First person view, also known as remote person view (RPV) or video piloting, is a method that is used to guide a radio-controlled vehicle from the point of view of the pilot. FPV is frequently abbreviated as "first person view." This approach is applied in radio-controlled aircraft the vast majority of the time. It's possible that the camera on the drone can function as both a transmitter and a receiver, enabling it to send the image it takes to the other device so that it can be viewed there. Vision sensors that are mounted on drones are more extendable and versatile, and they provide more comprehensive surveillance coverage. Drones have been increasingly popular in recent years. [Naqqash Dilshad, JaeYoung Hwang, and a number of other people in 2020]. The image is transferred from the receiver to the device that is serving as the display, which in this case is an Android smartphone. When shopping for a camera, the field of view that the camera offers and the focal length of its lens are the two aspects that are most critical to take into consideration. [Vijayakumar, P. Kiruba, et.al 2018]

Electronic speed controllers, often known as ESCs, are devices that give drone flight controllers the ability to regulate and adjust the speed of the electric motors that power the aircraft. Electronic speed controllers are also commonly referred to as ESCs. It is anticipated that they will have a high rotation speed, be simple to

regulate, have a high efficiency, and have a high density. Since the manufacturer of the drone sought to keep the weight and size of the device to a minimum, there is not a sensor on the device that can determine the speed it is travelling at. The electronic speed controller (ESC) reacts to a signal sent from the flight controller by modifying the voltage that is delivered to the motor in order to create the effect of changing the rpm of the propeller. This is done in response to the signal sent from the flight controller. An electronic speed controller (ESC) for a brushless DC motor is able to manage the spinning of the motor by selectively delivering current to the motor's phases. This allows the speed of the motor to be controlled. When current is passed through the stator windings, the flow of electric charge interacts with the magnetic field of the rotor. This interaction results in a force being exerted on the rotor, which can cause it to rotate. Even in the absence of feedback from the controlled device, a BLDC motor can be controlled by the controller in the same manner as a stepper motor. If, on the other hand, the location of the rotor is known, the controller will be able to identify which windings are the most effective to activate at any given moment in order to achieve the desired angular velocity, speed, and torque in the most efficient manner possible. In a good number of the BLDC motors that are now available on the market, the position of the rotor cannot be directly sensed by using direct sensing. On the other hand, if one looks at the back electromotive force, one is able to view this information (back-EMF). Back-EMF and current within a phase winding need to be in phase for the purpose of optimizing the amount of positive torque generated while simultaneously minimizing the amount of negative torque, as stated by Bum-Su Jun, Yoon-Sang Kook, Joon-Sung Park, and Chung-Yuen Won (2018). This is necessary for the purpose of optimizing the amount of positive torque generated. [Bum-Su Jun, Yoon-Sang Kook, et.al 2018]

A Brushless DC Electric Motor, also referred to as a BLDC Electric Motor, is a specific kind of electric motor that is commutated electronically as opposed to using brushes in the way that regular DC electric motors are. A source of direct current voltage is used to power this particular kind of electric motor. In today's world, brushless direct current (BLDC) motors are more prevalent than traditional direct current (DC) motors; nonetheless, the development of these sorts of motors has only been theoretically possible since the 1960s, when semiconductor circuits were

first developed. [Zhang, S.; Luo, F.L. 2009] Brushless direct current (BLDC) motors have gained appeal in a variety of applications, one of which being unmanned aerial vehicles. [BLDC] stands for brushless direct current. (UAVs). Brushless DC motors, also known as BLDC motors, are used often in a wide variety of applications due to the high levels of efficiency they offer as well as the remarkable controllability they provide. The brushless direct current (BLDC) motor utilizes power in a manner that is more productive than that of other types of motors. The most important advantages of brushless direct current (BLDC) motors are their high dynamic response, high power density, high speed and efficiency, compact structure, long life, low cost, their light weight per power unit, and their low maintenance requirements due to the absence of carbon brushes. Other advantages include their light weight per power unit and their compact structure. In addition, the lifespan of BLDC motors is significantly less than that of other types of motors. The maximum voltage that can be applied, the amount of electrical power that is readily accessible, and the number of appropriate electronic speed controllers are all factors that have the potential to restrict the use of BLDC motors. [Park, J.S.; Lee 2017] found that the most common form of BLDC motors have voltage levels that fall somewhere within the range of 6 to 24 V. Nevertheless, there is a movement toward higher voltage levels, and as a result, there is a trend toward reducing the current while still keeping the required level of power.

It has been demonstrated through research [S. Sakunthala, R. Kiranmayi, and P. N. Mandadi 2017] that BLDC motors have a high efficiency; however, the machine's durability is significantly worse when compared to that of induction motors. Because of the common usage of BLDC motors in applications that include dynamic motion, reliability control strategies of drive systems are an absolute necessity. Utilizing fault-tolerant control (FTC), electromagnetic interference control (EMI), and acoustic noise reduction are some examples of reliability control strategies that can be used to improve the practicability of motor drive systems in dynamic applications. Other reliability control strategies include electromagnetic interference control (EMI) and acoustic noise reduction. Brushless motors are ideal for use in drones because they do not have any brushes that could become worn out over time. Brushes are one of the most common causes of motor failure. The lifespan of brushless motors is consequently increased as a consequence of this factor. Brushless motors are

utilized in more professional drones that require power as well as reliability. This is due to the fact that brushless motors are not only more powerful all around, but they are also more potent in relation to their size.

A radio transmitter for an unmanned aerial vehicle (UAV) is a piece of electronic equipment that, by way of radio waves, communicates commands to a radio receiver that is connected to the unmanned aerial vehicle (drone) that is being remotely controlled. These directives are sent wirelessly over a certain radio frequency that has been set in advance. To put it another way, it is the part of the multirotor that receives instructions from the pilot and translates those instructions into motions that are carried out by the multirotor. The orders are transmitted over the channels by a First Person View (FPV) Drone Radio Transmitter. There are several channels, and each one represents a different action that is being relayed to the aeroplane. [Andrew Kanzler 2020]

A Radio Receiver is a device that has the capability of receiving commands from a Radio Transmitter, evaluating the signal that is transmitted by the Radio Receiver to the flight controller, and turning those commands into specific actions that are used to operate the aircraft. The Radio Receiver and the Radio Transmitter absolutely need to be compatible with one another in order for this to be possible. In addition to this, the frequencies that are utilized by the Rx and the Tx must be equal to one another. A radio receiver that runs at a different frequency, for instance, is incompatible with any radio transmitter that operates at 2.4 gigahertz. Therefore, when shopping for a transmitter and receiver for a drone, it is essential to make certain that the two devices are compatible with one another in terms of the frequency as well as the other criteria. This is because the drone will not function properly if the transmitter and receiver cannot communicate with one another. In addition to this, it is necessary for both of the components to possess the requisite dimensions as well as the functionality in order to complete the requirements that have been established. [Fernando G. Tinetti, et.al 2019].

A Linear antenna is the most basic type of antenna and works great for long ranges. Linear polarized signals oscillate either horizontally or vertically in one plane while

travelling through the air. The radiation pattern (i.e signal) is primarily focused on a single plane. For these antennas, the transmitter and receiver antennas should typically be 90 degrees to one another, resulting in the largest amount of signal overlap. Both transmitting and receiving antennas should be aligned to ensure maximum radiation overlap. Linear antennas provide adequate coverage for beginners, inexpensive to purchase. Antenna orientations must be aligned to one another for optimum reception. Does not withstand crashes very well

Unlike the linear antenna, circular polarized antenna signals are constantly rotating and provide more uniform coverage. It's important to note that the signal can rotate in two possible directions, Right Hand Circular Polarization or Left Hand Circular Polarization. A LHCP paired with a RHCP antenna will reject each other's signal so the direction must match the transmitter and receiver. Circular polarized antennas provide excellent coverage regardless of their relative orientation, withstands crashes very well. Wire clovers bend easily so consider purchasing models that are covered and protected, shorter range and great for FPV flight.

CHAPTER – 2

LITERATURE SURVEY

2.1 Apple Harvesting Drones by Tevel Aerobotics Technologies

Tevel Aerobotics, a young company based in Israel, says that. This is an emerging option that takes the shape of self-piloting aerial drones that are able to do the task. Each of the FAR (Flying Autonomous Robots) units in the system consists of a wheeled base vehicle that moves up and down the rows of fruit trees, as well as four quadcopter UAVs that are electrically tethered to that vehicle; the vehicle serves as the power source for the drones. The FAR units are called "Flying Autonomous Robots." According to reports, the drones are able to discern between specific fruits and other objects by utilizing the cameras aboard as well as computer vision algorithms based on artificial intelligence. They are also able to evaluate the size of each fruit as well as the degree to which it is ripe, and they are able to plot a flight route that avoids collisions as it makes its way toward the fruits that have been determined to be ready for picking.

Following this, the drones make use of a built-in grasper arm, in conjunction with specialized algorithms for stability, in order to actually collect the fruits, which they subsequently place on the deck of the host vehicle. As long as the center vehicle has access to an electric source, they are able to do so at any time of the day or night.

2.2 Fly - Cocobot for Harvesting Coconut by ICAR - CCARI & Goa University 2022

The Fly-Cocobot is an innovative piece of technology that combines the functions of many standard machines to provide a stunning utility. According to the ICAR-CCARI, the functional beauty of the gadget enables it to fly to the top of the palm and attach itself to the trunk using grasping arms. This is possible since the device is so well designed. After that, a second set of arms extends in order to cut the bunch of yields in accordance with the instructions provided on the visual display of the remote control. The entire process may be carried out at a safe

distance from the dangerous area without running the risk of one of the participants losing their lives. The apparatus is designed to generate between 12 and 15 fruits in a productive manner.

2.3 Smart Coconut and Palm Cutting Drone 2021

This intelligent drone was developed using the quadcopter flight principle as its foundation. The frame of the quadcopter is composed of four rotors, and the BLDC motor that drives it provides the forward motion. In parallel, the cutting process is driven by a DC motor that is coupled with a slider crank mechanism. This mechanism is responsible for the motion of the slider. A cutting tool made of stainless steel (SS 304) and a sliding link are attached to one another. When the crank is rotated by the motor's actuation, the slider link will cause the cutting tool to reciprocate. The transmitter had the ability to control not only the rotors of the quadcopter but also the auxiliary DC motor (F6-i6). A camera is attached to the front side of the drone framework, and it is used to view whatever is in front of it.

CHAPTER – 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 Aim

The aim of this project is to develop a model for a dual blade cutting tool and a common payload mount for hexacopter, that can be used in conjunction with UAVs for efficient and precise aerial cutting operations.

3.2 Objective

- To design and develop a tethered UAV system.
- To make a movable arm attached to the UAV, that helps mounting the cutting tool to stem of the fruit.
- Let the operator/user have a better control over the selection of the ice apple to be harvested
- To provide the operator/user live footage, through a wireless medium.
- By this project we are planning to reduce the requirement of skilled manpower and risk of human lives by making the ice apple harvesting process more safer.
- Creating an economic and cost-effective option for the palm tree owners, in order to harvest.

3.3 Problem Definition

Cutting operations at heights are essential in various industries, such as construction, forestry, and maintenance of infrastructure. However, performing such operations manually can be dangerous and time-consuming, particularly in challenging terrains and adverse weather conditions. The use of traditional cutting tools, such as handheld saws, increases the risk of accidents, injury, and property damage.

To mitigate these risks, there has been an increasing interest in using Unmanned Aerial Vehicles (UAVs) for aerial cutting operations. However, the current UAV-based cutting tools have limitations in terms of their efficiency and precision. Many

of these tools have a single blade, which can be inefficient in cutting thicker materials or multiple branches simultaneously. Furthermore, the existing payload mounts for hexacopters lack versatility, making it challenging to swap between different tools, reducing the overall effectiveness of the system.

Therefore, there is a need to develop an improved cutting tool and payload mount system for UAVs, specifically a dual-blade cutting tool and a versatile payload mount for hexacopters. Such a system could provide an efficient and precise solution to the challenges associated with manual cutting operations at heights. It would also improve worker safety, reduce the risk of accidents, and increase productivity.

The main challenge in developing such a system is to design a tool that can efficiently and accurately cut a wide range of materials, while also being lightweight and durable enough to be mounted on a hexacopter. Additionally, the payload mount must be versatile and easily interchangeable with other tools, enabling operators to perform different tasks efficiently. The project aims to address these challenges by developing a comprehensive model for a UAV-based dual-blade cutting tool and a common payload mount for hexacopters.

CHAPTER – 4

MATERIALS AND METHODS

4.1 Drone Frame:

There are three types of quadcopters - Plus shape quadcopter, Cross shape quadcopter, and H shape quadcopter. All the shapes are stable in forward flight, but quadcopter requires a yaw control input in forward flight. Corresponding to quadcopters, hexacopters are unmanned multirotor aircraft that use six rotors arranged in a circle around the main frame to create the lifting and propulsion force necessary to fly. The number of rotors separates a quadcopter from a hexacopter, and the additional rotors on a hexacopter give the aircraft more lifting power and stability. Hexacopters can fly faster and at higher altitudes than quadcopters. The frame composites should offer high strength, low density, and high stiffness to make light, rigid drone frames. Carbon fiber is a type of polymer that is composed of atoms of carbon. During the production process, these atoms are bonded together with crystals and measure between five and ten micrometers (0.0005 to 0.010 mm) in diameter. The fibers are woven into single sheets that are flexible and can have either a plain or twill weave pattern. When used in the production of hardware, it is typically molded by being layered over a mold and then being pressed into the desired shape. Because it may be shaped without any underlying structural support, it offers an exceptionally high degree of adaptability. They are easy to process and have good features such as low density, resistance to high temperatures, resistance to corrosion and friction, electrical and thermal conductivity, electromagnetic shielding, and electrical and thermal conductivity. When compared to other types of metal sheets, they are 31.5% lighter. The benefits of using carbon fiber in the design of products are readily apparent. When it is in its finished form, carbon fiber can be up to ten times more powerful than steel and twice as stiff. But perhaps most significantly, it weighs around one-quarter as much as steel does. Stabilizing, carbonizing, surface treatment, and sizing are the four processes that make up the manufacturing process for carbon fiber. In order to stabilize the fibers, they are subjected to temperatures of up to 590 degrees Fahrenheit for a period of time ranging from 30 to 120 minutes. During this time, the fibers will begin to attract oxygen molecules, and their existing bonding patterns will be changed in order to

produce a foundation that is stronger and more stable upon which to build. After the fibers have been stabilized, they are subjected to heating at extremely high temperatures, which can range anywhere from 1,830 to 5,500 degrees Fahrenheit. The precise temperature has a direct influence on the characteristics of the carbon product that is produced at the end. Carbon that has been heated to temperatures towards the lower end of the range has a tendency to be stronger than carbon that has been heated to temperatures towards the upper end of the range, which generally permits more elasticity. A commonly used hexacopter frame is shown below in fig 4.1.

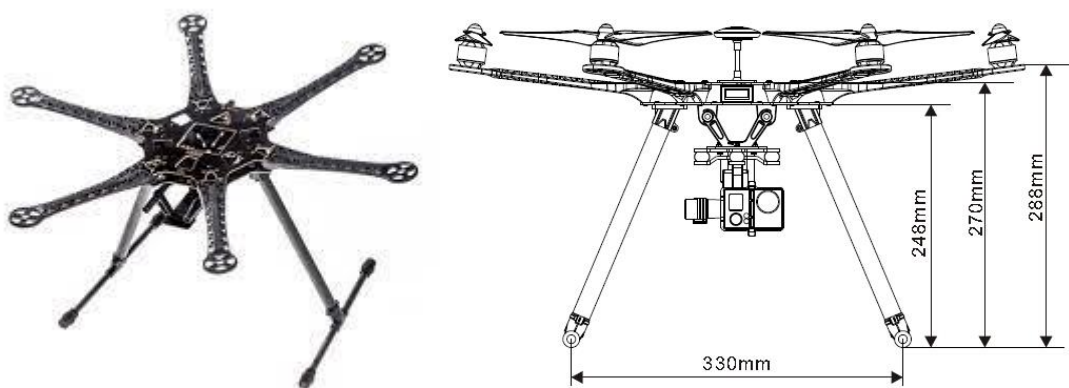


Fig 4.1: S550 Hexacopter Frame

4.2 Direct Current Brushless (BLDC) Motors:

Bearings, coils, magnets, and stator and end caps connected by bearings are all components that are found in brushless motors. Electromagnetism is the driving force behind how they function. When the windings of the motor get active (both of the motors contain coils), a temporary magnetic field is formed. This field competes with the permanent magnets that are found inside the motor and either repels or attracts them. This magnetic force is responsible for the creation of the repulsive force in the coil, which is what causes the shaft to spin and rotate. The windings are located on the stator, which is the component of the motor that does not rotate, and the rotor is the part of the motor that does rotate (bell with magnets). Additionally, there are a great deal of additional inconsequential components, such as bearings, coils, magnets, shafts, and so on. The rule of thumb is to shoot for a thrust-to-weight ratio of 2:1 whenever possible. An arrangement of silicon-steel sheets and windings,

which are collectively referred to as coils, can be found at the core of a brushless motor. When electricity is delivered into the stator of a single-phase motor, a magnetic field is formed. This magnetic field both attracts and repels the magnets in the rotor, which causes the rotor to spin through an entire rotation of 180 degrees. Alternating the positions of the electromagnet's poles at regular intervals of 180 degrees ensures that it will continue to spin. This is the process that results in the force that drives the motion of the motor. Even though the motor used on a drone is typically a three-phase design, the fundamental concept behind it has not changed. DC motors for drones transform the electrical power that comes from batteries or other power supplies into the mechanical energy necessary for flight. These motors are powered by direct current (DC). DC motors use a commutator, which is a device that reverses the direction of the electric current flowing through the rotor of the motor every time it completes a half turn. This prevents the direction of spin from changing in response to the magnetic field and maintains continuous rotation in a single direction. They offer a stronger torque to weight ratio than brushed motors and are more energy efficient than traditional motors.

4.2.1 KV Rating Voltage KV Connection:

The constant velocity that is maintained by a motor is referred to as its "KV," which is an abbreviation. Kilovolt is an abbreviation that should not be confused with "KV," which stands for the full term. As a direct consequence of this, the KV rating of a motor is an indication of the number of revolutions per minute (RPM) that the motor is capable of when it is supplied with a given voltage. Even though the configurations of two motors may be relatively like to one another, the windings of such motors will be distinct from one another (copper windings on the coil of the motor). The KV rating offers a straightforward method for making comparisons and drawing distinctions between two motors that are quite similar to one another in terms of their specifications. Two motors with the same configuration but different numbers of windings will have different KV ratings. This is because the KV ratings of motors are dependent on the number of windings.

4.3 Antenna:

A transducer that changes electrical power into electromagnetic waves and vice versa is called an antenna. Antennas are used in wireless communication. Both transmitting and receiving signals can be accomplished with the use of an antenna in various configurations. One type of antenna is the transmitting antenna, which is responsible for converting electrical impulses into electromagnetic waves and then radiating those waves. A receiving antenna is an antenna that transforms the electrical signals produced by electromagnetic waves received from a beam into other forms. When communicating in both directions, it is possible to use the same antenna for transmission and reception of the signal.

4.3.1 Front person view (FPV) flying antenna:

Frequency: the majority of first-person view (FPV) systems employ 5.8 GHz antennas. Due to the larger data rate at this frequency, 5.8 GHz does have slightly superior video and audio quality than lower frequency bands. If all conditions are perfect and there are no obstructions between the operator and the drone, then the maximum range should be no more than 500 metres. It is of the utmost importance to make use of good first-person view antennas if one want to have a really good range when employing 5.8 GHz.

4.3.2 Linear Antenna:

A linear antenna is the most fundamental type of antenna, and it performs exceptionally well across extended distances. As they move through the air, linearly polarized signals can fluctuate in either the horizontal or the vertical direction within the same plane. The signal, which represents the radiation pattern, is largely concentrated on a single plane. When using these antennas, the transmitting and receiving antennas should normally be positioned at an angle of 90 degrees to one another. This will produce the most amount of signal overlap possible. The antennas that are used for transmitting and receiving should be aligned so that there is maximum radiation overlap.

4.3.3 Radiation Plots/Charts:

Two different charts illustrate the general form of the radiation pattern produced by the antenna, which is highlighted by the radiation plots. The E-plane is the name given to one chart, and the H-plane is the name given to the other. The radiation pattern that corresponds to the side view of the antenna is referred to as the E-plane. In a similar fashion, the H-plane is the radiation pattern that may be seen when looking down (from a birds-eye view) on the antenna. The chart contains a variety of circles, each of which represents a signal gain number expressed in decibels (dB) as shown below in fig 4.2.

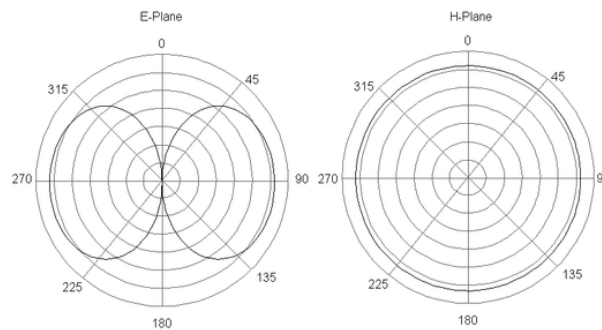


Fig 4.2 Radiation Charts

4.4 Electronic Speed Controllers (ESCs):

An electronic circuit known as the ESC can be found inside of a drone, and its primary function is to control the aircraft's speed while it is in the air. ESCs are also equipped with DC-AC converters, which convert the direct current (DC) power drawn from the battery into the three-phase, high-frequency alternating current (AC) power needed to drive the motors. Modern electronic speed controllers (ESCs) are solutions that are both powerful and space-saving, and they can be implemented using single-board computers (SBC) and microcontrollers like Raspberry Pi and Arduino. Electronic speed controllers, also known as ESCs, are devices that give drone flight controllers the ability to control and modify the speed of the electric motors that power the aircraft. The electronic speed controller (ESC) responds to a signal sent from the flight controller by adjusting the voltage supplied to the motor in order to achieve the desired effect of changing the speed of the propeller. Drones that use brushed motors and those that use brushless motors require different kinds of electronic speed controllers (ESCs) due to the various technological distinctions between the two types of motors. Drones with multiple rotors can either have

individual electronic speed controllers (ESCs) for each rotor or a single integrated ESC that controls all of the rotors at once. The electronic control systems (ECS) of many drones are developed in the form of a system-on-chip (SoC), which indicates that every component, including the microcontroller and the power management unit, is integrated into a single module. Because of this, space and weight are saved, making it the ideal answer for unmanned aerial vehicles that are limited in SWaP (size, weight, and power). A commonly used electronic speed controller is shown below in fig 4.3.



Fig 4.3 Electronic Speed Controller

4.5 Flight Controller Boards:

The flight controller is a unit that can be controlled remotely and is responsible for the movement of the drone. It is the location of the mother board, which acts as a connection point for communication, orders, and navigation. In addition, the flight controller has peripheral connector ports, such as USB or VGA, so that it may be programmed, debugged, flashed, and have its software and firmware upgraded. A flight controller is a critical component of a drone that manages its flight stability and controls its movements. It uses sensors such as gyroscopes, accelerometers, and barometers to gather data on the drone's orientation, position, and altitude. This data is then processed by the flight controller's microprocessor, which calculates the appropriate motor speeds and direction to achieve the desired flight path. The flight controller also includes software that allows the pilot to adjust various flight parameters, such as the maximum altitude, maximum speed, and flight mode. Some flight controllers even include GPS, which enables the drone to fly autonomously using pre-programmed waypoints. The flight controller can significantly enhance the stability, agility, and overall performance of a drone. It can make it easier to fly, especially for beginners, and enable more complex maneuvers for experienced

pilots. In addition, advanced flight controllers can help improve the safety of drones by providing features such as fail-safe modes that automatically land the drone in case of a signal loss or low battery. Overall, the flight controller is a crucial component that plays a significant role in the functionality and performance of a drone. Without it, flying a drone would be nearly impossible, and the risks of crashes or other accidents would be much higher. The block diagram of UAV flight controller is shown below in fig 4.4.

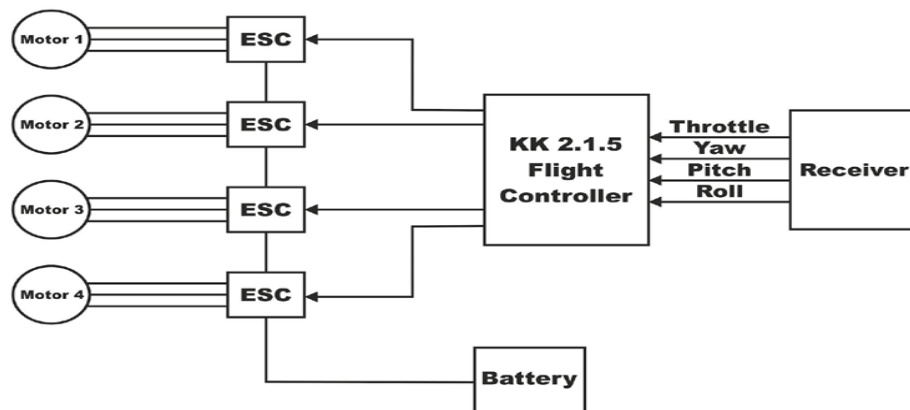


Fig 4.4 Block diagram of Flight controller for UAV

4.6 Propellers:

Standard and pusher propellers are the two types of blades that are generally seen on drones. These propellers are coupled to the motor of the drone. Aerodynamics are a primary consideration in the design of propellers. The standard propellers of a drone are positioned at the front of the aircraft and are responsible for the vertical ascent and descent of the aircraft. The drone's forward and backward thrusts are generated by the pusher propellers, which are located in the drone's tail and produce thrust in both directions. Plastic or carbon fibre, both of which are lightweight materials, are used to construct propellers. A commonly used Propellers is shown below in fig 4.5



Fig 4.5 Propellers

4.7 Radio Transmitter:

A board of an electronic device that performs the functions of transmitting and receiving data in two-way communications activities via radio waves is referred to as a transmitter. The receiver, which is directly connected to the flight controller located inside the drone, sends commands and data to the transmitter, which then processes the information. A radio transmitter, which is located on the drone controller, transmits radio signals, and a receiver, which is located inside the drone, receives those signals. As a consequence of this, drone controllers are also frequently referred to as drone radio controllers or drone radio transmitters. Radio frequencies of 27 MHz, 72 MHz, 433 MHz, 900 MHz, 1.3 GHz, and 2.4 GHz are the most common ones that transmitters for drones use. Drones and other radio-controlled (RC) equipment are typically controlled via the 433 MHz, 900 MHz, and 1.3 GHz frequency bands. The analogue signals of radio transmitter for UAV are given below in table 4.1. A commonly used Radio Transmitter for UAV is shown below in fig 4.6.

Table 4.1 Analogue Signals of Radio Transmitter for UAV

S.no	Signal	Comment
1	Roll	Moves your UAV left or right in the air
2	Pitch	Tilts your UAV forward or backward
3	Yaw	Rotates your UAV clockwise or counter clockwise, allowing you to make circles or patterns in the air.
4	Throttle	Controls the amount of power sent to your UAV, which makes the drone go faster or slower

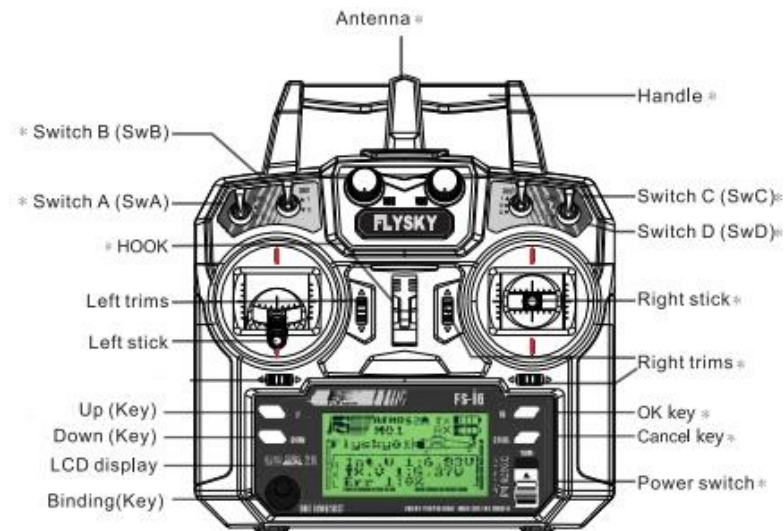


Fig 4.6 Radio Transmitter for UAV

4.8 Radio Receiver:

A Radio Receiver is a device that is capable of receiving commands from a Radio Transmitter, interpreting the signal sent by the Radio Receiver via the flight controller, and converting those commands into particular actions that operate the aircraft. A commonly used Radio Receiver for UAV is shown below in fig 4.7.

Radio Receivers can have the following features:

- ❖ Telemetry (sending data back to transmitter)
- ❖ Redundancy function (two receivers connected together, if one loses connection, second one takes over)
- ❖ Easily removable antennas (more convenient with connectors if antenna is to be replaced)
- ❖ Possibility of firmware upgrades (for bug fixes)



Fig 4.7 Radio Receiver for UAV

4.9 FPV Camera:

First-Person View (FPV) cameras are known for being portable, lightweight, and affordable. The FPV camera is installed on a drone, and real-time footage is transmitted from the drone to the ground through a video transmitter. You are able to see where the drone is flying and what it is viewing as if it had its own eyes thanks to the first-person view (FPV) camera. The performance of your FPV camera will be impacted by the image sensor inside of it. CMOS or CCD sensors are typically utilized within FPV cameras. The processing of all of the information received from the image sensor is what causes the latency that you experience when using your FPV camera. The latency is decreased proportionally to the speed of the processing. Action cameras such as the GoPro are capable of analyzing photographs with a high level of resolution (up to 4k) while simultaneously transmitting live video to the FPV transmitter. When we discuss the transmission of a drone video, we are referring to the process that is carried out with the help of a transmitter and a receiver. These components are able to function in a variety of radio frequency ranges, including 900 MHz, 1.2 GHz, 1.3 GHz, 2.4 GHz, and 5.8 GHz. Your first-person view (FPV) transmitter's resolution will have an effect on the amount of bandwidth that is needed to transport the video signal. A commonly used FPV camera for UAV is shown below in fig 4.6.

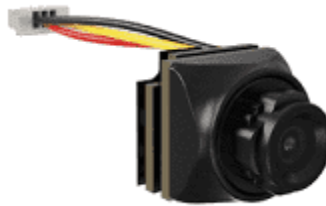


Fig 4.8 FPV Camera for UAV

4.10 Ground Station:

The ground control station for an unmanned aerial vehicle (UAV) is an essential component of the overall UAV system since it provides ground operators with a means of communicating directly with the UAV. The planning of the mission, the playback of the mission, and the communication data linkages are all included. The powers of control, communication, and data processing are all incorporated within it. The complete unmanned aerial vehicle system may be commanded and

controlled from just one location. In order for drones to have unrestricted autonomy, connection wires can be used to tether them to a power source on the ground. This choice ensures that there is a continuous source of electricity, prevents the operation of the drone from being disrupted by repeated charging, and drastically reduces the amount of weight carried by the batteries. Additionally, it permits the transfer of data in real time while maintaining both safety and speed, particularly when fibre technology is utilised. Fiber optic connections enable the transmission of electricity in the kilowatt range while also reducing the likelihood that the transmission will be detected.

4.11 Landing Gear:

The technique for designing the landing gear begins with the definition of the geometry of the landing gear in accordance with the criteria and specifications of the drone. Next, the material of the landing gear and the dimension of the pipe are defined. The material carbon fibre is utilised because of its lower overall weight in addition to its greater durability. Landing gears are what are utilised in order to set the drone firmly on the ground.

4.12 Cutting Tool Frame:

The tool is mounted to the drone as a payload and remotely operated via the controller. The cutting tool is mounted through a frame which houses all the other components of the cutting tool such as electric motor, propeller shaft, gears, and its casings. The blades with gear casing are mounted toward the fore side of the frame while the motor is placed on rearend of the frame, the motor and the gears are connected through a shaft which transmits the torque. The designed cutting tool frame is shown below in fig 4.9.

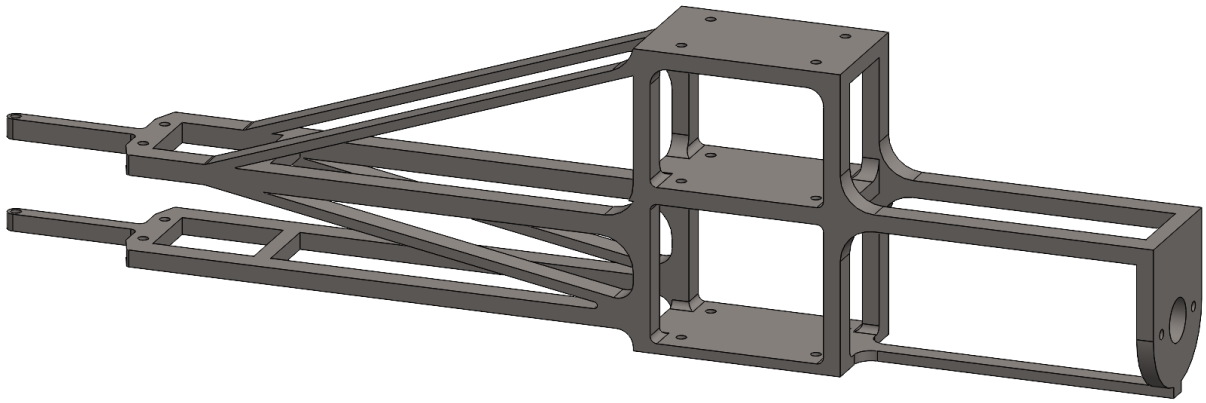


Fig 4.9 Designed Cutting Tool

4.13 RS-555 Motor:

The brushed DC motor RS-555 is a common choice for a variety of applications, including robotics, commercial equipment, and automotive systems. It is a strong, long-lasting motor that is made to deliver high torque and speed while functioning effectively and consistently. The RS-555 DC motor is cylindrical in shape, has a length of 57mm, and a diameter of roughly 35mm. It typically runs between 6 and 24 volts DC and has a maximum speed of up to 12,000 RPM. The commutator and carbon brushes in the motor make contact with the rotor to create the rotating magnetic field. The RS-555 DC motor's main benefits are its high torque output and suitability for applications requiring high starting and stopping torque. The motor's speed can also be easily controlled by modifying the voltage or applying pulse-width modulation (PWM) methods. The RS-555 Motor for Cutting Tool is shown below in fig 4.10.



Fig 4.10 RS-555 Motor for Cutting Tool

4.14 Differential Gearbox:

Differential gear, in automotive mechanics, gear arrangement that permits power from the engine to be transmitted to a pair of driving wheels, dividing the force equally between them but permitting them to follow paths of different lengths. The torque (turning moment) transmitted to the two propellers with the Pesquera differential is the same. Consequently, if one propeller slips, the torque to the other propeller is reduced. The designed differential gear box for cutting tool is shown in the below fig 4.11.

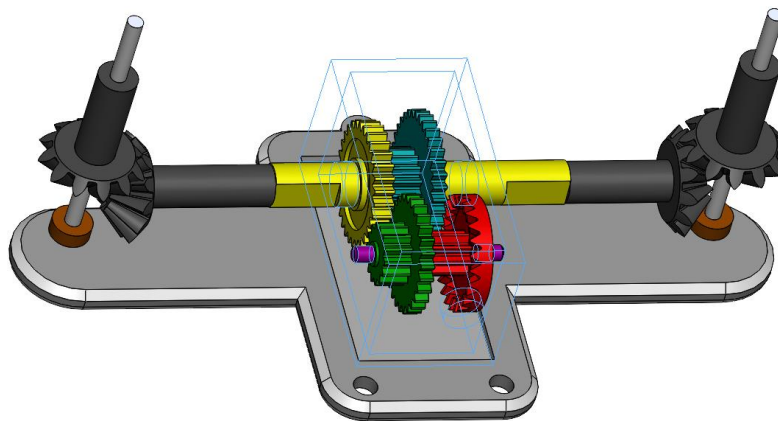


Fig 4.11 Differential Gear Box for Cutting tool

4.14.1 Bevel gear:

Bevel gears have a conical shape and can be used to transmit rotational power through shafts that are normally angled at an angle of 90 degrees to each other. Bevel gears can be used in a variety of mechanical applications. This functionality is helpful in a broad variety of applications, including cordless hand tools, automotive transmissions, and outboard motors, all of which are examples of situations in which the placement of the prime mover is not coaxial with the driven shaft. Bevel gears manufactured by Gear Motions are renowned for their reliability, precision, and consistency in performance. The used bevel gear is shown below in the figure 4.12.

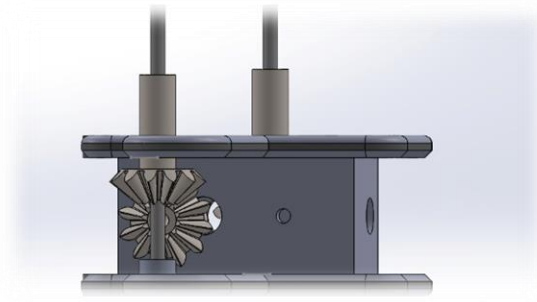


Fig 4.12 Bevel Gear used Differential gear box of Cutting tool

4.15 Common Payload Mount

Payload mounts are mechanical cargo holder or a certain type of frame extension, which holds the required cargo such as additional sensors, devices, or armaments. The mounts are either designed along with the drone or designed and developed separately for a desired drone in accordance to its frame on which it is to be mounted or attached on. Usually, the mounts are designed to be attached on the underside of the drone directly on to its frame; at the centre position to maintain the centre of gravity of the drone at the same position. The centre position for mounting payload has limitation such poor weight distribution in axes other than the central axis. To overcome this limitation, a new payload mount is been developed with the method of mounting the cargo holder to the primary joint of the rotor arms of the drone. This way of attaching the payload mount to the drone enables it to be stable in all three axes of hexacopter drones instead of one axis (centre vertical axis). The designed common payload mount is shown below in fig 4.13.

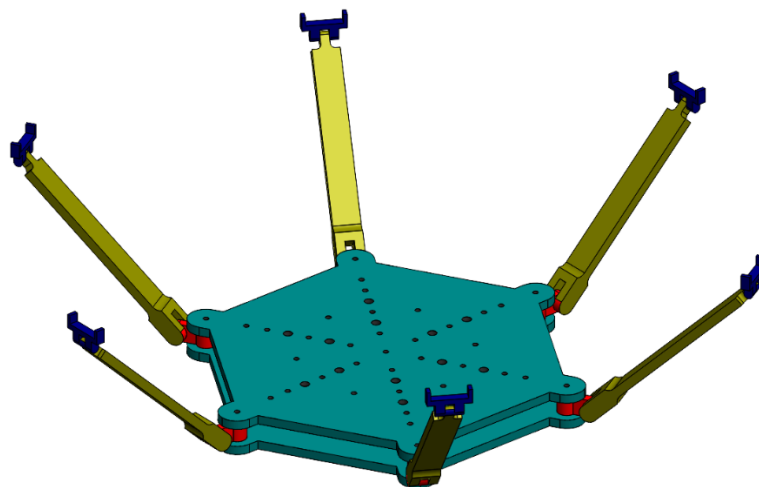


Figure 4.13 Designed Common Payload Mount

4.15.1 Material Selection: ABS Plastic

ABS Plastic was chosen as the material for the common payload mount as well as framework of the dual blade cutting tool due to the material's low point of melting and simplicity of use in 3D printing and injection molding. The finished plastic can withstand heavy use and unfavourable environmental conditions on account to its outstanding tensile strength, extreme resistance to physical impacts, and chemical corrosion. The physical properties of the material are given below in Table 4.2.

Table 4.2: Properties of ABS Plastic

Material properties	Values
Model type	Linear Elastic Isotropic
Tensile strength	$3e+07 \text{ N/m}^2$
Elastic modulus	$2e+09 \text{ N/m}^2$
Poisson's ratio	0.394
Mass density	$1,020 \text{ kg/m}^3$
Shear modulus	$3.189e+08 \text{ N/m}^2$

CHAPTER – 5

RESULTS AND DISCUSSION

The requirement and application of drones with payload carrying capability in various industries is very popular and steadily increasing. The developed common payload mount increases the versatility and flexibility to hold cargo of various shapes and sizes. The dual blade cutting tool decreases the need of manual labour and traditional methods by enabling the drone to perform tedious cutting task at hard to access places. Additionally, this system reduces the risk and loss of human life. The applications of this developed system are limitless and its ability to improve the way of aerial shipment and survey is extremely high. The 3D CAD model of common payload mount and the frame of dual blade cutting tool is imported into SolidWorks Simulation for structural analysis

5.1 Initial Tool Frame Prototype

A tool frame prototype is designed and fabricated. This tool is designed to cut the stem of a fruit bunch by an inward rotating cutting action. This cutting action is achieved by two individual BLDC motors and cutting wheels.

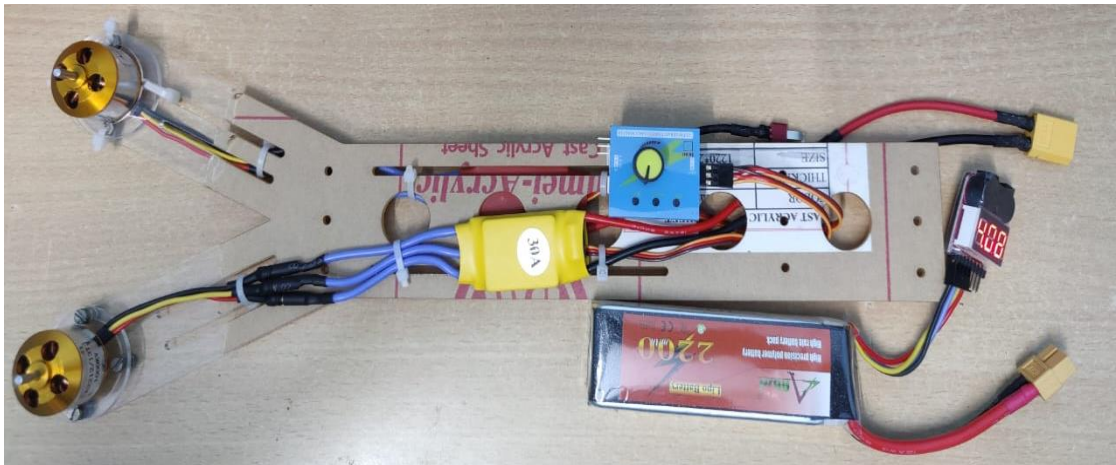


Fig: 5.1 Fabricated Cutting Tool for UAV

The above-mentioned design (fig 5.1) had problems with balancing and stability. To overcome this, the design is improvised by changing the tool frame and reducing the weight at the frontal end of the tool. The two-motor setup is changed and improvised to a single motor with the help of differential gears. The RS 555 motor

produces high torque and high revolutions per minute (RPM). Through a shaft, the torque is transferred to the differential gear box and to the cutting wheel by bevel gears. This improvised design of cutting tool has the center of gravity back towards the motor; this helps in stable flight and cutting operations.

5.2 Common Payload Mount

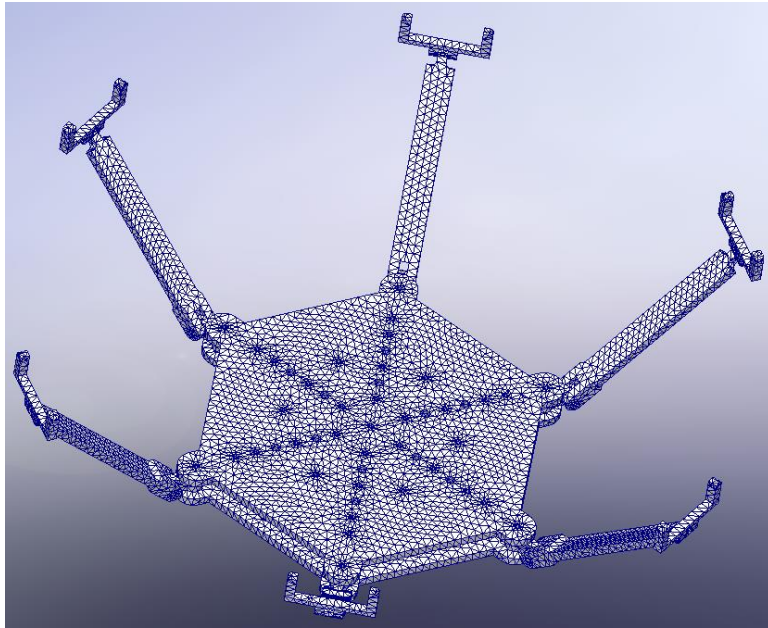


Figure: 5.2 Meshed model of Common payload mount

The requirement and application of drones with payload carrying capability in various industries is very popular and steadily increasing. The developed common payload mount increases the versatility and flexibility to hold cargo of various shapes and sizes. The dual blade cutting tool decreases the need of manual labour and traditional methods by enabling the drone to perform tedious cutting task at hard to access places. Additionally, this system reduces the risk and loss of human life. The applications of this developed system are limitless and its ability to improve the way of aerial shipment and survey is extremely high. The 3D CAD model of common payload mount and the frame of dual blade cutting tool is imported into SolidWorks Simulation for structural analysis, whose meshed parts is shown above in Figure 5.2.

5.2.1 Mesh Information – Details

Table 5.1: Mesh details for Common Payload Mount

Mesh parameters	Results
Mesh type	Solid Mesh
Jacobian points for High quality mesh	16 Points
Element size	4.07177 mm
Tolerance	0.203589 mm
Mesh Quality	High
Total Nodes	120372
Total Elements	67192
Maximum Aspect Ratio	12.939
Percentage of elements with Aspect ratio < 3	96.1
Percentage of elements with Aspect ratio > 10	0.0878
Percentage of distorted elements	0

The Common Payload Mount has been designed with a solid mesh type and a high mesh quality, utilizing 16 Jacobian points for optimal results. The element size is 4.07177 mm, with a tolerance of 0.203589 mm. The total number of nodes is 120372, with 67192 total elements. The maximum aspect ratio is 12.939, with 96.1% of the elements having an aspect ratio less than 3 and only 0.0878% of the elements having an aspect ratio greater than 10. There are no distorted elements, ensuring that the mesh quality remains high throughout the design. These mesh details were carefully chosen to ensure the Common Payload Mount is both structurally sound and efficient, providing optimal performance and durability. The detailed mesh information is given above in Table 5.1.

5.2.2 Analysis of Loads and Fixtures for Common Payload Mount

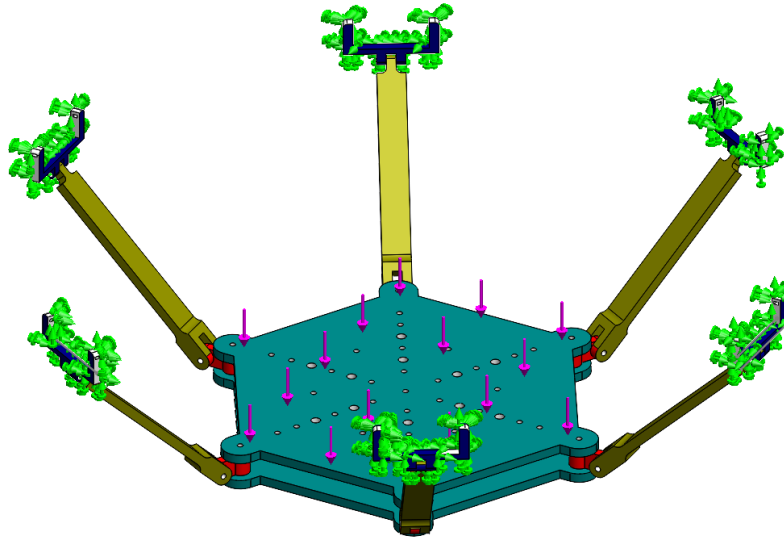


Fig: 5.3: Loads and Fixtures of Common Payload Mount

The weight estimation of the common payload mount and tool frame is carried out after applying ABS Plastic to the models, the weight estimation of the model is given below in Table 5.2.

Table 5.2: Weight estimation of the designed models

Components	Weight
Payload mount weight	353.02 grams
Tool Frame weight (without tool)	102.296 grams
Total weight	455.32 grams
Load experienced by each arm	$455.32/6 = 75.886$ grams

Table 5.3: Resultant Forces for Fixtures of Common Payload Mount

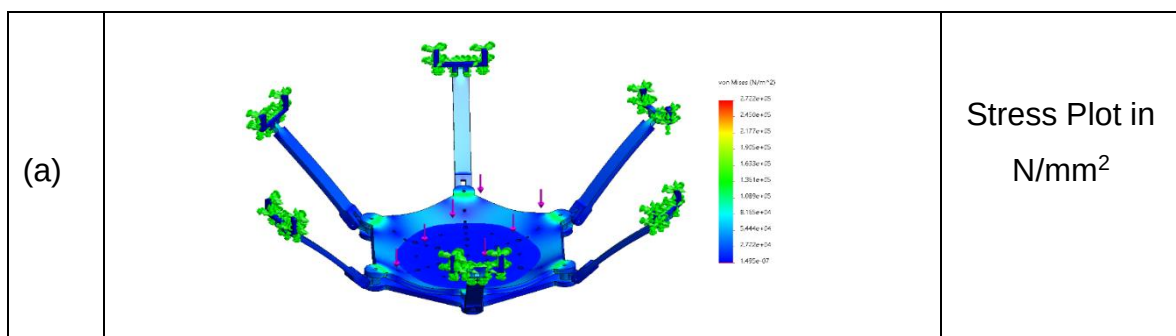
Components	X	Y	Z	Resultant
Reaction force(N)	-8.87755e-05	5.80017	-6.6869e-05	5.80017
Reaction Moment (N.m)	0	0	0	0

According to the data provided in the table 5.3, table 5.4 and fig 5.3. This means that when the Common Payload Mount is in use, it will experience a resultant force of 5.80017 N, which is the net force acting on it in all directions. The X, Y, and Z components of the forces indicate the direction of the forces acting on the mount. The negative X and Z components indicate that there is a force pulling in the opposite direction in those axes, while the positive Y component indicates a force acting upwards. It is important to note that the magnitudes of these forces and their components were calculated to ensure that the mount is structurally sound and able to withstand the loads and stresses it may encounter during use.

Table 5.4: Resultant Forces and Moment for Fixtures of Common Payload Mount

Types	Units	Sum X	Sum Y	Sum Z	Resultant
Reaction forces	N	-8.87755e-05	5.80017	-6.6869e-05	5.80017
Reaction moments	N.m	0	0	0	0
Free body forces	N	0.000934603	0.00166127	0.000547358	0.00198316
Free body moments	N.m	0	0	0	1e-33

5.2.3 Study Results of Common Payload Mount



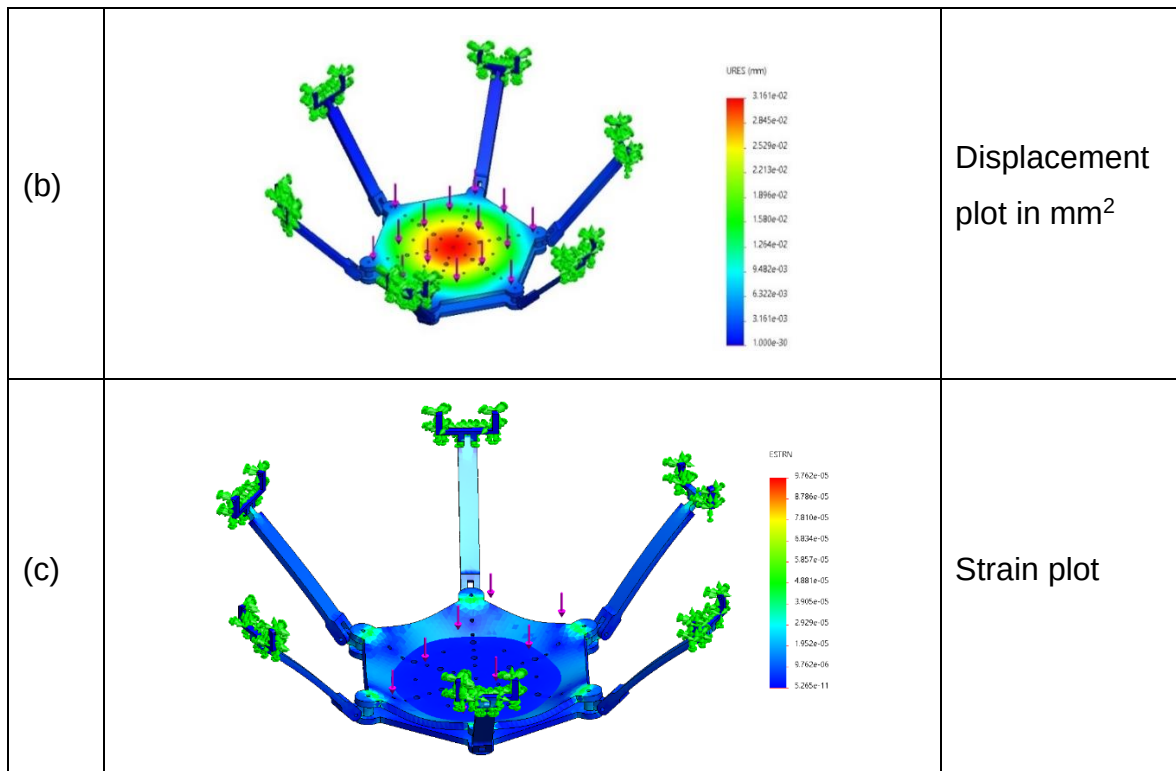


Fig 5.4 (a) Stress Plot of Common Payload Mount (b) Displacement Plot of Common Payload Mount (c) Strain Plot of Common Payload Mount

Fig 5.4 Explain the stress distribution, Strain and Maximum displacement along the Common payload mount. Table 5.5 shows the maximum and minimum values of Stress, Displacement and Strain,.

Table 5.5: Stress analysis, Displacement and Strain of Common Payload Mount

Type	Min	Max
VON: von Mises Stress	1.495e-07N/m ² Node: 33043	2.722e+05N/m ² Node: 101382
Resultant Displacement	0.000e+00mm Node: 2031	3.161e-02mm Node: 1832
ESTRN: Equivalent Strain	5.265e-11 Element: 39088	9.762e-05 Element: 16534

5.3 SECONDARY TOOL FRAME DESIGN

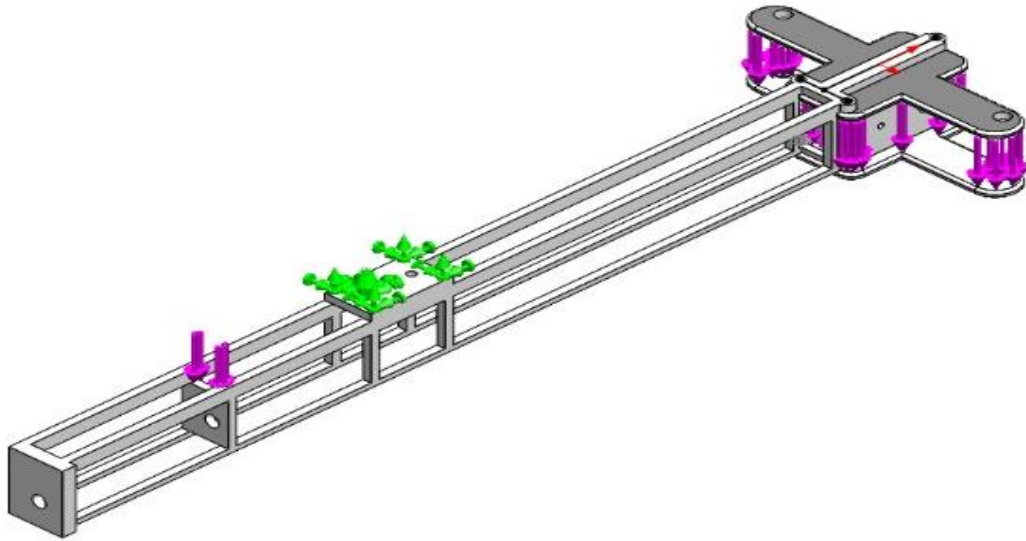


Fig: 5.5 Model of Secondary cutting tool frame design

According to the mesh details provided below in the table 5.6 and fig 5.5, the Secondary Cutting Tool Frame has been modelled using a solid mesh, with the mesher set to "Standard mesh". Automatic transition and include mesh auto loops have been turned off. The mesh quality is high, with Jacobian points set at 16 points. The element size is 1.84523 mm, and the tolerance is 0.0922613 mm. This indicates that a high-quality mesh has been used to model the Secondary Cutting Tool Frame, with small element sizes and high levels of accuracy to ensure that the resulting model is precise and reliable. The choice to turn off automatic transition and include mesh auto loops may have been made to allow for greater control over the meshing process and to prevent the generation of unnecessary elements that could impact the accuracy of the model. Overall, these mesh details suggest that the Secondary Cutting Tool Frame has been designed with a great deal of attention to detail and precision.

5.3.1 Mesh Information – Details

Table 5.6 Mesh details for secondary tool frame design

Mesh parameters	Results
Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points for High quality mesh	16 Points
Element Size	1.84523 mm
Tolerance	0.0922613 mm
Mesh Quality	High

5.3.2 Analysis of Loads and Fixtures for Secondary Cutting Tool Frame design

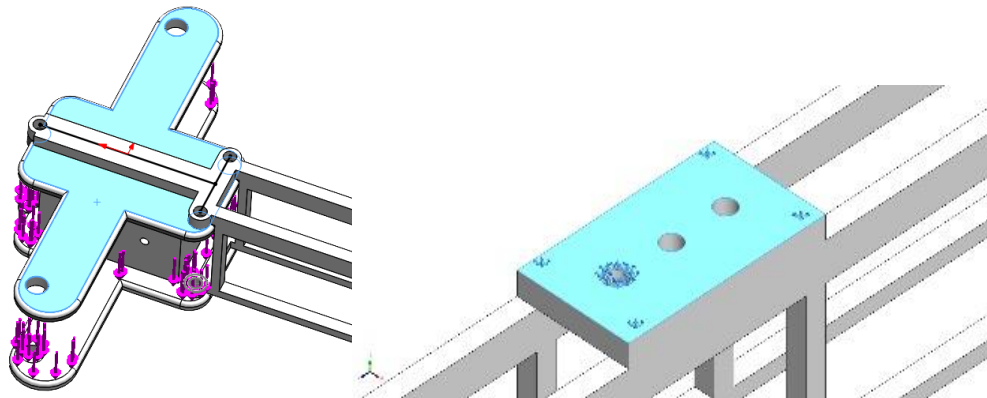


Fig: 5.6 Loads and Fixtures of Secondary Cutting Tool Frame design

Table 5.7: Resultant Forces for Fixtures of Cutting Tool Frame

Components	X	Y	Z	Resultant
Reaction force(N)	-3.1377e-05	0.399923	1.99014e-05	0.399923
Reaction Moment (N.m)	0	0	0	0

The total force acting on the Cutting Tool Frame is 0.399923 N, with components in the X, Y, and Z directions. The X component is a very small negative force, the Y component is the largest force and is positive, and the Z component is a small positive force.

Table 5.8: Resultant Forces and Moment for Loads of Cutting Tool Frame

Resultant Forces	Units	Sum X	Sum Y	Sum Z	Resultant
Reaction forces	N	-3.1377e-05	0.399923	1.99014e-05	0.399923
Reaction Moments	N.m	0	0	0	0
Free body forces	N	0.000146087	-0.000709698	0.00114852	0.00135798
Free body moments	N.m	0	0	0	1e-33

According to the table 5.8, the resultant forces and moments for loads of the Cutting Tool Frame are important factors in determining its structural stability. The reaction forces and moments that act on the fixtures of the frame are -3.1377e-05 N in the X direction, 0.399923 N in the Y direction, and 1.99014e-05 N in the Z direction, with a resultant force of 0.399923 N. The free body forces that act on the frame are 0.000146087 N in the X direction, -0.000709698 N in the Y direction, and 0.00114852 N in the Z direction, with a resultant force of 0.00135798 N. The free body moments are negligible at 1e-33 N.m. These values are important in ensuring the proper design and function of the Cutting Tool Frame for safe and effective operation.

5.3.3 Study Results of Secondary Cutting Tool Frame design

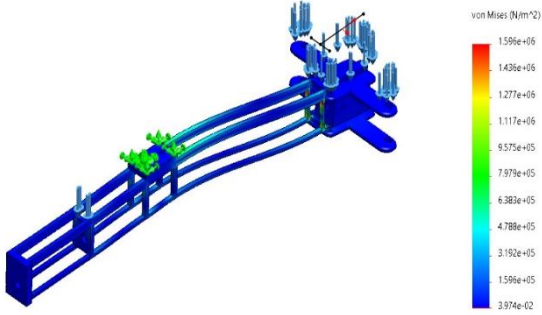
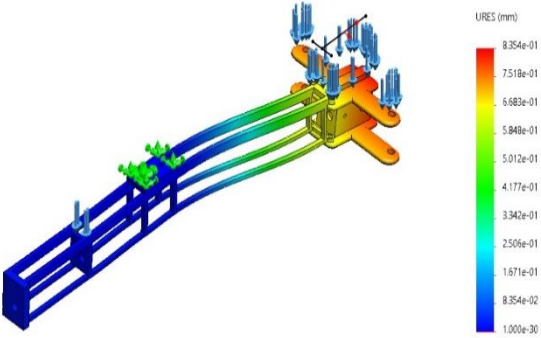
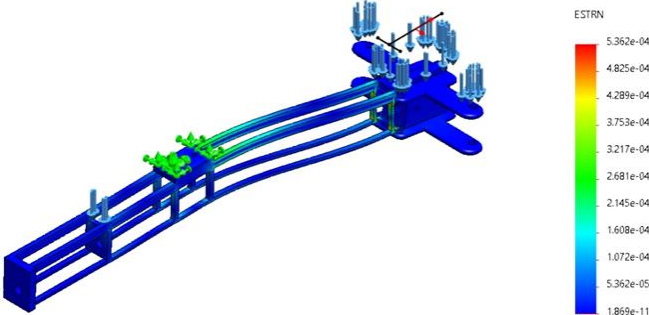
(a)	 von Mises (N/mm²) 1.596e+06 1.430e+06 1.277e+06 1.117e+06 9.575e+05 7.979e+05 6.383e+05 4.788e+05 3.192e+05 1.596e+05 3.974e-02	Stress Plot in N/mm ²
(b)	 URES (mm) 8.354e-01 7.518e-01 6.683e-01 5.848e-01 5.012e-01 4.177e-01 3.342e-01 2.506e-01 1.671e-01 8.354e-02 1.000e-30	Displacement plot in mm ²
(c)	 ESTRN 5.362e-04 4.825e-04 4.289e-04 3.753e-04 3.217e-04 2.681e-04 2.145e-04 1.608e-04 1.072e-04 5.362e-05 1.869e-11	Strain plot in

Fig 5.7 (a) Stress Plot of Secondary Cutting Tool Frame (b) Displacement Plot of Secondary Cutting Tool Frame (c) Strain Plot of Secondary Cutting Tool Frame

Fig 5.7 Explain the stress distribution, Strain and Maximum displacement along the Secondary Cutting Tool Frame. Table 5.9 shows the maximum and minimum values of Stress, Displacement and Strain,.

Table 5.9 Stress analysis, Displacement and Strain of Secondary Cutting Tool Frame design

Type	Min	Max
VON: von Mises Stress	3.974e-02N/m ² Node: 2974	1.596e+06N/m ² Node: 17677
URES: Resultant Displacement	0.000e+00mm Node: 13884	8.354e-01mm Node: 186
ESTRN: Equivalent Strain	1.869e-11 Element: 6292	5.362e-04 Element: 25850

5.4 CUTTING TOOL FRAME

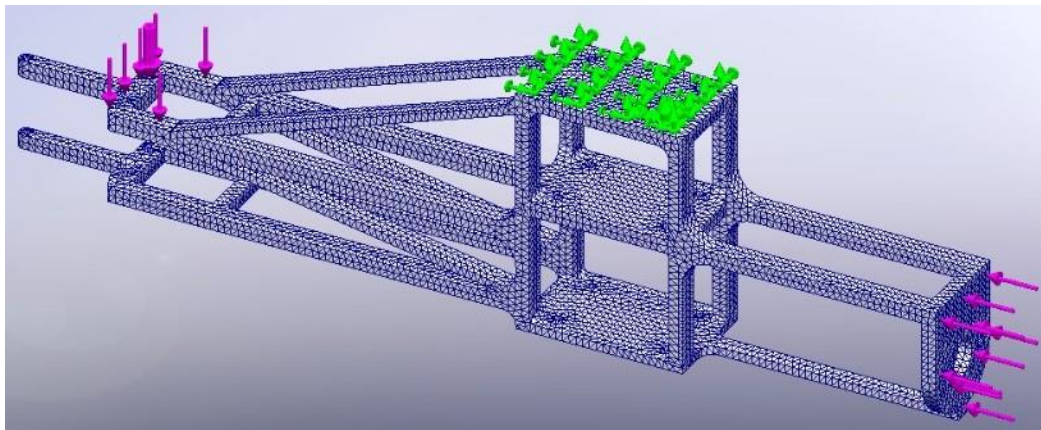


Fig: 5.8 Meshed model of Cutting tool frame

According to the mesh details for the Cutting Tool Frame mentioned below in Table 5.10 and fig 5.8, the mesh type is solid mesh, with 16 Jacobian points for high-quality mesh. The element size is 2.62945 mm, and the tolerance is 0.131472 mm, resulting in a high-quality mesh. The total number of nodes is 81821, and the total number of elements is 45449. The maximum aspect ratio is 15.031, but the majority of elements have an aspect ratio of less than 3, indicating good quality. The percentage of elements with an aspect ratio greater than 10 is low at 0.044%, and there are no distorted elements. In simple terms, the mesh for the Cutting Tool Frame is of high quality, with a good distribution of elements and nodes, and minimal distortion.

5.4.1 Mesh Information – Details

Table 5.10: Mesh details for Cutting Tool Frame

Mesh parameters	Results
Mesh type	Solid Mesh
Jacobian points for High quality mesh	16 Points
Element size	2.62945 mm
Tolerance	0.131472 mm
Mesh Quality	High
Total Nodes	81821
Total Elements	45449
Maximum Aspect Ratio	15.031
Percentage of elements with Aspect ratio < 3	98.6
Percentage of elements with Aspect ratio > 10	0.044
Percentage of distorted elements	0

5.4.2 Analysis of Loads and Fixtures for Cutting Tool Frame

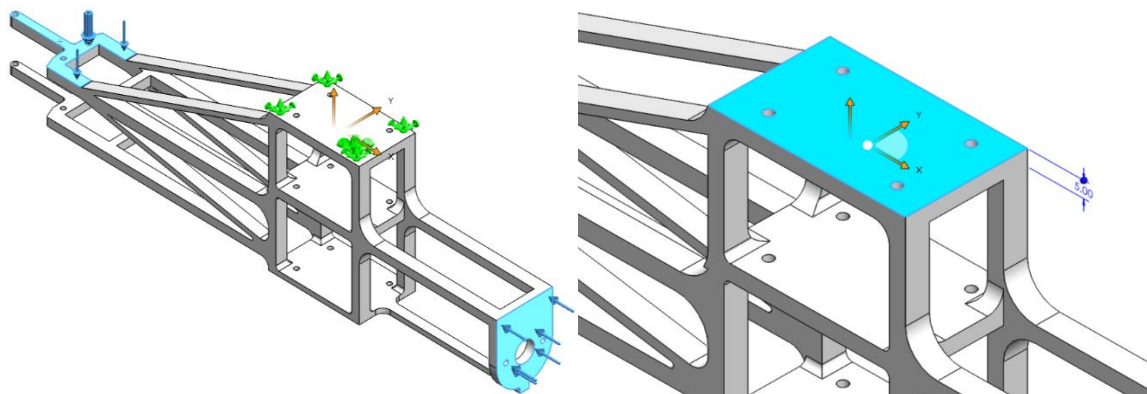


Fig: 5.9: Loads and Fixtures of Cutting Tool Frame

Table 5.11: Resultant Forces for Fixtures of Cutting Tool Frame

Components	X	Y	Z	Resultant
Reaction force(N)	4.5	4.49998	-0.000107674	6.36394
Reaction Moment (N.m)	0	0	0	0

This is according to table 5.11, that the fixture is only applying forces to the Cutting Tool Frame and not causing any rotation. The forces in the X and Y directions are nearly equal, indicating that the fixture is well balanced in those directions. However, there is a small force in the negative Z direction, indicating that the fixture is applying a slight downward force to the Cutting Tool Frame. The resultant force of 6.36394 N represents the total force being applied by the fixture to the Cutting Tool Frame.

Table 5.12: Resultant Forces and Moment for Fixtures of Cutting Tool Frame

Types	Units	Sum X	Sum Y	Sum Z	Resultant
Reaction forces	N	4.5	4.49998	-0.000107674	6.36394
Reaction moments	N.m	0	0	0	0
Free body forces	N	0	0	0	0
Free body moments	N.m	0	0	0	0

The table 5.12 shows the resultant forces and moments for the fixtures of the Cutting Tool Frame. The X component is 4.5 N, the Y component is 4.49998 N, and the Z component is -0.000107674 N. The resultant force is 6.36394 N. There is no reaction moment or free body forces/moments in any direction.

5.5 Study Results of Cutting Tool Frame

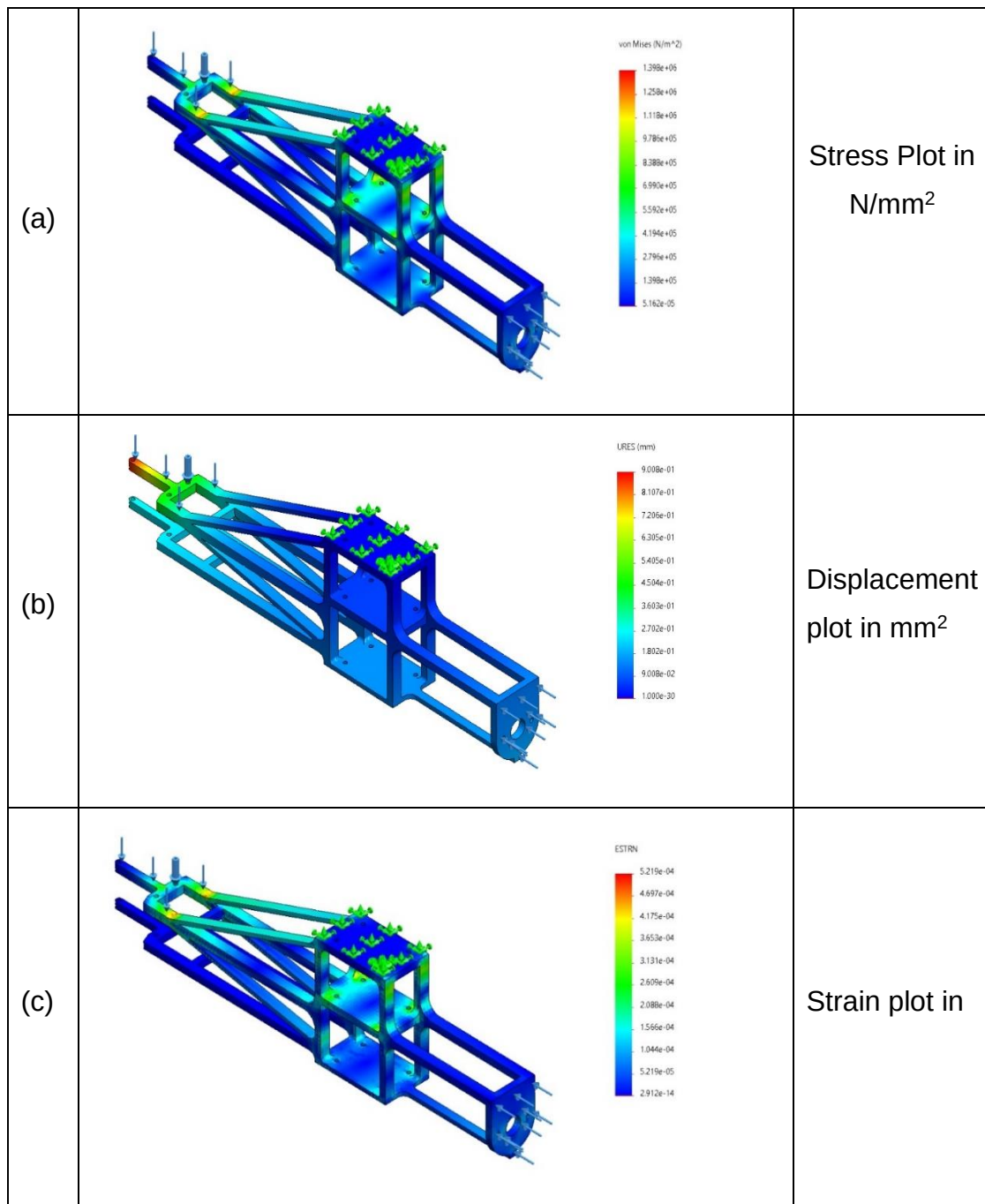


Fig 5.10 (a) Stress Plot of Cutting Tool Frame (b) Displacement Plot of Cutting Tool Frame (c) Strain Plot of Cutting Tool Frame

Fig 5.10 Explain the stress distribution, Strain and Maximum displacement along the Cutting Tool Frame. Table 5.13 shows the maximum and minimum values of Stress, Displacement and Strain,.

Table 5.13 Stress analysis, Displacement and Strain of cutting tool frame

Type	Min	Max
VON: von Mises Stress	5.162e-05N/m ² Node: 51732	1.398e+06N/m ² Node: 75614
URES: Resultant Displacement	0.000e+00mm Node: 80	9.008e-01mm Node: 425
ESTRN: Equivalent Strain	2.912e-14 Element: 40028	5.219e-04 Element: 15230

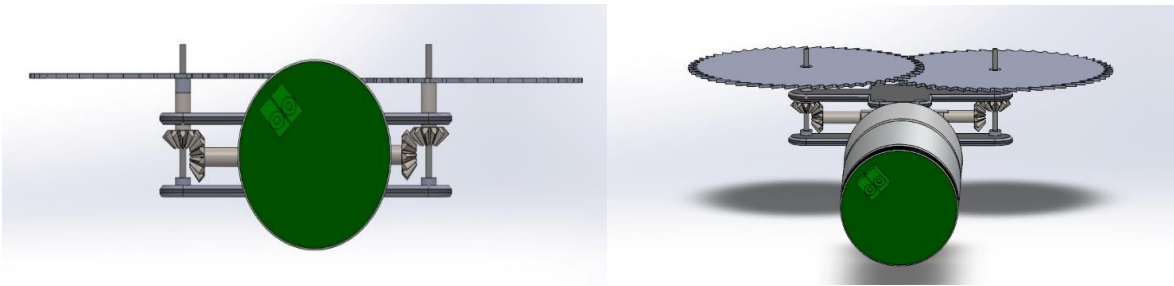
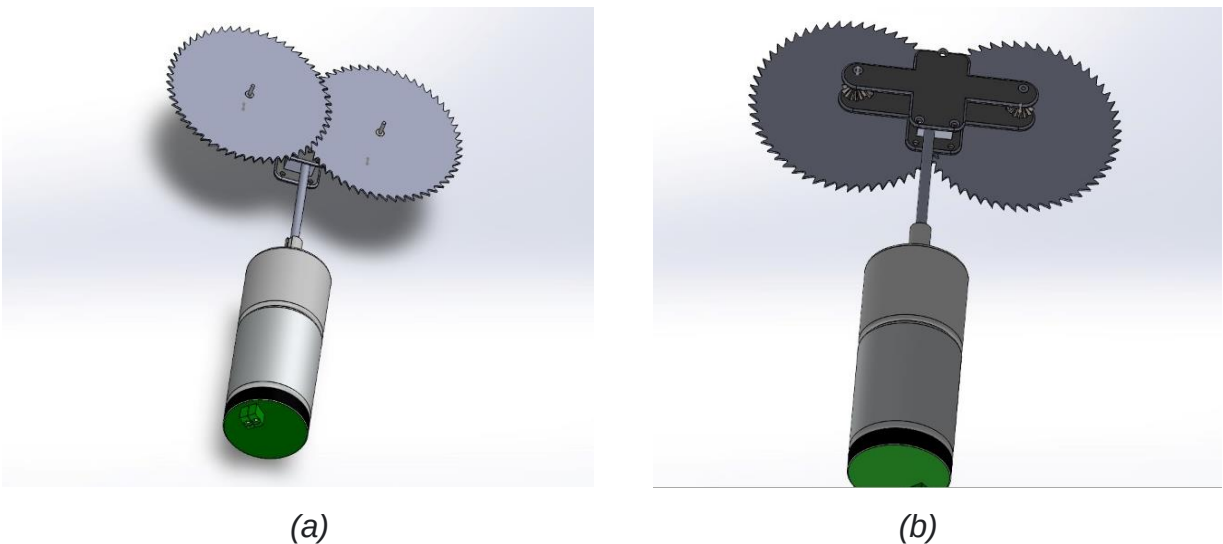


Fig: 5.11 CAD Model of Improvised Cutting Tool using SOLIDWORKS



**Fig: 5.12 (a) Top view of Cutting tool
(b) Bottom view of Cutting tool**

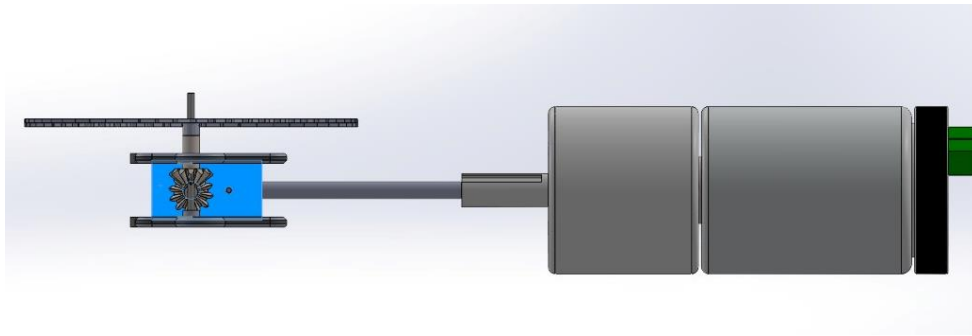


Fig: 5.13 Side view of Cutting Tool

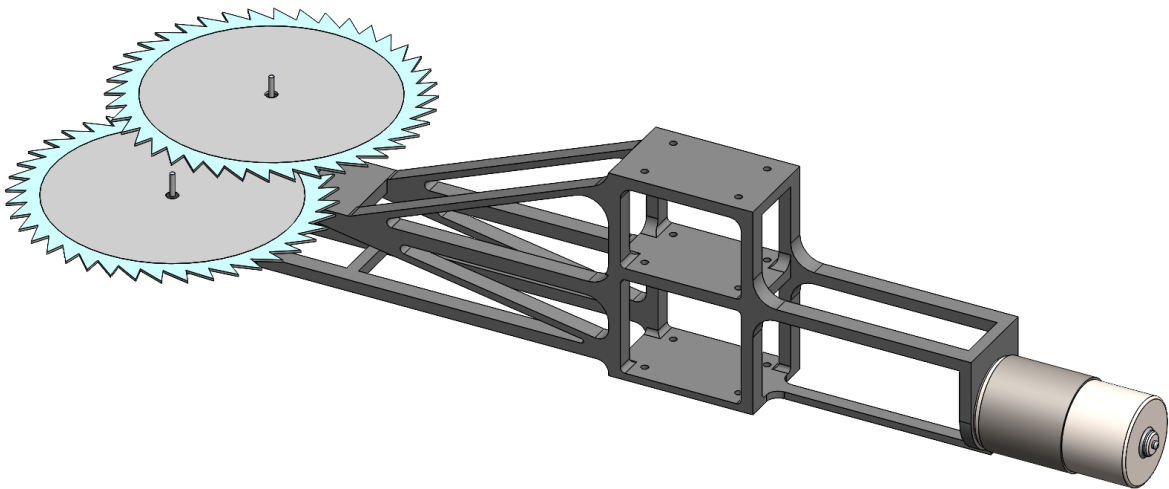


Fig: 5.14 Final Cutting Tool Design

This is SolidWorks image of this dual blade cutting tool shown as a 3D model. The blades are designed to rotate at high speeds inward direction, allowing them to cut through materials quickly and efficiently as shown in the above fig: 5.11, 5.12, 5.13, 5.14.

CHAPTER – 6

SUMMARY AND CONCLUSIONS

This paper presents the design and structural analysis of common payload mount and a dual blade cutting. The development of the novel system of payload mount and dual blade cutting tool has proven to be a highly thriving. It is capable of providing payload carrying capability irrespective to their size and shape, also the tool increases the ability to cut objects at great heights. Therefore, with this system a single drone can carry out a wide range of operations and reduces the need of customization and separate equipment for different drones at different tasks. By analysis results of all the design, the cutting tool frame undergoes a total displacement of $9.008e-01$ and max stress of $1.398e+06\text{M/m}^2$, the common payload mount is undergoing less total deformation of $3.161e-02\text{mm}$ and maximum stress experienced by the model is $2.722e+05\text{N/m}^2$ which is comparatively very less. Hence, it can be concluded that the common payload mount is the best design for carrying heavier payload. Therefore, it can be concluded that the majority of the machinery that is utilised for the harvesting of coconuts and palm fruits is still operated manually. The gathering of coconuts will need the creation of a First-Person-View (FPV) drone system that can operate while tethered. When the drone is in a position where it is close to the coconut or ice apple bunch, a command is given to it to begin the cutting process so that the coconut may be harvested by cutting the stem of the bunch where it is attached to the tree. This allows the coconut to be removed from the tree. A human operator on the ground or a application running on a mobile device, such as a smartphone, has the ability to use a wireless interface to control a drone. Alternatively, the application might be operated by the drone itself. The cable system offers the advantage of a nearly unlimited flight time, which enables vehicles to perform longer missions or carry heavier payloads than would be possible with other propulsion methods. The drone is equipped with a wireless camera that can provide confirmation that it is now positioned in the area of interest. When it comes to the harvesting of ice apples and coconuts, tethered unmanned aerial vehicles (UAVs) are the best option.

REFERENCES

- [1] Amrita Vishwa Vidyapeetham, “An aircraft for harvesting”, 2020
A Drone Aircraft For Harvesting Coconuts - Patent (quickcompany.in)
- [2] Ashish Mishra, “Build your own Drone using KK2.1.5 Flight Controller”, 2021, Volume-1,
- [3] Benjamin Tefay, BazleEizad, Peter Crosthwaite, Surya Singh, Adam Postula, “Design of an Integrated Electronic Speed Controller for Compact Robotic Vehicles”, 2011
- [4] Boukoberine, M.N., Zhou, Z., Benbouzid, M., “Power Supply Architectures for Drones—A Review”, 2019, Institute of Electrical and Electronics Engineers (IEEE):
Piscataway, NJ, USA, pp. 5826–5831
- [5] Bum-Su Jun, Yoon-Sang Kook, Joon-Sung Park, Chung-Yuen Won, “A Development of Electronic Speed Control (ESC) for PMSMs Driving used in Drone”, 2018
- [6] C. R. Balamurugan, P. Vijayakumar, P. Kiruba, S. Arun Kanna, E. R. Hariprasath, C. AnuPriya, “First Person View Camera Based Quadcopter with Raspberry Pi”, 2018
- [7] Design and Development of Drone based Remote Controlled Honey Harvesting Machine, 2021 Fifth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), IEEE, 20 December 2021, Senthil Kumar Muthusamy; S.V.Tresa Sangeetha; Aida Saud Al Busaidi; Khalid Sulaiman Al Moqbali, Saba Ahmad Al Mawali, Muhannad Al Balushi
- [8] Design and Development of Hexacopter for Controlling Crowd, International Journal of Creative Research Thoughts (IJCRT), Volume 8, Issue 7 July 2020, Swetha S, Mohamad Omar Zin Al Abdin, Aijaz Ahmad Mir, Vaishnavi Kandalgaonkar, Mithlesh Agrahari
- [9] Design and Static Structural Analysis of Plus Configuration Octa-Copter, IJSRD - International Journal for Scientific Research & Development| Vol. 7, Issue 09, 2019, Santosh Yadav, Lalitha R, Ashwini N, Ranjitha V, J K Bhushan
- [10] Different Types of Drones Frames: Monocopter to Octocopter, December

27, 2021, Ashish Mishra

- [11] Donald F. Adams, "Airframe Structural Materials for Drone Applications" R-581/4-ARPA July 1971
- [12] Eugenio MERCATALI and Dr. Elisabetta Punta, "Feasibility study for the propulsionsystem of a tethered UAV", 2019
- [13] Fernando G. Tinetti, Oscar C. Valderrama Riveros, Fernando L. Romero, "UnmannedVehicles: Real Time Problems in Drone Receivers", 2019
- [14] ICAR-CCARI & Goa University, "Fly-Cocobot for harvesting coconut", 2022 Goa: Soon, a drone may be able to do your coconut-plucking - Times of India (indiatimes.com)
- [15] Jalu A. Prakosa; Dmitry V. Samokhvalov; Gabino R. V. Ponce; Fuad Sh. Al-Mahturi "Speed Control of Brushless DC Motor for Quad Copter Drone Ground Test", 2019
- [16] KanzlerMay Andrew, "Transmitter and Receiver for Drones", 27, 2020
- [17] Karan P. Jain, Prasanth Kotaru, Massimiliano de Sa, Mark W. Mueller, KoushilSreenath, "Tethered Power Supply for Quadcopters: Architecture, Analysis and Experiments", 2022
- [18] Lalanne Laurent, "RC Transmitter Wizard", 2016, [online] Available: <https://librepilot.atlassian.net/wiki/spaces/LPDOC/pages/5669344/RC+Transmitter+Wizard>.
- [19] LidaZikou; Christos Papachristos; Anthony Tzes, "The Power-over-Tether system forpowering small UAVs: Tethering-line tension control synthesis", 2015
- [20] M. Madic, M.Radovanovic and B.Nedic, "Correlation between Surface Roughness Characteristics in CO2 Laser Cutting of Mild Steel", 2012, Tribology in Industry, Vol. 34,232-238.
- [21] Mahmoud W. A., Elkaoud N. S., Abu El-Maaty A. E, "Possibility of applying a slider-crank mechanism to design sugarcane buds cutter", 2021
- [22] A Review - Drone platform for energy systems monitoring - Mohamed

Nadir Boukoberine, Zhibin Zhou, Mohamed Benbouzid – oct-2019

- [23] Mohamed Damir, Engy Rashed, Ahmad Elkhatab, "Effect of Manufacturing Tolerances and Assembly Errors on the Characteristics of Small-Scale Slider Crank Mechanisms", 2018
- [24] Montanya, J., Lopez, J.A., Fontanes, P., Urbani, M., van der Velde, O., Romero, D., "Using tethered drones to investigate ESD in wind turbine blades during fair and thunderstorm weather", 2018, In Proceedings of the 34th International Conference on Lightning Protection, ICLP, Rzeszow, Poland, 2–7 September 2018; Institute of Electrical and Electronics Engineers Inc.: Piscataway, NJ, USA,
- [25] Naqqash Dilshad, JaeYoung Hwang, JaeSeung Song, NakMyoung Sung, "Applications and Challenges in Video Surveillance via Drone: A Brief Survey", 2020
- [26] Park, J.S., Lee, K.D. "Design and Implementation of BLDC Motor with Integrated Drive Circuit. Int. J. Power Electron. Drive System." 2017, Volume-8, 1109–1116.
- [27] Peter R.N. Childs, mechanical design engineering hand book (2nd edition) 2019 Pg: 475- 511.
- [28] S.Meivel, S. Maheswari " Design and Aluminium framework of drone using Solidworks" January-2020, International journal of Grid and Utility computing 12(2):85-97
- [29] S. Sakunthala, R. Kiranmayi and P. N. Mandadi, "A study on industrial motor drives: Comparison and applications of PMSM and BLDC motor drives", Proc. Int. Conf. Energy Commun. Data Anal. Soft Comput. (ICECDS), pp. 537-540, Aug. 2017.
- [30] Tevel Aerobotics Technologies, "Apple Harvesting Drones", 2022 <https://dronedj.com/2022/01/31/apple-drones-are-now-reality-in-orchards-cultivating-fruit/>
- [31] The use of drones for the delivery of diagnostic test kits and medical supplies to remote First Nations communities during Covid-19, Volume 50, Issue 8, August

2022, Pages 849-856, Kristin Flemons, Barry Baylis, Aurang Zeb Khan, Andrew W. Kirkpatrick, Ken Whitehead, Shahab Moinid, Allister Schreiber, Stephanie Lapointe, Sara Ashoori, Mishal Arif, Byron Berenger, John Conly, Wade Hawkins

- [32] Vadim Carev, Jan Roháč, Michal Schmirler, “A Multilayer Brushless DC Motor for Heavy Lift Drones”, 2021
- [33] Vemema Kangunde, Rodrigo S. Jamisola Jr., Emmanuel K. Theophilus, “A review on drones controlled in real-time”, 2021
- [34] Wojciech Walendziuk, Daniel Oldziej, Maciej Slowik, “Power Supply System Analysis for Tethered Drones Application”, 2020
- [35] Xu, Z.W., Zhang, Z., Li, H.; He, M.X., Tang, J.C., Xu, K., Ren, X., Chen, Q., “1-kV input 300-kHz SiC LLC converters with matrix transformers”, In Proceedings of the Conference Proceedings—IEEE Applied Power Electronics Conference and Exposition— APEC; Institute of Electrical and Electronics Engineers Inc.: Anaheim, CA, USA, 2019, pp.2337–2343.
- [36] Zhang, S., Luo, F.L., “Direct Control of Radial Displacement for Bearingless Permanent-Magnet-Type Synchronous Motors”, IEEE Trans. Ind. Electron. 2009, 56, 542–552.
- [37] <https://www.hackster.io/akanzler007/transmitter-and-receiver-for-drones-bb1be1> - Akanzler.
- [38] <https://www.dronezon.com/learn-about-drones-quadcopters/what-is-fpv-camera-fov-tvl-cmos-ccd-technology-in-drone> - Drone Zon.
- [39] <https://www.dronetechplanet.com/what-is-fpv-camera-technology-in-drones-best-uses> - Drone tech.
- [40] <https://www.getfpv.com/learn/new-to-fpv/all-about-multirotor-fpv-drone-radio-transmitter-and-receiver/>
- [41] <https://www.bestonlinedrones.com/overview-fpv-drone-antennas/> Carlo Santarelli may19 2019
- [42] <https://learnmech.com/working-of-differential-gear-box-for/> - Sachin Thorat

[43] https://www.researchgate.net/publication/335729104_Innovative_Design_of_Drone_Landing_Gear_Used_as_a_Receiving_Coil_in_Wireless_Charging_Application - Tommaso Campi, Silvano Cruciani, Francesca Maradei, Mauro Feliziani – September 2019

ANNEXURE:

- Design Patent has been applied for UAV BASED DUAL BLADE CUTTING TOOL on 2ndFebruary, 2023.
- Design Patent has been applied for COMMON PAYLOAD MOUNT FOR HEXAROTOR DRONE on 16thFebruary, 2023.
- A detailed abstract for "Modelling of tethered UAV system for coconut / ice apple harvesting" has been applied and approved by Tamilnadu State council for science and technology - Student project scheme 2022 - 2023
- Review Paper on the title of “Modelling of Tethered UAV System for Coconut/ Ice Apple Harvesting– A Review” by Pugazh Sivakumar, R. Kaushik, Sangeetha .M has been presented in ICAARS conference conducted by PSG College, Coimbatore on 10th December, 2022.
- Review Paper has been communicated to AIP Journal.
- Research on the title of “Modelling of Commonly Equipping UAV Based Cutting tool/ Payload Mount for Hexacopter” by Pugazh Sivakumar, R. Kaushik, Sangeetha .M has been presented in RASET conference conducted by Bannari Amman Institute of Technology, Sathyamangalam on 9th April, 2023.