Design and Development of a Quadcopter

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***Abstract*— A quadcopter with a claw mechanism can grip and manipulate items. The claw mechanism underwent different iteration i.e., shell type grippers and teeth type grippers in which the teeth type grippers were finalized because of its enhanced grip strength and versatile grasping capability. This abstract summarizes the paper. The quadcopter's frame holds motors, propellers, flight controller, and batteries. The quadcopter's claw mechanism is an actuated grasping system that can hold various things. Development has numerous stages. First, SolidWorks software designs the quadcopter and claw mechanism. The design seeks a lightweight yet strong framework that can endure flight and object manipulation pressures. Next, the flight controller, motors, and claw mechanism servo motors are chosen and integrated. Flight controllers stabilize and control quadcopters. Software development follows hardware integration. Algorithms provide steady flying, altitude control, and maneuverability. Software controls provide accurate claw mechanism grabbing. The quadcopter's safety, stability, and performance are tested during development. Claw strength, dependability, and adaptability are assessed. This paper shows that a quadcopter is produced with a claw mechanism that can retrieve, deliver, and manipulate objects. The design may be used in search and rescue, infrastructure inspection and maintenance, and logistics. Finally, a quadcopter with a claw mechanism can manipulate objects in the air. An adaptable, dependable airborne platform with environmental interaction is created by integrating mechanical, electrical, and software components.**

***Index Terms*— Quadcopter, Teeth type grippers, Claw mechanism**

I. INTRODUCTION

A quadcopter with a claw mechanism is designed to accomplish flight and manipulation duties. A claw mechanism lets the quadcopter grasp and carry objects, making it perfect for search and rescue, package delivery, and industrial inspections. The quadcopter is designed with a lightweight yet durable chassis, numerous rotors for stability and maneuverability, and a remote-controlled claw mechanism. This novel mix of flight and gripping capabilities expands unmanned aerial systems' practical usage and efficiency.

A quadcopter with a claw mechanism can manipulate and retrieve targets. A quadcopter with a claw mechanism can grab and transport various objects. This design goal is to improve the quadcopter's functionality and broaden its uses, such as search and rescue, inspection and maintenance in hard-to-reach places, and delivery. The quadcopter can accomplish complex tasks that a typical aerial drone cannot because of its claw mechanism.

Drones—civil unmanned aerial vehicles (UAVs)—have become important in recent years. UAVs must be built to work reliably and safely in many climates. They must operate autonomously without threatening other aircraft or ground people. As technology advances, UAVs will have more uses, making this a promising study area. [1]

Applications for quadcopters include aerial recognition, lift and drop mechanism search-and-rescue operations, and industrial monitoring tasks, among others. [2] Drone lift and drop operations have several advantages, including increased effectiveness, safety, and price. The solution also improves drones' adaptability, accessibility, and capacity for real-time monitoring and payload delivery. These advantages make the lift and drop approach useful in a variety of fields.

Numerous studies have been conducted on the creation of a universal gripper for a UAV. Due to this research, small, light-weight grippers that can move items of all sizes and forms have been created. Delivery, inspection, and surveillance are just a few of the uses for these grippers. [3]

There are many applications of drones for delivery in the healthcare sector such as delivery of medicine, defibrillators, blood samples, and vaccines. Drones can transport urgently required tiny products in hard-to-reach places. The hub-and-spoke distribution technique delivers medical supplies to local hospitals and clinics by drone. This could reduce travel costs and improve access to crucial medicines and supplies in neglected areas. [4]

Robots that interact and affect their surroundings need autonomous grasping, manipulation, and transportation. Recent advances in relevant technologies and commercially available micro aerial vehicles (MAVs) are moving autonomous grasping, manipulation, and transportation to the airborne domain in theory and demonstrations. A Design of gripper was created. A servo motor drove four hooks into the plane to grab an object. Standard fishing hooks were cheap, sharp, sturdy, and available. [5]

Micro Unmanned Aerial Vehicles, often known as MAVs, have found employment in a diverse array of industries and fields. On the other hand, there are only a handful of studies that discuss the use of MAVs to grip and deliver payloads. [5] [6] [7] A quadrotor remotely piloted aerial vehicle (quadrotor MAV) with an actuated appendage that enables gripping and object retrieval at high speeds has been designed, with inspiration drawn from the aerial hunting done by birds of prey. [6]

UAV grippers are made in different ways depending on what they are used for so that they work best for that use. The mantis gripper is a very interesting type of gripper that has been made. The Mantis Claw is a gripper that doesn't need any actuators. Instead, it has a one-way locking mechanism built into it that opens when it grabs an item but doesn't let go. The Mantis claw is not a fixed hand. Instead, a rope connected to the UAV keeps it in the air. [3]

The claw mechanism was chosen as the application for the drone because the drone's utility and versatility can be increased with the addition of a claw mechanism, which enables the drone to complete tasks that require direct physical touch or manipulation. It is possible for a claw mechanism to be uncomplicated and lightweight, which will result in decreased complexity as well as decreased power consumption. The drone can grasp or hang on a variety of objects or surfaces thanks to a claw mechanism that has the potential to be both adaptable and sturdy.

"Design and Development of a Quadcopter with a Claw Mechanism" is about making a quadcopter drone with a claw mechanism. The thesis discusses selecting materials, integrating the claw mechanism with the quadcopter's frame, developing control algorithms for precise manipulation, and testing and evaluating the system's performance. The final goal is to provide a thorough blueprint for developing a quadcopter drone with an efficient and effective claw mechanism, broadening its applications in search and rescue, logistics, and industrial automation.

There are several crucial steps in the design and development of a quadcopter with a claw mechanism. First, the quadcopter's general design and measurements are established while considering variables like weight, size, and payload capability. After that, the design is chosen, and the required electronic parts—such as the motors, propellers, flight controller, and battery—are incorporated. The quadcopter may then grasp and release objects thanks to the claw mechanism, which is normally developed utilizing servo motors and gripping mechanisms. The quadcopter's control system is set up to allow for precise flight management and claw operation, frequently including remote control or autonomous functions. In order to ensure the quadcopter's successful operation and efficient use of the claw mechanism for a variety of applications, it is tested, improved upon, and optimized for performance, safety, and stability.

II. Materials And Fabrication Methods

The various components of a typical Quadcopter are:

1. **Frame**: Frames made up of various materials are present out there like Plastic, Glass Fiber, and Carbon Fiber. The type of frame to choose depends upon the application of the quadcopter. But we have fabricated the frame by Aluminium Sheet.
2. **Brushless DC Motor**: The brushless motor is the quadcopter’s most critical component. The motors should be strong enough to allow for flight. The motor’s rated speed in KV. The motor’s RPM changes with its KV rating and input voltage. Lower KV rating motors often give greater thrust, whereas higher KV rating motors typically provide lesser thrust. Our approximate weight of drone is 1,600 gms. Therefore, have used low KV rating motor i.e., (1000KV). Aside from thrust, another aspect of motor performance is the amount of current drawn from the battery.
3. **Electronic Speed Controller (ESC)**: An ESC is an electrical circuit that controls the speed and direction of a brushless motor. An ESC transforms DC battery power into 3-phase AC for use in operating brushless motors. It serves as the link between the motors and the flight controller. During the selection of ESC, the current rating must be higher than the ampere drawn by all motors and other components. Electronic Speed Controllers provide high-power, high-frequency, high-resolution 3-phase AC electricity to motors, allowing them to fly. Here we are using SimonK 30A BLDC ESC Electronic Speed Controller with Connectors.
4. **Propeller**: The propeller serves as the flight’s wings. It propels the air downward, causing the drone to fly. Different types of propellers are available in almost every size. Propellers have a significant impact on the flying speed, weight, and manoeuvrability of quadcopters. You may choose the length and pitch of the propellers based on these characteristics. Here, we use 10 x 4.5 propeller. Longer propellers produce more lift at lower RPM, but they take longer to accelerate and decelerate. Shorter propellers alter the speed of the quadcopter quickly and create improved manoeuvrability. When compared to longer propellers, shorter propellers take more energy/current to spin. This puts undue strain on the motors, perhaps shortening their lifespan.
5. **Flight Controller**: The Quadcopter’s brain is the flight controller. This is a compact computer board equipped with numerous sensors that detect the movement of the ship. It includes sensors such as a gyroscope, accelerometer, barometer, and magnetometer. According to the signal that comes from the transceiver, it controls the motors and craft. Flight controllers configured with computer software. It uses computer software like Cleanflight, Betaflight, Mission planner etc. Here we use F4 Pro V2 V3.5 v3s Flight Control Built-in OSD / BEC.
6. **Transmitter and Receiver**: Radio Transmitter is an electronic device that uses radio signals to transmit commands wirelessly via a set radio frequency over to the Radio Receiver, which is connected to flight controller of quadcopter being remotely controlled. Radio transmitters and receivers manipulate electricity resulting in the transmission of useful information through the atmosphere or space. The transmitter sends a signal over a frequency to the receiver. The transmitter has a power source, that provides the power for the controls and transmission of the signal.
7. **Lithium-Polymer Battery**: Finally, to power on the quadcopter, we need Lithium polymer (LiPo) battery. Flight time of the quadcopter depends on the battery capacity. Generally, the LiPo batteries are rated with their capacity in mAh, i.e., the battery which we are using is Flipo 3300 mAh 3S 40C/80C (11.1V).
8. **Landing Gear**: The main purpose of Landing Gear systems in Drones is to facilitate safe take-off and landing of Unmanned Aerial Vehicle. The stand was made of ABS material.

Fig. 1: Isometric view of a Landing Gear

Fig. 2: Side view of a Landing Gear

9. **Servo Motor**: A rotary actuator known as a servo motor (or servo) enables precise control of angular position, velocity, and acceleration. Servos are a common component in toys, home electronics, automobiles, and aircraft. Servos are also found in the background of many of the gadgets we use every day.
10. **Arduino UNO**: The Arduino Uno is an open-source microcontroller board created by Arduino.cc and first made available in 2010. It is based on the Microchip Atmega328P microprocessor. Sets of digital and analogue input/output (I/O) pins are included on the board, allowing it to be interfaced with other expansion boards (shields) and other circuits. The board contains 6 analogue I/O pins and 14 digital I/O pins, six of which may be used for PWM output. It can be programmed using the Arduino IDE (Integrated Development Environment) with a type B USB connector. A barrel connection that can handle voltages between 7 and 20 volts, such as a square 9-volt battery, or a USB cable are both options for powering it.
11. **Bluetooth Module**: A Bluetooth BLE module is a piece of technology that sets a mechanism for data transmission between devices and serves as an interface for wireless Bluetooth Low energy connections between any two devices. The average mediated data transmission range of a Bluetooth low energy module is typically tens of meters, and data is transmitted in designated frequency bands. Bluetooth modules come in a variety of brands, kinds, models, and categories. One of the most widely accepted Internet of things (IoT) communication protocols, Bluetooth Modules have a wide range of applications.
12. **Quadcopter Arm**: The purpose of the quadcopter arm is to provide structural support and house essential components for the functioning of the quadcopter. Each quadcopter arm typically holds a motor, propeller, and electronic speed controller (ESC). The motor generates the necessary thrust to lift and maneuver the quadcopter, while the propeller converts the rotational motion of the motor into upward or downward force. The ESC regulates the speed and power distribution to the motor, allowing precise control of the quadcopter's movement. Additionally, the quadcopter arm may also contain wiring and connectors for power distribution and communication between components. The design and construction of the arm ensures stability, balance, and proper weight distribution, ultimately contributing to the quadcopter's flight performance and overall functionality.

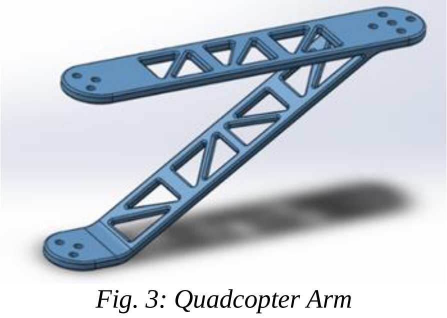


Fig. 3: Quadcopter Arm

13. **Spacer**: The purpose of quadcopter spacers is to securely join and maintain the spacing between different components of the quadcopter frame. Spacers, also known as standoffs, are typically cylindrical or hexagonal pillars made of materials like plastic, aluminum, or brass. They are inserted between the frame's plates or layers to create a gap or separation. The spacers serve several important functions. Firstly, they provide structural integrity by reinforcing the connection points between the frame components. This helps distribute the load and stress evenly across the frame, reducing the risk of components coming loose or breaking during flight. Secondly, spacers ensure proper spacing and alignment between different layers of the frame. By maintaining a consistent distance, they help prevent interference between components, such as the flight controller, power distribution board, or other electronics. Lastly, spacers can also facilitate easier maintenance and repairs. They provide accessibility by creating sufficient space to maneuver tools or access specific components without disassembling the entire quadcopter. Overall, quadcopter spacers play a crucial role in ensuring structural integrity, alignment, and effective operation of the various components within the quadcopter frame.
14. **Servo Cage**: The purpose of the servo cage in a quadcopter is to securely house and protect the servo motors, which control the movements of the control surfaces. It provides a stable structure to mount the servos and protects them from external impacts or damage. Additionally, the servo cage helps with cable management, ensuring proper routing and securing of servo wires for reliable operation. Overall, the servo cage enhances the performance and longevity of the servo motors, leading to precise control and maneuverability of the quadcopter.
15. **Claw**: The purpose of the claw mechanism in a quadcopter is to enable the quadcopter to grasp and manipulate objects. The claw, typically located underneath the quadcopter, consists of mechanical arms or grippers that can open and close to securely hold onto objects. This mechanism expands the capabilities of the quadcopter, allowing it to perform tasks such as object retrieval, delivery, or even assembly operations. By incorporating a claw mechanism, the quadcopter gains versatility in its applications. It can be used in scenarios were picking up and moving objects are required, such as search and rescue missions, industrial inspections, or even recreational activities.
The claw mechanism underwent several iterations before reaching its current state. The figure illustrates the shell-type gripper that was the initial version that was created after the problem was identified.

Fig. 4: Claw mechanism with Shell type Gripper

The design of the shell-type grippers had some restrictions that needed to be followed. The Shell-type grippers had a size and shape that was always the same, hence their capacity to grasp objects of different sizes and shapes was constrained. They function most effectively with things that may be gripped within the range that has been predetermined for them. Another drawback was that the gripper, which was of the shell type, had a fixed shape, making it less than ideal for use with objects of a more irregular shape. It has difficulty maintaining a solid grasp on things that have uneven surfaces or unusual geometries. Additionally, the drone was made heavier by the addition of shell-type grippers, which had a negative impact on both its overall flight performance and its payload capacity.
The smooth grippers were the second iteration of the grippers, and they were utilized in the claw mechanism of the drone at the time of the design in SolidWorks software.

Fig. 5: Claw mechanism without Teeth type Gripper

When compared to teeth type grippers, the teeth type grippers were distinguished by the presence of teeth or serrations, which boosted the ability to maintain a firm hold on the object and this was unique about the teeth type gripper. Also, because of the way the teeth interlocked with one another, the gripper was able to generate higher frictional forces, which enabled it to hold items more securely, particularly in circumstances in which the object may be slippery or have uneven surfaces. Additionally, the teeth-type gripper was versatile in that it could hold objects of a wide range of sizes and forms. The serrations were able to conform to the shape of whatever was being held, which resulted in a more secure grip on the item. Because of its adaptability, the teeth-type gripper was an excellent choice for handling objects with non-uniform or irregular forms.

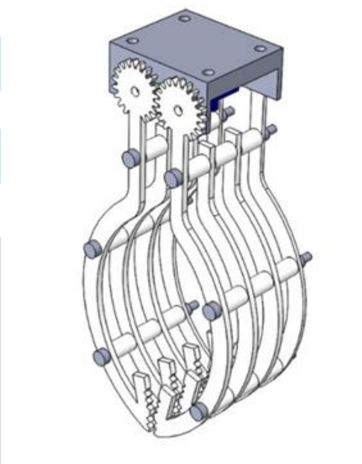


Fig. 6: Claw mechanism with Teeth type Grippers

The uniqueness of the teeth type gripper is the great gripping surface to lift weight up to 100g. To increase the gripping effect, sandpaper was used.

16. **Assembly of a Quadcopter**: The purpose of assembling a quadcopter is to create a fully functional aerial platform that can be used for various applications. During assembly, the different components such as the frame, motors, propellers, flight controller, ESCs, and other electronics are carefully connected and integrated. The assembly process ensures that all components are properly installed, aligned, and secured, allowing them to work together harmoniously. By assembling a quadcopter, individuals can customize and tailor the specifications of the drone to their specific needs. They can choose components with desired features and performance characteristics, enabling them to optimize the quadcopter for their intended applications. Moreover, assembling a quadcopter provides an opportunity for individuals to gain a deeper understanding of the drone's internal workings and mechanics, fostering a sense of ownership and control over their aerial platform. Overall, the purpose of quadcopter assembly is to create a personalized and fully operational drone that meets specific requirements. It empowers individuals to have a hands-on approach in building their quadcopter and allows for customization and flexibility in design and functionality.

Fig. 7: Assembly of a Quadcopter

The overall quadcopter structure was built around the gross weight of 1323 g which can carry the payload capacity of 100 g The entire quadcopter was designed in consideration with reliability as well as low power consumption criterion to maintain the maximum endurance limit.

Fig. 8: Manufactured Quadcopter

17. **Analysis of a Quadcopter Arm**: **Fig. 9** shows the Static Structural-Total Deformation of a Quadcopter Arm. Maximum Deformation was 0.4368 mm. **Fig. 10** shows Static Structural-Equivalent (von-Mises) Stress of a Quadcopter Arm. The maximum stress induced on the Quadcopter Arm is 3.9534 MPa. **Fig. 11** shows the Static Structural Factor of Safety of a Quadcopter Arm. Minimum and Maximum Factor of Safety of the Quadcopter Arm are 10.472 and 15 respectively. Finally, **Fig. 12** depicts the Forces and Supports on a Quadcopter Arm. Position A shows that the Force of 7.848 N is applied on the Quadcopter Arm and Position B is the fixed support.

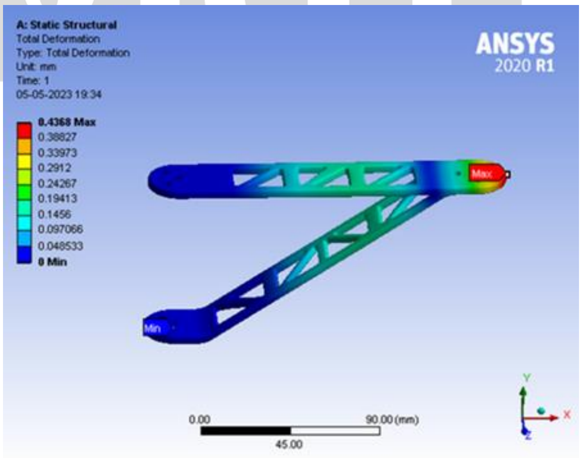
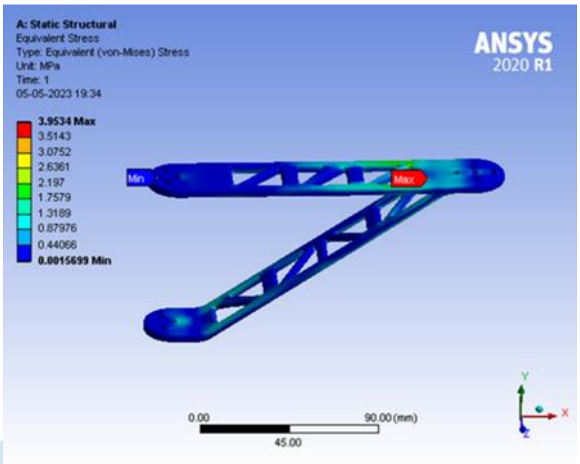


Fig. 9: Static Structural-Total Deformation of a Quadcopter Arm



Fig, 10: Static Structural-Equivalent (von-Mises) Stress of a Quadcopter Arm

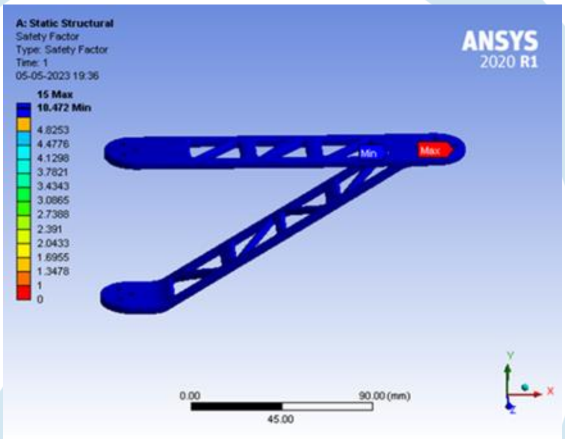


Fig. 11: Static Structural-Factor of Safety of a Quadcopter Arm

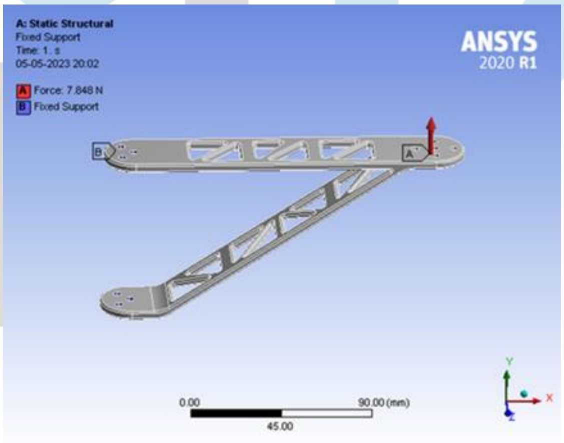


Fig. 12: Forces and Support on a Quadcopter Arm

18. **Analysis of a Stand**: **Fig. 13** shows the Static Structural-Total Deformation of a Stand. Maximum Deformation was 1.113 mm. **Fig. 14** shows Static Structural-Equivalent (von-Mises) Stress of a Quadcopter Arm. The maximum stress induced on a Stand is 2.356 MPa. **Fig. 15** shows the Static Structural-Factor of Safety of a Stand. Minimum and Maximum Factor of Safety of the Stand are 15 and 15 respectively. Finally, **Fig. 16** depicts the Forces and Supports on a Stand. Position A shows that the Force of 4.412 N is applied on the Stand and Position B is the fixed support.

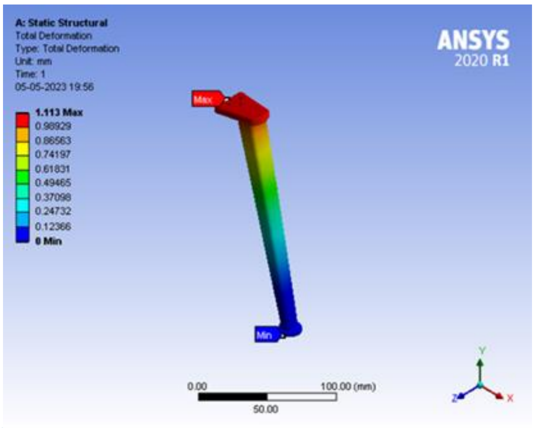


Fig. 13: Static Structural-Total Deformation of a Landing Gear

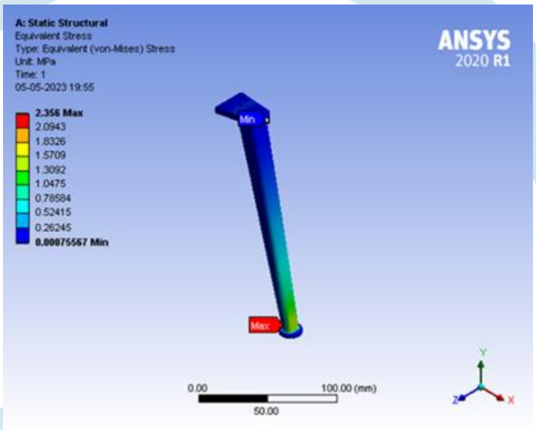


Fig. 14: Static Structural-Equivalent (von-Mises) Stress of a Landing Gear

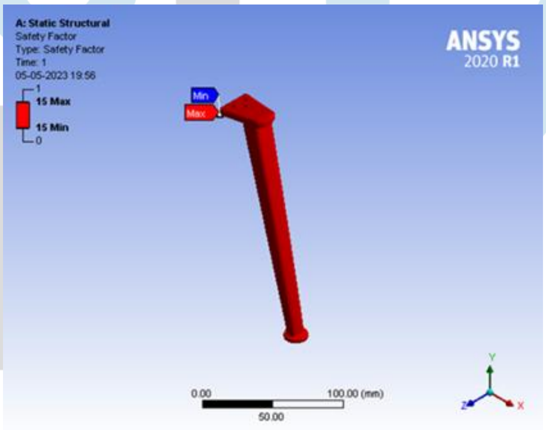


Fig. 15: Static Structural-Factor of Safety of a Landing Gear

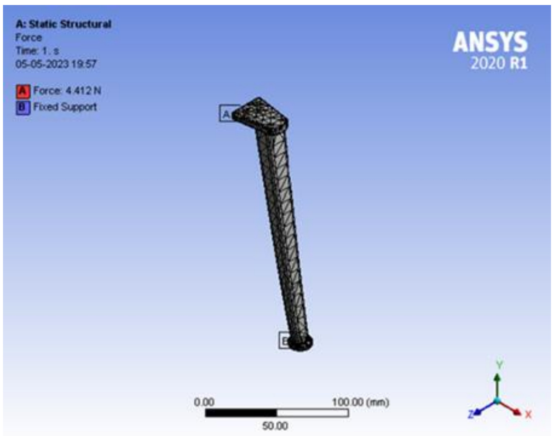


Fig. 16: Forces and Support on a Landing Gear

19. **Analysis of a Gear Claw**: **Fig. 17** shows the Static Structural-Total Deformation of a Gear Claw. Maximum Deformation was 8.1723 mm. **Fig. 18** shows Static Structural-Equivalent (von-Mises) Stress of a Gear Claw. The maximum stress induced on a Gear Claw is 17.054 MPa. **Fig. 19** shows the Static Structural-Factor of Safety of a Gear Claw. Minimum and Maximum Factor of Safety of the Gear Claw are 2.4275 and 15 respectively. Finally, **Fig. 20** depicts the Forces and Supports on a Gear Claw. Position A shows that the Force of -1.655 N is applied on the Gear Claw and Position B is the fixed support.

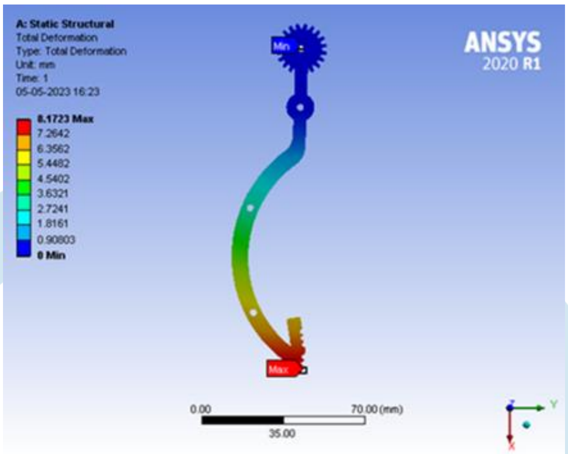


Fig. 17: Static Structural-Total Deformation of a Gear Claw

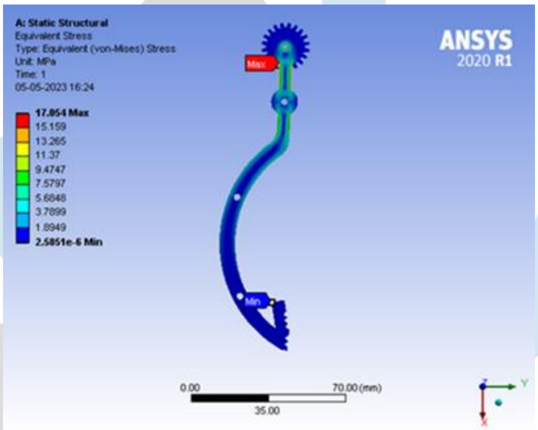


Fig. 18: Static Structural-Equivalent (von-Mises) Stress of a Gear Claw

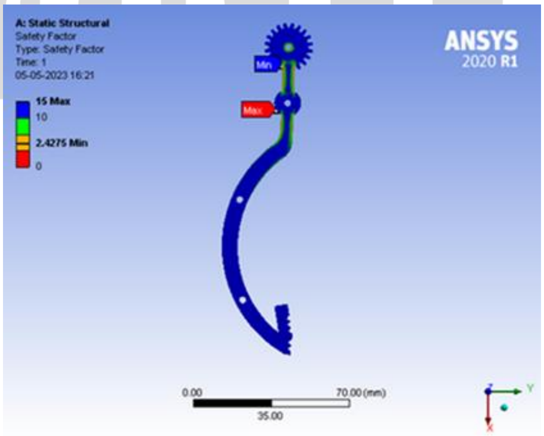


Fig. 19: Static Structural-Factor of Safety of a Gear Claw

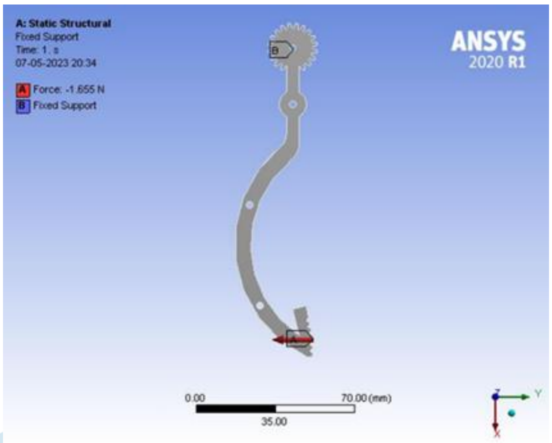


Fig. 20: Forces and Support on a Gear Claw

III. CALCULATIONS

1. **Motor KV rating Selection**:
   Considering the BLDC Motor Model A2212 Motor Performance Data:

Table 1: Model A2212 Motor Performance Data

Model	KV (rpm/V)	Voltage (V)	Propeller	Load Current (A)	Pull (g)	Power (W)	Efficiency (g/W)	Li-Po Cell	Approx Weight (g)
A2212	930	11.1	1060	9.8	660	109	6.1	2-4S	52
	1000		1047	15.6	885	173	5.1		
	1400		9050	19.0	910	210	4.3		
	2200		6030	21.5	732	239	3.1		

The Pull or Thrust that a motor is generating = 885 g
Therefore, 4 motors are generating = 3540 g
Now, considering the weight of the drone = 1.8 kg or 1800 g
It is important to ensure that the motors used in the drone can provide about 50% more thrust than the actual weight of the drone for all forms of multirotor.
Therefore, 1800 + 50% of 1800 = 2700 g < 3540 g
Hence it is safe to use the Model A2212 with 1000 KV motor specification.

2. **ESC Selection**:
   From XA2212 1000KV motor test record table:
   15.6 A of current is drawn by 1 BLDC motor at 100% full throttle.
   Therefore, 62.4 A of current will be drawn by 4 BLDC motors at 100% full throttle.
   We can say that,
   30 A of current by 1 ESC is suitable for 15.6 A of current by 1 BLDC motor.
   Hence it is safe to use SimonK 30A BLDC Electronic Speed Controller (ESC)

3. **Battery Selection**:
   4 BLDC Motors are drawing 62.4 A of current.
   4 ESCs are drawing 120 A of current.
   Current drawn from other components i.e., Flight Controller and Receiver = 2 A (Assume)
   Therefore, total current drawn = 184.4 A
   Battery capacity = (184.4 ×1000)/60 = 3073.3333 mAh at 100% throttle.
   At 70 % throttle, Battery Capacity = 2151.3333 mAh
   From the above calculation, we select 3300 mAh battery capacity.

4. **Flight Time Calculation**:
   Battery selected is 3300 mAh.
   Therefore, Battery Amperes = 3300/1000 = 3.3 Ah
   Maximum Motor Ampere = 15.6 Ah
   Now, at 50% throttle, Motor Amperes = 15.6 × 50% = 7.8 Ah
   For 4 BLDC motors = 7.8 × 4 = 31.2 Ah
   Therefore, Flight Time Duration in minutes = (Battery Amperes)/(Motor Amperes) × 60 = 6.3462 minutes
   Hence, the flight time duration is ***6mins 21secs***.

5. **Servo Motor Torque Calculation**:

Weight of a block = 0.1 × 9.81 = 0.981 N
Weight = Normal = 0.981 N
Frictional Force = μN
Here, μ = 0.35
Therefore, frictional force = 0.35 × 0.981 = 0.3434 N
Force from one side of a set of four grippers = 0.981 + 0.3434 = 1.3244 N
Force from both the sides = 1.3244 × 2 = 2.6488 N
Torque by Servo Motor = 2.5 kg-cm
Distance = 1.26 cm
Torque required = 2.6488/9.81 × 1.26 = 0.3402 kg-cm
Therefore, Torque by Servo Motor > Torque required; hence we select MG 90S Servo Motor.

IV. Conclusion

The goal of this paper was to demonstrate the idea of a claw mechanism using pick-up and-place quadcopters. Three iterations were made to choose the best iteration for the quadcopter. The uniqueness of the teeth type grippers were the ability to keep a strong hold on the object, which distinguished the teeth type gripper from other types of grippers. This idea was established to improve convenience and efficiency while keeping costs down. These types of quadcopters also have the advantages of shorter delivery periods, lower emissions, and immediate fulfilling. Many modifications and developments are possible in the design. Future attempts will be aimed at modifying the claw mechanism. Studies will also be carried out to improve the quadcopter's flying time.

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