RAMAIAH INSTITUTE OF TECHNOLOGY

(Autonomous Institute, Affiliated to VTU, Belegavi)

Bengaluru – 560 054

Project Report on

MODELLING AND ANALYSIS OF A HYBRID LANDING MECHANISM FOR A DRONE SYSTEM

Submitted in partial fulfillment of the requirement
For the award of

BACHELOR OF ENGINEERING

In

MECHANICAL ENGINEERING

Submitted By

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RAMAIAH INSTITUTE OF TECHNOLOGY, BENGALURU – 560054

2022

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DEPARTMENT OF MECHANICAL ENGINEERING

CERTIFICATE

Certified that the project work entitled **"MODELLING AND ANALYSIS OF HYBRID LANDING MECHANISM FOR A DRONE SYSTEM"** is a bonafide work carried out by students **Ms. Nithasree S (1MS19ME115), Ms. Nidhi V (1MS19ME109), Prekshit S Parakh (1MS19ME133) and Raghav S (1MS19ME137) of the Department of Mechanical Engineering, Ramaiah Institute of Technology, Bangalore,** in partial fulfillment for the award of **Bachelor of Engineering in Mechanical Engineering** of the Visvesvaraya Technological University, Belagavi during the year 2022**.** It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library. To the best of our knowledge, this report does not contain any work which has been previously carried out by others and the report has been approved as it satisfies the academic requirements in respect of project work prescribed for the Bachelor of Engineering Degree.

Mr. GURURAJ	**Dr. RAJI GEORGE**	**Dr. N.V.R. NAIDU**
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Signature of External Examiners:

Name **Signature**

1)_________________________ ____________________

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DEPARTMENT OF MECHANICAL ENGINEERING

DECLARATION

We hereby declare that the entire work embodied in this project has been independently carried out by us under the supervision of internal guide Mr. GURURAJ, Assistant Professor, Department of Mechanical Engineering, Ramaiah Institute of Technology, Bengaluru in partial fulfilment of the requirement of the Bachelor of Degree in Mechanical Engineering. We further declare that the report has not been submitted either in part or in full to any other university for the award of any Degree.

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ABSTRACT

Drones have recently been widely used in the defense industry for surveying. Surveying requires the drone to hover around a singular region and gather visual data of the surroundings. In general, the visual data is captured with a camera. But in this case, battery endurance is a major setback in the scenario where the drone has to continuously monitor a particular region. In case the battery has to be replaced the drone loses sight of the region for a brief period of time. To overcome this issue of battery endurance, in the present study a gripper has been introduced in our design. The gripper is designed to perch on to nearby branches or any kind of support. This will allow the drone to grab on to the surface and turn off its propulsion systems instead of just hovering around a region if necessary. This will increase the endurance of the battery enormously as opposed to that of the conventional systems. This particular application can be extended to other fields like Forest Surveying, pick and place, drop and delivery. This system can specifically be used in case of First Rescue as well.

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CHAPTER I
INTRODUCTION

UAV possesses great potentials in both civil and military applications because of its excellent characteristics such as small volume, simple structure, flexible operation, vertical take-off and landing, etc. During take-off and landing process, the height and velocity of an aircraft was very low, and the control ability gets reduced. However, the slope of the landing surface can severely limit viable landing areas. As a result, take-off and landing processes can be dangerous. When an aircraft experiences a hard landing, it must be inspected for damage before its next flight, which costs a lot of time. An adaptive landing gear can solve the problem aforementioned.

The design, modelling, simulation, and testing of a landing gear system that enables a UAV to perch on an object or surface is the need of the hour.

The working principle of the landing gear is inspired by the anatomy of birds that grasp and perch as tendons in their legs and feet are tensioned. In a similar fashion, as the UAV sets down on a structure, its weight tensions a cable which actuates opposing, flexible, multi-segment feet to enclose the target. To analyse the grasping capability of the design, a hybrid empirical–computational model is developed that can be used to simulate the kinematics of the system as it grasps objects.

A multi-finger robot system is designed to realize the adaptive landing and aerial manipulation of UAVs. It is reliable to find a flat area for landing through the landing site detection algorithm. However, there are many unexpected situations in real rescue or inspection missions, which may require UAVs to land nearby on the inclined top of buildings or rugged ground therefore our design is a bioinspired landing system for UAVs that can adapt to various cylindrical surface structures and reduce impact.

Adding actuators will increase the weight of the UAV system and affect its endurance and load performance. This project aims to enable the UAV to have grasping and perch functions by equipping one mechanism. Having a functioning battery is one of the most important parts of flying a drone. This is why it's important to properly charge the battery before trying to take flight. When the drone is not in use, it's best to store the battery in a cool, dry place -- the battery should not be left in the drone when it's not in use. This can help maintain the charge and increase the lifespan of the battery. Additionally, it's important to not overcharge the battery, which can drastically decrease its lifespan. All in all, taking good care of the battery will ensure it lasts as long as possible. Perching helps small unmanned aerial vehicles (UAVs) extend their time of operation by saving battery power.

However, most strategies for UAV perching require complex manoeuvring and rely on specific structures, such as rough walls for attaching or tree branches for grasping. Many strategies to perching neglect the UAV's mission such that saving battery power interrupts the mission.

We suggest enabling UAVs with the capability of making and stabilizing contacts with the environment, which will allow the UAV to consume less energy while retaining its altitude, in addition to the perching capability that has been proposed before UAV on a wide range of different structures by perching and resting. Modularization allows our framework to adapt to specific structures for resting through rapid prototyping with additive manufacturing. Actuation allows switching between different modes of perching and resting during flight and additionally enables perching by grasping.

This framework can be used to perform UAV perching and resting on a set of common structures, such as street lights and edges or corners of buildings. The design is effective in reducing power consumption, promotes increased pose stability, and preserves large vision ranges while perching or resting at heights. Figure 1.1 displays several ways in which animals with powered flight have adapted to temporarily exploit contacts with structures in their habitat for saving energy.

For example, birds can be observed placing their feet on supports while still flapping their wings, and bats are known to hang upside down while grasping suitable surfaces. In all of these cases, some suitably shaped part of the animal's foot interacts with a structure in the environment and facilitates that less lift needs to be generated or that power flight can be completely suspended.Our goal is to use the same concept, which is commonly referred to as "perching,"for UAVs.

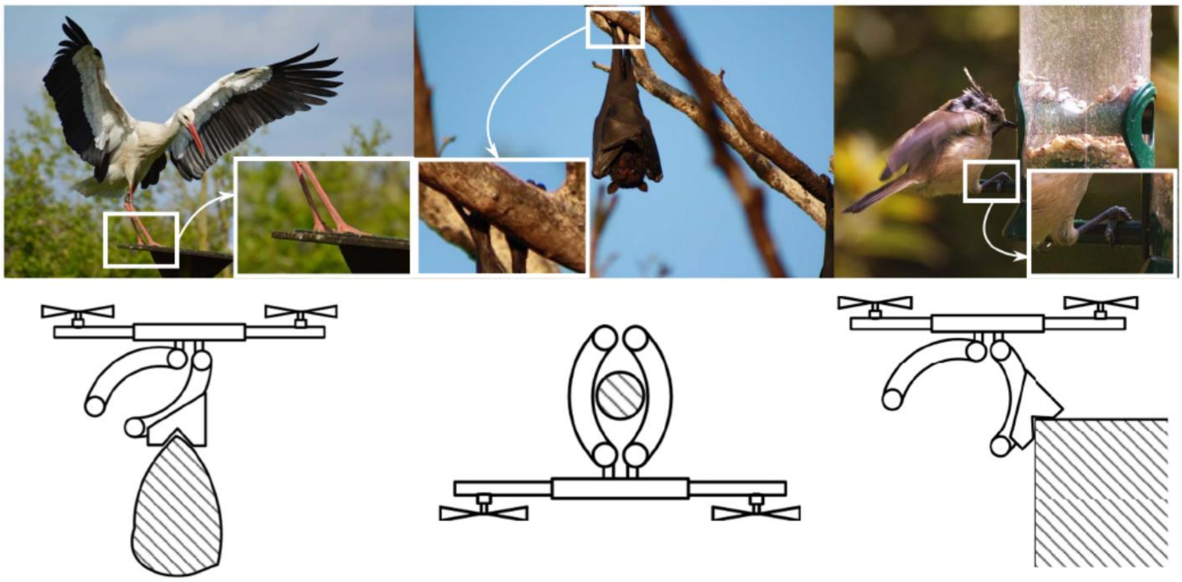


Fig. 1. Example perching and resting actions in nature. Flying animals such as birds or bats often make use of structures in the environment to save energy. In choosing, they select locations that can be approached and evacuated by simply maneuvering in the air while still allowing them to execute a mission such as observing the environment or looking for prey.

Fig 1.1: Perching and Resting actions in nature

Source: Scihub.org

With recent advances in lightweight, low-power sensor technology and onboard computation, unmanned aerial vehicles (UAVs) are now engaging in missions with an unprecedented degree of autonomous Onboard sensors such as cameras, ultrasonic sensors, and accelerometers not only provide advanced perception capabilities that are low increasingly complex missions but also enable more powerful control methods.UAVs can reliably fulfill missions such as aerial videography, autonomous surveillance, object delivery, and construction site inspection and are deployed in crisis response to provide on-site measurement.

Autonomous UAVs are often deployed to conduct long-duration missions that require watching an area on the ground from heights for an extended period of time, such as in an autonomous surveillance task. For this reason, energy consumption is one of the primary concerns in the operation of lightweight UAVs because mission duration is limited by battery power. Because UAVs require constant motor action to create lift to stay in the air, more energy-efficient control and aircraft design are therefore of high interest to reduce the energy consumption during flight. However, the most effective way of saving energy is to directly reduce the required lift during execution of the mission.

Our goal is to use the same concept, which is commonly referred to as ‘perching’ for UAVs. Perching requires attaching and detaching from a structure in the surroundings on command and relies on the availability of certain structures in the surroundings, such as tree branches. It is therefore limited to a small set of mission environments; when the perching location does not provide a good view range, it will result in mission interruptions. To address the problem of allowing UAVs to reduce their power consumption in a mission, we propose to enable UAVs with the capability of making and stabilizing contacts with the environment to obtain force support. With this capability, UAVs require less lift generated by the motors and can save energy. Moreover, it enables UAVs to be able to exploit a much larger range of structures in the environment to conduct missions without interruptions.

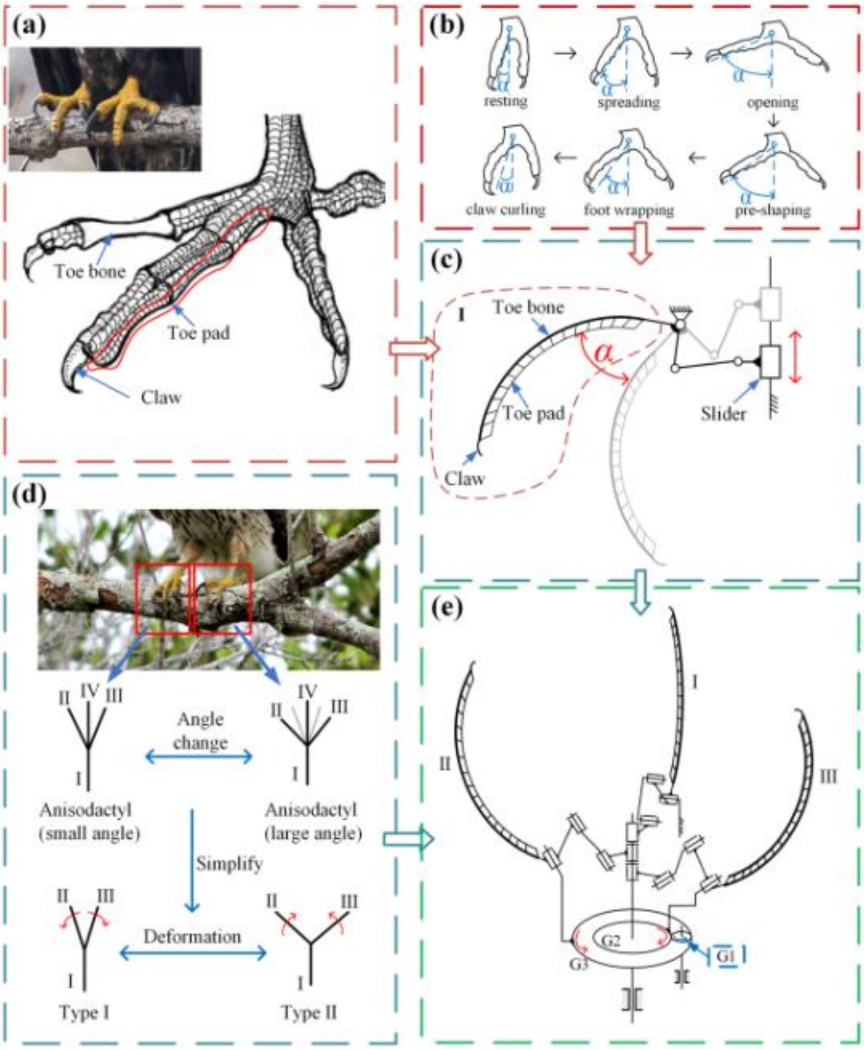


Fig 1.2: Bionic Principle of Perching

Source: Scihub.org

CHAPTER II
SCOPE OF THE PROJECT

Due to the characteristics of vertical take-off and hover, the rotary-wing unmanned aerial vehicle (RUAV) has a growing trend of application in disaster relief, material delivery, regional patrol, and intelligent agriculture. Although the landing of RUAV have lower requirements on the surrounding environment compared with fixed-wing UAV, it still requires a relatively flat area. The landing inclination angles of RUAV exceeding 8^{o} may be dangerous.

This project proposes the design concept of the mechanism, analyzes the kinematics of the robot system, and introduces the hardware configuration of the whole machine.

For tasks like defence surveys, post-disaster rescue, cable maintenance and forest survey, we hope that the UAV has the functions of emergency landing on and grasping objects. Installing a manipulator or a multi-DOF landing gear for the UAV is the most straightforward choice, but multiple motors are required in the multi-DOF mechanical structure, which increases the weight of the UAV and adds the complexity of the control system.

UAV has been widely used in the intelligence surveillance and reconnaissance, traffic monitoring and management, search and rescue etc. It has played a significant role in those fields. However due to size and loading limitations, there are limited onboard power supplies in the UAV, which usually results in a short flight time.

Further, the gripper system can be used to pick and place light weight objects too with specific design changes. This can help aid the process of delivery of first-aid kits, food supplies, lightweight protective gear, etc during post disaster rescue.

Chapter III

LITERATURE SURVEY

3.1 An overview of the prior art related to the field of hybrid landing mechanisms for drone systems

3.1.1 [1] Jian Liu, Dan Zhang, Chenwei Wu, Hongyan Tang, Chunxu Tian, A multi-finger robot system for adaptive landing gear and aerial manipulation.

In this study, a bioinspired multi-finger robot system (MFRS) is designed based on the characteristics of eagle claws. The MFRS is attached to a rotary-wing unmanned aerial vehicle (RUAV), which can be enabled to land on uneven terrain. In addition, the robot can also grab target objects or perch on a cylinder. The finger of the robot can simultaneously rotate three revolute joints only relying on one motor, to achieve an action similar to the grip of the eagle claw. The outdoor environment is mostly uneven terrain, which greatly restricts the application of the RUAVs. To ensure that the RUAV can land in complex terrain, The paper proposed a system that can complete 3D terrain reconstruction and landing site detection.

3.1.2 [2] Elsa S. Culler, Gray C. Thomas, Christopher L. Lee, A Perching Landing Gear for a Quadcopter

The design, fabrication, and testing of two prototypes of a landing gear mechanism that would allow a quadcopter to grasp and perch upon branch-like structures are presented. The prototypes are based upon a snapping-claw mechanism which is triggered by the impact of landing. The results from the flight tests with commercial off-the-shelf quadcopter tests are presented which demonstrate the performance of the mechanism.

3.1.3 [3] Long Bai, Hao Wang, Xiaohong Chen, Jia Zheng, Liming Xin, Yupeng Deng, Yuanxi Sun, Design and Experiment of a Deformable Bird-inspired UAV Perching Mechanism

This paper proposed that Energy consumption and acoustic noise can be significantly reduced through perching in the sustained fights of small Unmanned Aerial Vehicles (UAVs). Aiming at solving these problems, a deformable UAV perching mechanism with strong adaptability and high loading capacity, which is inspired by the structure and movements of birds' feet, is presented in this paper. In addition, it is shown the energy consumption of the UAV perching system when perching on objects can be reduced to 0.015 times that of hovering.

3.1.4 [4] Kaiyu Hang, Ximin Lyu, Haoran Song, Johannes A. Stork, Aaron M. Dollar, Danica Kragic, Fu Zhang, Perching and resting—A paradigm for UAV manoeuvrings with modularized landing gears

The Paper presented a a modularized and actuated landing gear framework that allows stabilizing the UAV on a wide range of different structures by perching and resting. Their result show that results show that this framework can be used to perform UAV perching and resting on a set of common structures, such as street light poles and edges or corners of buildings. They have further shown that the design is effective in reducing power consumption, promotes increased pose stability, and preserves large vision ranges while perching or resting at heights.

3.1.5 [5] Kiren Setty, Theo van Niekerk, Riaan Stopforth, Generic gripper for unmanned aerial vehicle.

In this paper the gripper was designed to be capable of gripping complex-shaped objects with a UAV which may not have been designed to be gripped by a conventional UAV gripper. The gripper is required to be as lightweight as possible to reduce the overall load on the UAV, whilst still being capable of gripping heavy and large objects. Tests were performed with the UAV gripper, to identify if it is able to grip different shape objects Tests were performed with the gripper to determine the capabilities of the device to grip objects.

3.2 Articles

3.2.1 [1] Jernej Prešeren, Dejan Avguštin, Tadej Mravlje, Guidelines for the design of robotic gripping systems

This paper describes guidelines for the design of grippers for use in modular manufacturing work cells. Gripper design is an important and often overlooked aspect of the design of a complete assembly system. Here, guidelines are presented which can be applied to a wide variety of grippers. Guidelines are divided into three major categories: those that improve system throughput, those that increase system reliability, and those that decrease cost. Designs of several grippers, currently being used in a modular manufacturing work cell, are presented as examples of the application of the guidelines to real world problems. The paper further emphasizes that the design of the end-of-arm tooling for a robotic assembly system is very important for reducing errors and decreasing cycle times.

CHAPTER IV

OBJECTIVES OF THE PROJECT WORK

Modelling

- To model a gripping system capable of perching onto branches or other types of supporting surfaces using SolidWorks.
- For the integration of the gripping system to a drone, modelling of an adaptor using SolidWorks.

Analysis

- Analysis of the above modelled gripping system to find out the deformation occurring at the fingers due to the perching mechanism using ANSYS.
- To perform the static analysis with respect to stress, deformation and animation of deformation and FOS.

Finally, the underlying objective of conceiving such a project is to develop a hybrid landing system capable of **perching**, pick-and-place, drop-and-delivery as well as camouflaging for defence purposes.

CHAPTER V

METHODOLOGY

DESIGN METHODOLOGY:

1. The primary goal is to design a gripper capable of perching onto a branch and sustain the weight of the drone.
2. The gripper was chosen to have 4 fingers due to:
    a) Higher flexibility over 3 fingered, 2 fingered and single fingered system.
    b) Higher payload Capacity.
    c) Greater Adaptability to wide range of surface.
3. The available options for a gripper was – Pneumatic gripper, Vacuum Gripper, Hydraulic gripper, Electric Grippers. Due to availability of space in the drone system, only electric gripper was feasible.
4. Out of the major 2 types, Friction Gripper and Encompassing Gripper, encompassing type of gripper was chosen to be used as the type of surfaces to be gripped upon are very irregular and is of unknown surroundings.
5. To support the above claim, the gripping system is again employed with 4 fingers which can encompass a cylindrical surface of any diameter.
6. A servo motor is used for actuating such a movement of the fingers. The advantage of a servo motor is the fact that the angle turned by the motor can be precisely set by the user by giving a particular PWM value which is used to control a servo motor
7. Also, an advantage of a servo motor is that it allows continuous movement of the fingers instead of discrete points of displacement.
8. There were multiple options for placement of the servo motors:
    a) One was to place an individual servo motor in every finger and actuate the fingers individually. But this defeats the entire purpose of increasing battery endurance as this adds a large amount of weight.
    b) The other option is to just use a single servo motor and actuate all the 4 fingers by using a Motion distributor system.

Hence, we chose to use the second option.

9. For the motion distribution system, we chose to use a screw mechanism.

10. A primary screw is used to receive motion from the actuator, in this case a servo motor. As the screw converts rotary motion into linear motion of moving upwards and downwards, it decreases and increases the inclination of a link that connects the claw link to the mechanism holder. This transmits the motion from the servo motor to all the joints of the fingers, thus, actuating the entire system.
11. The claw was made to have rough patches at the tip to increase the coefficient of friction thus making it more capable of gripping.
12. The gripper also has a model mounting adaptor at the top for mounting itself to the drone. This adaptor can be changed based on requirements. Based on the type of drone to be integrated with, the adaptor design can be changed

CAD MODELS:

The below figures show the cad model of the gripper. The gripper design has 4 fingers for better adaptability and flexibility. A single servo motor is used as the actuator. The motion is transmitted to all the 4 fingers using a screw mechanism. The tip of the claw is made to have rough patches to enhance the friction between the object and the gripper. The software used for the 3D design of the model is "SolidWorks" which was developed by Dassault Systemes .

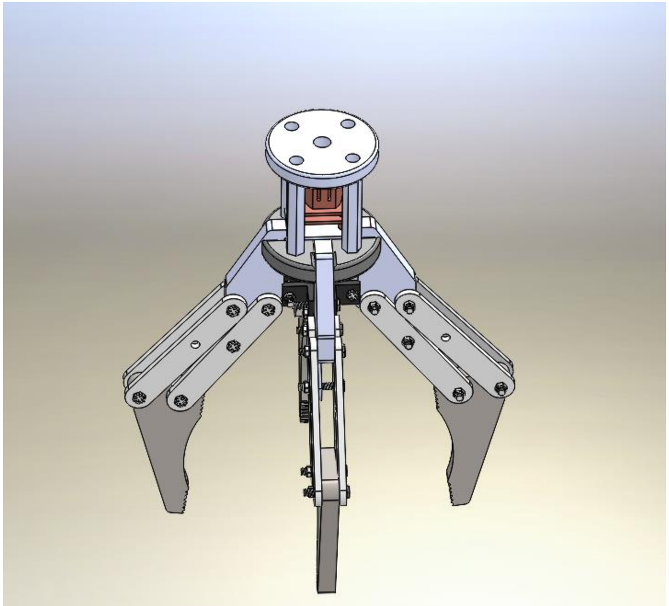


Fig 5.1: Front View

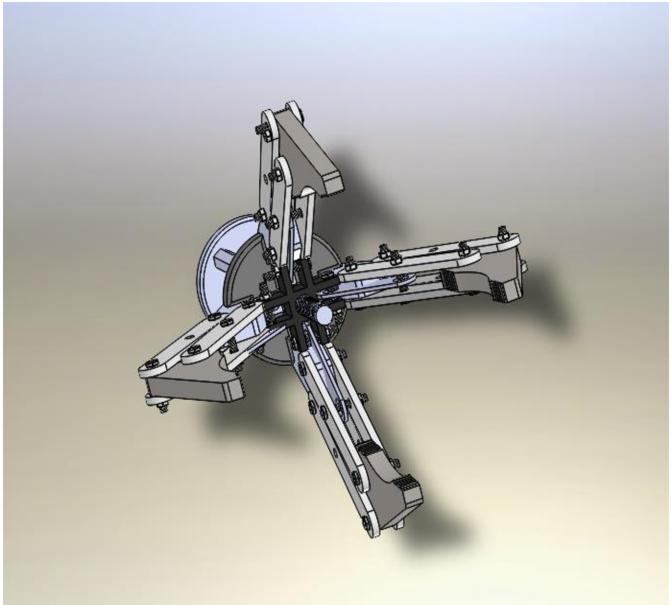


Fig. 5.2: Bottom View

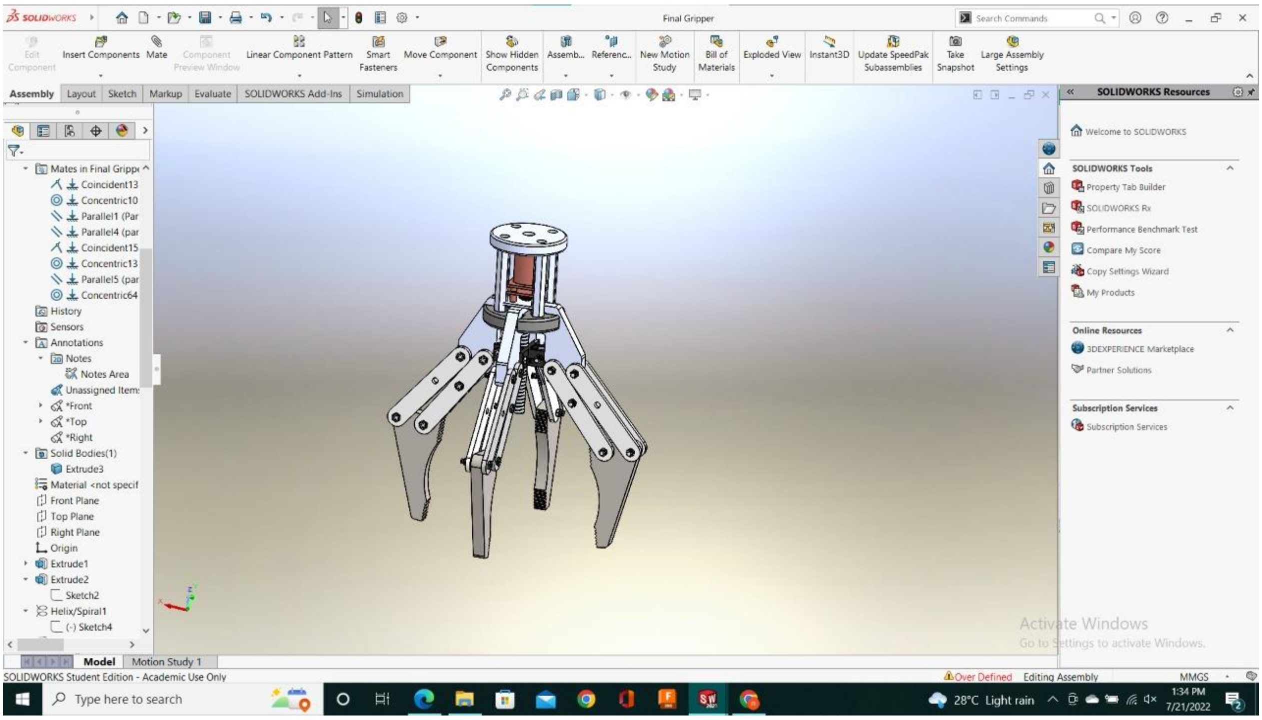


Fig 5.3: Isometric View

MANUFACTURING DRAWINGS:

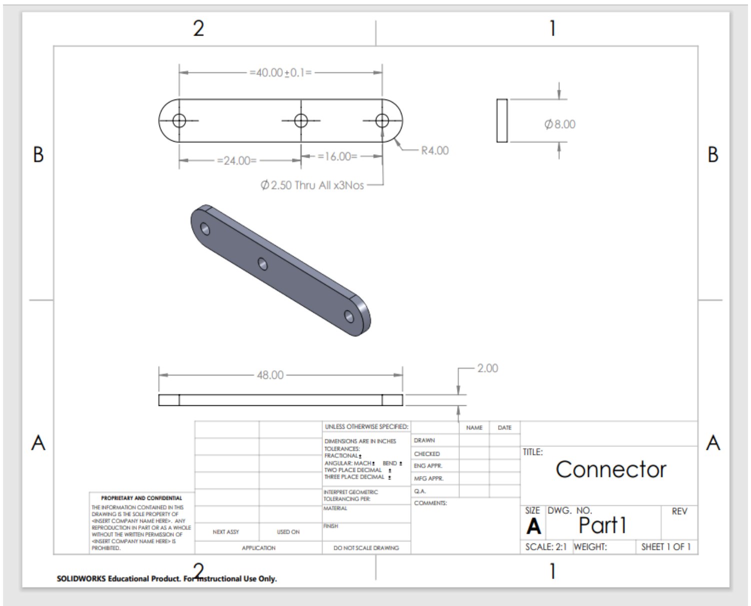


Fig 5.4: Connector drawing

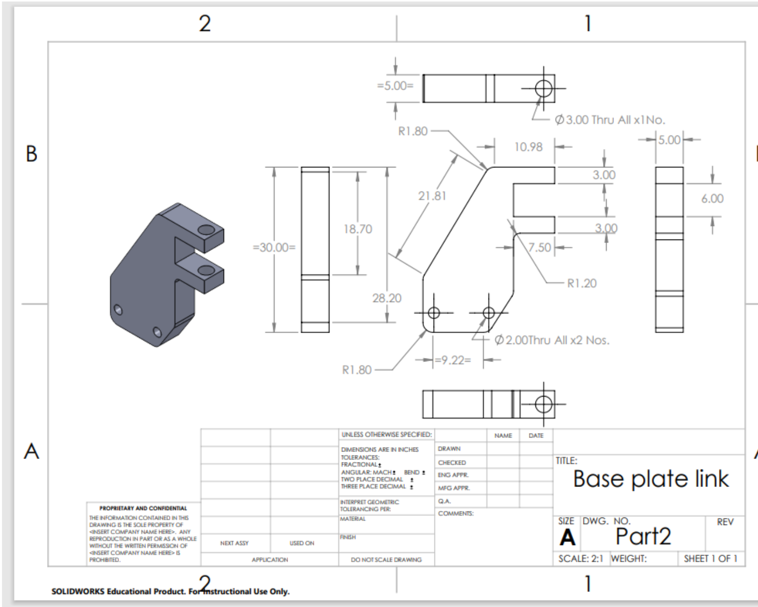


Fig 5.5: Base Plate Link

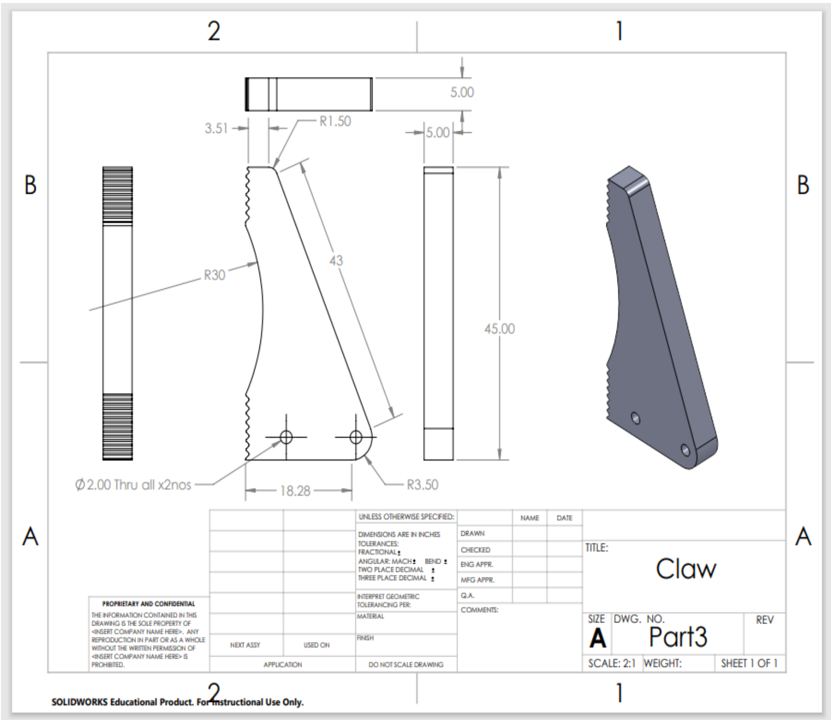
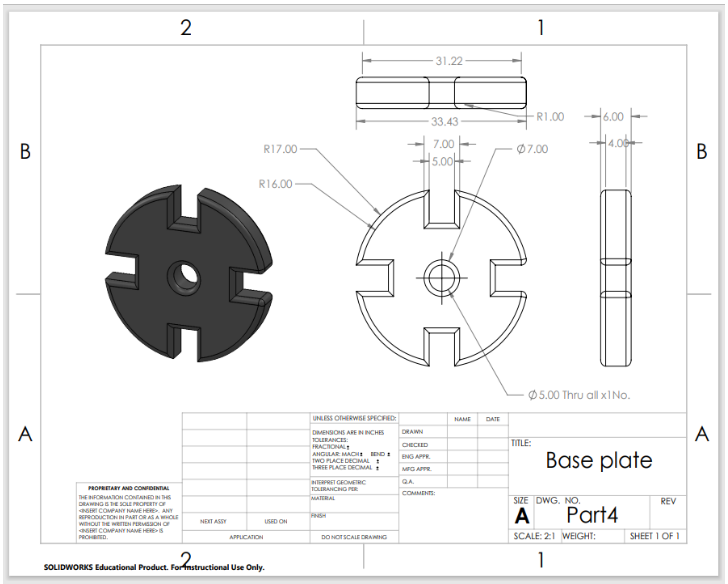


Fig 5.6: Claw drawing



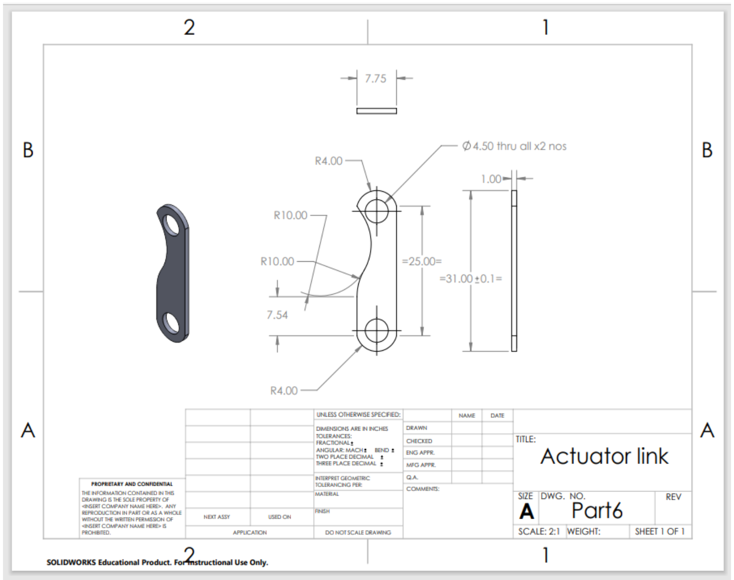


Fig 5.7: Base Plate drawing

Fig 5.8 : Actuator Link drawing

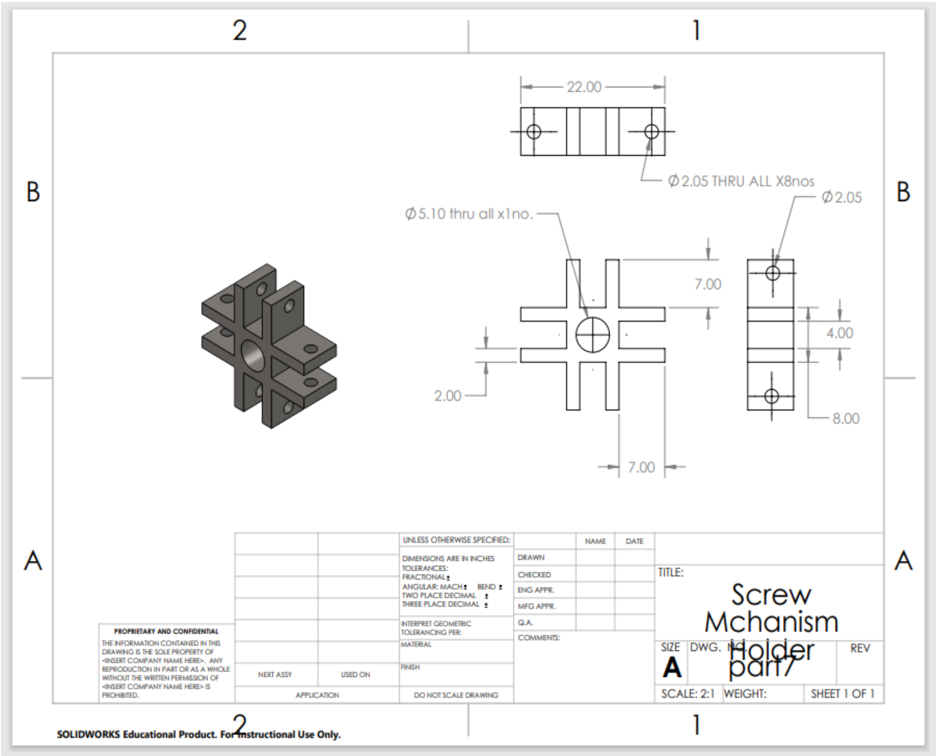


Fig 5.9: Screw Mechanism Holder drawing

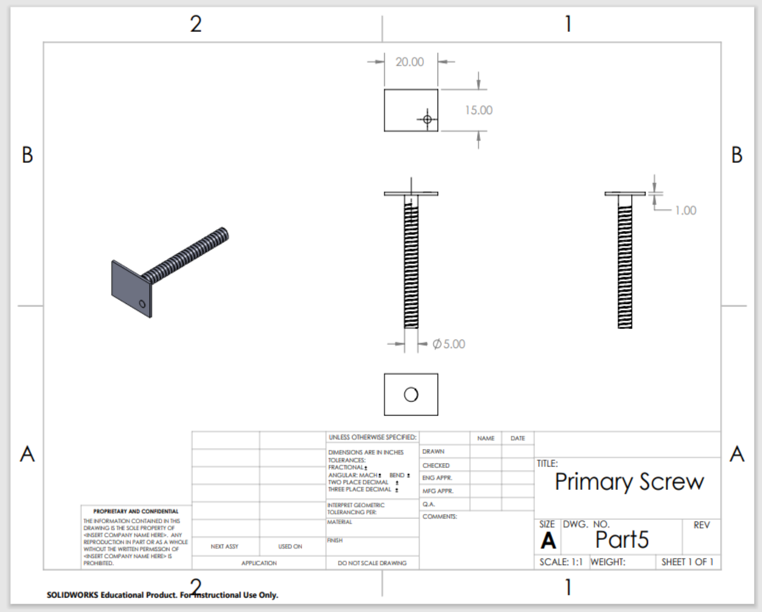


Fig 5.10: Primary Screw drawing

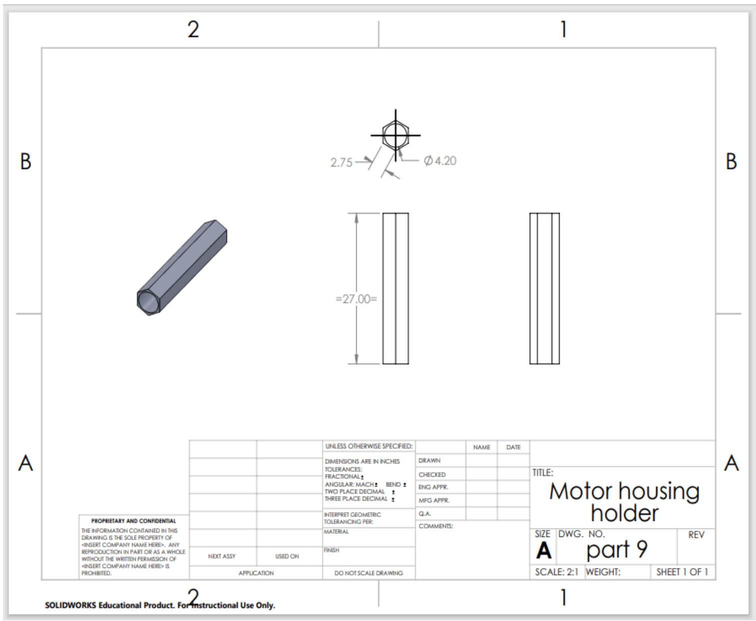


Fig 5.11: Motor Housing Holder drawing

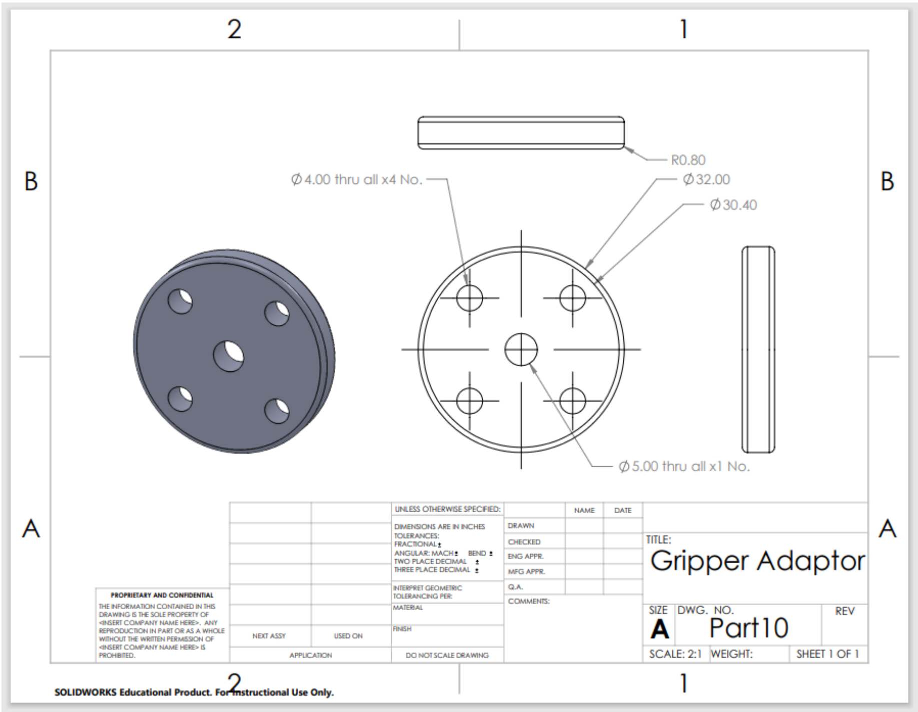


Fig 5.12: Gripper Adaptor drawing

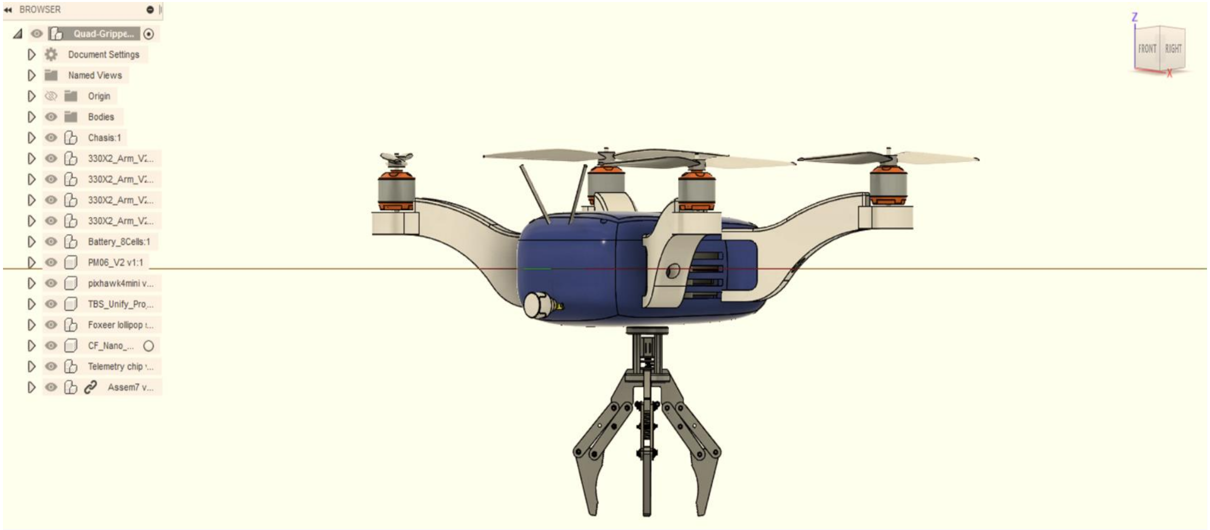


Fig 5.13: Integrated System

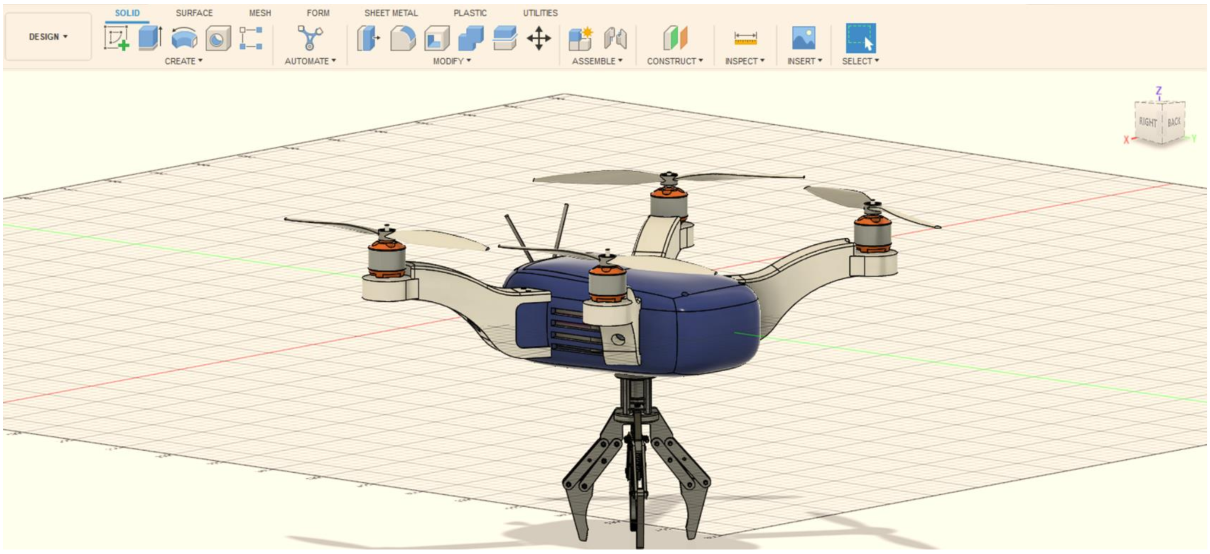


Fig 5.14: Isometric View of the Integrated System

5.2 MATERIAL SELECTION

Increased payload capacity, extended flying time, reduced inertia, noise and vibration with improved manoeuvrability by selection and designing of components called light weighting. The highlighted material looked at is carbon fibre reinforced composites due to their high tensile strength, high stiffness and low density yet stronger than steel. Woven carbon fibre clothes made into hard sheets by combining them a thermoset plastic known as resin, this has lower tensile strength than carbon fibres but higher flexural modulus. Carbon fiber composites have almost zero thermal expansion.

In other words, its coefficient of thermal expansion (CTE) is close to 0. In simple terms, carbon fibre parts will become dimension stable when subjected to heat. Aluminium, titanium, and steel all will increase when subjected to heat and shrink when subjected to cold. The presence of the epoxy resin in carbon fibre composites drastically reduces its heat conductivity. In fact, the conductivity of carbon fibre composites with epoxy resin is 40 times less than aluminium and also 10 times less than steel. So, it will not be completely wrong to assume that carbon fiber is a good insulator. This low thermal expansion and high-temperature tolerance accounts to why most drone makers prefer carbon fibre.

In summary, carbon fibre composites offer great benefit in drone making. Its malleability allows machining carbon fibre sheets into various shape relatively easy. The high percentage of carbon atoms in it gives it the advantage of high tensile strength, high stiffness, and low weight. It also has very good chemical resistance which prolongs its lifespan. Finally, carbon fibre composites are the future of drone making as it is gradually phasing out the use of titanium, aluminium and steel.

Extreme lightweight is one of the main attributes of carbon fibre parts. It weighs about five times less than steel and 1.5 times less than aluminium even though it is five times stronger in stiffness. This weight advantage contributes largely to the design of drones. The use of carbon fibre can drastically reduce the weight of drones by 20-40 percent compared to aluminium.

CHAPTER VI
RESULTS AND DISCUSSIONS

Stress analysis has been done on the gripper and the material selected is carbon fibre, which has enhanced properties compared to traditional metals, the multi fingered gripper has a division of two materials which are aluminium 7000 series and carbon fibre reinforcements, material used for gripper is CF composites, and material used for the component holding the gripper to position is AL 7071-T6. A detail comparison was done on different materials and above materials were selected.

Simulation results:

A detail analysis was done on the gripper using SolidWorks simulation. The results are shown above including pictures showing max stress, deformation CONDITIONS AND FOS

A LOAD OF 300N was applied on the holding portion of the gripper and taking automotive standard into consideration FOS was supposed to be set from 2-3. Keeping this standard, we have designed the gripper to withstand 3 times of the maximum load applied and have obtained the FOS of 2.7. The maximum stress acting on the gripper is 4.623e+01, where yield strength of the material used is 250MPa. The maximum stress acting was found to be on the stepped region inward to the multi fingers, and the maximum deformation was found to be on the sharp edges therefore the design considered was with fillets rather than sharp edges to reduce the stress concentration and optimized the design. Fine meshing has been done to simulate the parts to obtain accurate simulation proceeding stress, deformation and FOS analysis has been done, hence **concluding our design as safe.**

6.1 ANALYSIS

Static simulation is done on the gripper to find the maximum stress, maximum displacement, Factor of safety acting on it. The material chosen is carbon fibre and simulations are done accordingly.

The load is depicted in the purple arrows which has been applied on the inner region of the multi finger gripper and the top most area the gripper showing green arrows is constraint and has no degree of freedom, but the finger possesses two degrees of freedom.

Material selection: carbon fibre body is chosen based on its high tensile strength, good impact absorption properties and the properties shown below. Carbon fibre also has higher compression strength when compared to materials like aluminium and steel.

Table 6.1 **Details of the Material properties of Carbon Fibre**

Name	**Carbon Fiber**
Phase at STP	**solid**
Density	**2000 kg/m3**
Ultimate Tensile Strength	**4000 MPa**
Yield Strength	**2500 MPa**
Young's Modulus of Elasticity	**500 GPa**
Brinell Hardness	**N/A**
Melting Point	**3657 °C**
Thermal Conductivity	**100 W/mK**
Heat Capacity	**800 J/g K**

Fine meshing has been done as it is one of the most important step in performing an accurate simulation using FEA analysis. Meshing is a process of turning irregular shapes into more recognizable volumes to get the accurate simulation results, therefore meshing is required and meshing is done. Mesh is made up of elements which contain nodes that represent the shape of a geometry as shown below.

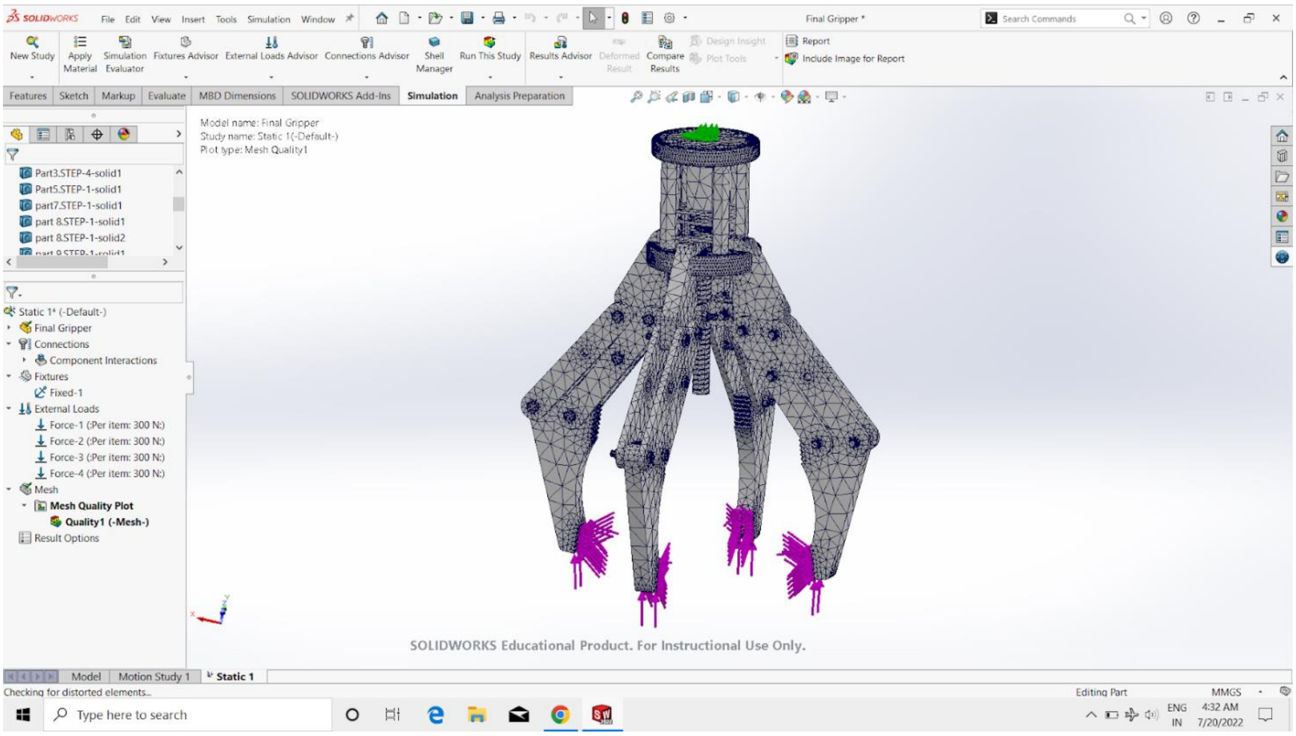


Fig 6.1: Meshing shown on gripper

Stress analysis on the gripper:

Fixture: the top most portion possessing green arrows is the fixture of the model.

Loads applied: A force of 300N has been applied on the inner part of the multi fingered gripper. This is the condition of the gripper when the gripper is in active state of gripping/perching.

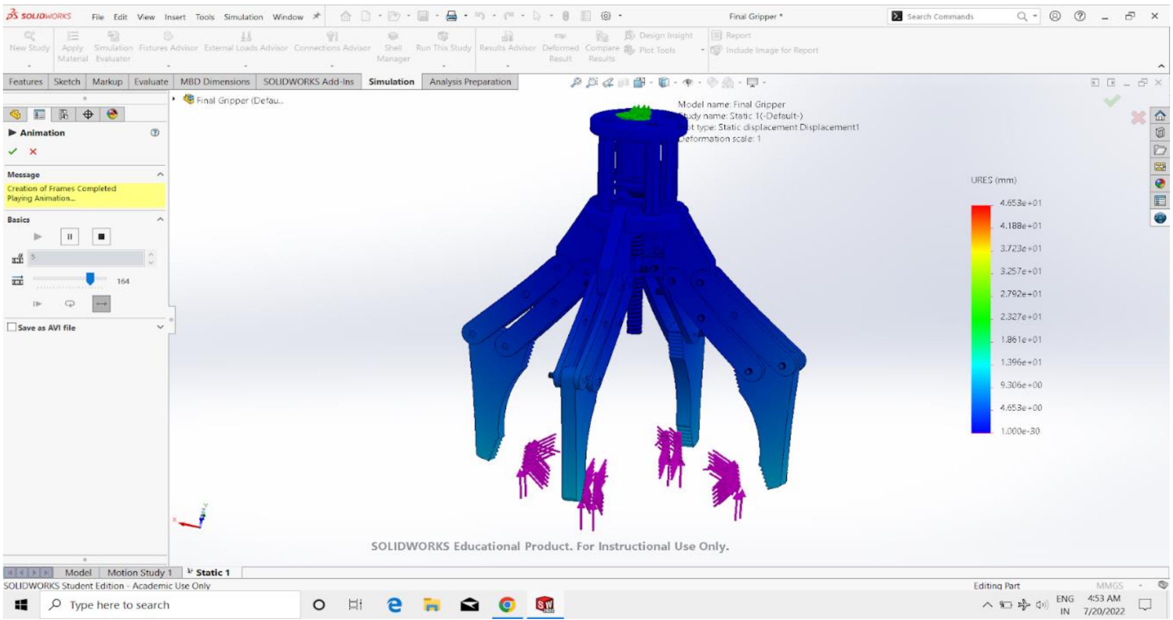
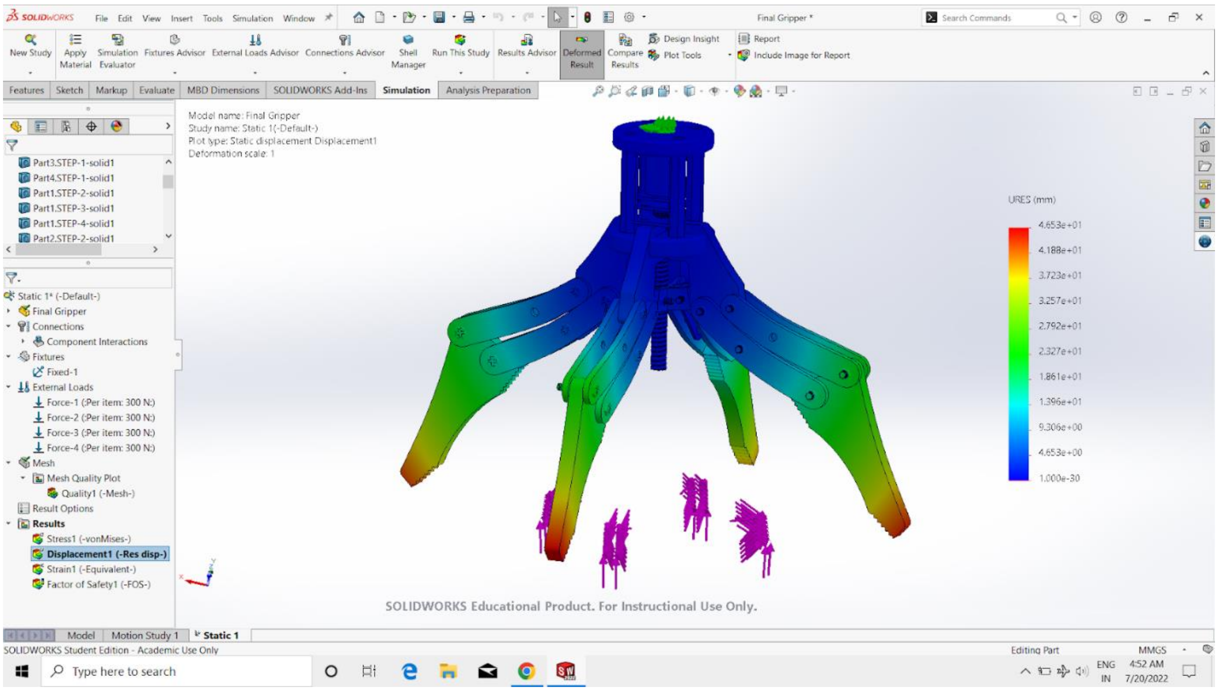


Fig 6.2: Stress Distribution Diagram



6.3: Stress distribution Diagrams

The figure 2 of the gripper shows the stress distribution on the fingers of the gripper and the red colour region is where the maximum stress is acting and the blue colour region is where there is no stress acting and the green region where there is minimal stress acting.

The maximum stress acting on the gripper is 4.623e+01, where yield strength of the material used is 250MPa so therefore a good factor of safety has been obtained.

CHAPTER VII
CONCLUSIONS

To improve the endurance, concealment and adaptability of the existing flying perching robots, a deformable bird-inspired UAV perching mechanism has been designed and presented in this report.

Results from an exploratory design and analysis of a novel perching landing gear for an RC quadcopter have been presented. The landing gear mechanism can be opened and closed to enable grasping of branch-like objects. It was found that contact area and friction were critical factors to allow the quadcopter to remain upright during perching.

In future research, the robot vision and onboard computer will be considered to realize autonomous perching towards typical targets. Simultaneously, researches about how to make the robot perch on inclined and vertical objects will also be carried out to further improve its adaptability.

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APPENDIX

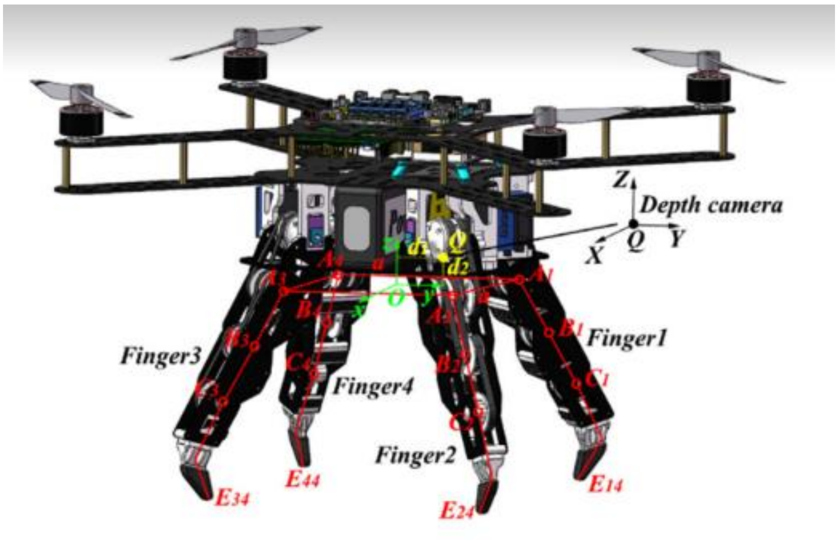

Fig 1: Reference Prototype

Fig 2: Future prospects

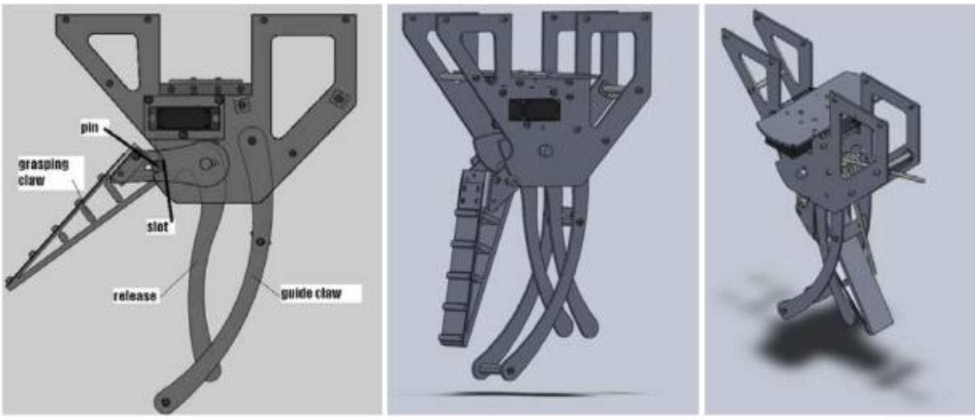

Fig 3: Alternative Design (Snapping Mechanism)

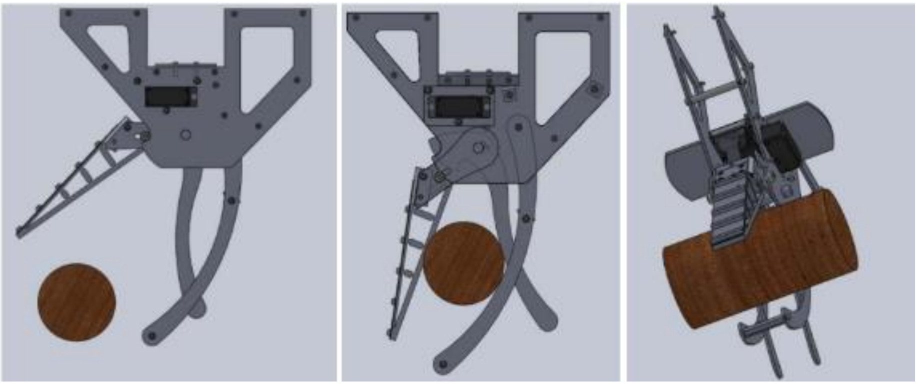

Fig 4: Working of the Snapping Mechanism