Redesign and analysis of cargo containers for delivery drone applications

Capstone Project Report submitted in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

Submitted by

SHIVANSHU MISHRA (1714101099)
VISHAL KUMAR (1714101119)

IN
MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

Under the Supervision of

Mr. Abdul Gani
Professor of
Mechanical Engineering

Mr. Faisal Shameem
Professor of
Mechanical Engineering

GALGOTIAS UNIVERSITY
(Established under Galgotias University Uttar Pradesh Act No. 14 of 2011)

JUNE- 2021

DEPARTMENT OF MECHANICAL ENGINEERING
CERTIFICATE

It is Certified that this project report **"Redesign and analysis of cargo containers for delivery drone applications"** is the bonafide work of Shivanshu Mishra (1714101099) and Vishal Kumar (1714101119) who carried out the project work under my supervision.

SIGNATURE OF DEAN SIGNATURE OF SUPERVISOR

DECLARATION

We, here by, declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Shivanshu Mishra
1714101099

Vishal Kumar
1714101119

Date: 14-06-2021

APPROVAL SHEET

The title "**Redesign and analysis of cargo containers for delivery drone applications**" by **Shivanshu Mishra** and **Vishal Kumar** is approved for the degree of Bachelor of Technology in Mechanical Engineering.

Supervisor

Project Coordinator

Date: _____________
Place: _____________

ACKNOWLEDGEMENT

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It was great privilege and honor to work and study under their supervision.

We are grateful to our supervisors.

Shivanshu Mishra

Vishal Kumar

ABSTRACT

Drone or octo-copter drone is a new generation innovation which can perform operations like surveillance, media, etc. with ease setup and cost efficient. The delivery drone is the upcoming evolution in the field of engineering. The report study's meteorology of octocopter done and it has been observed that with use of ducted fan or turbo fan on top of body will give it more power and speed to perform desired actions and also a cargo section beneath it will allow it to do tasks like fast delivery, transportation, etc. The design of cargo container attached in drone affects the parameters like the speed, efficiency, dynamics and controls so, it's important to have aerodynamic shape system for greater efficiency and power.

The present work proposes a modified elliptical shaped design instead of a regular rectangular cargo container and mounting of a ducted fan on top of delivery drone to increase the speed and power. For light weight and durability carbon fibre as a material is also proposed for cargo container. The shape was analysed through computational fluid dynamics technique by using Ansys. The results of the study showed that the new ellipse shape design of cargo container is more practical to use in high speed operation and results in increase efficiency of the system like drone.

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List of abbreviations

1.	3D	- Three dimensional
2.	CFD	- Computational fluid dynamics
3.	m	- Meter
4.	mm	- Millimeter
5.	m/s	- Meter per second
6.	ATM	- Atmospheric pressure
7.	Kg	- kilogram
8.	Mph	- Miles per hour
9.	W	- watt
10.	V	- voltage
11.	Dc	- direct current

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Chapter 1
INTRODUCTION

Project background

In the last few years, several public and private research developers started investing a considerable amount of resources for the construction of human-friendly unmanned aerial vehicles (UAVs), or ‘drones’. These devices immediately found a great deployment in the society opening an incredible amount of new opportunities as useful tools to address a variety of societal challenges, including agriculture and forest analysis, identifying property boundaries, surveying construction sites or corridors for roads and railroads, stockpile volume calculations, flooding and coastal erosion assessments, building information management, disaster planning and handling, surveys in remote or undeveloped areas, and the delivery of goods.
The possibilities of digitalization and technology development address societal challenges such as making societal sectors and domains more ecosystems friendly, efficient and competitive. This project will work to define societal challenges and ways to address those using applications of drone technology. The project will also study potential (unintended) consequences of such applications in terms of risks and ethical questions.

Despite the enormous achievements, drones have sufficient control autonomy and capability to complete only part of these activities and the majority of the applications previously described still rely on human supervision. This platform represents an important opportunity to develop and combine cross-disciplinary research activities in several strategic fields.

Lund University has several ongoing activities and expertise related to autonomous drone flights, e.g. the drone pilot education at the School of Aviation in Ljungbyhed, the infrastructure projects ICOS, ACTRIS, NordSpec, and SITES Spectral, and research in remote sensing, drone archaeology, image analysis, machine learning, robot technology, air quality, and GIS. It will also stimulate regional development and innovation by increasing the collaboration with local companies and authorities.

RESEARCH PURPORSE AND MEANING

The main purpose of the project is to increase the speed of large, heavy drones to satisfy fast delivery /operations timings and more no. of products delivered at a given amount of time.

As increasing demands of machine learning, artificial intelligence, etc. this project experiments with the new technologies, Literatures, machines and found the meaning of time management in operations hence, came up with an idea of modifying the structure of drone parts to increase the thrust force of heavy delivery drones.

There is a very high potential for use of drone data within a variety of societal fields, however, currently there is a knowledge gap between technology developers and stakeholders. The project aims at bridging this gap by creating an arena for knowledge sharing and to identify needs and means for technology to address the societal challenges. Communication and information exchange is a key tool in this process. The project will stimulate this exchange across several sectors, and also focuses on cost-efficient and economical means to drive practicality of the research.

OBJECTIVE

1. To study the octocopter delivery drone and analyze the role of ducted fan mounted on top of drone to increase the power and efficiency of system.

2. Study and analyze the ideal cargo container for delivery drone operations and redesigning the cargo container to increase Parameters like speed, efficiency, dynamics and control.

Chapter 2
Literature review

Introduction

The advancement in today's technology has extended the boundaries of drone technologies. The major application of drone is in military, civil and agriculture services. Due to its wide applications, drones are now used in delivery purposes to solve efficient and reduced delivery time problems [1]. The major advantage of drone is it can cut short 80% of delivery time compared to ground vehicles based on its flexible routes and parallelized operations [2]. Due to its cheap, flexible and fast delivery drone can bring revolution in delivery department.

The shape and size of the cargo container in delivery drone plays a vital role in overall efficiency of the operation as most of the cargo containers are rectangular in shape which occupies a huge air resistance at it surface making overall delivery drone design less efficient. Some studies did air flow analysis on different structures of freight vehicles and it has been observed that the streamline shape is most efficient as air flows smoothly over the surfaces at high wind speed operation [3]. The main demerit of an ideal rectangular shape cargo container is that at high speed operations the container becomes heavily unstable and limits the operational speed [4]. Therefore, we redesign the structure of cargo container into an ellipse shape, changed the material of construction to make it durable- light weight and carried out CFD analysis to know the results with respect to efficiency, control and dynamics. The new design is separated into 3 different storing sections to utilize space and maintain equal weight distribution during operation.

Literature review

The emerging role of AI and robotics has pushed the boundaries of drone application; drone when attached with a cargo container can deliver various products in less time and more efficiently [5]. If we consider suburban area and compare deliveries by a truck only delivery and truck-drone delivery we see that the truck-only delivery is very advantageous economically [6]. Thus, it is important to study the drone characteristics and air flow analysis to be economical. Changing the design of light UAVS has resulted in more stability and performance [7]. These days drone can also perform its operations in automated modes with high velocity where their operation paths are predefines, Path generation is achieved by a unit quaternion curve and an associated parallel transport frame in the interactive process. [8]. But, it’s important to select the specific type of drone for the delivery operations with respect to weight of cargo as more the number of motors and blades it has the more it consumes power therefore, a study was conducted on octocopter drone and dodecacopter drone with, without periodic disturbance and it was observed that octocopter is more stable than dodecacopter without disturbance [9]. Hence, we can choose octocopter application for delivery drones.

Body of the delivery drone:

The body of the project comprises of three sections where, the first section or the upper area will include a ducted fan attached to the main octacopter drone with help of aluminum pipe to satisfy higher horizontal thrust requirement.

The second section or the middle area will have a proper octo-copter drone which will be the heart of system providing required energy from its in-build components and thrust force vertically as well as horizontally.

The third section or the bottom area will have a cargo section made up of plastic material for transporting small-medium goods as per requirement.

Octocopter drone:

The octacopter drone is a type of drone which has 8 motors and propellers. All the motors and propellers are situated at 45-degree angle apart to each other which gives it more adequate and dynamic controls over other drones in market, its design is such that it shows silent flying features over Quadra or hexa copter drones. The octacopter drone has similar flying functions of hexacopter drones with more control, power and stability. It can withstand higher wind speeds and various aerodynamic changes. This type of drone is considered as most powerful drone for lifting heavy weights. Since, octocopter drones have greater number of motors and propellers it can even fly and operate on 7-6 motors in case of any failure or emergency therefore, providing higher safety of region over failure.

R-C unit Ducted fan:

An r/c unit ducted fan is small size ducted fan which produces high speed. The weight of such fan is lesser and gives high power performance. It consists of propeller inside duct which when rotates generates power. Ducted fans shows silent features in compare to propellers, it reduces tip speed and intensity of vortices and cover-up the blade noise, it has advantage over low speed and high static thrust lever. It offers safety on land as it is covered by duct.

Octocopter drone movements: (Yaw, Pitch and Roll)

Yaw:

It is a movement which is develops when all motors of blade act at center of geometry and eliminate each other at point of geometric center. If it does not eliminate resultant vector it has positive as well as negative magnitude about which the octocopter rotates.

Pitch:

This movement is generated when the resultant of rotational force vector is either positive or negative, the drone moves forward or backwards. This is achieved when axis passes horizontally parallel to plane towards front or back of drone.

Roll:

The rolling movement is caused by axis that passes horizontally to plane of drone extending from left to right. All motors acts at center and cancel out each other at exact center.

Electronic Control Unit:

An electronic speed control (ESC) is an electronic circuit that helps in controlling and regulating the speed of an electric motor. It also supports braking and reversing of motors. Miniature electronic speed controls is used in various electrically powered radio controlled models and this is the model that will control the system of new delivery drone.

Brushless DC Electric Motor:

Brushless DC electric motor (BLDC motor or BL motor), also known as electronically commutated motor (ECM or EC motor) and synchronous DC motors, are synchronous motors powered by direct current (DC) electricity via an inverter or switching power supply which produces electricity in the form of alternating current (AC) to drive each phase of the motor via a closed loop controller. The controller provides pulses of current to the motor windings that control the speed and torque of the motor. This control system replaces the commutator (brushes) used in many conventional electric motors.

Battery:

We are using lipo 10S, 37 V, 10000mah, 1.7 kg. In octacopter we are using 8 motors , the total current draw will be about 8 x10a= 80A and let’s consider the power drawn by the remote controller will be 1A so total current will be 81A. Therefore, 10000mah 10C battery will be sufficient for our octacopter as it will provide a continuous supply of100a.

Propellers:

In this project we have taken octacopter over quadcopter because it has 8 blades and can generate more thrust than quadcopter, more the number of blades more will be the thrust. To carry a payload of 5 kg approx. we need more thrust generation and stability. The rotation of propellers depends mainly on the external factors like wind speed, air density, weather conditions but if we take these factors ideal then it depends only on the propeller speed. The diameter and pitch of the propeller is clearly written on the propeller. Propeller- 1038(10 is the diameter and 3.8 is the pitch). We are taking less pitch propeller because the lesser the pitch is the more torque it can produce and lesser current consumption and more stability. Less KV value have more stability, less vibrations.

The aerodynamic characteristic of the cargo container plays a major role in stability and performance parameters in delivery drones. A study on freight wagon was done where air flow analysis was done on the freight wagon the Reynolds number of the flow came out to be 10^5 [10]. Such shape containers with slung load is subject to massively separated unsteady flow and is limited by stability to operational airspeeds well below the power-limited speed of the configuration [11]. Thus, we believe there need to be change in design of cargo containers for high speed delivery applications. The shape that can withstand the high speed drag, giving more stability and dynamic controls. Cargo can be highly unstable while in motions and needed to be tied up for so but, locking and unlocking cargo can consume more time hence, we can use baffle at different intersections of container to reduce the instability of cargo similar to baffle used in liquid containers which reduces the amplitude of fluid slosh in partly filled tanks [12].

Proposed Design of cargo container:

The design is developed on Autodesk software, the conventional design of cargo section is rectangular shaped so we modified it to give the cargo section a shape of an ellipse [Figure 1]. This design is aimed to minimize resistance and drag caused by air thus making cargo section more aerodynamic and will eventually enhance the productivity of the drone to carry out the delivery operation in a less time and power.

The exterior of the design is develop like an ellipse shape as it has very less air resistance, the front and back edges have smooth [figure 2], which helps in creating aerodynamic path and increases controls due to less air resistance.

The interior of the cargo section is divided into three parts namely cargo 1, cargo2, cargo3 separated by baffle [Figure 3]. We have divided it in 3 parts because by separating each compartment the weight distribution will be balanced and there will be less chances of instability while in motion.

The cargo area 2 and 3 are built to store small or light weight goods whereas cargo area 1 has large storage area for large heavy goods. They both has separate door for loading unloading cargo situated at top. The Interior of the new design consist of single door situated between the cargo area 1 and 3 and also performs as baffle between the surfaces [Figure 3]. The door lock mechanism and stopper will be situated at top and bottom of cargo area 1. Additionally, user can construct an area on top of cargo area 1 to mount the container and drone.

The top view of the design is replica of bottom view shown in figure 4 and the back view of the design is replica of front view of design shown in figure 5.

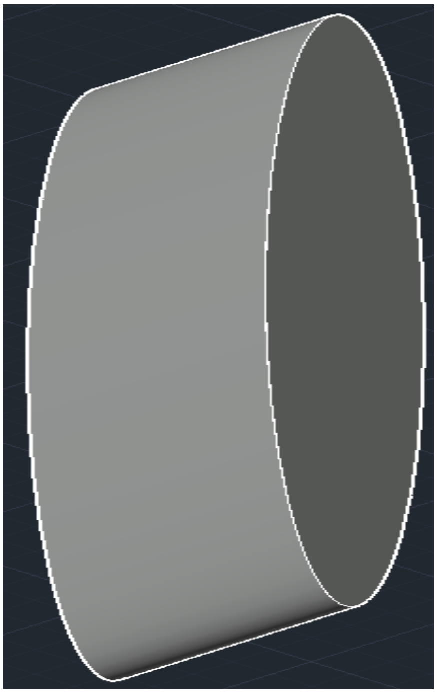

Figure1. 3D view of proposed cargo container for drone application.

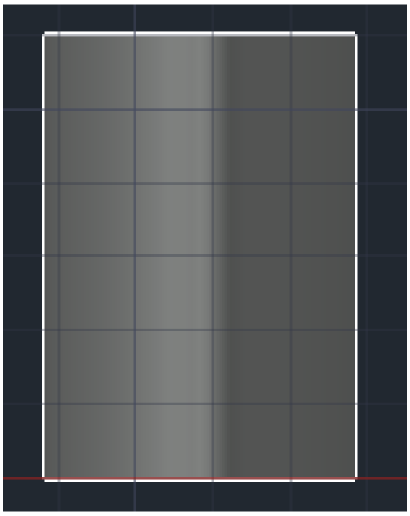

Figure2. Top view of proposed cargo container for drone application.

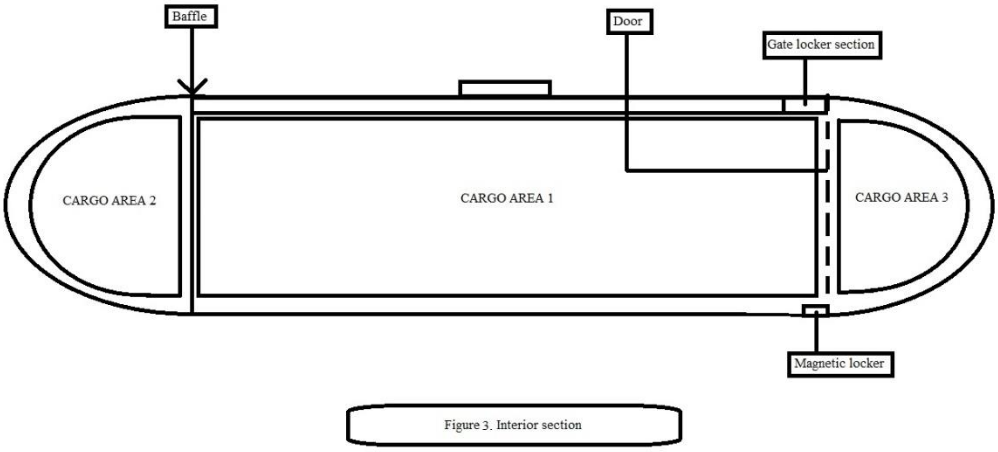

Figure3. Interior of proposed cargo container for drone application.

Figure4. Bottom view of proposed cargo container for drone application.

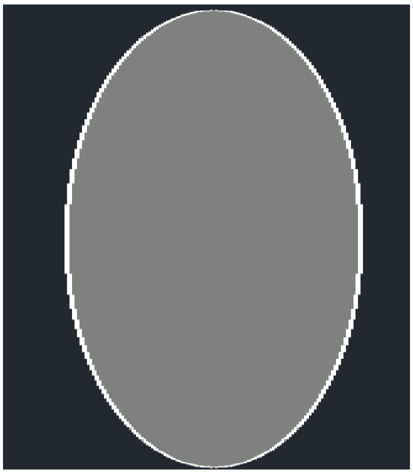

Figure5. Front view of proposed cargo container for drone application.

CFD Analysis

We carried out computation fluid dynamics (CFD) analysis on ANSYS 2021 software. The design was and exported to ANSYS for simulation results. The air flow analysis was performed with Air as inlet material, we first exported the design and various geometry was set which provided the enclosure. Meshing was done and various input parameters were given mentioned below for simulation result.

In computational fluid dynamics, the k–omega (k–ω) turbulence model is a common two-equation turbulence model that is used as an approximation for the Reynolds-averaged Navier–Stokes equations (RANS equations). The model attempts to predict turbulence by two partial differential equations for two variables, k and ω, with the first variable being the turbulence kinetic energy (k) while the second (ω) is the specific rate of dissipation (of the turbulence kinetic energy k into internal thermal energy). This design required SST k-omega turbulence model to calculate the value of lift force and drag force

The two-equation model (written in conservation form) is given by the following:

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho u_j k)}{\partial x_j} = P - \beta^* \rho\omega k + \frac{\partial}{\partial x_j}\left[\left(\mu + \sigma_k \frac{\rho k}{\omega}\right)\frac{\partial k}{\partial x_j}\right]$$

Where,

$$S_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

Specifications of cargo Container:

Velocity formulation	30m/s
Viscous model	k-omega
Time	Steady
Flow	Fluent
Material	Air
Boundary conditions	Inlet velocity – 30 m/s Pressure outlet – 1 ATM
Number of nodes	44758
Number of elements	187788

Enclosure dimensions	length 12000mm breadth 4000mm height 2000mm
Inflation	10 layers
Element size	Minimum. 0.2 m Maximum. 0.5m
Converge	140 iterations

Specifications of octocopter delivery drone:

The total weight of drone	25kg
Weight of ducted fan	5 kg
Payload	5-7kg
Dimensions of the octacopter	0.44 x0.44 x0.2 meters
Speed of drone	70 mph (31 km/h approx.)
Blades	8 blades of size more than 8 inches

Motor	8 brushed DC motors (Dual sky XM7015 MR-5 320) (320 KV or RPM/V, 1434W POWER)
Battery	LiPo 10S, 37 V, 10000mah.
Weight of battery	1.7 kg
Height of body of drone	0.2m
Height of cargo-section	0.15m
Height of ducted fan	0.15m
Total height of the octacopter	0.2+0.15+0.15 = 0.5m

Chapter 3
Problem description

Problem description

Octocopter delivery drone:

- **The octacopter used in this project is 25 kg approx. (including wt. of ducted fan and weight of body) which is quite heavy for a drone to fly smooth and fast.**

The octacopter used in this project is 25 kg approx. (including wt. of ducted fan and weight of body) which is quite heavy for a drone. To make our octacopter drone fly we are using a ducted fan and 8 propellers. The propellers are connected with 8 brushed DC motor(Dual sky XM7015 MR-5 320)(320 KV or RPM/V,1434W power) and the motor is connected to a 10000mah,37V LiPo battery which provides a continuous 100 A current supply to the drone , single motor will consume 10A so 8 motor consumes 10*8=80A.

So 100 A of continuous current is sufficient for the operation. The propellers will generates enough thrust to lift the drone from the ground to a specific height.

Research has considered every factor like power consumption, drag and thrust of the drone to fly at a high speed with stability and taken every parameter according to that. Here thrust force=363.875N which is more than enough for the drone to take off and fly.

The normal drone available in the market is quite light (approx. 500g) but they lack the load carrying capacity. In this octacopter we have designed this in such a way that it can carry a load of unto 5 Kg easily and deliver it very fast to the customer. The ducted fan attached to the drone give the drone necessary power to fly fast. After achieving a specific height the drone will move forward at that time the ducted will operate and give more thrust to the drone.

We have studied Design Improvement of a Versatile Ducted-Fan UAV Vol. 9, No. 1, 1-17, 2012, and understand that changes ducted fan can cause on an octacopter and we tried to overcome that. We kept the weight of the drone as low as possible so that it can provide more thrust as well as maintaining the overall weight of the octacopter.

- **The ducted fan attached on octacopter imbalances the aerodynamics of the drone. The effect of ducted fan on drone.**

The octacopter attached with ducted fan can affect the aerodynamics of the system. We observed that thrust of the ducted fan shows a quadratic increase with the increasing revolution speed i.e. if the revolution speed increases the thrust will increase too drastically. This octacopter operates ducted fan when moving forward as moving velocity increases, the drag, and thrust will also increase. When angle of attack increases, the drag of the ducted fan system increases and the lift first increases and then decreases.

To maintain the stable lift of the drone, the ducted fan will not function on the lift of the done till a stable position. To move the drone forward, the ducted fan will function normally at that moment, making sure the octacopter will be stable till a point. Unless the octacopter doesn't move forward, ducted fan will not function.

In ducted fan in starting a weak vortex is formed in the middle of the inner wall of the upwind side and a low pressure zone is formed in the lip section of the drone causing a pressure difference. After a while a large vortex is formed in the middle of the inner wall of the upwind side, a high pressure zone is formed in the middle part of the outer wall of the upwind side and the duct lip section in the downwind section, and a large low pressure zone is formed in the duct lip section of the upwind side. Therefore, the ducted fan generates large lift, drag and positive moment in forward flight.

The lift of the ducted fan increases for a moment then decreases as the angle of attack increases. Whereas, the drag of the ducted fan increases as the angle of attack increases because the thrust of the coaxial fans decreases and the drag of the duct increases. The lift and drag of the ducted fan increase as the forward velocity increases.

The thrust of the ducted fan can be increased by increasing the rotation of the fans. The thrust of the ducted fan will increase first then it will decrease as the vertical velocity increases.

- **The addiction weight due to ducted fan increases the overall weight of the drone. Does the attachment of ducted fan beneficial for the octacopter.**

The octacopter attached with ducted fan significantly increases the overall weight of the drone. The increased weight of the drone will be overcome by the thrust produced by the ducted fan. The main purpose of this octacopter is to maintain high speed delivery purposes. so by increasing the thrust of the drone, the speed of the drone will increase drastically. The weight of the ducted fan affects the aerodynamics of the octacopter which we will configure by changing the shape and size of the drone.

The addition of ducted fan over the octacopter will increase the drag of the octacopter. When the forward velocity of the octacopter increases, the drag also increases, this is a negative impact on the octacopter speed. To configure this negative impact we will provide more thrust to the octacopter through propellers.

The performance achieved by attachment of ducted fan will surpass the effect of weight of ducted fan on octacopter.

- **Reducing the drag of the octacopter?**

While designing this drone, we have kept in mind to reduce the drag of the octacopter where ever possible. One of the ways to reduce the drag is changing the design of the wings. The formula used is:

D= spcDv^2/2

Where, cD= coefficient of drag, cD is further calculated by using the formula

cD= cD,o+ cD,i

Where cD, o is the zero-lift drag coefficient

cD, i is the lift-induced drag coefficient

The material used in this octacopter is carbon fibre as carbon fibre is very strong and light in weight.

The ducted fan attached to the octacopter will provide more thrust and speed to the drone as a result the drag on the octacopter will increase drastically. We can reduce it by changing the shape and size of the ducted fan.

- **Providing energy to the propellers and ducted fan as this drone needs significantly more power.**

The octacopter is attached with 8 motor and a battery of 10000 mah, 37V battery to provide continuous 100 A current supply. The weight of the battery is 1.7 kg. The ducted fan is connected to another 10000 mAh LiPo battery to provide power to the ducted fan.

BY using the formula to find the power consumption of the octacopter,

Power consumed by the octacopter = Thrust x velocity of the octacopter

= 363.875N x 8.611 m/s

= 3133.32 W

This power consumption will be easily managed by the battery provided considering the external factors like wind, pollution.

- **The octacopter is designed mainly for delivery purposes. Increasing the speed of the drone.**

The octacopter we have designed weights around 25kg approx. including payload. For a drone to fly the thrust generated must be equal to the gravitation force on drone. As we have derived from the equation the thrust generated= 363.87 N (with load and ducted fan) and the gravitational force on drone = 25 x 9.8= 245N. The thrust is more than the gravitational pull on the drone considering the drag on the drone. So the conditions are fulfilled and the octacopter can fly applying a thrust equal to gravitational pull on the drone.

To generate such thrust we are using larger blades and battery (LiPo 10S, 37 V, 10000mah) providing enough energy to the drone.

To provide speedy delivery, we have attached ducted fan on the octacopter which will provide more thrust to the drone. Hence increasing the overall speed of the drone.

Cargo container:

- **Interior space or cargo area of proposed design**

  The proposed design is divided in such parts so that all areas should be utilized for loading space. If we compare the interior space of ideal cargo container and the new proposed design we can find that the baffle in new design plays a role in balancing cargo in Free State whereas there is no concept of baffle in ideal cargo container. Although if we compare the total space we have more space in ideal design but there are more chances of cargo imbalance in Free State.

- **The efficiency of proposed design**

  If we compare shape of new design and ideal cargo container we can see that the new design has more aerodynamic characters compare to ideal cargo container as the shapes are curved from front and back to bypass and resist the air friction flowing over surfaces whereas, the rectangular shape of ideal cargo container is more prone to air resistance hence, the new proposed design is more efficient that ideal cargo container.

- **Mounting of new design on delivery drone**

  There are various ways to attach the cargo container on delivery drone but the most appropriate one is fixing cargo container in bottom of delivery drone through aluminum pipe, where one end will be mounted on bottom of the delivery drone and the other end will be mounted on top of new cargo container. As, the properties of aluminum are light in weight and ductile it results in less weight of overall delivery drone system and gives tough support to attachments.

- **Sideway forces**

  The sideway forces refers to force acting from the sides of surfaces. The force in air can act in from any direction and it is important to consider side design of profile, the new design is curved from the sides which can help in withstanding sideway forces in comparison to idea cargo container design which is rectangular from all the directions.

- **wind turbulence**

  The new design is curved from front and back which gives more aerodynamic characteristics which helps in bypassing the wind turbulence or high wind speeds whereas, there are more chances of unbalancing of ideal cargo container as the air resistance of such shapes are nearly 0% which can cause major unbalancing and can destroy cargos kept in for delivery purpose.

Chapter 4

Result and Discussion

1. Octocopter delivery drone:

Thrust force

The net thrust force can be measured by considering two factors thrust force Ft, and the download gravitational force, mg, we can write:

Ft= may+ mg

Where, ay=4.755 m/s^2

Thrust force when there is no load

Ft= may+ mg

Ft= 20x4.755 + 20x9.8

Ft= 291.1 N

Thrust force when there is load

Ft=may+ mg

Ft=25x4.755 +25x9.8

Ft= 363.875 N

Thrust force when there is no ducted fan and no load

Ft=may+mg

Ft= 15x4.755 + 15x9.8

Ft=218.325 N

Power consumption

Power consumed by octacopter can calculate by multiplying the vehicle velocity in the air with the thrust.

The estimated total weight of the octacopter is 25kg including the payload. The optimal drag on the octacopter is 3N

Now, the thrust =363.875N

Velocity of drone = 31 kmp/h=8.611 m/s

Power consumed by the octacopter =Thrust x velocity of the drone

= 363.875N x 8.611m/s

=3133.32 W (with the payload)

Power consumed by the octacopter =Thrust x velocity of the drone

=291.1N x 8.611 m/s

=2506.66 W (without payload)

Power consumed by the octacopter =Thrust x velocity of the drone

=218.32N x 8.611m/s

=1879.95 W (normal octacopter)

2. Cargo container:

Figure 6, 7a, 7b, 8, 9, 10, 11 and 12 are derived from air flow simulation and we can see that the graph stables up after peak of air which shows the lower air resistance on surfaces.

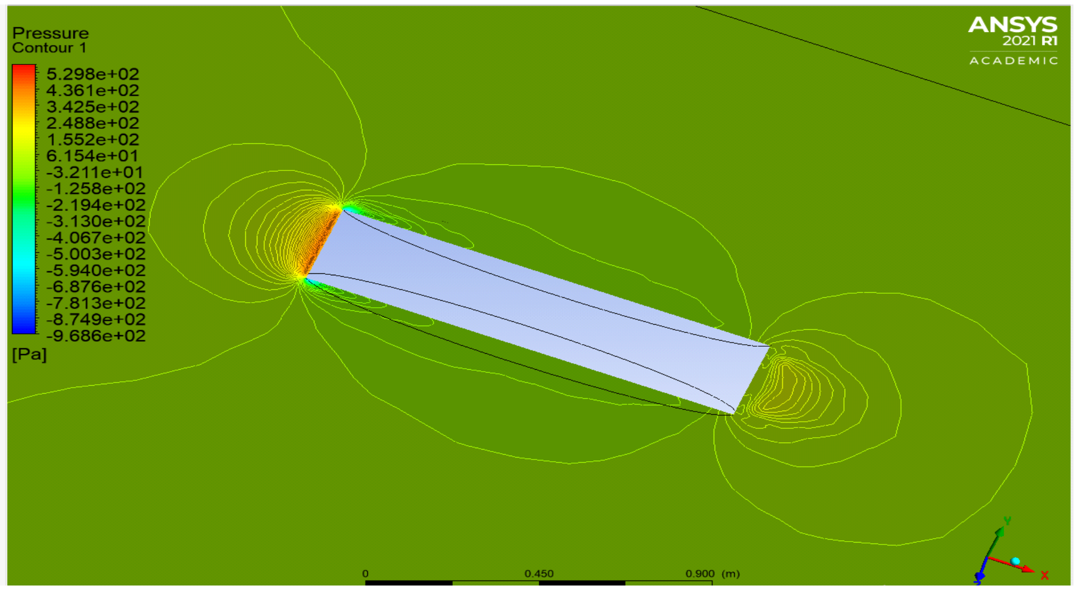

Figure6. Pressure contour line with respect to Pascal.

Figure6. In CFD-POST, the figure show the pressure magnitude by the means of contour lines dawn on a physical body. The pressure values have been maintained at constant atmospheric pressure. The difference in contour lines and its colour clearly shows the pressure difference at inlet and outlet.

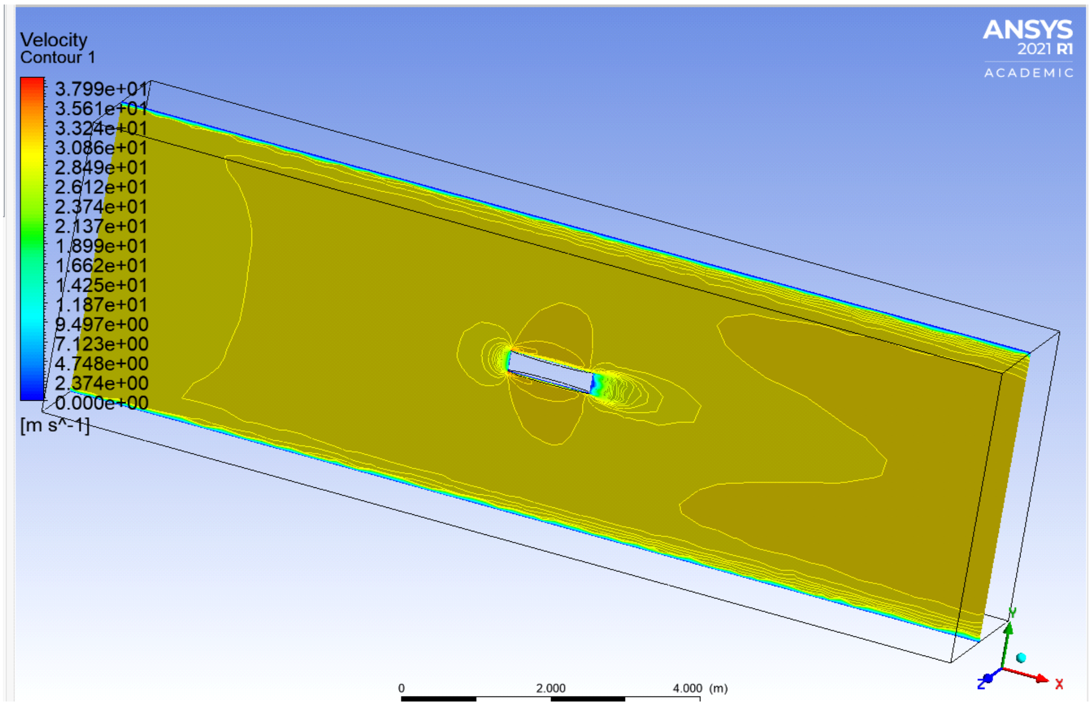

Figure7a. Velocity contour lines with respect to kilohertz.

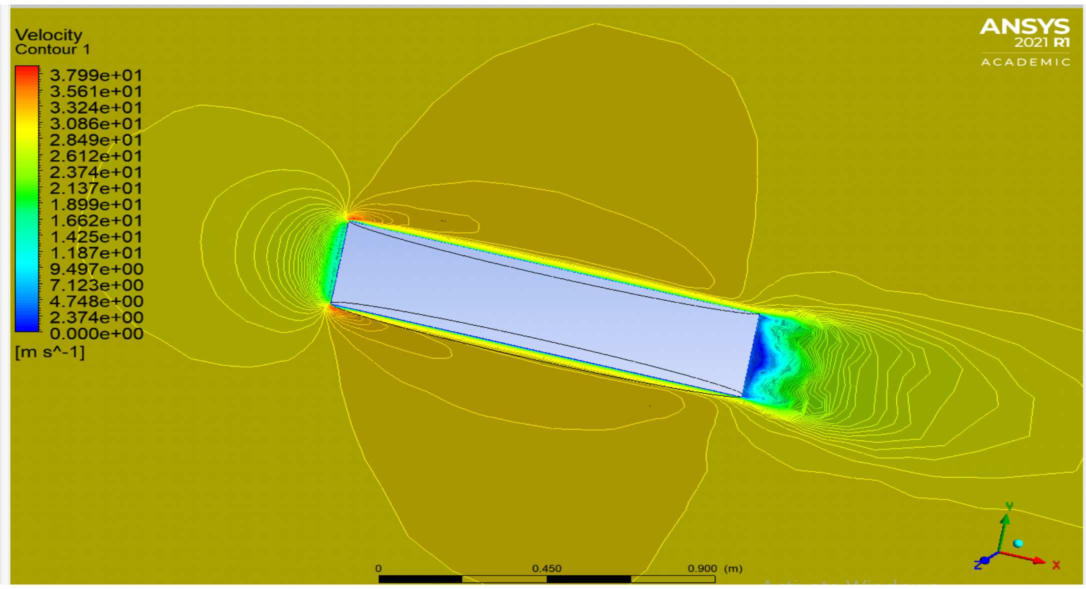

Figure7b. Velocity contour lines with respect to kilohertz.

Figure7a and 7b: In CFD-POST, we can see the velocity difference of air at inlet and outlet. The inlet velocity has been set to be 30 m/s while at outlet the velocity is set default. The velocity of air at inlet will be much more than the velocity at outlet. The difference has been demonstrated with the help of contour lines.

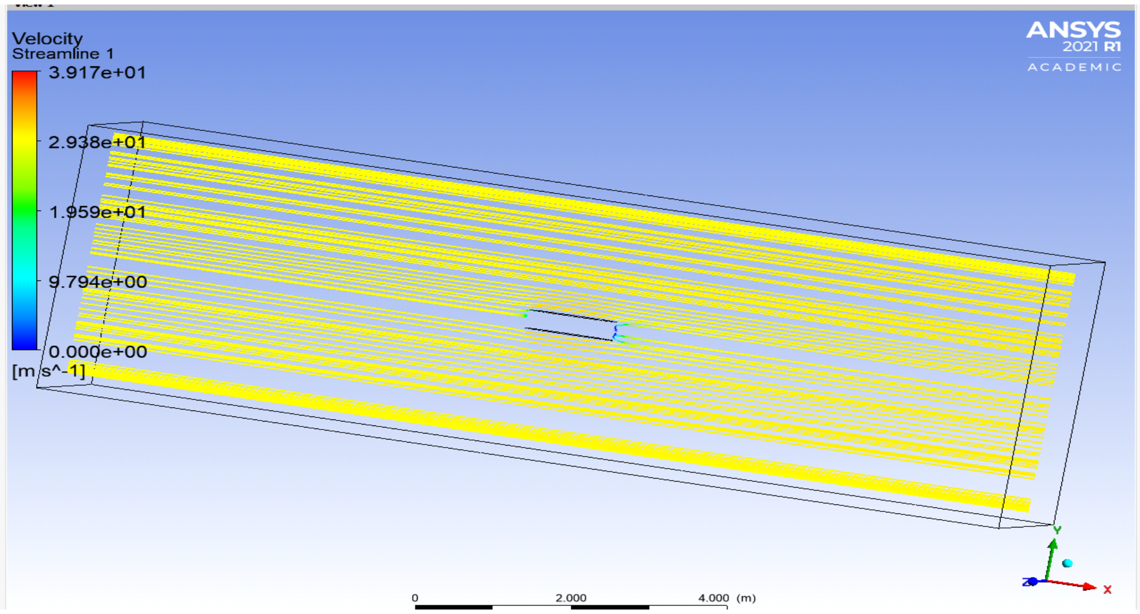

Figure8. Velocity streamline with respect to kilohertz.

Figure 8 shows the flow of massless particles through the entire domain to show the velocity difference at different point on the domain.

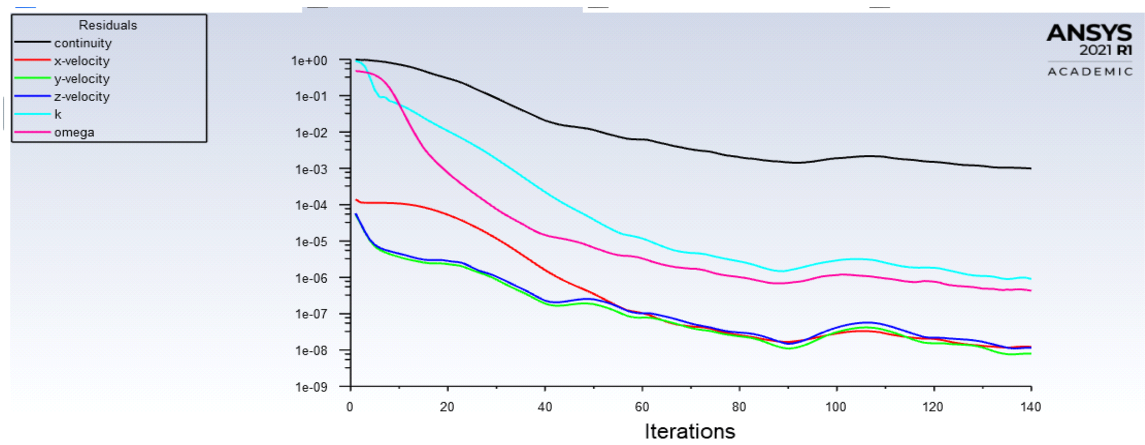

Figure9. Scaled residual plot, where x axis is number of iterations and y axis is equal to residuals.

Figure 9 directly quantifies the error in the solution of the system of equations, as it measures the local imbalance of conserved variable in each control volume. The graph represents the residual value of every cell solved equation.

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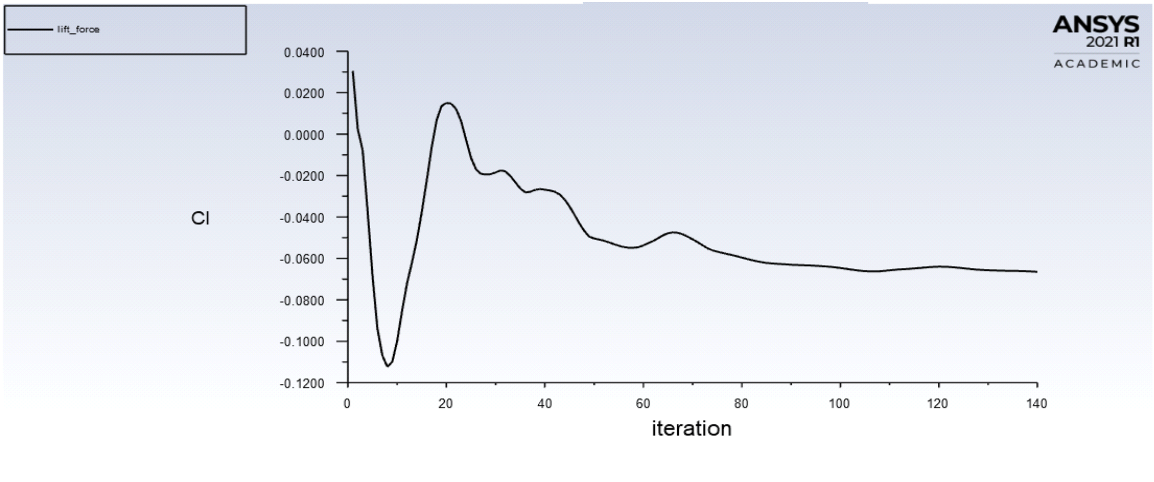

Figure10. Lift force plot, where x-axis is number of iteration and y-axis is equal to Coefficient of lift.

Figure 10 is the lift force graph, as the graph stables up after some readings it specifies the lift performance of the new design.

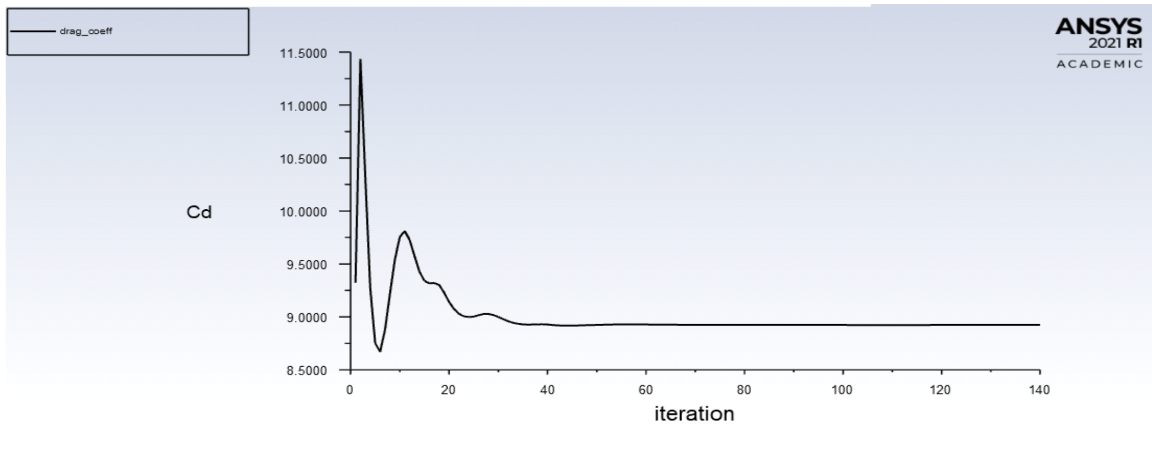

Figure11. Drag coefficient plot, where x-axis is number of iteration and y-axis is equal to coefficient of drag.

Figure 11 is the drag coefficient plot which specifies the air resistance on the surface;

the graph gets constant after the initial force, i.e. air gets diverge through first phase of air, increasing the aerodynamic of design.

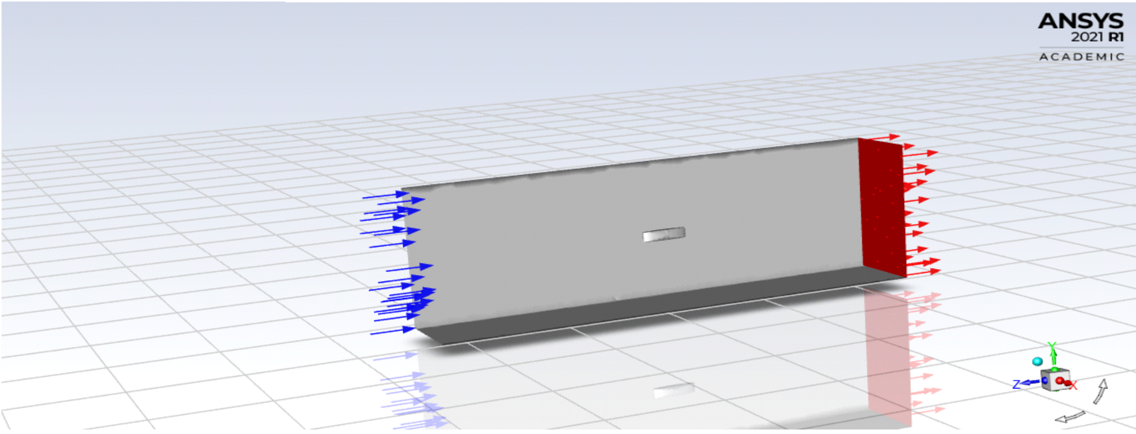

Figure12. Air inlet and outlet inside enclosure.

Figure 12 is the plot of fluid flow from inlet to outlet, in the figure the blue arrow shows the direction of fluid through inlet section under the enclosure section and red arrow specifies the outlet of fluid.

Chapter 5
Conclusion

By theoretical approach, the ducted fan attached on octacopter will give the drone more thrust and it is aerodynamics stable. Research has changed the design of the drone in such a way that it is more aerodynamic stable and fast. The attachment of ducted fan will give more speed to the delivery drone thus making it more time efficient.

From the CFD results, we can say that the new designed shape of cargo container for drone application is more practical to use as the new design results in less drag due to its curved shape from front and back side which helps in resisting air to a great extent, the new material of construction which is carbon fibre make design durable and helps in decreasing weight.

When the design comes in contact with high wind it becomes aerodynamic and its controls increases, the easier it is for a drone carrying cargo to move, the less energy the system needs making it a valuable part for delivery drones operating at high speed.

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