

DESIGN AND ANALYSIS OF AERIAL EMERGENCY VEHICLE FOR EMERGENCY SERVICES

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering / Technology degree in Mechanical
engineering.

by

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

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

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **MARIA ANTONY JESHWIN TREASHO W (37150117)** and **NANDHA KUMAR L (37150125)** who carried out the project entitled "**DESIGN AND ANALYSIS OF AERIAL EMERGENCY VEHICLE FOR EMERGENCY SERVICES**" under our supervision from November 2020 to March 2021.

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We, **MARIA ANTONY JESHWIN TREASHO W** and **Nandha Kumar L** Hereby declare that the Project Report entitled **DESIGN AND ANALYSIS OF AERIAL EMERGENCY VEHICLE FOR EMERGENCY SERVICES** done by me under the guidance of **Dr G. Arunkumar., M. E, Ph.D., (prof. Head)** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in **MECHANICAL ENGINEERING**.

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ABSTRACT

Avion-e is a manned emergency flying vehicle, which is a replacement to ambulances used these days. In short it is an **ambulance which flies**. It will be ergonomically designed to carry an operator, a medical representative and the patient. **The goal of this design is to reach the emergency spots at the shortest time possible**, and the easiest way to do it is to avoid road traffic and taking **air routes**. After boarding on the vehicle, the patient will be taken to the nearest hospital to provide expert medical assistance. This vehicle has the capability to achieve **vertical lift off and landing**, which in turn eliminates the need of a runway. To sum up we strongly believe that our aerial ambulance will be the fastest flying ambulance on the planet.

List of Abbreviations

CPAP	continuous positive airway pressure
EMS	Emergency medical services
BIBS	Built-in breathing system
AOD	Ambulance offload delay
HAA	Helicopter air ambulance
PWM	Pulse with modulation
BLDC	Brushless DC
NFC	Neuro fuzzy controller
VR	Variable resistance
PED	portable electronic devices
NiCd	Nickle cadmium
NiMH	Nickle metal hydride
Lion	Lithium ion
TQM	Theorem of quantity of motion
Ra	Armature's resistance
Kv	Speed constant
A	Angular speed
SmCo	Samarium cobalt
NdFeBo	Neodymium iron and boron alloy

5N5S	5 poles north and 5 poles south
V	Input voltage
N	Rotational RPM
T	Motor torque
I	current absorbed
BEC	Battery elimination circuit
ESC	Electronic speed controller
LiPo	Lithium polymer
Li Fe Po	Lithium-ion polymer
CC/CV	Constant current/ constant voltage
IMU	Internal measurement device
GPS	Global positioning system
UAV	unmanned aerial vehicle
MEMS	Micro electromechanical systems
9DOF	Nine-degree internal unit
Ve	Input tension
Ie	current
Rc	connectors and cable's resistance
Ψ	Alpha
Θ	Beta
Υ	Gamma
L	vertical thrust
$d\Psi/dt=\dot{\Psi}$	Alpha velocity
$d\Theta/dt=\dot{\Theta}$	beta velocity

$dY/dt=Y$	Gamma velocity
$dL/dt=L$	Lift velocity
PP	Polypropylene
ABS	Acrylonitrile- butadiene styrene
SLS	Selective laser sintering
PLA	Polylactic acid
PEAK	Polyaryletherketones
PEI	Polyetherimides
CFD	Computational fluid elements
CL	Lift coefficient
CD	Dag coefficient
M	Mach number

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CHAPTER 1

INTRODUCTION

The main aim of this project is to innovate a design of an intelligent ambulance which will reach the hospitals through aviation without any problems of heavy traffics and hard to reach dessert areas.

1.1 EMERGENCY VEHICLE

A vehicle used by emergency responders to respond to a crisis is known as an emergency vehicle. These services are typically run by approved entities, who are frequently government agencies, but they may also be non-governmental organisations or private corporations that have been expressly authorised by statute. In order to get to their destination, emergency services could be excluded from certain standard road regulations.in the fastest possible time, such as driving through an intersection when the traffic light is red, or exceeding the speed limit.

1.2 REQUIREMENT OF THE PROJECT

This particular project is designed for the cities with heavy traffic. E.g.: in Bangalore the roads are always busy and is heavily traffic jammed almost all the time. Most of the time the traffic will at least last for 100 meters. In this distance the traffic police can't hear the siren from the ambulance to make way for the ambulance. So, the fact is there remains a ambulance stuck in the traffic is mostly ignored. Then the ambulance has to wait till the traffic is left. Sometimes this may take much less traffic time but to consider the other way around, this may also take more than the least 30 minutes. So, by this time anything can happen to the patient. This project is to avoid these disadvantages and be helpful is saving the patient's life by making the patient reach the hospital the as quickest as possible.

This initiative is focused on the principle of eliminating ambulances from highways and recreate them and power them so that they can fly above the traffic. With the exclusion of traffic by flying, there is one more thing to be considered which are the buildings. Generally, the traffics are high in a metropolitan city and the buildings are approved and sanctioned till 8 floors, which will measure roughly around 32 meters. This project is designed in such a way that it can attain an altitude of 50 meters so it can fly freely above the buildings overcoming the traffic.

1.3 TRAFFIC COLLISION

When a vehicle collides with another vehicle, a pedestrian, an animal, road debris, or another fixed object such as a tree, pillar, or building, a traffic impact, commonly known as a car crash or a car collision, occurs. Traffic accidents result in accident, illness, death, and collateral harm, as well as societal and individual financial costs. Road travel is the deadliest situation that people face on a regular basis, but the number of people killed or injured in such accidents receives less public coverage than other, less common forms of tragedies. Vehicle design, speed of activity, road design, weather, road climate, driving skills, disability due to alcohol or drugs, and actions, including distracted driving, speeding, and street racing, all contribute to the risk of collisions.

Almost all high-income countries are seeing a decrease in traffic-related deaths, while the majority of low-income countries are seeing an increase. With 20 deaths per 100,000 people, middle-income countries have the highest rate, accounting for 80 percent of all road accidents and 52 percent of all cars.

In 2019, Traffic crashes injured 54 million people around the world. In 2019, 1.4 million people died as a result of this, compared to 1.1 million in 1999. Around 68,000 of these cases involved children under the age of five. Though Asia has the highest mortality rate (24.1 per 100,000

inhabitants), Europe has the lowest mortality rate (10.3 per 100,000 inhabitants).

Drivers who were bothered by their phones were almost four times more likely to crash than those who were not. The riskiest diversion is dialling a phone, which increases a driver's risk of crashing by 12 times, followed by reading or writing, which increases the risk by ten times. With all these distractions happening it is very much possible for accidents to happen. Accidents are something that happens out of the blue but the victim is to be treated medically and saved. But in a slow-moving traffic location the traffic is hard to be cleared for the ambulance to reach the accident spot on time and help the victim

1.4 TRAFFIC CONGESTION

Slower speeds, longer trip times, and prolonged vehicular queueing are all symptoms of traffic congestion in transportation. Since the 1950s, traffic congestion on metropolitan road networks has risen dramatically. Congestion occurs when traffic demand is high enough that driver interaction reduces the level of the traffic stream. Although congestion may occur in any form of transportation, the focus of this article would be on traffic congestion on public roads. Traffic is analysed quantitatively as a flow through a fixed point on the path, comparable to fluid dynamics.

When it comes to congested highways, many people immediately think of the delay. There seems to be added pressure during the morning commute and traffic congestion will cause some people to be late for work. And, by the end of the day, the afternoon rush hour is a stressful time when people want to go home and rest after a long day of work, but traffic prevents them from doing so. The majority of the people are impacted by

these disruptions and they are encountered by everyone who drives on congested highways.

The failure to predict travel times is a secondary consequence of road congestion induced delays. Many that drive through congested areas on a daily basis know how long it takes to get through a certain area based on the time of day or week. These seasoned city drivers must factor in extra time "just in case" traffic is poor. This reduces spare time and time available for other activities during the day. Even, if traffic is exceptionally low on a given day, the built-in extra time will be useless, and the individual will arrive too early. When you call 108 for an ambulance and the emergency service is unable to arrive in a reasonable period of time due to road congestion, you and your property could be at risk. There are systems that will help ease the issue by encouraging emergency services to adjust the traffic signals remotely to keep the line going.

1.5 MODELLING

The initial model if this project is developed to fit a pilot, a patient on a bed and a medical attender. The logical dimensions of the real time vehicle body is height - 7ft, width - 6ft and length -10ft.

The vehicle body is modelled according to the Bernoulli's equation. The model has an aero foil shape to cut through the air and provide maximum lift that can be obtained. The vehicle is modelled accordingly so that the air lift is much sufficient to glide even with the least required throttle given.

With the full-sized model in mind, a prototype size of the model is modelled and with the instalments of the power equipment, can be operated as an unmanned aerial vehicle.

1.6 VEHICLE SPECIFICATIONS

The model is supposed to carry 3 persons along with equipment like a bed, a pilot chair, a chair for attender, a ventilator and basic medical equipment and first aid kit.

The exterior of the model is designed and developed with a pair of wings for extra lift while flying and the body is mounted with handles for the motors.

The model is destined to have a door which opens two ways which will be very much sufficient for the pilot and the medical attender to get down and board and the boarding of the patient with the bed/ stretcher is also made easy and sufficient with the installation of doors.

1.7 ELECTRIC POWERED

The term "electric powered" refers to this aerial vehicle that is propelled by electric motors. Batteries, ground control cables, ultracapacitors, fuel cells, and power beaming are all options for supplying electricity. Since the 1970s, small, electrically driven model aircraft have been flown, with one unconfirmed record dating back to 1957. Since then, they've evolved into lightweight unmanned aerial vehicles which is now put to use in many circumstances and scenarios

Electric motors driving thrust-generating propellers or lift-generating rotors have driven all electric aircraft to date. Airships have been among the propeller-driven types.

1.8 BATTERIES

Due to their high capacity, batteries are the most common energy carrier component in electric aircraft. The first source of electricity was batteries, which were used to power airships in the nineteenth century. These early batteries were extremely heavy, and it wasn't until the second half of the twentieth century that technologies such as nickel-cadmium rechargeable batteries became available. That batteries became a viable aircraft power source Lithium-based battery, as well as a few other less

common technologies, are used in modern batteries. Today, such batteries are still widely used as a source of energy. Despite this, their range is restricted due to their limited endurance between charges. Batteries are often used to store energy provided by another source for a short period of time. According to Textron Aviation, the ability of electric and hybrid-electric propulsion for general aviation is restricted since the specific energy of electricity storage is only 2% of aviation fuel.

Airliners provide a hybrid configuration: lithium-ion batteries, including packaging and accessories, provide 160 Wh/kg, while aviation fuel provides 12,500 Wh/kg. Since electric machines and converters are more powerful, the shaft power available is closer to 145 Wh/kg times that of a battery, compared to 6,545 Wh/kg times that of a gas turbine: a 45:1 ratio. This 1:50 ratio, according to Collins Aerospace, prohibits electric and hybrid-electric engines for long-range aircraft, since a 500-mile mission for an all-electric, 12-passenger aircraft would necessitate a six-fold increase, whereas a three-fold increase would necessitate a three-fold increase is projected between 2019 and 2029. And this project is making use of it. According to Roland Berger, the best Li-ion batteries will reach 300 Wh/kg by 2019, which is sufficient for small aircraft, but a regional airliner will need a 500 Wh/kg battery pack. To enter service 30 years later, a hybrid, limited-range Airbus A320-sized single-aisle will require 2 kWh/kg, up from 0.25 kWh/kg in 2019.

1.9 MOTOR

Brushless DC motors are the majorly used motors in the development of a quadcopter. As the prototype resembles a drone, brushless dc motor is the choice for the motor selection.

In brushless dc motor, the mechanical commutator connections are replaced by an electronic servo mechanism. The angle of the rotor is detected by an electronic sensor, which regulates semiconductor switches such as transistors that transfer current through the windings at the right

angle, either changing the direction of the current or, in certain motors, turning it off, so the electromagnets produce torque in one direction. Brushless motors have less vibration and a longer life due to the removal of the sliding contact; their working life is only shortened by the lifespan of their bearings.

When stationary, brushed DC motors provide optimum torque, which decreases linearly as velocity increases. Brushless motors solve some of the drawbacks of brushed motors, such as higher reliability and reduced resistance to mechanical wear. These advantages come at the expense of control electronics that are theoretically less rugged, more complicated, and more costly. Permanent magnets spin around a fixed armature in a brushless motor, avoiding the issues involved with binding current to the rotating armature. The brushed DC motor's commutator assembly, which constantly changes the process to the windings to hold the motor spinning, is replaced by an electronic controller. Instead of using a commutator mechanism, the controller uses a solid-state circuit to conduct similar timed power delivery.

Brushless motors have many benefits over brushed DC motors, including a higher torque-to-weight ratio, improved performance (producing more torque per watt), increased stability, decreased noise, longer lifespan (due to the lack of brush and commutator erosion), elimination of ionizing sparks from the commutator, and a reduction in electromagnetic interference overall (EMI). They are not exposed to centrifugal forces because there are no windings on the rotor, and because the windings are protected by the housing, they can be cooled by conduction, requiring no ventilation inside the motor for cooling. As a result, the internals of the engine will be fully sealed and shielded from soil and other foreign matter.

Brushless motor commutation can be done in software using a microcontroller or microprocessor computer, or it can be done with analogue or wireless circuits. Electronic commutation, rather than brushes, allows for greater versatility and capabilities not possible with brushed DC

motors. Speed limitation, "micro stepped" operation for slow and fine motion control, and a holding torque while stationary are all features included. The controller programmed may be tailored to the particular motor in use, resulting in improved commutation performance. Heat limits the potential power that can be added to a brushless motor; too much heat weakens the magnets and damages the insulation of the windings.

Brushless motors are more effective than brushed motors at turning energy into mechanical power. The frequency at which the electricity is shifted is dictated by the location sensor input, and this improvement is largely attributed to it. The lack of brushes results in additional benefits by reducing mechanical energy loss due to friction. In the no-load and low-load regions of the motor's output curve, the increased efficiency is highest. Brushless motors and high-quality brushed motors are also efficient under high mechanical loads.

Maintenance-free operation, high speeds, and operation where sparking is dangerous (i.e., explosive conditions) or could impact electronically sensitive devices are both examples of environments and specifications where brushless-type DC motors are used.

A brushless motor's construction is similar to that of a stepper motor, but the motors vary significantly in terms of application and function. Brushless motors are typically designed to achieve continuous rotation, unlike stepper motors, which are often stopped with the rotor in a given angular position. Both motor types can have a rotor location sensor for internal feedback, but they seldom do. A well-designed brushless motor can retain finite torque at zero rpm as a phase motor.

Brushless motors are becoming increasingly common for model aircraft such as helicopters and drones. The demand for electric-powered model flight has been revolutionized by their attractive power-to-weight ratios and wide variety of possible sizes, ranging from under 5 grammes to massive motors rated at well into the kilowatt output range. Except for low-

powered, mostly toy-grade aircraft, almost all brushed electric motors are displaced. [requires citation] They've also promoted the development of simple, lightweight electric model aircraft, rather than the bigger, heavier ones that were previously powered by internal combustion engines. New batteries and brushless motors have a higher power-to-weight ratio, allowing models to rise vertically rather than steadily. Another explanation for their appeal is their low noise and low mass as opposed to small glow fuel internal combustion engines. Legal prohibitions on the use of combustion engine-powered model aircraft in some countries, mostly due to the risk of noise emissions (despite the availability of purpose-designed mufflers for nearly all model engines in recent decades), have aided the transition to high-power electric systems.

1.10 WINGS

Wings are a magnificent and intricate engineering feat. Simply put, they're on the verge of being alive. To conform to flight conditions, computer program control the wing's components. — gusts, wind shear, turbulence, also getting far too high for landing, and more — all without the pilot's input. Those wing sections will sometimes change rapidly, with almost imperceptible corrections — and on landing, those motions can occur regularly. This article delves into some of the parts of an aeroplane wing that can be seen from the passenger seat.

1.11 AILERONS

Ailerons, in which a commercial airliner has two, monitor the aircraft's vertical rotation, allowing it to roll from left to right. Aileron means "little wing" in French, and that's just what they are. When seen from the side, the aileron is tear-shaped like the wing and has the thinnest point at the rear. When viewed up close, the aileron is remarkably big. When seen from the side, the aileron is tear-shaped like the wing and has the thinnest point at the rear. When viewed up close, the aileron is remarkably big. Indeed,

you will find that the aileron returns to its flush-with-the-wing location while your aircraft is banking in a turn, but the aircraft continues to bank. This is due to centripetal power, which keeps it in a switch.

When a pilot shifts the control column to the right (or, more frequently than not, by the autopilot), the aileron on the right wing is lifted, while the aileron on the opposing wing is lowered. (They pass in opposing directions.) The act of raising the aileron on the right-wing lowers lift on the right-wing, and when lift is reduced, wings decrease. The right-wing dips down in a controlled right turn here.

The flaps deploying is the first machine-like whirring noise you hear as the plane descends for landing. Flaps can be used to both lift and drag objects. When the pilot deploys flaps, he or she will descent and sustain lift at a much slower speed on approach. Around the same time, applying flaps creates inertia, which causes the plane to slow down. There are inboard and outboard flaps on most modern jetliners, with the inboard flaps being closer to the fuselage. As the plane descends for landing, they are deployed in stages. The flaps are lifted and lowered by aircraft hydraulics within the track fairings, which are torpedo-shaped bodies under the wing. They also have the added benefit of enhancing the aerodynamic flow under the wing.

The outline of a wing is altered by wing flaps. As required, they divert the air around the wing. The flap's setting decides whether it is used to maximize lift (as on take-off) or drag (as on landing) (used on landing.) The camber of the aerial vehicle is so that the wings can provide more lift while the flaps are up. Depending on the aircraft, the flap settings are usually between five and fifteen degrees. After lift-off, the wing flaps are retracted completely so that they do not begin to produce drag. Extending the flaps, on the other hand, results in a "torn wing," which raises drag. The airplane's

stall speed is therefore reduced as a result of this. It aids in the airplane's slowing down. The flap setting is normally set between twenty-five and forty degrees by pilots. This causes the pilot to approach the landing field at a steeper angle. If the rise in drag is abrupt, pilots flying high-wing planes can experience a noticeable pitch up in the aircraft's nose.

1.12 VENTILATOR

A ventilator is a system that delivers breaths to a patient who is physically unable to breathe or breathing insufficiently by transferring breathable air into and out of the lungs. Patients can also be ventilated using a manual, hand-operated bag valve mask. Ventilators are computerized microprocessor-controlled devices, but they can also be used with a simple, hand-operated bag valve mask. Ventilators are most commonly used in intensive care, home care, and emergency medicine (as stand-alone units), as well as in anaesthesiology (as a component of an anaesthesia machine). Ventilators are sometimes referred to as "respirators," a term that was popular in the 1950s (particularly the "Bird respirator"). However, the term "respirator" is now used in hospital and medical terminology to refer to a protective face mask. Owing to the elasticity of the lungs, the patient will exhale passively as the overpressure is relieved, and the exhaled air is normally expelled into a one-way valve inside the patient circuit called the patient manifold. Ventilators can also have backup batteries, oxygen supplies, and remote control, as well as tracking and warning devices for patient-related parameters (e.g., pressure, length, and flow) and ventilator operation (e.g., air leakage, power loss, mechanical failure). Nowadays, a computer-controlled turbopump often replaces the pneumatic system. Modern ventilators are operated remotely by a small integrated device that allows precise pressure and flow characteristics to be tailored to the needs of each patient. Ventilator configurations that have been fine-tuned often allow breathing more tolerable and convenient for the user. Respiratory therapists are in charge of tuning these settings, while biomedical technologists are in charge of maintenance. The patient circuit is normally made up of three sturdy, but lightweight plastic tubes that are divided into

functions. The patient-end of the circuit may be non-invasive or invasive, depending on the type of ventilation used. A nasal mask is used in non-invasive methods such as continuous positive airway pressure (CPAP) and non-invasive breathing, which are suitable for patients who only use a ventilator while sleeping and resting. Invasive procedures necessitate intubation, which is usually a tracheotomy cannula for long-term ventilator dependency, since it is often more convenient and practical for long-term treatment than larynx or nasal intubation.

1.13 STRETCHER

A stretcher, litter, or pushchair is a piece of equipment used to transport people who need medical attention. Two or three persons must carry a basic kind (cot or litter). Variable height plates, spokes, tracks, or skids are common features of a wheeled stretcher (also known as a gurney, trolley, bed, or cart). Stretchers are mainly used by emergency medical services (EMS), troops, and search and rescue teams in acute out-of-hospital care circumstances. In medical forensics, a corpse's right arm is left dangling from the stretcher to indicate that it is not an injured patient. In the United States, they are also used to restrain inmates during lethal injections. The most basic stretchers are simple stretchers. They're made of canvas or other plastic material suspended between two poles or a tubular aluminium frame, and they're compact and waterproof. All of them are retired military vehicles and are held as emergency materials.

The folding stretcher, also known as a top deck or collapsible stretcher, is similar to the basic stretcher in shape, except it has one or more hinged points of articulation that enable it to be folded into a more compact form for easier handling or storing. In certain versions, the patient will also be able to sit upright in a Fowler's or Semi-posture.

The Roberson orthopaedic stretcher, also known as the scoop stretcher, is used to transfer people from the ground to an emergency stretcher or a spinal board. The stretcher's two ends can be separated from each other, dividing it into two longitudinal halves. To load a patient, one or both stretcher ends are removed, the halves of the stretcher are inserted under the patient on either side, and the stretcher is fastened back together. When working with obese patients, the risk of unintentionally pinching the patient's back when shutting the stretcher remains, so caution must be taken not to hurt them.

The litter, also known as a rescue basket or Stokes's basket, is intended to be used in situations where travel is restricted or there are other dangers, such as enclosed spaces, hills, or wooded terrain. It is used in search and rescue operations and is often shaped to accommodate an adult in a face up stance. The individual is secured in the basket, allowing for a successful escape. For patient safety, the litter has elevated sides and often has a flexible head/torso cover. The litter can be wheeled, pulled by hand, mounted on an ATV, dragged behind skis, snowmobile, or horse, and raised or lowered on high angle ropes after the individual is secured in it.

A flexible stretcher covered longitudinally by wooden or plastic planks is known as a Reeves Sleeve, SKED, or "flexible stretcher." It's a kind of tarpaulin that has handles on it. It's often used to get a patient into tight spaces, such as a short corridor, or to elevate obese patients. Six handholds on Reeves's stretchers enable several rescuers to assist with extrication.

The WAK board is often made to fit into tight spaces. Straps are used to lock the patient to the floor. It has two wheels on one end and a foldable footrest on the other, allowing the patient to be moved by one human, similar to how a hand truck moves cargo. It can also be used at all angles, making it easier to navigate barriers like narrow stairwells.

1.14 OXYGEN CYLINDER

Oxygen tanks are used to store gas for the following purposes:

- medical breathing in medical services and at home altitude breathing in aviation, either in a decompression emergency or on a regular basis (as in unpressurized aircraft)
- first-aid packs with oxygen
- Open-circuit oxygen sets - mostly used for accelerated decompression in technical diving several forms of diving rebreather: oxygen therapy gas mixing, for making breathing blends such as nitrox, trimix, and helix open-circuit oxygen sets - mostly used for accelerated decompression in technical diving in climbing, oxygen rebreathers and fully closed-circuit rebreathers are used. "Bottled oxygen" refers to oxygen tanks used in mountaineering manufacturing operations, such as steel and Monel production.
- The following techniques are used to provide breathing oxygen from the holding tank to users: oxygen mask, nasal cannula, full face dive mask, diving suit, demand valve, oxygen rebreather, built in breathing system (BIBS), oxygen tent, and hyperbaric oxygen chamber.
- In contrary to common opinion, seldom use oxygen tanks. The vast majority of divers use oxygen or nitrox from a diving chamber to

breathe. Trimix, helium, and other exotic gases are inhaled by a limited percentage of the population. Any of this could be equipped with pure oxygen for rapid decompression or as part of a rebreather system.

Owing to the possibility of fire caused by high temperatures caused by adiabatic heating as the gas changes pressure when passing from one vessel to another, oxygen is seldom retained at pressures greater than 200 bars (3,000 psi). Liquid oxygen Airgas tanks for medical use are normally 350 psi (24 bar).

To minimize the chance of combustion, all equipment that comes into contact with high pressure oxygen must be "oxygen clean" and "oxygen compliant." "Oxygen clean" refers to the absence of any material that may trigger an ignition source. Internal materials do not burn or degrade quickly in a high-pressure oxygen atmosphere to be "oxygen compliant."

There are regulatory and insurance provisions and limits on the use, handling, and transportation of pure oxygen in certain countries. Oxygen tanks are typically held in well-ventilated areas away from external fire sources and crowds.

CHAPTER 2

LITRATURE REVIEW

2.1 AMBULANCE OFFLOAD DELAY

Peter Vanberkel (dec 22,2019) made a study on ambulance off-road delay that When the care of arriving ambulance patients cannot be moved directly from paramedics to personnel in a hospital emergency room, ambulance offload delay (AOD) occurs (ED). This is usually attributed to overcrowding in emergency departments. This issue has piqued the interest of both academics and physicians, and it has become a major source of anxiety for many health care professionals. This essay discusses the literature on the topic of ambulance offloading delays. Improved interpretation and assessment of the issue, study of the root causes and impacts of the problem, and implementation and evaluation of interventions are among the topics covered in the research. Many studies have looked at areas such as emergency room crowding and ambulance diversion, but research focusing specifically on the ambulance offload wait issue is minimal, according to the study. There were 14 articles that looked at the causes of ambulance offload delays, 14 articles that looked at the consequences, and 89 articles that looked at potential remedies among the 137 articles reviewed (of which, 58 articles studied ambulance diversion and 31 articles studied other interventions). The fact that this issue affects health, organisational, and administrative aspects was a recurring theme in the publications examined, and that it must be handled in a system-wide way to be mitigated. Nonetheless, it produces contentious outcomes. A variety of proposals for future studies in this field are made. Conducting a system-wide mitigation intervention, addressing the root causes of ED crowding and connectivity blockage, and providing more operations testing models to test AOD mitigation interventions prior to deployment are among them. Furthermore,

AOD dimensions can be enhanced in order to more reliably determine the Scale and scope of the issue

2.2 AIR AMBULANCE

A Euro copter AS 350 B2 helicopter was dispatched to a hospital on August 26th, 2011 for surgical evacuation of a patient to another hospital (NTSB/AAR-13/02). The pilot told the company's EMS contact centre during patient pickup that he didn't have enough fuel to finish the second leg of the flight. The helicopter ran out of fuel and crashed while en-route to refuel, killing the pilot, flight nurse, flight paramedic, and patient on board. The NTSB proposed that the corporation revise policies so that pilots are no longer entirely responsible for non-routine operating decisions and are now expected to seek permission from the operation control Centre (OCC) to approve, deny, or proceed a task when faced with elevated risk circumstances (NTSB/A-13-015). The need for enhanced coordination protocols and activities specifically related to Crew Resource Management standards applicable to helicopter air ambulance (HAA) operations was demonstrated by this inquiry. CRM has been identified as a key contributing factor in many HAA incidents, including the one mentioned above. A Helicopter Accident Analysis Team comprised of government and industry helicopter experts was established in June 1998 to examine 34 fatal helicopter accidents from NTSB accident dockets that occurred between 1988 and 1992. (Table 1).

Table no: 2.1

CRM Cause with accident	Number of accidents associated	Percentage of Accidents with CRM cause
Communication		
Coordination with Ground Personnel	3	9%
Coordination with ATC	2	6%

Coordination with Other Pilots	3	9%
Judgement / Decision Making		
Sense of Urgency Led to risk taking	10	29%
Diverted Attention / Distraction	7	21%
Flight profile unsafe for conditions	17%	50%
Poor CRM	6	18%
Perceptual Judgement errors	7	21%
Procedural Errors	14	41%
Pilot control / vehicle handling deficiencies	8	24%
Use of unauthorized equipment	1	3%
Situation Awareness		
Aircraft position and hazards	12	35%
Aircraft state	5	15%
Local and enroute weather	8	24%

Only two patients survived to leave hospital, according to a historical review of emergency incidents attended by the Derbyshire Royal Infirmary Crash Flying Team. A total of nine cases of cardiac arrest have been investigated in greater depth. In both of these cases, it was discovered that the announcement of cardiac arrest had been made prior to the dispatch of the Flying Squad, and that the condition had become critical prior to the arrival of the emergency staff. Regardless of time, the Flying Squad team took more than 3 minutes to arrive in each event. A review of the literature continues to support the conclusion that, due to the time difference,

emergency teams are of no benefit when called to cardiac arrest at any distance from the hospital. More advanced medical care, ideally provided by highly qualified hospital staff, should be available immediately. Such primary care will receive sufficient assistance from medical teams.

2.3 MOTORS

2.3.1 HALBACH ARRAY MOTORS

a Halbach magnet array is a variation on the standard magnet configuration used in electric motors. the magnetic field around the array can be changed such that the magnetic flux is oriented to just one side by alternating the polarity of the magnet array in periods other than 180 degrees. as will be discussed in this section, this can be very useful in electric motors, beginning with the history of halbach arrays, their uses, and their advantages in motors.

2.3.2 THE HALBACH ARRAY

The term halbach array refers to any arrangement of permanent magnets whose poles are not aligned parallel to one another (in linear or planar configurations), or aligned concentrically (in circular orientations). Figure 2.1.1 shows examples of a linear, planar, and circular halbach array.

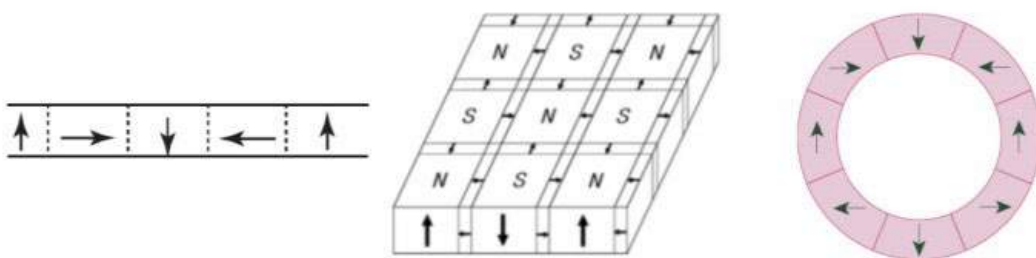


Fig 2.1

Figure 2.1: Examples of Halbach Arrays that are a) Linear [20], b) Planar [21], and c) Circular [22].

Klaus Halbach, who was researching the use of rare-earth cobalt permanent magnets, invented the first halbach series in 1979. (PM). He was able to establish a near-unidirectional magnetic field, namely a dipole field, with this series, which needed no external control. He continued working on these novel arrays in 1986, suggesting that they be used as particle accelerators in medical equipment and spectrometers. The bulk of dipole field research, however, has been based on synchronous electric equipment, such as energy storage and electromagnetic generators and motors.

One benefit of using this dipole field in motors and generators is that the rotor has no electric coils or permanent magnets, just current-laden wire flowing perpendicular to the magnetic field axis. This facilitates mechanical action with very little inertia. Figure 1 illustrates a dipole field motor.

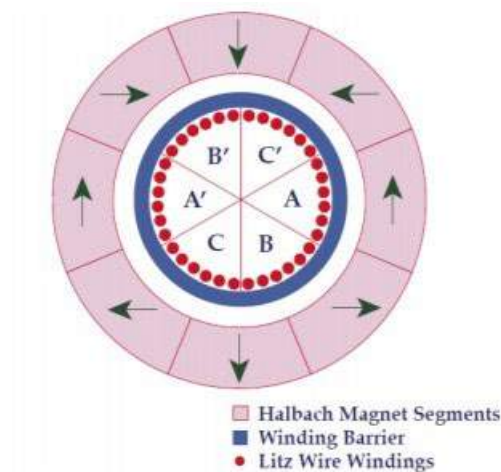


Fig 2.1.1

Figure 2.1.2: Schematic of a Dipole Field Motor Containing no Electromagnetic Coils

Although the dipole field is an intriguing design that has contributed to advancements in a variety of areas, another feature of the halbach array has had a greater influence. As opposed to a normal magnetic array, the halbach array's ability to efficiently direct magnetic field lines and allow the permanent

magnets' flux to be used more effectively improves the field density by a factor of 1.4. When contrast to a traditional magnet array, which provides a balanced field, this effect happens because the array concentrates the magnetic field to one face, a phenomenon known as electromagnetic shielding.

2.3.3 BRUSHLESS DC MOTOR

PWM (pulse width modulation) is a method for adjusting the frequency of a signal. The TMS320F240 optical signal processor is used to monitor the speed of a brushless dc motor drive using the PWM technique. Because of its high mechanical power density, simplicity, and cost effectiveness, BLDC is commonly used. TMS 320F240 digital signal processor, which has special features for digital motor control, is used to construct the full BLDC controller. Brushless DC (BLDC) motor drives are powered by a new adaptive Neuro-Fuzzy Controller (NFC). As compared to standard fuzzy and/or neural networks used in electrical drive implementations, it needs less computation. The suggested controller is used to regulate the speed and/or torque of a BLDC motor drive. A PI sensor for speed modulation of a BLDC motor was used to show the NFC's ability to follow the reference speed and reject unwanted disruptions. Three fuzzy logic controllers and three PI controllers are used in the controller. The PI controllers' outputs are added together and used as the new controller's feedback. P controller is the new controller. The fuzzy logic control is eventually mastered and becomes the primary efficient control. The use of controls to regulate the speed of a BLDC motor is presented in this article. i) Sensor-based control system ii) Sensor-less control method iii) Digital control method iv) Genetic-based proportional control are some of the methods for regulating the speed of brushless DC motors. Sensors are used to control the speed of a brushless D.C. motor drive. 1. Hall-effect sensors are widely used because they are inexpensive. 2. Electromagnetic sensors with variable reluctance (VR) 3. Accelerometers have long been used to determine motor direction and time.

2.3.4 LI ION BATTRIES

PEDs (portable electronic devices) are promising sites for real-time knowledge sharing. Their success is becoming increasingly dependent on the amount of energy consumed. It is the main energy source is rechargeable batteries, which are critical to ensuring their desired output reliability. With the rapid progression of battery technology, multifunctional PEDs have arisen to fulfil the demands of our everyday lives in a comfortable manner. If the market for high-performance PEDs continues to rise, so does the pursuit of ever more efficient rechargeable battery systems. In this analysis, we demonstrate how battery innovations have led to the exponential growth of personal electronic devices (PEDs) in recent decades. Next, a detailed history of PED innovations is presented. Following that, four types of representative rechargeable batteries are defined in detail, along with their implications for the realistic advancement of PEDs. The future research focuses and growth patterns for a new generation of batteries are also discussed.

PEDs have increased in popularity in recent decades as computer technology has evolved and innovated. The primary motivation for this practise is that PEDs are commonly used in our everyday lives, ranging from personal devices to high-tech devices used in aerospace, thanks to their ability to incorporate and communicate with humans, bringing great simplicity and epochal improvements, and have also become an integral part of almost everyone's existence. In general, stable operating energy sources are required in these devices in order to achieve the desired results. 1 Furthermore, because of the portability of PEDs, it is critical to create energy storage sources with a high level of protection. The capacity of energy storage systems should be updated to meet the growing requirement for long runtime of PEDs. To meet the current challenges of PEDs, it is vital to investigate reliable, long-life, secure, and large-capacity energy storage devices. For decades, electrochemical energy storage systems, especially rechargeable batteries, have been commonly used as PED energy sources, fostering the thriving growth of PEDs. Major advances in electrochemical outputs of rechargeable batteries have been achieved to meet the ever-

increasing demands of PEDs. 4–6 PED rechargeable batteries have used lead acid, nickel cadmium (NiCd), nickel metal hydride (NiMH), lithium ion (Lion), and other materials. As time progresses, their basic energy and specific strength increase dramatically.

The new battery technology, on the other hand, cannot keep up with the exponential growth of PEDs. 7 The current state of rechargeable battery technology for PEDs has uncovered a range of shortcomings, including low energy storage capacity, short cycle life, and fast self-discharge, all of which have become a bottleneck for PED production. 8 – 10 Multifunctional PEDs, for example, require energy storage systems with higher energy, smaller space, lighter weight, and longer operating time due to their high-power usage. Present batteries, on the other hand, are finding it difficult to meet the ever-increasing demands of new electrical and technological equipment. Therefore, the rational design and production of novel batteries has been a relentless-pursued goal for the future PEDs. The electrochemical efficiency of batteries has been the focus of intensive studies. According to recent literature, substantial change has been made. 11 to 16 There are also a slew of outstanding articles on the evolution of battery technology. 17 to 31 Despite this, there are few articles that concentrate on the rundown of rechargeable batteries for PEDs. Given the importance of battery technology in the production of PEDs, a summary of the advancement of rechargeable batteries for PEDs over the past decades is of great interest.

We hope to present and demonstrate how battery innovations lead to the rapid growth of personal electronic devices (PEDs) in this contribution. We continue with a detailed review of PED developments throughout history. Four types of representative rechargeable batteries are listed in detail, along with their functional implications for the production of various types of PEDs. Traditional PEDs, such as smart phones, smartphones, and compact cameras, are given special consideration, as are newly emerging PEDs, such

as portable computing devices and commercial drones. Finally, the existing state of battery technology growth and potential prospects are discussed.

2.3.5 SOLIDWORKS AND NX

Low cost, efficient 3D rendering capabilities, and user-friendly user interface make SolidWorks, one of the most commonly used CAD programmes on the market. As a result, it is often used in research institutions. However, although it lacks the surfacing ability of Dassault Systems' other software, CATIA, it can still produce competent results. Engineers and builders use it the most, but architects aren't as fond of it. His software is considered intermediate CAD software, and it is one of the most user-friendly CAD systems. It would, however, take some instruction since there are various features and resources to think about.

You will use this app to build both 2D and 3D templates. To make your template easier to understand, you may add hatchings or change the opacity of unique components. You may also select from a library of materials such as wood, concrete, and glass. Custom resources can also be created and saved to your library. If the illumination and photorealistic representation aren't quite as compelling as in CATIA, they're still good for helping clients, co-workers, and bosses imagine the job. These techniques are particularly useful when working on small projects, such as individual parts, but they are less effective when working on massive, complicated projects, such as plane engines.

You may use the snap tools to make components match up to certain locations to make the design process simpler. You may also disable any of the snap features to improve precision. You can add and edit any document, whether it's 2D or 3D, and this CAD programme, like most, operates in layers, allowing you to quickly pick and modify various sections without having to

change the whole interface. When annotating and operating with files from other applications, you can make 3D models from 2D images and vice versa, which can save time. The Element of Protection Wizard in SolidWorks will also help you look over your work and see if there are any structural defects that might make your designs risky. This helps you to make adjustments to your designs before they are printed. The ability to change and configure your tool palette is one of the aspects that makes this app easy to use than other CAD systems. To make your workflow more effective, keep your most commonly used resources in unique locations.

Although this software has a command line, it doesn't manage as many properties as certain other programmes, but you can use macros to speed up the development process.

SolidWorks supports DWG, DXF, Move, and STL files, allowing you to work with AutoCAD and SketchUp Pro files as well as 3D print your designs. It also lets you deal with PDFs and assorted raster image files, giving you more options when it comes to designing. This app will work for e-Drawings, but it isn't compatible with Mac OS X.

CHAPTER- 3

AIM AND SCOPE OF THE PROJECT

3.1 AIM AND OBJECTIVES:

- This vehicle aims to provide rapid emergency assistance to the injured person by immensely reducing the time taken to reach the hospital.
- Elimination of the runway by equipping the vehicle with vertical take-off and landing facility helps achieving the transportation between the accident zone and the hospital to be much faster.
- Usage of electric jet engines is much eco-friendly and owing to its compact size it has the capability to land anywhere.
- The ability to carry a nurse to attend to the patient immediately will increase the chances for the patient to receive aid at a much faster pace.
- To provide round-the-clock care in all areas by prioritising lives, regardless of the region in which the accident occurred.

3.2 SCOPE OF THE PROJECT

In accident-prone areas and areas where mass disasters occur regularly, our vehicle would be extremely useful. The vehicle can take off and land vertically in any place, regardless of the terrain. The vehicle's highlight is that it is entirely electric and hence totally environmentally sustainable since it emits no contaminants and saves life as well as the environment. It also has emergency medical equipment on board to assist as the vehicle flies to a nearby hospital. The vehicle is also facilitated with communication devices, which inform the targeted hospital about the patient's health status as well as the appropriate equipment to be held on hand and used when the patient arrives at the hospital premises.

The design and analysis project developed now can be further developed into a prototype model with the model developed. With the

successful development of the prototype, the working of the prototype can be prototype being experimentally analysed, the project can be further developed into a real time product which has a scope of being used in the day-to-day life and replace the ambulances used now.

CHAPTER- 4

EXPERIMENTS AND METHODS

4.1 OBTAINING THE OPTIMUM SIZES OF THE VEHICLE TO INITIATE THE DESIGN PROCESS:

The vehicle aims to carry three persons (a patient, a medical representative and an operator).

By considering this fact,

Height:

Nominal Height of person (sitting) = 1220 mm
(4 ft)

Headroom = 915 mm (3 ft)

Total height of the vehicle = 2140 mm (7 ft)

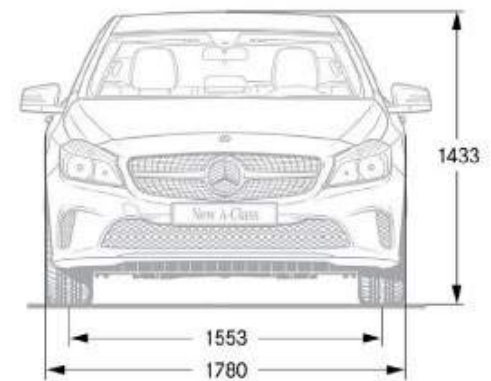


Figure 4.1

Width:

Patient's Bed width = 610mm (2 ft)

Space for medical equipment's = 915mm (3 ft)

Total width of vehicle = 1828 mm (6 ft)



All dimensions are in millimetres. The dimensions shown are mean values and apply to

Figure 4.2

Length:

Average Height of a person = 1676mm (5.5 ft)

Patient's Bed length = 1767mm (5.8 ft)

Width of person while sitting = 914mm (3 ft)

Length of the vehicle = 3048mm (10 ft)

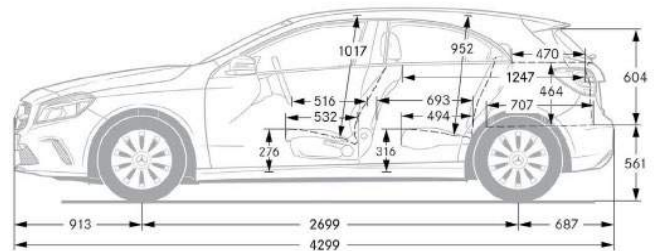


Figure 4.3

The prototype of the vehicle is scaled down to 1:10 ratio and the following dimensions were fixed.

Dimensions of the Prototype:

Length = 305 mm

Width = 182 mm

Height = 214 mm

Based on this dimension, a concept sketch of the model was designed based on several criteria. They are as follows

1. The vehicle must be in an air foil shape to ensure better aerodynamics and increase the efficiency of the vehicle.

An air foil is normally in the form of a tear drop, with the bottom side being slightly flatter. This is so that the influence of Bernoulli's theory will take place. In planes, an air foil is used to produce lift which is a consequence of this concept. In simple terms, the top side of an air foil allows the surrounding air to flow faster towards the air foil's end, reducing the average air pressure above the air-foil and allowing the higher pressure below it to force it upwards. This is what allows planes to take off and land.

2. The vehicle must be able to land in an area of 12x12 feet.
3. It has to be aesthetically good looking and futuristic so that it can portray its potential on its first look.

Keeping all these criteria, several concept sketches were tried and the best one among them was

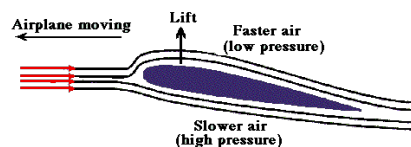


Figure 4.4

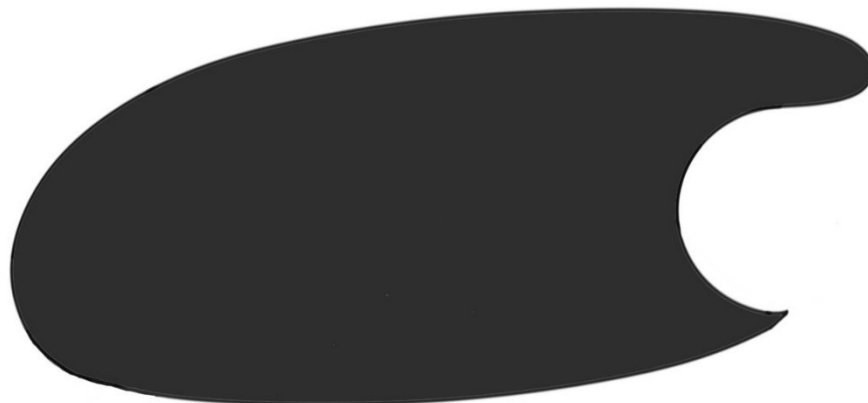


Figure 4.5

The model was much more effective than any other sketches and it also met the dimensional specification of the vehicle.

The weight of the model is the most basic step in determining what type of brushless motors to use and how many battery packs are required for the vehicle to achieve a flight time of 30 minutes, and from that data an estimated thrust value can be determined and the engineering process continues further.

The airflow around the prototype was then visualized using a 3D CAD concept model created in Siemens NX(Unigraphics) software.

The design is as follows

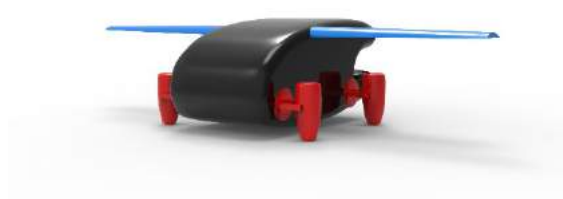


Figure 4.6



Figure 4.7



15 *Figure 4.8*

By using the above model as a surface body, the airflow around the body was visualized and the lift and drag coefficients of the body was calculated. The analysis was performed several times to check the accuracy of it. After finalizing the body in reference to the preliminary design, the detailed design of the vehicle took place.

The Detailed design of the prototype of the vehicle was also modelled on Siemens NX (Unigraphics) software. This includes the designing of

- Exterior Surfaces
- Wings
- Doors
- Hinges
- Windshield
- Headlamps
- Siren
- Motors
- Hydraulic Leg mechanisms
- Interior surfaces
- Patient's bed
- Medical Equipment (Ventilator, Oxygen Cylinder etc.)
- A compartment which holds small medical devices
- A chair for the medical assistant
- A pilot seat with all vehicle controls on it and
- The Boot Battery Space

The designs are as follows:

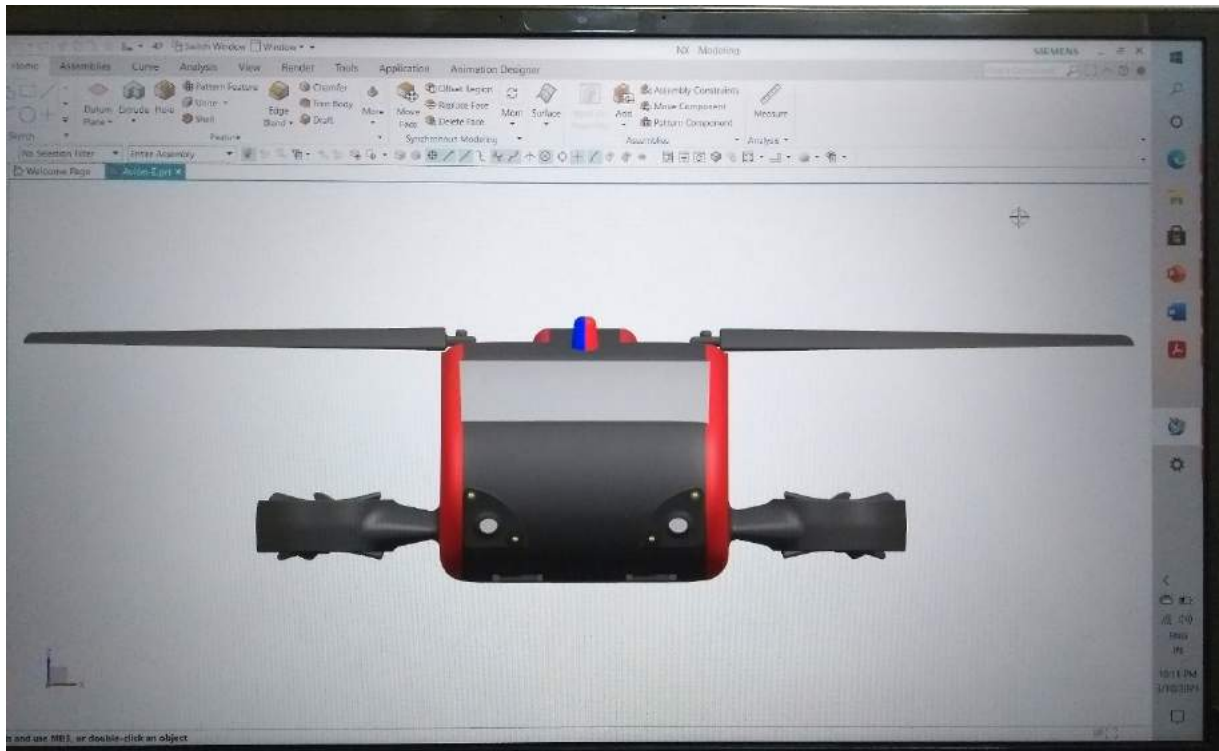


Figure 4.9

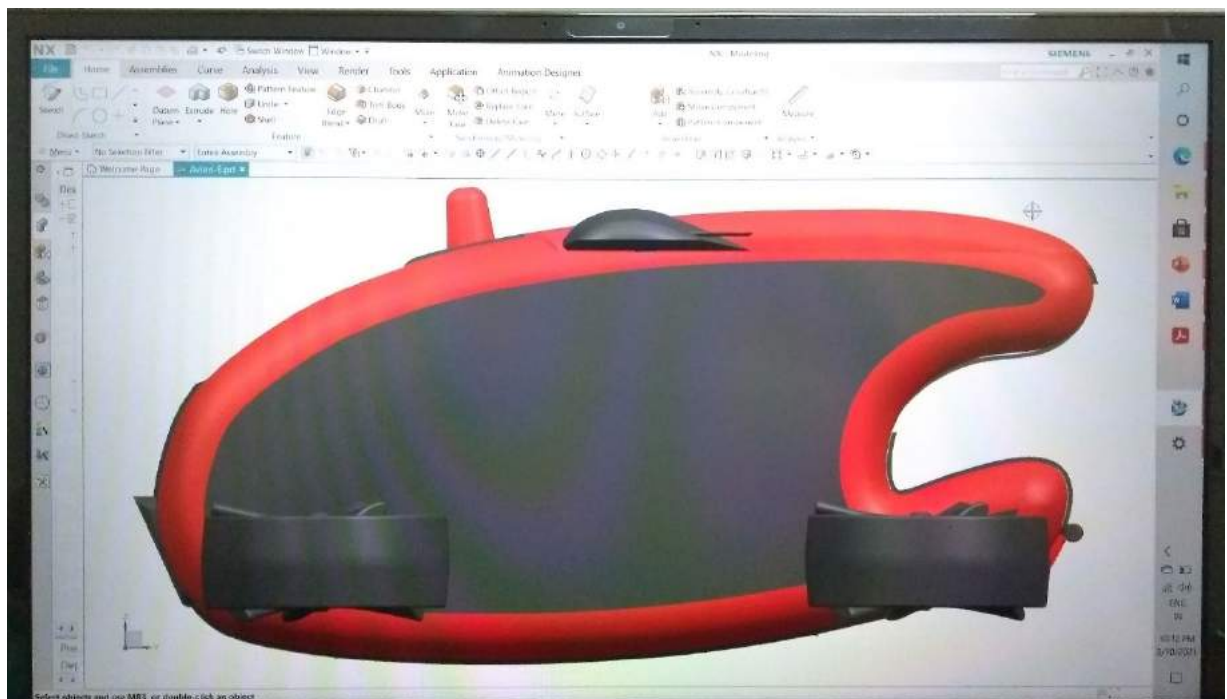


Figure 4.10

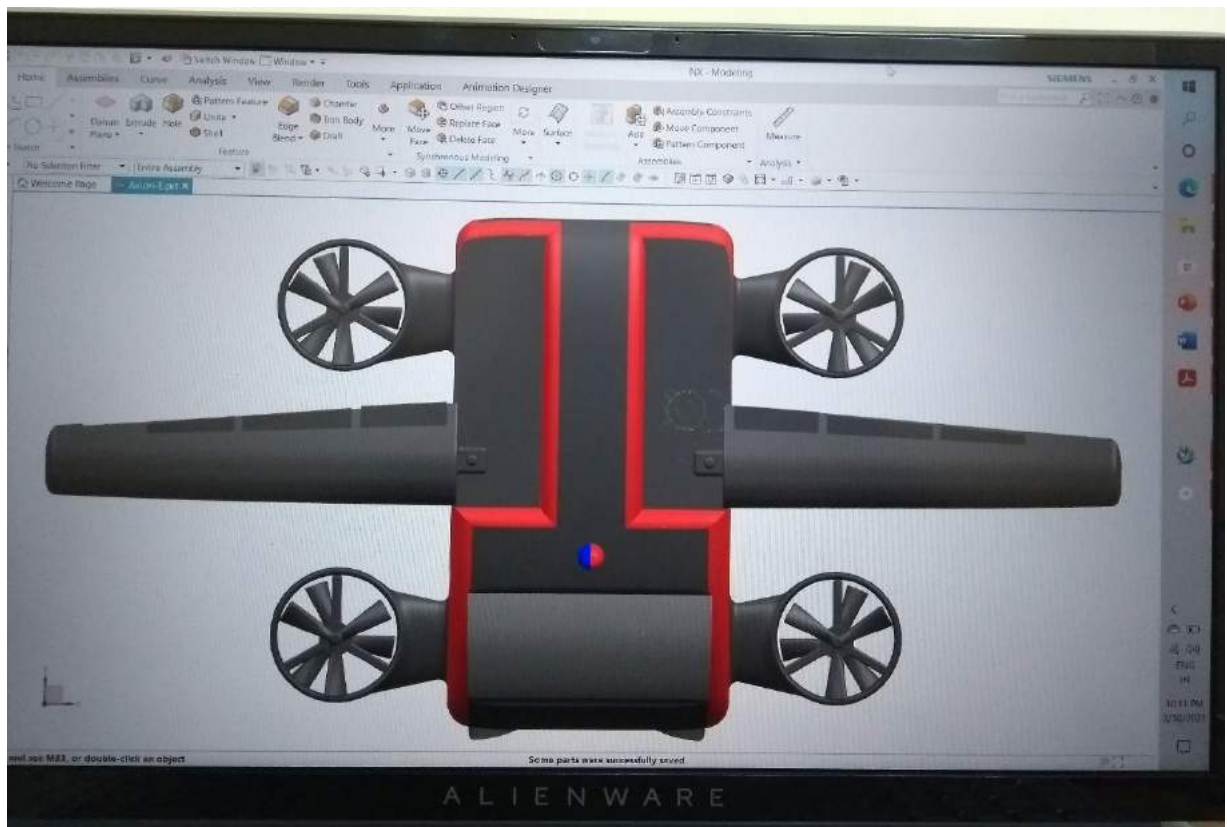


Figure 4.11

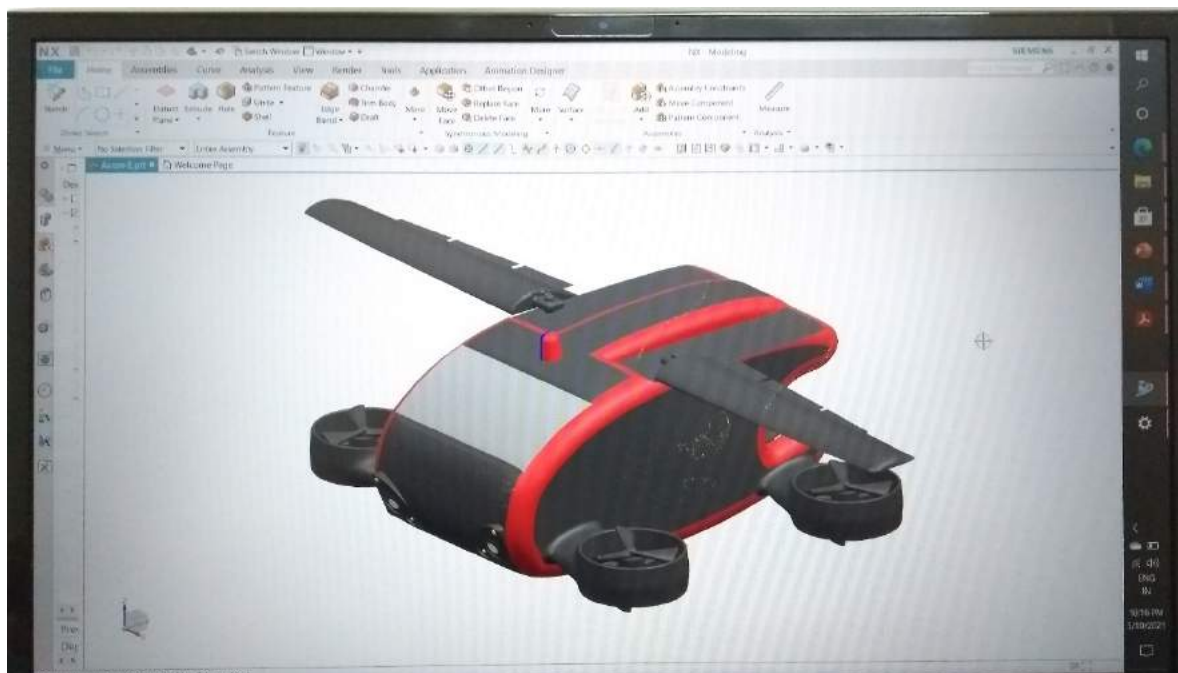


Figure 4.12

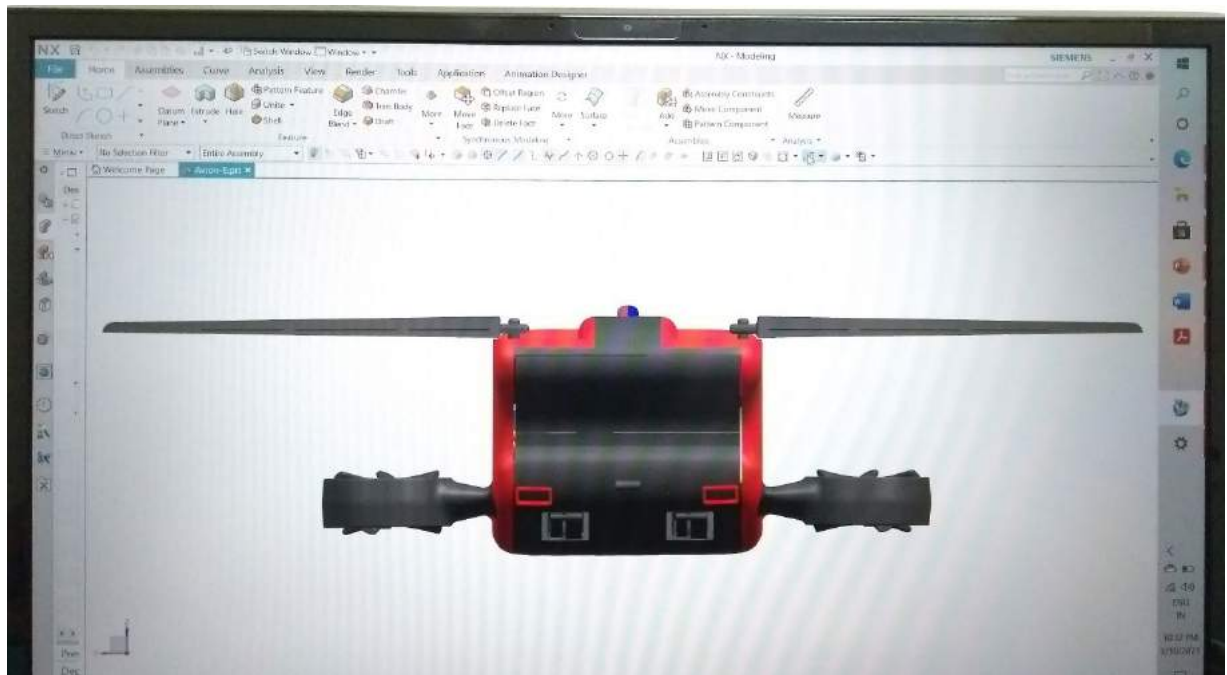


Figure 4.13

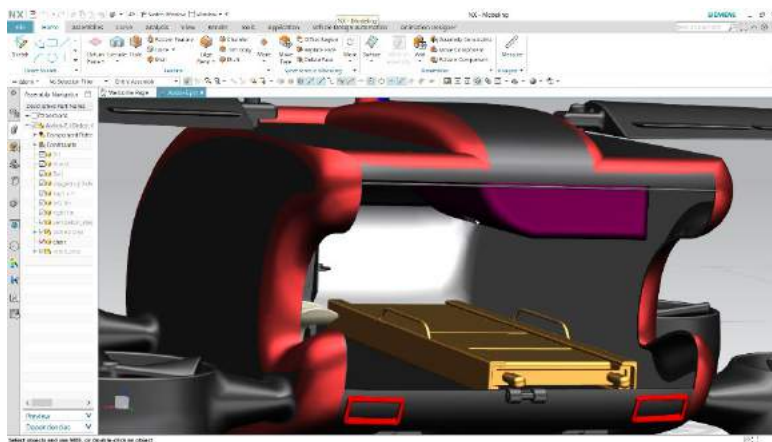


Figure 4.14

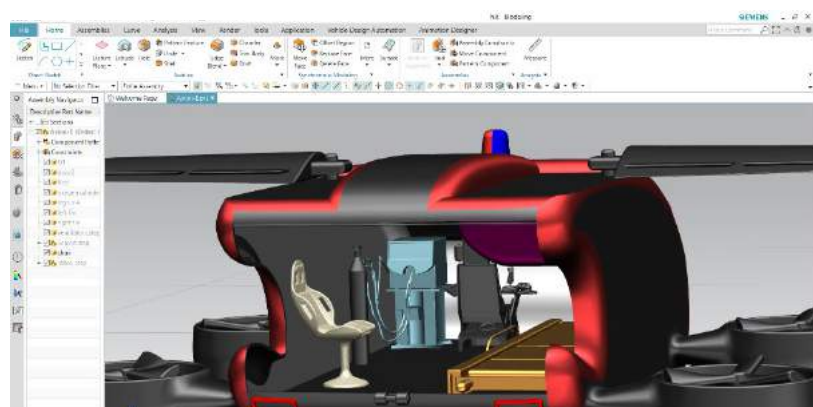


Figure 4.15

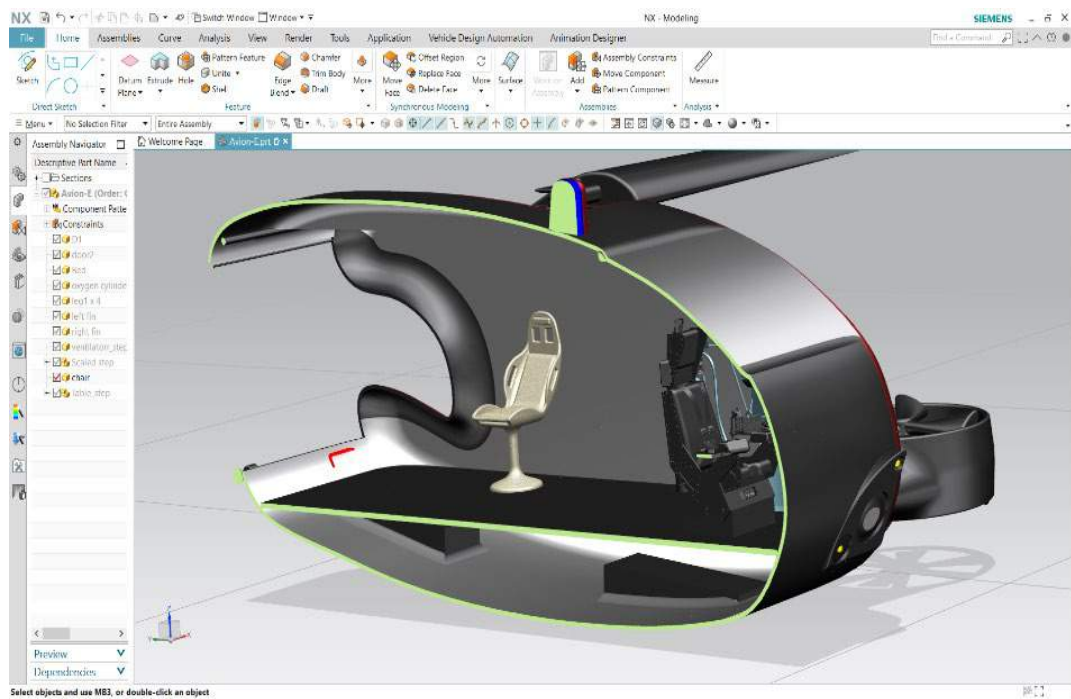


Figure 4.16

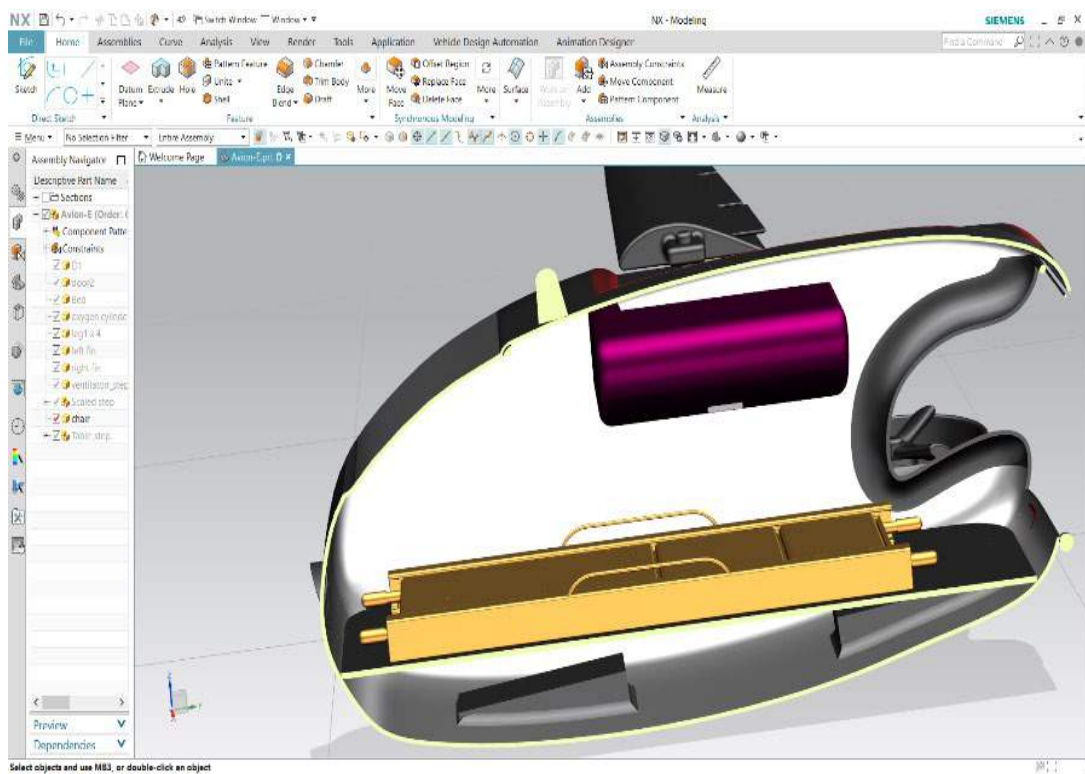


Figure 4.17

4.2 WORKING OF THE PROTOTYPE:

The physical concepts that enable an aerial emergency vehicle to travel in three spatial axes will be described as follows.

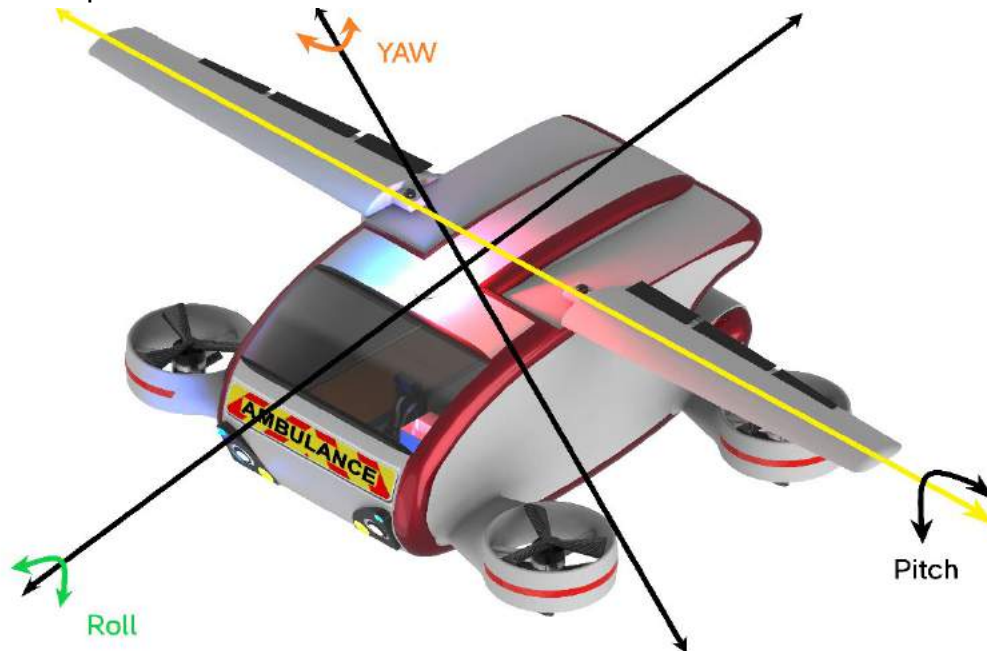


Figure 4.18

Figure 4.18 depicts the aerial emergency vehicle with its three displacement axes.

Pitch refers to the rotation on the lateral axis that leads to bites or ascents (Pitch). Roll is the rotation around the longitudinal axis used to depart from a rectilinear flight direction, while Yaw is the movement around the vertical axis used in planes in conjunction with warping.

The names of the motions and axes are similar in a multirole aircraft, but it is important to note that forward pitching would be followed by displacement (forward) in the same direction, and vice versa (retreat). Right and left warping motions, on the other hand, allow the aircraft to fly in the same directions. Following that, all four basic flight conditions will be examined: level stationary flight, forward (forward) and backward, right and left (right and left) scrolling, and yaw in a constant clockwise and counter clockwise rotation.

To understand how a multirotor works, we must first understand the idea of the reaction pair, which is taken from Newton's third law. It can be explained simply, as applied to a motor that drives a propeller, as follows: if a motor turning a propeller clockwise at a certain speed of rotation n produces a torque of value p , an equivalent torque will appear on the motor's bench and opposite pair. In the case of a helicopter, as previously said, the tail rotor compensates for this pair in flight.

Another thing to remember is that a torque is the product of a force and the distance from the source of the force. Significant assumptions about the system's behaviour can be drawn from this fact:

- The reaction torque increases as the torque increases.
- For a given pitch (which will be specified later but can be inferred for the time being as the angle of inclination of the blades), the larger the propeller's diameter, the greater the reaction torque.

After these clarifications, it is sufficient to state that all multirole aircraft motions would be dependent on compensating or decompensating the reaction pairs of the various rotors to produce a resultant in the desired direction. As a result, the working of the vehicle will begin with the most basic situation of level stationary flight.

4.3 LEVEL FLIGHT:

The aerial emergency vehicle is believed to be flat and stationary (hovering). That is, at a certain height above the ground, static. The red arrows in the following diagrams are perpendicular to the black plane and represent each rotor's vertical thrust (sustentation), the orange arrows indicate the direction of the motor's reaction torque (opposite its direction of rotation), and the green arrow clearly points to the aircraft's nose. The yellow circles represent rotors that rotate clockwise, while the blue circles represent rotors that rotate counter clockwise.

The aerial emergency vehicle with configuration in X uses four clockwise rotating motors and four counter clockwise rotating motors, as seen in the diagram. The blades on the propellers are shaped anti

symmetrically, because even if the rotational direction is opposite, they all generate push down (lift). It is very simple to examine how the aircraft manages flight until you understand the physical theory of the reaction pair. Since all eight motors spin at the same time, their reaction pairs are identical, and since the frame positions them symmetrically, they balance each other out. As a result, there is no force that will cause the aerial emergency vehicle to rotate along its vertical axis, and the thrust of the eight motors will remain static and level. The above study is obviously theoretical since various aerodynamic effects, residual asymmetries, and ambient conditions do not allow for continuous stationary flight if the control and stabilization mechanism does perform minor corrections at present time.

4.3.1 FORWARD AND BACKWARD PITCH (FORWARD AND REVERSE):

The other motions made by the aerial emergency vehicle would be very straightforward to interpret until the stationary flight is known. The ambulance then transitions from stationary flight to a forward pitch, which causes the tail rotors to up and down the nose rotors. Simply increase the thrust of the two tail rotors equally, or decrease the thrust of the two nose rotors equally, to achieve this result. The red

arrows that show vertical thrust are greater in the back than in the previous graph, as can be seen in the graph.

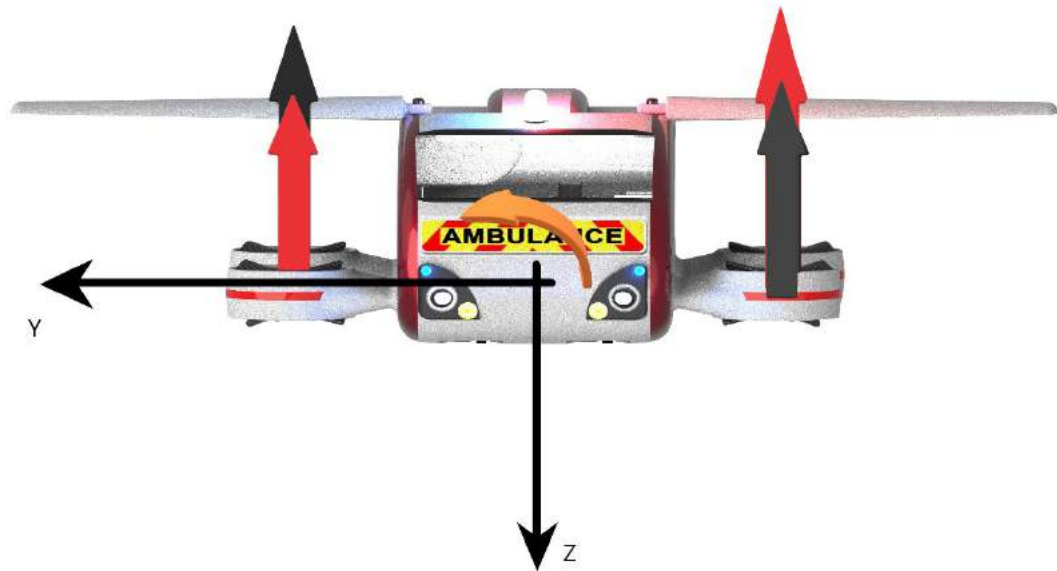


Figure 4.19

The reaction pairs will be altered as the spin regimes change. The reaction pairs for this movement are insignificant because the ones for the rear engines compensate each other equally, whereas the two for the forward engines do not. It's important to remember that as the aerial emergency vehicle goes on, the motors' force vectors will no longer be perpendicular to the field, decomposing into two forces: one vertical and the other in the pitch direction. As a result, once the plane starts to pitch over, it begins to move in that direction. The control system can ensure that no height is lost during the process.

The inverse of the above-mentioned backward pitching trend. It's important to remember that, like forward pitching, backward pitching can be synonymous with the aerial emergency vehicle's backward rotation.

According to the Theorem of Quantity of Motion (TQM from now on), the forces on the z axis must compensate for the weight in order for the

vehicle to be steady and at a certain height. There are no motor force components on the y axis in this state.

4.3.2 EQUATION FOR THE Z-AXIS OF EQUILIBRIUM:

$$\sum_{i=1}^4 T_i = mg \quad (1)$$

If the differential added in motor 3 is the same as the differential removed in motor 1, no variation in the state of the vehicle is introduced. The mass centre, on the other hand, is assumed to be at the intersection of the three axes previously described, according to the Kinetic Moment Theorem applied to the mass centre):

$$GK = \sum GP \times F_{ext}(P) \quad (2)$$

$$I_G \dot{\Omega} = \begin{bmatrix} 0 \\ d \\ 0 \end{bmatrix} \times \begin{bmatrix} 0 \\ 0 \\ -T_1 \end{bmatrix} + \begin{bmatrix} -d \\ 0 \\ 0 \end{bmatrix} \times \begin{bmatrix} 0 \\ 0 \\ -T_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -d \end{bmatrix} \times \begin{bmatrix} 0 \\ 0 \\ -T_3 \end{bmatrix} + \begin{bmatrix} d \\ 0 \\ 0 \end{bmatrix} \times \begin{bmatrix} 0 \\ 0 \\ -T_4 \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix} \begin{bmatrix} \ddot{\theta} \\ \ddot{\phi} \\ \ddot{\psi} \end{bmatrix} = \begin{bmatrix} -dT_1 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ -dT_2 \\ 0 \end{bmatrix} + \begin{bmatrix} dT_3 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ dT_4 \\ 0 \end{bmatrix} = \begin{bmatrix} d(T_3 - T_4) \\ d(T_4 - T_2) \\ 0 \end{bmatrix} \quad (4)$$

As can be seen in equation (4), as T_4 equals T_2 , the moments on the y-axis vanish. In the other hand, a difference of moments is formed in the x-axis, resulting in the presence of an angular displacement in that axis, resulting in the previously described shift. The above is the expression for the angular acceleration that occurs.

$$\ddot{\theta} = \frac{d(T_3 - T_1)}{I_{xx}} \quad (5)$$

We may extract design parameters from this basic analysis since it has been shown that a longer arm and/or slight inertia results in greater accelerations.

4.3.3 RIGHT AND LEFT WARPING (LATERAL DISPLACEMENT) :

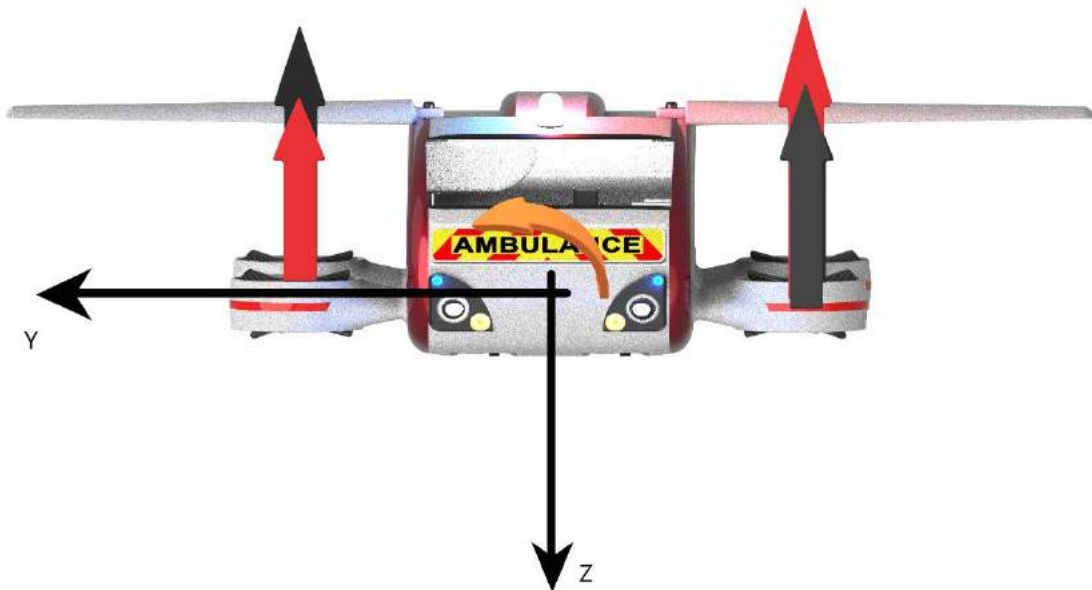


Figure 4.20

The warping mechanism is the same as that defined for pitch movements. The only exception is that in this situation, the aerial emergency vehicle's speed-increasing motors are mounted on the aerial emergency vehicle's sides (seen in its normal direction of advance). The warping mechanism is the same as that defined for pitch movements. The only exception is that in this situation, the aerial emergency vehicle's speed-increasing motors are mounted on the aerial emergency vehicle's sides (seen in its normal direction of advance). If the right pair of rotors is warped, the left pair of rotors will increase their lift, their reaction pairs will compensate for each other, and the longitudinal axis will rotate towards the right side. The warping against the left side occurs in the reverse direction.

In the same way that the vector arising from vertical thrust was decomposed into two forces in the pitching motion: one to compensate for the weight of the aircraft and the other forward to generate its advance, the decomposition of forces in this case would give rise to a portion that will induce, in a similar way, the aerial emergency vehicle's lateral displacement.

As are often seen in equation (4) the moments on the coordinate axis disappear as T4 is up to T2. On the other hand, a differential of moments within the coordinate axis is formed, that causes the look of an angular acceleration therein axis, giving rise to the movement antecedental explained. The expression for the angular acceleration that seems is as follows.

$$\ddot{\varphi} = \frac{d(T4-T2)}{I_{yy}} \quad (6)$$

Similarly, a horizontal aspect occurs, which induces translation movement in the direction of the vehicle's inclination.

4.3.4 STAG FLIGHT IN LEVEL STATIONARY FLIGHT (TURN ON ITSELF):

A tail rotor is needed in a multi copter to offset the torque exerted by the blades, much as it is in a helicopter. As a result, there are many options for dealing with this issue.

Since the most common thing in a multi copter is a pair of helices, the most common way to regulate the yaw is to turn half of the motors in the opposite direction from the other half, causing the reaction pairs formed by the Helices to cancel each other out. The downside of this approach is that it necessitates the use of two different kinds of propellers. Because the propellers have a defined aerodynamic profile, simply turning them upside down will not suffice; although thrust will be generated, it will be insufficient.

Another option is to switch all of the motors in the same direction and create counterparts with a specific design feature. To offset the torque

generated by the propellers, the main solution is to turn all of the rotors away from vertical (Figure). As in the previous example, we can control the variable yaw speed of two of the four rotors in this manner (in the case of the aerial emergency vehicle).

Alternatively, a procedure similar to the one described above, in which one of the rotors is given a degree of freedom of rotation perpendicular to the limb, can be used to keep the eight propellers rotating in the same direction. A servomotor mounted to the flight control controls this degree of independence, and a yaw is accomplished in one direction or the other based on the movement of the engine. It should be remembered that the motor's rest orientation is rotated rather than parallel to the rest of the motors to prevent an unwelcome yaw. This type of yaw control is commonly found in tri-rotors, where a higher level of mechanical sophistication is needed to control the yaw.

The final option is to install control surfaces at the propeller's outlet that channel air flow and provide a counterbalance. The yaw movement is achieved by changing the angle of these surfaces.

The first approach would be used in our case because we want to simplify both mechanical and aerodynamic construction.

Assume the aerial emergency vehicle is levelled in stationary flight and induce a yaw or twist motion along its vertical axis for the study to be discussed below.

This movement is founded on a distinct physical phenomenon than the previous ones. The motors' reaction pairs were compensated in pairs in the cases tested, so no force capable of forcing them to rotate around the vertical axis was caused in the aerial emergency vehicle. For the yaw movement, however, the exact opposite is required: the resultant pairs of the four motors must be decompensated and a resultant in the desired rotational direction must be obtained. This can also be accomplished by acting in pairs on the generators, but this time in pairs that are transversely positioned. The distribution of thrust and reaction pairs corresponding to a counter clockwise yaw movement is seen in Figure (7). As seen in the diagram, the reaction

torque or resultant rotational force is obtained by reducing the rotation speed of the rotors marked in blue, as well as their lift (vector in red) and reaction torque (vector in orange).

Obviously, the absolute lift (vertical thrust) must be maintained if the aerial emergency vehicle is not to lose height. The increase in lift provided by the yellow rotors compensates for the loss of blue rotor lift, keeping the aircraft steady and level. As a consequence of the fact that the reaction pairs of the four rotors are no longer compensated, counter clockwise rotation occurs, resulting in a torque / force that induces rotation around the vertical axis. The yaw clockwise works on the same principle as the yaw counter clockwise, but on the opposite set of motors.

It's worth noting that aerial emergency vehicle yaw rotation is less effective than that of a helicopter in general. That is to say, the rotation around the vertical axis is slower. The reason for this is simple: while the tail rotor of a helicopter is solely responsible for the rotation of a quadrant, the decompensation of the thrust of the engines in a aerial emergency vehicle cannot achieve the same degree of torque since the thrust of the engines must stay within the limits required to keep the aircraft level.

The following equation can be used to express the moment that causes this movement:

$$\sum_{i=1}^4 \tau_{mi} = \sum_{i=1}^4 (\tau_{mlzm} \cdot \omega_i - \tau_{drag_i})$$

As previously said, the yaw moment is calculated by combining the four rotational moments of the four engines. In a steady state, rotating two in one direction and the other two in the opposite direction balances and keeps the drone stable in yaw rotation.

By increasing the rotational speed of even motors and decreasing the rotational speed of odd motors in the same manner, a moment is generated in the same direction as motors whose rotational speed is decreased. This occurs in order to maintain the volume of movement. If the positive z-axis is

considered while the drone points towards the ground or plan if the images are detected, the drone would be aligned anti-clockwise.

Odd numbers of rotors are used in certain particular systems of multicopter equipment to achieve greater mobility for this movement. In any case, a high yaw rate isn't necessary for industrial applications, and that type of configuration is typically reserved for acrobatic aerobatics, such as servo-controlled variable pitch propellers.

The apparatus' top speed would be determined by two factors: the apparatus' support and air resistance. The aerodynamic resistance of the apparatus cannot be calculated by empirical form due to the difficulty of the apparatus's aerodynamic study.

We can also figure out the highest slope at which the apparatus can sustain its height and, as a result, its maximum linear acceleration.

$$\theta_{max} = \frac{\cos^{-1} \frac{M_{tot} \cdot g}{F_{max}}}{}$$

Where F_{max} equals $F_1 + F_2 + F_3 + F_4$

We can now calculate the overall linear acceleration using the angle.

$$a_{max} = \frac{F_{max} \cdot \sin \theta_{max}}{M_{tot}}$$

4.4 PROPELLERS:

The propeller will be the starting point for the analysis of the aerial emergency vehicle's components because it is the most important component because each propeller is a rotating wing for a multirotor team. The rotary wing is named in this document because rotating wings were developed with the invention of the auto gyro flight theory.

The propeller is in charge of converting the engine's output into useful power for the flight.

A propeller is made up of a series of aerodynamic profiles that are similar to those found on an airplane's wing and have a variable angle from the centre to the tips. The thrust effect is produced in each section of the propeller (each profile) and is no more than the lift.

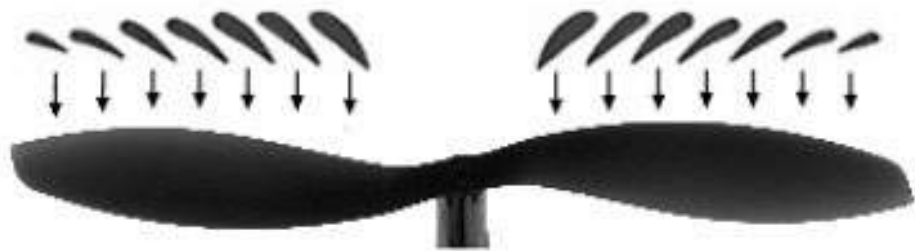


Figure 4.21

Analysing the variables that influence the lift or the fluid dynamics that generate it is pointless given the characteristics of this document. It's enough to know that in our horizontal case, the propeller's profile movement generates more pressure in the back than in the previous one, resulting in vertical thrust (lift). The following diagram (Figure 12) depicts the aerodynamic profile of a propeller's

cross section at 75% of its diameter. The highest edge is known as the leading edge, while the lowest is known as the trailing edge.

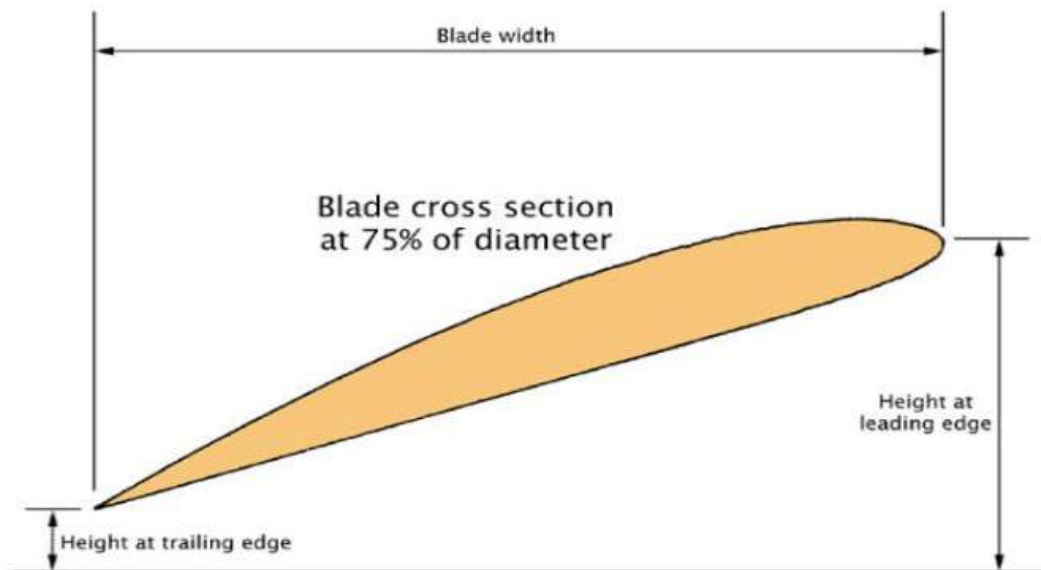


Figure 4.22

The angle of attack is the angle formed by the line connecting the leading edge to the air (relative wind). When you look at a propeller like the one seen below, it is visible that the torsion angle of each blade

changes as you move from the tips to the middle. It's a little narrower at the ends and a little bigger in the centre. Since the lift provided by an air foil is proportional to its relative velocity of movement with respect to the air, the blades have taken this form. As a result, if the linear velocity of the profiles positioned in that area is higher at the ends of the propeller where the radius is smaller, it is clear that the propeller's torsion (angle of attack) must be reduced. In modelling, this fact can become very extreme at times. As the angular velocity at the propeller tips of small models of small diameter propellers rotating at speeds greater than 20,000 rpm is calculated, it is found to be at the speed of sound. When this occurs, the air no longer qualifies as an incompressible fluid, and it enters the so-called supersonic regime.

The propellers' ends are constructed with negative angles of attack in these situations.

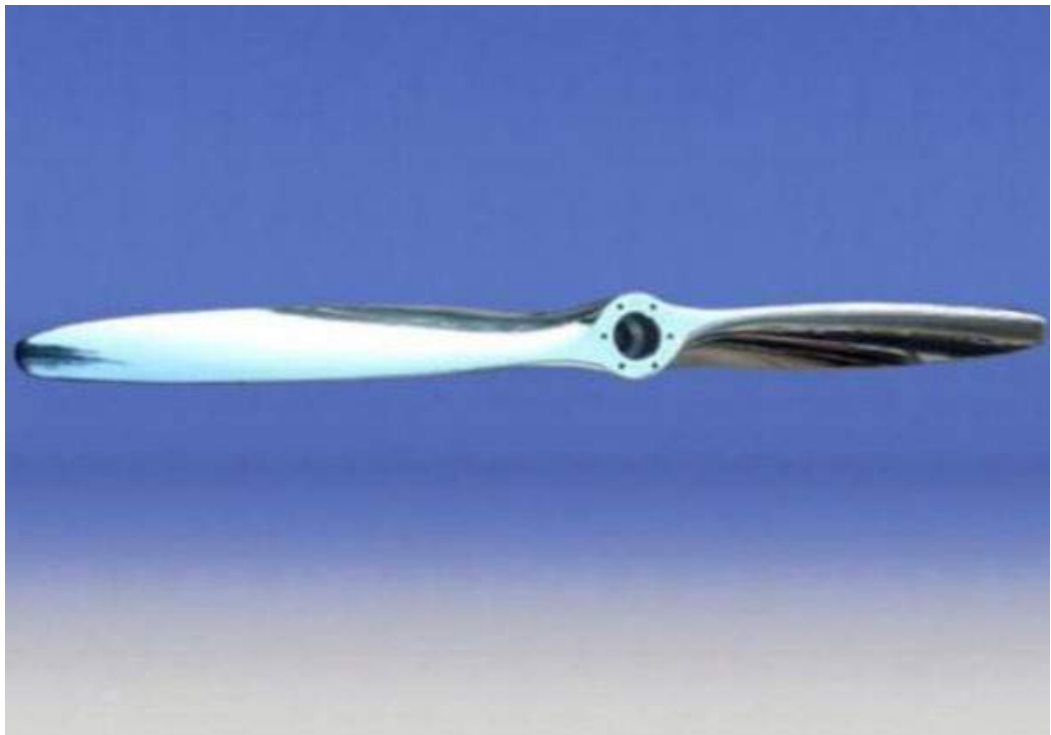


Figure 4.23

A pair of propellers, one puller and the other pusher, are needed in a multi rotor vehicle. The names correspond to the propeller's rotational direction in order to produce a driving force in the vehicle's direction of travel.

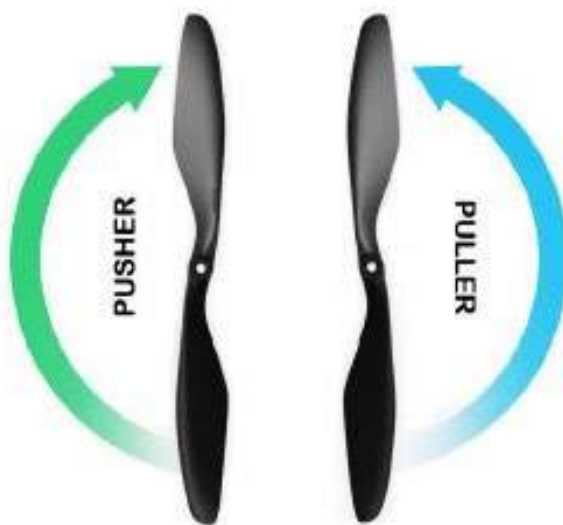


Figure 4.24

Figure 14 depicts a sequence of forces that operate on every propeller and must be understood.

The torque that turns it A, the thrust it produces C (thrust), and the resultant of these three factors composing A and B.

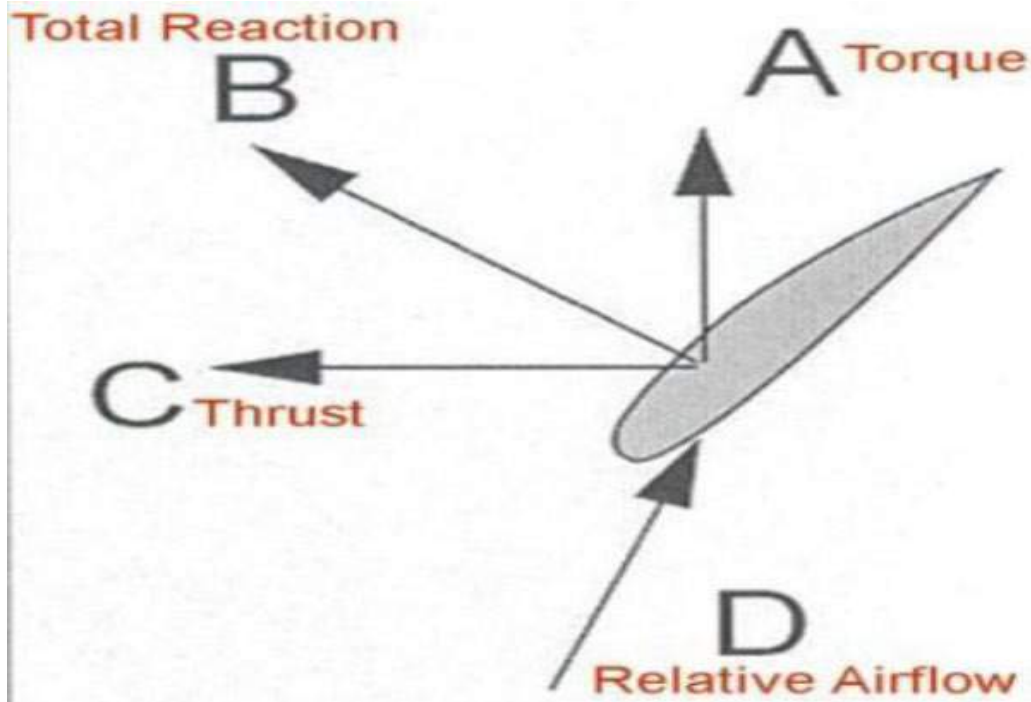


Figure 4.25

The torque is the force that propels the engine forward. It's important to understand that a running propeller's pair is a quadratic pair. That is, it is of the form $K \cdot V^2$, where K is a value determined by the propeller's characteristics and V is the speed of rotation.

The quadratic nature of the propeller resistor has significant consequences for multi-rotor aircraft flight. Taking the following scenario into consideration. It produced a p-weight aerial emergency vehicle that runs on a 2000mAh battery. The autonomy is thought to be greatly diminished, and the battery pack is replaced by a 4000mAh battery that weighs three times as much. One would assume autonomy to double as a first approximation.

However, in order to maintain the devices in flight, it would be important to raise the battery's extra weight, which would necessitate increasing the motors' rotational speed. If we exaggeratedly presume that the rotational speed must be doubled, the torque produced by the motor would be four times greater. Brushless DC engines will use nearly 4 times more current in these conditions than in the original conditions. As a result, the autonomy would have been cut in half compared to the light battery.

While the analogy is dramatic since it is dependent on the requirement of doubling the speed of rotation, it is intended to demonstrate that the fact that pairs are quadratic has just as serious consequences as reasonable changes in the speed of rotation, which, as a result of the rise in weight, cause consumptions to be much greater than they would be if the pair were linear.

Two numerical dimensions characterize a propeller: its diameter in inches and its pitch.

Real propeller configurations include 9x5, 10x4.7, and 11x3.3. The diameter leaves no question about the meaning. Following that, the term "step" will be specified.

The passage of a propeller can be described as the amount of time it takes for a full revolution of a propeller to advance an aircraft in horizontal flight. That is, a 9x5 propeller's 5 "pitch" means that the aero plane it propels advances 5" forward with each revolution. The geometric step is the step that is given as the definition of the helix. Owing to an aerodynamic effect known as slipping in Spanish, the aircraft's overall forward progress would be reduced. The slip could be demonstrated intuitively by relating the propeller to a screw that is screwed into a material, without getting into complicated fluid dynamics specifics. Since "the screw" "slips" when working with a fluid material, it does not move the same distance with each turn of the screwdriver as it does with a solid material.

4.4.1 SELECTING A PROPELLER:

When choosing a propeller for a multi rotor vehicle, the first thing to remember is the nature of the manufacturing and rigidity of the propeller. It's important to remember that an aerial emergency vehicle is a rotating-wing plane, which means the four propellers are the wings that must carry the weight in static conditions and even more so during manoeuvres where the load factor rises due to centrifugal force.

As a result, use propellers that are as stiff as possible, ideally carbon fibre or wood. Any low-cost versatile propeller can deform into a cylinder, compromising the equipment's flight and stability.

Where it comes to diameter and pitch, the decision must be taken in conjunction with the engine, though there is one parameter that can be split: the diameter. As shown by a propeller's output, the larger the diameter, the better. The first approximation is to try to match the propeller's diameter to that of the frame occupying during the turn as large as possible without clearly intervening with the rotors (except in the case of extreme space constraints).

It's important to understand that the best aerodynamic efficiency comes from using a two-blade propeller with the maximum possible diameter.

This truth has been recognized since the dawn of aviation, though seeing classic aero planes with multi-blade propellers can be shocking. However, understanding the need to reduce the diameter by increasing the number of blades is sufficient when considering the space constraints that a traditional aircraft faces for take-off and landing. In the case of multi-rotors, the propeller diameter can be selected to cover the largest possible area of the chassis, provided that no tandem aerodynamic friction occurs, which

occurs as the vortices of the rotors collide. This phenomenon is shown in the diagram below:

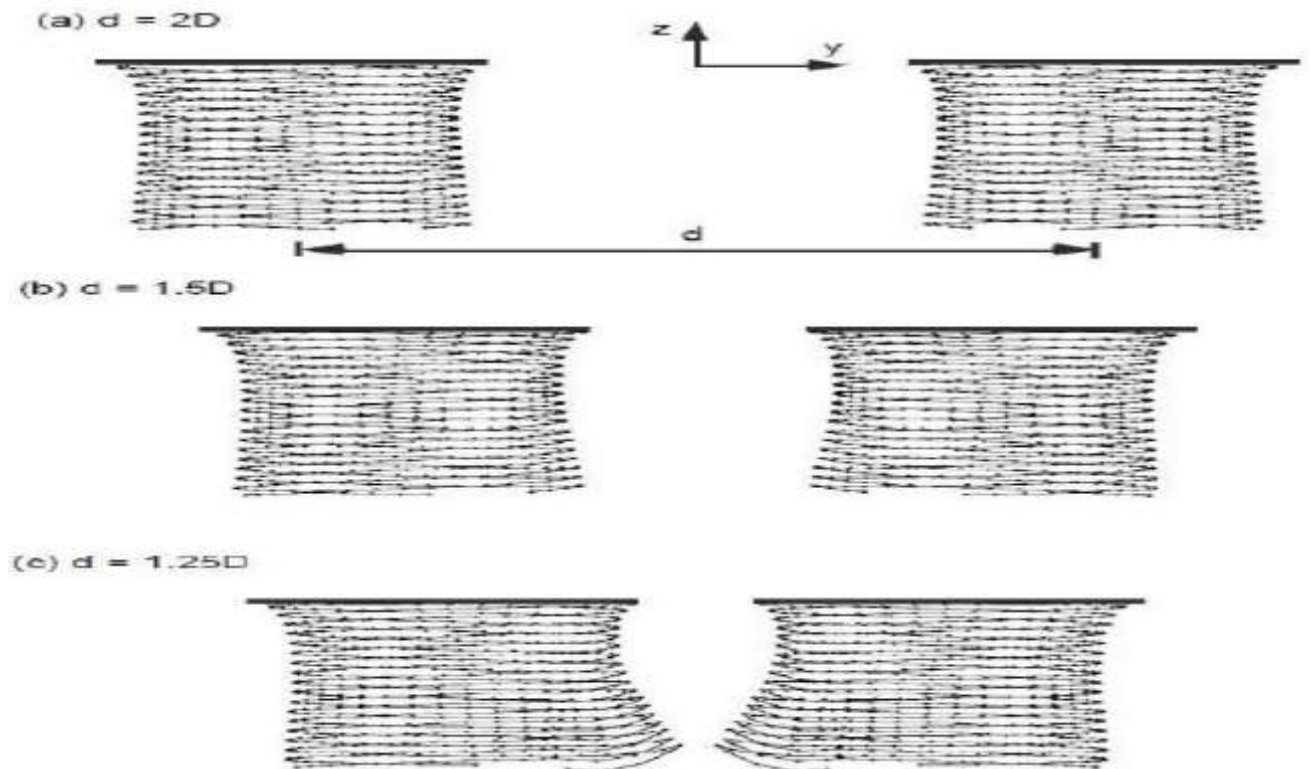


Figure 4.26

The vortices of the rotors were interpreted for various distances between the motors' axes. The axes of the motors are divided by a distance D equal to 2 times the diameter of the propellers in the diagram. 1.5 times the diameter in figure B, and 1.25 times the diameter in figure C.

The effect of tandem vortex interaction can already be seen in the third figure. As a result, separations that are less than this value can be avoided.

Reviewing the most common aerial emergency vehicles, such as the Quantum Nova, Phantom, and others. The manufacturers appear to have adhered to both criteria: on the one hand, they attempted to occupy the maximum available area, and on the other, the recommended propellers establish a distance criterion slightly greater than 1.25.

4.5 BRUSHLESS DC MOTORS (BLDC) OR ELECTRONIC SWITCHING ENGINES:

Despite the added complexity of its electronic switching circuit, the BLDCM has several advantages over its counterpart, including higher torque/weight ratio, less operational noise, longer lifetime, less electromagnetic interference generation, and much more power per volume, which is practically limited only by its inherent heat generation, which is usually transferred to the outside environment.

The BLDCM's dynamic model can be roughly approximated by the well-known BDCM's, despite their performance differences. The simple electrical circuit of such a motor is seen in Fig. 17, where is the voltage applied to its armature, R_a is the armature's resistance, and $v_b = kv!$ is the armature's back-electromotive power, kv is the speed constant, and $!$ A is the angular speed.

A BLDC can be thought of as a traditional DC motor with the brushes and manifold substituted by electronic equipment that injects current into the necessary windings based on the rotor position to produce torque.

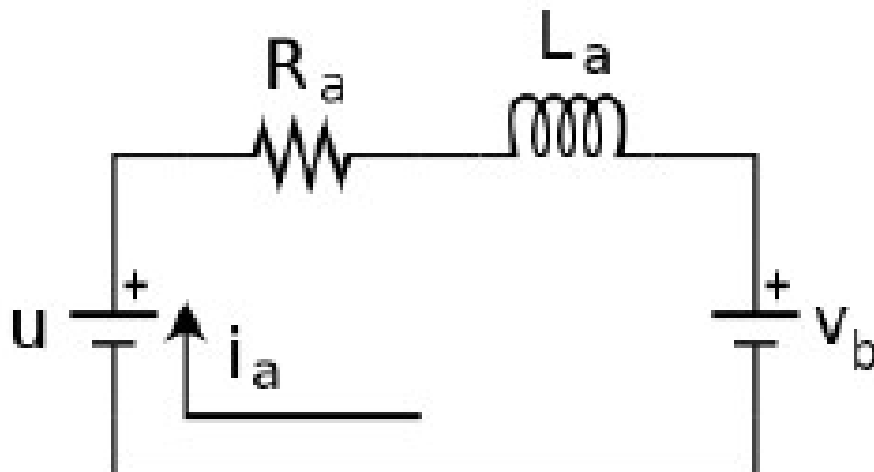


Figure 4.27

The BLDC, on the other hand, is a synchronous computer in terms of electrical engineering since its rotating speed is synchronised with the frequency of the electronic equipment that feeds it. In reality, the variable speed drive's speed is regulated and varied by changing the switching frequency of the transistors that make up the drive.

To comprehend this clarification, it is important to first describe the components and operation of a BLDC.

The rotor and stator are the two components of a BLDC engine. The first is obviously the one that runs, while the second remains stationary. In most electric motors, the rotor is a cylindrical cylinder that rotates around a larger hollow cylinder that serves as the stator. However, two topologies are possible in this style of machine: "In runner" and "Outrunner" engines. These names, which do not have a clear Spanish translation, simply mean whether the rotor is positioned within the stator (in runner) or outside the stator (outrunner), with the stator remaining stationary.

The configuration of a BLDC in runner, in which the rotor rotates within the envelope, as seen in the diagram below. The rotor, as seen in the table, is a cylinder containing permanent rare earth magnets such as SmCo or NdFeBo. The second group consists of workers who are actually working on simulation software. Coils are wrapped around polar cores of ferromagnetic material to make the stator. As current is passed through the coils, new magnetic poles are created, which interfere with the rotor's permanent magnetic poles to cause the system to rotate. The graph's motor has four poles in the rotor and six poles in the stator. This arrangement is often referred to as 5N5S, or 5 poles north and 5 poles south, since the poles would have opposite signs. Engines with asymmetric configurations, where the number of north and south poles differs, are popular, particularly in outrunner engines that produce more torque. When you look at the machine's stator, you'll see that the coils have been coded in three distinct colours. This graphic guide, for example, shows that the upper pole's green winding is connected in series with the lower pole's green winding, forming one of the three stator stages. The same thing occurs with the other pairs of coils so that they can

be bound internally to a similar point: winding in a star or forming a triangle with outlets at its vertices.

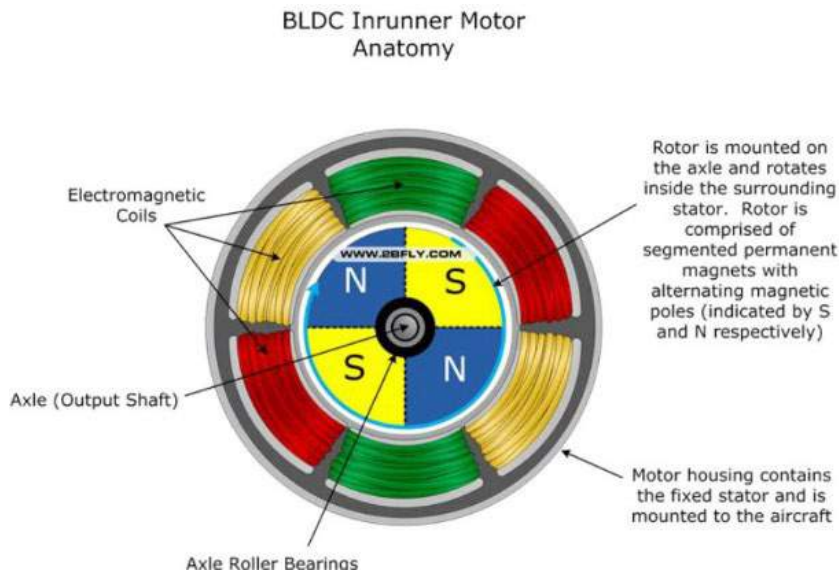


Figure 4.28

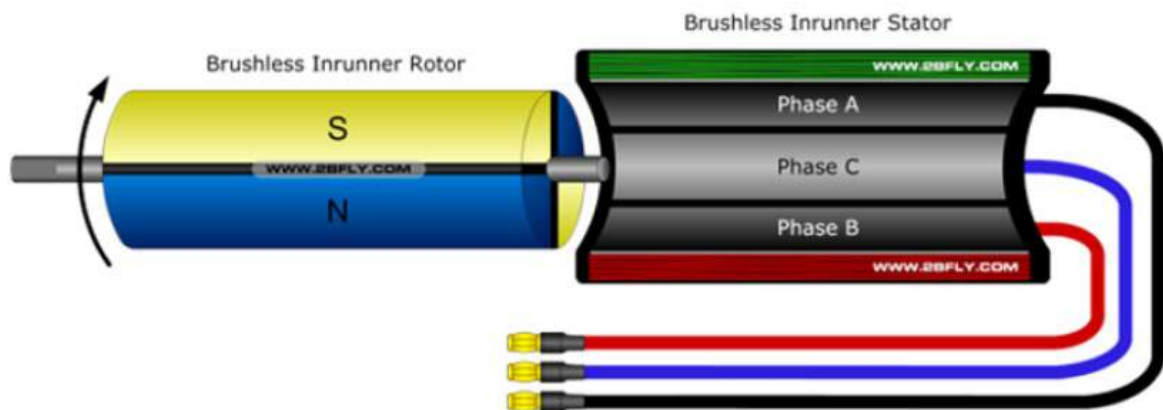


Figure 4.29

Figure 4.28 depicts a side view of an in-runner engine, showing how the rotor is housed within the envelope containing the polar masses on which the machine's three phases' windings have been wound.

Figure 4.29 depicts a setup of an outrunner engine. Permanent magnet poles have adhered to the inner portion of the outer casing, which is

movable and rotates on bearings, in this case. As a result, this envelope of magnets is the machine's rotor, which takes the shape of a drum and is known as an outrunner when it rotates from the outside. In this case, the stator winding is installed in the middle on the polar masses that are attached to the back support of the anchorage.

The motor's exterior appearance is shown in Figure 4.30. It clearly shows the anchoring bench on the right side, as well as how the outer drum, which contains the permanent magnets, performs the spinning.

Shaft outlets on both sides and mounting attachments that enable them to be anchored to the model in various positions are very popular in motors equipped with this configuration for modelling applications.

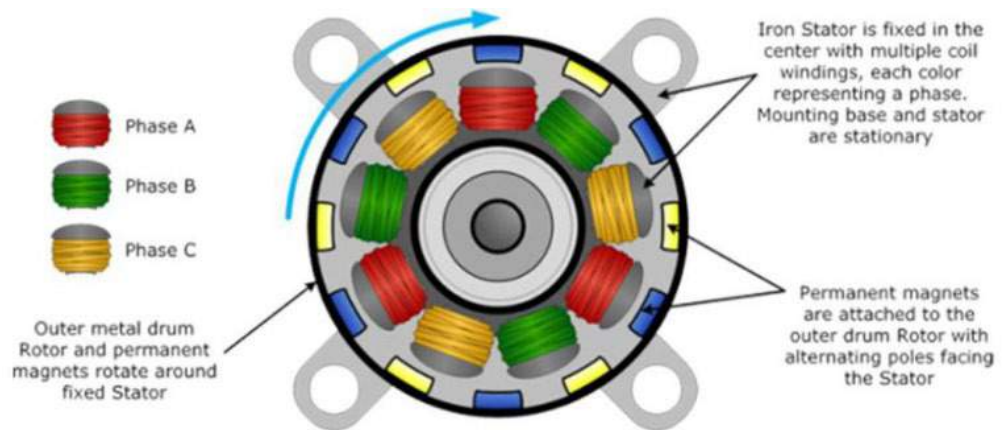


Figure 4.30

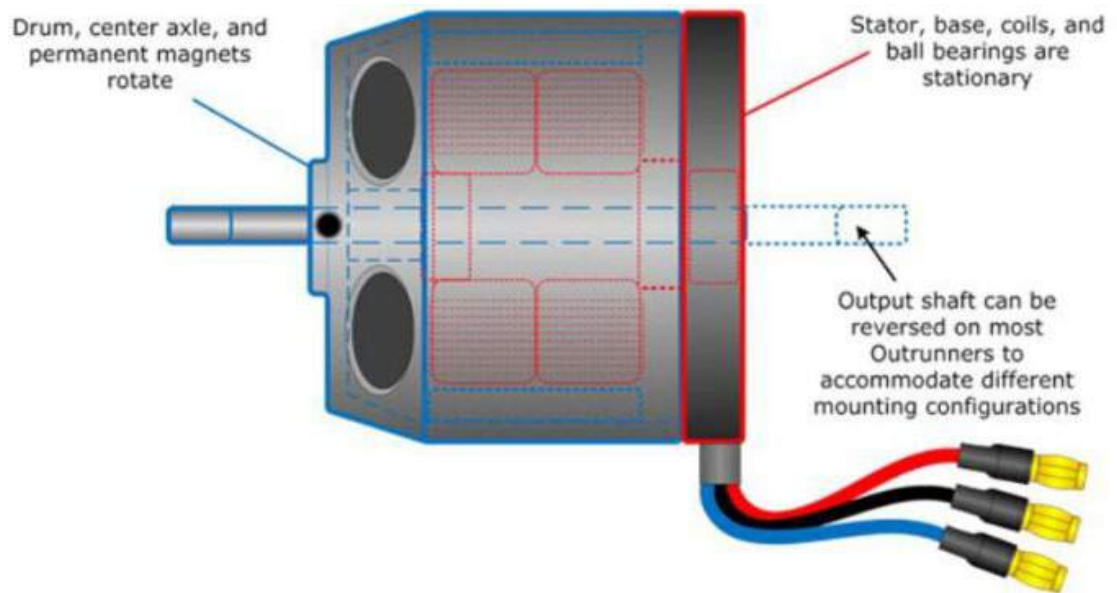


Figure 4.31

While the two types of motors are conceptually similar and have the same equations and operating theory, their spatial topology, like that of industrial synchronous machines, greatly alters their characteristics and implementations. The key distinction between an external rotor motor and an internal rotor motor, without getting into more complicated descriptions, can be stated as the speed of rotation and the ability to generate torque.

Since the inner rotor motor is slimmer and longer, it can spin at even higher speeds without generating major centrifugal forces. In particular, models with engine speeds above 20,000 rpm are not rare. As a result, one might say that this sort of motor is well suited to moving small diameter propellers that must spin at a high rate of rotation, such as those used in ducted fan systems for aeroplanes.

The outer rotor or revolving housing engines, on the other side, are flatter and have a smaller diameter. This arrangement already indicates what the rotational speed will be. Lower, and the torque is much greater. In reality, a BLDC disc or rotary drum motor is specifically designed to produce a high torque. One of the most unexpected uses of this model of system, which is built in the shape of a flat and narrow disc, is the use of electric traction to perform taxiing tasks (taxiing until arriving at the head of the track and returning to the point of parking). This results in increased fuel efficiency, lower temperatures, and less turbine wear.

They can be considered ideal for driving larger diameter propellers and not very high passages at moderate speed regimes in their simulation application.

Principle of operation: Electronic Switching

The main characteristics of BLDC motors have been described so far, but the operational principle has not been mentioned. The rotation of the rotor in a BLDC motor is controlled by electronic switching, which is a term used in electrical engineering. The diagram of figure 18, which will be repeated here for convenience, will be used to understand it in a simple way

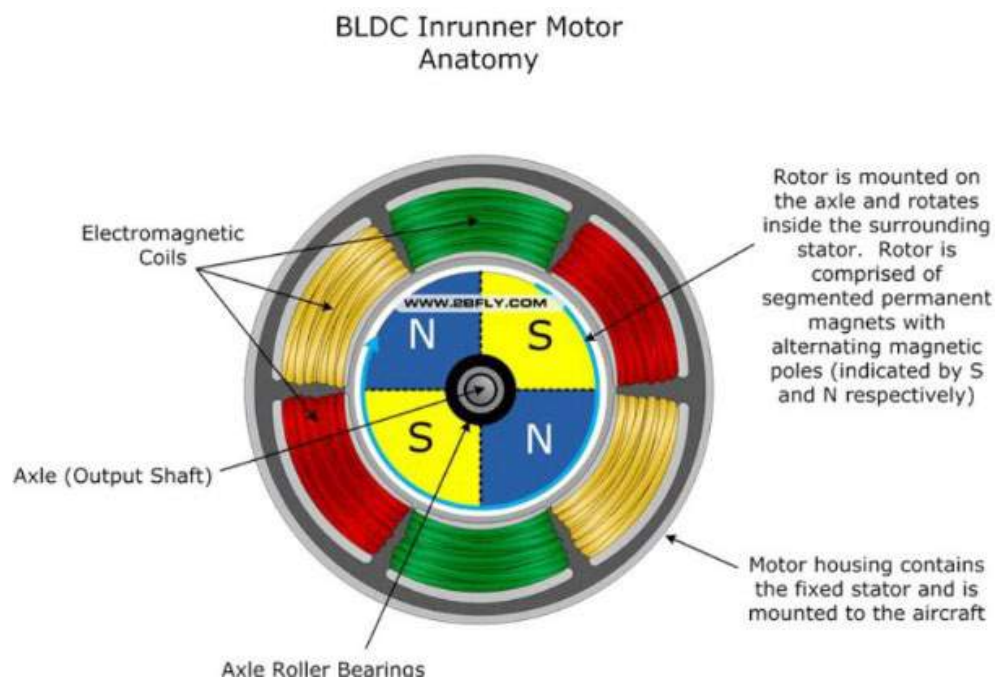


Figure 4.32

The rotor in the motor seen in the previous figure remains at rest if no current is applied into any of the coils. Consider what happens if an external device adds current in the yellow process in such a way that two magnetic poles are formed, one with north polarity and the other with south polarity, as seen in the diagram. If this happens, the north (blue) poles of the rotor will be repelled, while the south poles (yellow) will be attracted to the same-coloured winding. The rotor would have rotated a fraction of a turn as a result of this.

If the current state is continued, the engine will stop rotating, retaining the previous position's stability.

However, once the rotor is free of the power of a pair of stator poles, the current is nullified in them and introduced into the second, resuming the mechanism of magnet attraction and repulsion. As a result, if the current is pumped at regular intervals in the correct angular direction, the motor will rotate. Electronic switches inside the variable speed drive perform these current injections and shutdowns, which is referred to as electronic switching. Increase the frequency of activation and deactivation of the flowing currents by the stator winding to change the motor rpm. This entails altering the frequency at which the inverter's electrical switches open and close.

The previous switching method begins with a theory that is not technically possible in reality. It is presumed that the injection or extinction of current in each step occurs only when the rotor's magnetic poles are in the proper angular orientation. This is theoretically impossible because the motor has a device that reminds the variator of the rotor's angular orientation. The motor includes on the shaft an encoder (rotary encoder) that supplies the direction of the rotor to the speed variator in BLDC motors for industrial applications, such as car addresses with electric assistance. There are several models for these devices on the market, and because modelling engines do not use them, it is pointless to discuss anything other than their presence and the need to remind the variator of the rotor's location.

How does a BLDC simulation engine work properly if it does not have any external structures that report the rotor's position? The use of a control algorithm for the inverter called sensor less control provides the answer to this issue.

At the end of the nineteenth century, the laws of Lenz and Faraday developed that if a magnetic field passes in the vicinity of a series of coils, an electromotive force (tension) is produced in them. This law is the foundation of the sensor less regulation that modalism variators use to prevent having to install mechanisms for measuring the rotor's angular orientation.

The following is a brief explanation of how the control system works: Regardless of the rotor location, the motor begins by injecting currents in a certain direction. This current injection allows the motor to drive in an unpredictable manner, even attempting to start in the opposite direction of the intended direction. Due to the Law of Lenz, electromotive forces are induced in the phases that are not injecting current during travel. The variator's calculation of these electromotive forces allows the rotor position to be estimated and the electronic switching to be aligned with the rotor position. This transitorily unstable state can be seen when gas is added very slowly to the aerial emergency vehicle's engines, causing a minor delay at the start of the propeller rotation.

Characteristic curves and parameters that define a BLDC motor. Before describing the typical parameters obtained from BL = DC motors, it's important to understand the two equations that govern their activity. It can be seen that torque and rpm in a BLDC motor satisfy the following two requirements.

$$V = K_1 \cdot N$$

$$T = K_2 \cdot I$$

Where V denotes the input voltage, N denotes the rotational rpm, T denotes the motor torque, and I denotes the current absorbed. Each motor's own constants, K_1 and K_2 , are determined by its constructive type, flux density of the magnets, and other factors.

The first equation's constant provides the most well-known BLDC parameter, commonly referred to as kV and expressed in terms of rpm / V. (in fact it would be the inverse of the constant indicated in the equation). In a simpler way, the constant kV of a BLDC motor shows the RPMs required for a given supply voltage. When fed at 1 V, a 1200 kV motor can spin at 1200 rpm.

The second equation is unrelated to any data typically provided by the manufacturer, but it is critical to comprehending the machine's function. The reading of equation (13) shows that the current to be consumed is

proportional to the proportionality constant K_2 , and that the current consumed is directly determined by the torque that the motor must produce. As previously said, the resistant torque of a helix is quadratic, and if the speed of rotation is supposed to be doubled, the torque and thus the current absorbed will be compounded by four.

1. The vacuum current (no load current) usually supplied for a given supply voltage is one of the other parameters that describe this kind of motor followed by,
2. The resistance of the windings' conductors.
3. The highest current that can be used (supplied normally along with the maximum time that can develop it).
4. The amount of electrical energy consumed (sometimes in different conditions or for a set of propellers)
5. There are a certain number of poles. Normally written as 15N15S, 14N16S, and so on.

If the motor is not among those chosen, it is reasonably simple to obtain the vacuum current and the resistance of the windings, which, when combined with the number of poles, enables the motor to be fully described.

The graph below depicts all of a BLDC motor's characteristic curves and provides guidance on which operating point to choose for each type.

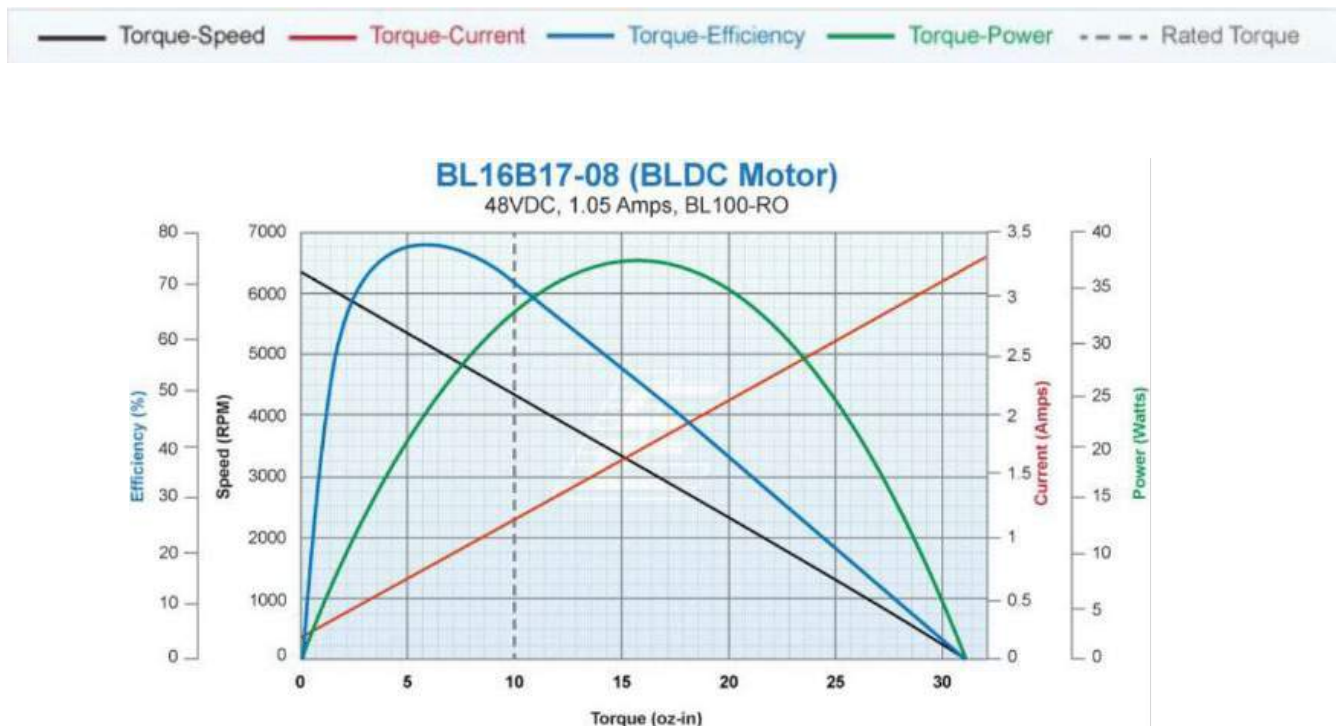


Figure 4.33

Many of the definitions discussed above can be seen in these diagrams. When the velocity curve is examined in purple, it can be seen that the torque provided by the motor is marginally more than 30 oz-in with the stalled rotor, and that when rotating in vacuum, the rotation speed is more than 6000 rpm.

When we look at the red curve (torque-current), we can see that equation 13 is satisfied and the current grows linearly as the pair grows. A current of around 0.2 A corresponds to the torque zero point. When the motor rotates with nothing connected to the shaft, this is the no load present, which implies the motor's consumption to magnetise and counteract friction losses.

Finally, the blue curve is more interesting because it represents output as a function of the pair formed. The amount of electrical power consumed to generate mechanical power in the shaft is measured by performance.

A low yield point means that a significant portion of the electrical power consumed is used to heat the engine rather than to generate mechanical work. As a result, the operating point at which the propeller is pushed to the engine must be as close to optimum output as possible. Otherwise, not only would the battery be squandered, but the engine would be overheated.

Low pairs are typically used to indicate the motor's highest output stage. As a result, selecting a propeller that carries the engine to its optimum output is practically difficult.

However, choices should be made as close to this value as possible, and any combination that returns less than about 70% should be discarded after a simulation. The graph depicts a line of points corresponding to the motor's chosen work point. A turn to the right often results in an increase in the motor's absorbed power and flowing current.

Before concluding the section on engines, it is necessary to mention the temperature at which they operate. If the temperature rises, the flux density of permanent magnets decreases. If the temperature rise experienced by the motor is not excessive, the magnet recovers its magnetism after cooling. A permanent magnet, however, loses its magnetism at a temperature known as the Curie Temperature.

As a result, two elements of a permanent magnet motor's operation must be considered:

1. Even though the Curie temperature that induces irreversible engine harm is not reached, the increased temperature of the magnets decreases flux density and causes the motor's working characteristics to deteriorate.
2. The engine would be irreparably disabled after the Curie temperature or values similar to it have been achieved.

As a result, the architecture should try to keep the engine as cool as possible. The optimum working temperature is about 40 degrees Celsius, and 60 degrees Celsius can never be surpassed.

4.6 SPEED VARIABLES OR ESCS (ELECTRONIC SPEED CONTROLLERS):

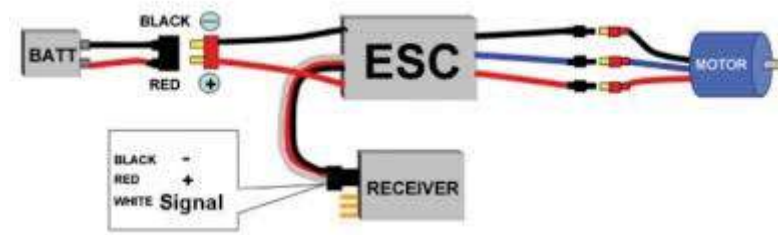


Figure 4.34

The composition of an ESC, its operating theory, and certain factors to consider when selecting one will be explored next. An outstanding diagram of the components of an electronic variator can be seen in the figure below. The following components can be seen by analysing the diagram from right to left:

1. Output filter capacitor: This is a capacitor that acts as a filter for the voltage wave that is applied to the engine.
2. A collection of three vertical leg branches called FET. These six switches are MOSFET-JFET transistors with low-resistance channels (the ones they present when they are in saturation, i.e., closed). Every branch's central point is linked to the three phases of the motor. It is thus possible to add positive, negative, or zero voltage to each of the phases of the motor by doing various variations with the closed and open switches.
3. FET Driver Circuitry: this part essentially adapts the microcontroller's logic outputs to the voltage and current levels necessary to reach the transistors' gates and produce their cutting and saturation (opening and closing).
4. Microcontroller: the software for controlling the transistors is stored on it. It takes the gas signal (throttle) as well as the measurement of the electromotive forces induced in each step, as defined in the sensor less

control of BLDCs section. The BEC portion found in most inverters provides their strength.

5. BEC = Battery Elimination Circuit: The BEC is a linear voltage regulator, or an electrical circuit that decreases and stabilises the voltage of the batteries to feed the microcontroller and other devices that include logical amounts of voltage, which in our device is usually 5 V.

The name BEC came from the fact that older versions needed an extra 4.8V battery to power the servos, receivers, and other electronic circuits.

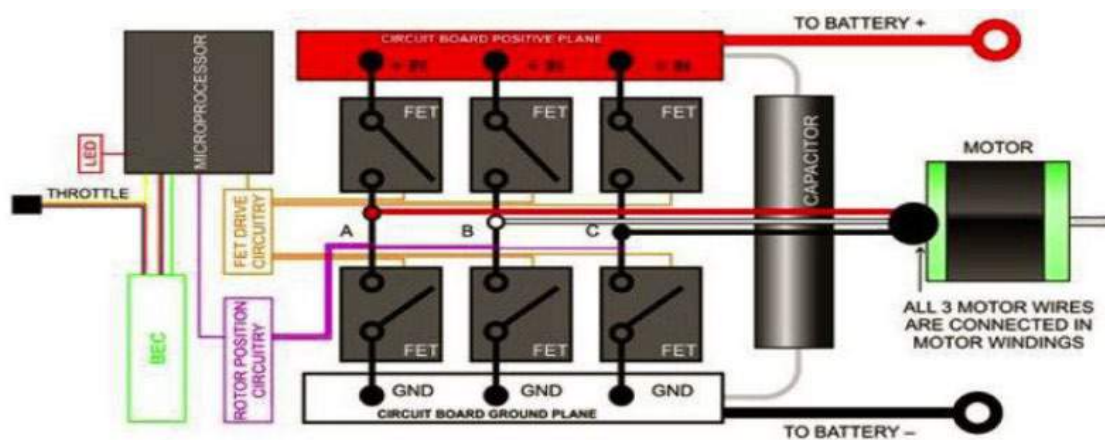


Figure 4.35

With its components identified, the system's operation can be summarised as follows:

1. The inverter is wired to the receiving apparatus, and an adjustment is made to inform the microcontroller of the gas channel input signal's range of variance. This technique differs from one maker to the next. Motor braking, motor cut-off when battery discharge reaches a certain stage, and other advanced operating parameters may also be chosen.
2. As the transmitter is triggered by raising the gas control, the signal reaches the microcontroller through its Sensor less control algorithms, which adjust the opening and closing frequency of the transistors before the appropriate rotating speed is achieved.

In today's market, there are an unlimited number of variants with a wide range of characteristics. Two of the most common are depicted in the diagram below.

The following factors must be considered when making your decision:

1. The maximum current capacity
2. The number of cells it is intended for (battery voltage)
3. Whether BEC should be used or not
4. Programming method: passive card or beeps or leds from the transmitter.
5. The presence of opt coupling: galvanic isolation of the transistor doors from the motors.

4.6.1 WEIGHT

Brushless electric motors have an electronic speed controller (ESC) that connects the control and power stages. It takes a low-power microprocessor signal and transforms it to a three-phase, high-power alternating signal.

The signal is usually a pulse width modulation (PWM) signal, whose frequency and service cycle are set by the manufacturer. The service cycle is normally between 1 and 2 milliseconds, and the frequency will range between 50 and 490 hertz.

4.6.2 BEC AND UBEC POWER SUPPLY SYSTEMS (Battery Elimination Circuits):

The linear regulator that included the ESC was more than enough to power all of the model's electronic circuitry in the first generation of electric models. Currents of the order of 1 A were given by the BECs integrated into the inverter in the form of linear regulators. When the battery to be used has a large number of batteries, the BEC built on a linear regulator has a downside. For example, a Lithium-Polymer 4S hybrid uses four 3.7V cells that have been freshly charged at 4.2V. As a result, the logic power supply in electronic circuits must be reduced from nearly 17V to 5V using a linear regulator. This voltage reduction comes at the expense of dissipating the required power in the regulator, which is inefficient in the first place and causes excessive heating in the second, particularly if the regulator is intended to extract a large current.

The UBECs, which are not linear regulators but DC-DC reducing converters, emerged as a solution to this issue. Since they are switched outlets, there is no issue with power dissipation, and the UBEC's ability to provide current is much higher and more in accordance with the consumption of the devices that a multirotor system integrates.

The UBECs can be used in the variable speed drive or bought separately as a basic DC converter that lowers the battery voltage and adapts it to power the whole device.

Its functional use is incredibly straightforward. The battery is its supply, and the power connector for all electronic components is its output. A UBEC of 10gr of weight with a 5V and 5A production can be seen in the diagram below.

4.7 SELECTING BATTERIES:

The only batteries used in the early days of electric modelling were NiCad batteries, which are still banned for domestic use due to the inclusion of heavy metals. It was heavy, had a low energy density, and had a small

discharge power. They had a huge edge in terms of power and endurance. Following that, NimH batteries with far higher capacities were used, but since the intense charging and discharging processes in this type of battery are highly exothermic, the number of life cycles remained low without addressing the weight problem. The first Kokum Lithium Polymer (LiPo) batteries appeared in Spain at the end of the 1990s. The batteries came in individual cells, and installation had to be performed manually. It had a much lower energy output and a discharge capacity that was around 15 times lower than the existing capacity.

The invention of LiPo batteries, as well as certain derivatives such as LiFePo, has been unstoppable since that time. In reality, using another compound at this time will be impossible, given its tremendous price drop and higher everyday benefits. As a result, a brief overview of this category of battery will be given, followed by a list of the most important parameters that describe them, and finally some guidance on the standards to use in their selection.

A Lithium-Ion Polymer battery is the same as a Lithium Polymer battery. There are no physical distinctions between Li-ion and LiPo batteries, in other words. The distinction between the first and second is that the liquid electrolyte of the latter is substituted with a rigid polymer, such as polyethylene oxide, polymethyl methacrylate, or a variety of other compounds. The battery's activity is dependent on the circulation of lithium ions between two metal plates that serve as anode and cathode, respectively.

While this battery has the maximum energy density and discharge capability, it is not without flaws: when they are overcharged, they stretch to the point of bursting and burning. Secondary chemical reactions, oxidation of anodes and cathodes, and the risk of expansion and fire exist if they are discharged below a certain level. In particular, several reports of fire triggered by faults during the loading period, or the use of batteries that had

experienced impacts or deformations, were gathered on the Internet in the early days of its use.

LiPo battery packs are made up of collections of cells attached in series or also in parallel series variations of series, and are used in both modelling and industrial applications.

Each cell has a nominal voltage of 3.7V, but when fully loaded, it reaches 4.2V.

Their discharge depth (the lowest voltage they will achieve when in use) should not be less than 2.8V.

4.7.1 PARAMETERS THAT DEFINE A "PACK" OF LIPO BATTERIES:

1. The batteries are designated as nSmP, for example 3S2P, based on the number of cells. This means the battery in question is made up of two divisions of 3.7V cells that are linked in sequence before being connected in parallel. To achieve large capacities, series-parallel combinations are used, but the most common configurations of all the cells in series are: 1S, 2S, 3S, 4S, and so forth. The battery's average voltage is calculated by multiplying the number of cells by 3.7.

2. The power of the battery pack is indicated in mAh and is denoted by the letter C. That is, the information provided is the amount of energy the battery will deliver. For eg, a battery with a capacity of C = 4000mAh might potentially have a current of 4A for one hour by lowering its voltage slightly.

3. Discharge capacity: This information is supplied in C increments, so a battery could be 25C - 50C, 40C - 60C, and so on. This shows the maximum current that can be pulled continually from the battery as well as the maximum current that can be lost over a limited period of time. If the previous C = 4000mAh packet is labelled as 40C-60C, it means that it

is ideal for work by constantly discharging $40 \times 40000\text{mA}$, or 160 A, and momentarily discharging $60 \times 4000\text{mA}$, or 240 A. Obviously, the battery life in the first case would be reduced by at least 40 percent, and in the second case, it would be reduced by at least 60 percent. In fact, the reduction is much larger because the action is not linear and capability reduces as the amount of discharge C grows.

Both of the above principles are easily grasped thanks to a collection of curves provided by a battery pack maker for modelling:



Figure 4.36

In the family of curves, it is easy to see how as the discharge increases in multiples of C, the battery's internal voltage drops and its power decreases.

Right charging of a lithium polymer battery is critical for its longevity as well as avoiding some kind of accident or breakdown that may jeopardise the safety of the person handling it. As previously said, the voltage of a cell of this type of battery is 3.7 Volts; however, this voltage is not constant and varies depending on the amount of charge when the battery is at 100% charge, which is 4.2 Volts. As a result, during the charging phase, do not

surpass this cap, as this can degrade the battery. Due to this drawback, it is best to use a LiPo battery charger and to choose the number of cells that are correctly connected; if the value is incorrect, the battery can be overcharged. To prevent dangers, the vast majority of chargers on the market have a built-in system that automatically senses the number of cells attached.

The charger uses a well-known constant current/constant voltage (cc/cv) charging mechanism, which ensures that during the first step of charging the battery, a fixed current is applied and the voltage of the battery is near to the limit of 100%. During the remaining step, the charger automatically reduces the current level and adds a steady voltage. Once each cell reaches a voltage of 4.2 Volts, the charger stops the charging process.

It's also crucial to choose the charging current that the charger can send to the device. In most cases, it adheres to the maxim that the battery can never be charged beyond its maximum, i.e., above 1C. If a battery with a capacity of 2000 mAh is available, for example, a current of more than 2 Amps must never be supplied during the charging process.

However, since the technology is specialised, commercially viable options are available.

Batteries that can handle charging currents of 2C, 3C, and even 5C. As a result, we'll be able to cut down on loading times. The battery will be fully charged in 1 hour if charged at 1C; but, if charged at 5C, the charging time will be shortened to 1/5 Hours, 12 Minutes.

The balance of the battery is also critical, as it helps you to charge all of the cells to the same amount of 4.2 Volts without breaching this limit.

If more than one cell is present, such as in a 3S battery, the charger can exceed 12.6 Volts when the charging period is finished. If the cells have different voltages at the start of the process, there's a chance they'll have different levels at the end. Although one may reach 4.2 Volts, the others may

not be completely powered. To stop this and complications, a balance is used that loads all the cells equally, with an error of 0.001-0.03 Volts, and reads the voltage of each cell independently using a link that has all LiPo batteries, the rolling wire.

The adapter has a built-in circuit that allows you to charge the cells using the battery's main power cord.

4.7.2 CRITERIA FOR THE CORRECT SELECTION OF A BATTERY PACK:

While a brief outline of the process can be offered, exposing all of the variables that influence the option of one or the other battery pack is exceedingly time-consuming and repetitive.

1. Cell number selection: in these situations, the most popular method is to use a modelling application to select the entire traction mechanism, propeller, engine, variator, and battery. Alternatively, decide the correct supply voltage such that the propeller motor assembly is operating in the appropriate output and thrust range, and then multiply by the number of cells. The most popular configurations are 2S, 3S, and 4S.

2. Space selection: capacity must be determined based on the desired flight time and package weight. As previously stated, a fair improvement in autonomy is not necessarily accomplished by dramatically expanding flexibility if a significant increase in weight is made.

3. Discharge power selection: the discharge capacity must be adequate to keep the battery's full current consumption within the range that the manufacturer considers appropriate for continuous discharge. For example, if my device draws 100 amps and my battery has a capacity of 5000mAh, its permanent discharge capacity must be at least 20 degrees Celsius. In this regard, it is critical to remember that selecting batteries with extremely high discharge capacities is not necessarily a smart choice. For eg, if our power specifications in mAh are 2000mAh, and my maximum usage is 40 A, any battery with a discharge capacity of 20C, or a higher value, such as 25C, 30C, 40C, or higher, may be used. While it will seem rational at first, choosing the battery power of 40C would be an error. The weight of a battery

increases as its discharge potential increases, as does its internal resistance and, as a result, its voltage decrease. As a result, using a battery with a constant discharge capacity of 40C would add weight and lower voltage than a battery with a discharge capacity of 25C, which is smaller and has a lower voltage drop. As a result, this requirement can be summarised as follows: batteries with very high discharge capacities should not be chosen if they would not be used. As a result, in this situation, the option of 25C, which requires a continuous download of 60 A for an application that will consume a limit of 40 A, is perfectly true and provides a margin of protection in the event that any future configuration changes increase the consumption.

4.8 GLOBAL TRACTION AND CONTROL SYSTEM: ELECTRICAL DIAGRAM:

Finally, a complete aerial emergency vehicle relation with all of the elements mentioned will be demonstrated. They show how all of the modules are connected to the control mechanism, and they don't need any more clarification than to state that the motors must turn in opposite directions in pairs.

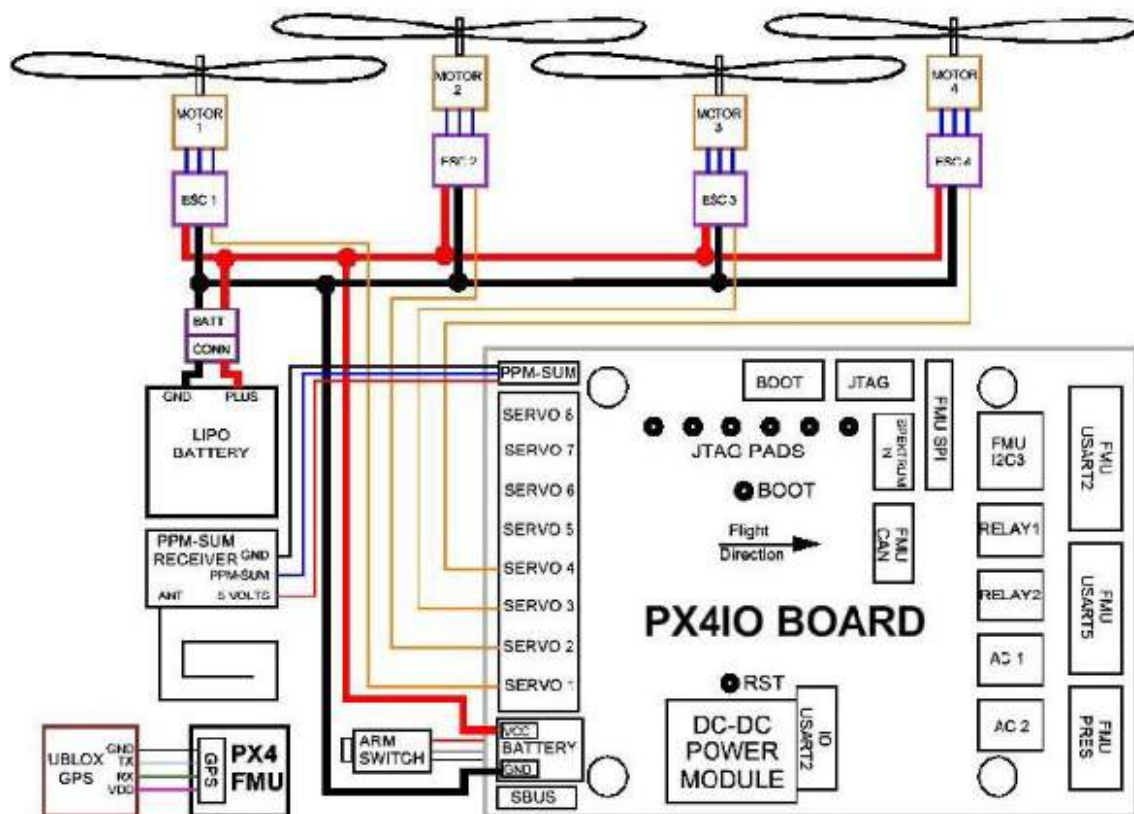


Figure 4.37

4.8.1 CONNECTIONS:

The primary control cord and the roll wire are the two kinds of connectors used on most batteries. The first is in charge of transmitting and receiving electricity.

The second, which has the tank, is in charge of conducting the above-mentioned proper balancing of the battery cells.

There are several connectors for each of these cables, the preference of which would be determined by the battery's usage and the power specifications of the chosen design. All of them have protection measures to prevent inverting the polarity when connected.

4.8.2 THE CONNECTORS FOR THE CONTROL CABLE ARE AS FOLLOWS:

JST Connector: A compact connector that can handle up to 5 amps of current. Used in low-capacity batteries (less than 1500 mAh) to fuel the motors of very small UAVs and the onboard electronics of higher-range versions.

Dean Ultra connector: A commonly used type of connector that can withstand a rated current level of up to 50 Amperes and has a comparatively high price compared to its rivals.

Bullet connectors with a continuous current rating of 60 amps are known as EC3 connectors. The "bullet" type, as seen in the illustration, is very common in high-power applications due to its larger contact surface.

EC5 Connector: A larger variant of the EC3, with 5-millimetre pins, which raises the contact surface and hence the rated current power to 120 amperes.

Connector XT-60: Due to its low cost, the XT-60 is one of the most common connectors on the market for model aircraft. The EC3 connectors, too, use "bullet" technology to make the connection and can handle currents of up to 65 amps. The protective case is made of nylon, which does not melt while welding, and its structure makes connecting and disconnecting them easy.

A higher version is available that can handle up to 90 Amps of current at rated level. The connectors of the cables used to do the rolling, on the other hand, come in a variety of styles and can vary depending on the manufacturer brand, with the JST-XH type being the most common.

Thunder Power, Polyquats, and JST-EH are some of the other versions available.

When designing the feeding and loading system, it is important to consider the uniformity of the connections made before purchasing and selecting the best choice. Most specialised manufactures provide flexibility in the manufacture of the battery, allowing the connector that best meets the project's needs to be incorporated.

4.11 CONNECTIONS:

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Figure 4.38

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4.12 POWER DISTRIBUTION BOARD:

The power delivery pad, which is responsible for transferring the power of the power system between the various engines, is another important component of multi-rotor unmanned aerial vehicles. This board is a printed circuit capable of withstanding high current speeds, with a set of ports to which the various elements are attached, as well as a port through which the battery (or alternate control system) terminals can pass. The power outputs of the plate will be attached to the internal circuit of the plate, the number of which will be determined by the number of rotors on the aircraft. The most basic only include this power transfer circuit, but there are others on the market that can have a circuit that supplies power or transmitting of signals at a lower voltage than the aircraft's electronics, as long as there is an additional power supply system.

The plate, as its name implies, is in charge of supplying fuel, but it lacks any knowledge of how to do so; instead, the drive connected with each motor is in charge of ensuring sufficient battery supply at all times in accordance with the instructions obtained from the flight controller. If a motor has to spin quicker to perform a task, the inverter attached to the distribution board is in charge of supplying the required power to the motor's windings, allowing it to turn at the desired speed.

When selecting the correct plate, keep in mind the highest current flow possible, which happens when both motors spin at their maximum revolutions.

When both motors need full supply, the distribution plate must be able to handle the nominal current flow rate, leaving a safety margin to prevent potential breakdowns; this value is supplied in Amperes and must be supported by the producer. Since the volume of energy that circulates around it is an area resistant to heat, it should be supplied with the best possible ventilation. The distributor plate is usually positioned in the body of the aircraft as oriented as possible for a greater reach for both the variators and associated motors.

4..13 FLIGHT CONTROLLER:

The flight controller is the aircraft's head, capable of correctly spinning the engines to accomplish the desired movement as directed by the ground controller or automatically following the software instructions in automated flight.

It's a variable-complexity circuit with a number of inputs and outputs, as well as a number of built-in sensors that decide the aircraft's location in real time. The controller is in charge of interpreting both sensor data and address data in order to transmit the necessary commands to the motors using PWM signals for proper flight using a set of algorithms.

The number and efficiency of sensors that the controller incorporates vary by model. Few drivers have a basic gyroscope that signals the aircraft's direction in space, although most of the existing drivers have an Inertial Measurement Device (IMU). The IMU is an electronic instrument that can measure and record the aircraft's altitude, inclination, and the gravitational forces acting on it. Accelerometers, gyroscopes, and magnetometers are used to collect this information.

Other types of sensors, such as a sonar or laser, may provide additional status data to the controller, such as the vehicle's distance from a location.

A GPS unit, capable of providing real-time information on the aircraft's geographical coordinates, is another system that is normally used in the flight controllers of this type of vehicles. In addition to monitoring the UAV's direction, GPS allows for waypoint flights, which are three-dimensional reference coordinates that enable the aircraft to automatically follow a path defined by the user between a variety of locations.

The controller can perform a variety of tasks thanks to the input it receives, and based on each individual's ability, it can learn more complicated or less complex flight capabilities.

Depending on the job at hand, the aircraft can choose one type of controller over another. As the degree of difficulty and capabilities of the controller increases, so does the price.

When selecting a flight control system, it's also necessary to consider the system's ability to change its programming. The majority of programmes are closed platforms that are available to include the services described by the manufacturer; however, open access devices are available if the customer wishes to change the behaviour or add additional features. A microcontroller board can also be designed to execute the controller's functions.

4.14 INERTIAL MEASUREMENT UNIT:

The inertial measurement unit, or IMU (Inertial measurement unit), is an electronic sensor that calculates a mobile system's velocity, orientation, and gravitational forces. This sensor owes its existence to the advancement of MEMS-microelectromechanical systems, which saw the first consumer products appear in the 1990s, including inertial sensors produced by Analog Devices Inc. for automotive applications. Microelectromechanical Systems (MEMS)

A mechanism for deciding a mobile device's attitude is made up of gyroscopes, accelerometers, and magnetometers, which together constitute a nine-degree inertial unit (9DOF). Since gyroscopes are typically influenced by external noise and drift continually, they cannot provide a perfect measure of a UAV's rotational motions. As a result, a sensorial fusion algorithm is needed to combine magnetometers and accelerometers (the latter are very sensitive to vibrations, but in the presence of a gyroscope, it is possible to distinguish between vibration and rotation). (2008, Flux)

4.15 ELECTRICAL PARAMETERS:

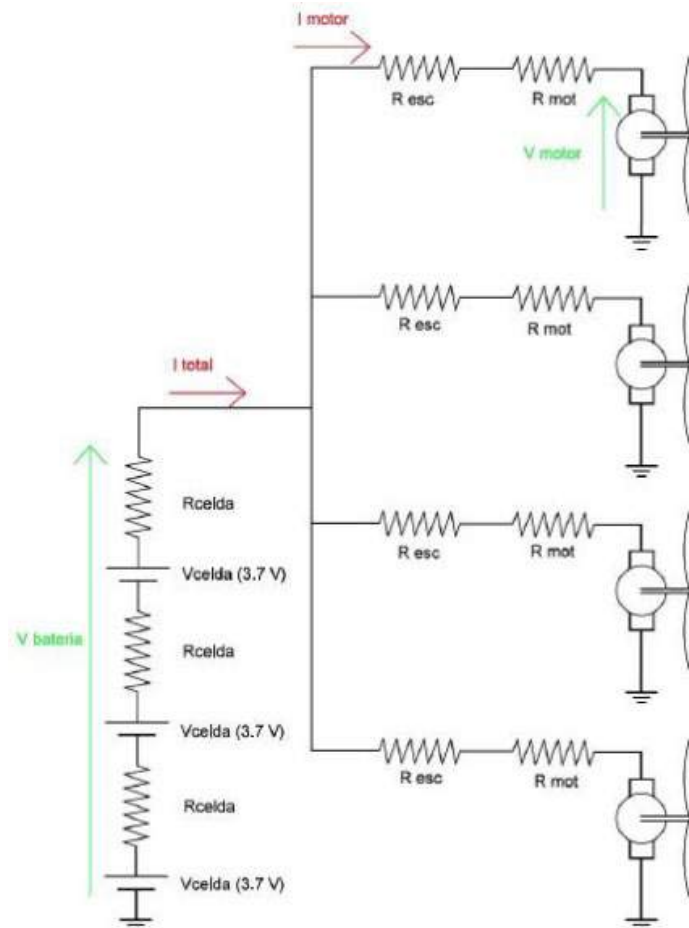


Figure 4.39

BLDC (Direct Brushless Direct Current) motors are currently categorised primarily based on the parameter K_v , where:

$$K_v = \frac{RPM}{Volts}$$

We know that:

$$K_t = \frac{30}{K_v \cdot \pi}$$

The parameter is obtained by this way:

$$K_t = \frac{P_{power}}{Ampere}$$

We can now relate the angular velocities and required force to the voltage and current of each motor:

$$RPM = \frac{V_e}{K_v}$$

$$J = \frac{I_e}{K_t}$$

The input tension is V_e , and the current is I_e . However, we must account for the input resistance of the connectors and cables as well as the connectors' resistance, so the calculations remain as follows: R_c is the connectors' and cables' resistance:

$$\frac{RPM}{Kv} = (Ve - Rc \cdot I)$$

The term Rc also refers to the battery's internal resistance. Internal resistance determines the optimum discharge power of lithium batteries in general. Manufacturers, on the other hand, seldom have it. There is no universally accepted criterion for grading the efficiency of aeromodelling batteries, and the distinctions between batteries of varying prices are obscure.

The current consumed by the motor without load, which reflects the current of Vacuum I_0 , must be taken into account, so the above equation is:

$$J = KtI_e - KtI_0$$

Then:

$$\frac{J + KtI_0}{Kt} = I_e \quad (22)$$

The input electrical power can be calculated as:

$$P = I \cdot V$$

Calculation of parameters at maximum power:

When treating BLDCs as conventional DC motors, we'll presume that the optimum is achieved by connecting the batteries' full voltage to the motor terminals. In this case, we'll need to solve the system of equations below,

where c_p is an empirical constant defined by the density of the air and the propeller's aerodynamic profile.

$$RPM = K_v \cdot V_{mot}$$

$$P_e = C_p \cdot Pitch \cdot D^4 \cdot RPM^3$$

$$I = \frac{I_0 + J}{K_t}$$

$$V_{mot} = V_{bat} - I \cdot R_{tot}$$

Other parameters:

Engine Efficiency: $\eta_{mot} = P_{mec} / P_{ele}$

Battery duration: $Duration = I_e / (Capacity / 10000)$

4.16. THE CONTROL SYSTEM :

The balance of conventional, line, and sports aircraft is configured to be self-stabilizing. That is, if an external provocation causes them to deviate from their level flight, the aircraft's normal instinct is to return to the neutral state on its own. This does not apply to acrobatic planes or fighter jets, which have less configuration to improve manoeuvrability.

The problem is difficult in the case of aircraft with spinning wings because the helicopter, with a single rotor, already has an uneven topology and accurate correction systems. If an unregulated yaw movement is not needed, it is sufficient to realise that control of the tail rotor is required to compensate for the reaction torque generated by the main rotor.

The condition is much more complicated in the case of multirotor systems. While a multicopter has technical benefits, its degree of instability

makes flight and handling difficult without a stabilisation mechanism that acts automatically on the rotors' spinning regimes. It's referred to as "Fly by Wire" in the case of some planes.

This section would describe the control system of an aerial emergency vehicle and the components that make it up in general. We'll start by describing some of the variables that will occur later since we'll need to use an equation.

If the rotor angular speeds are numbered w_1, w_2, w_3, w_4 from left to right and from front to back, so

The aerial emergency vehicle's displacement angles would be:

1. Alpha = φ
2. Beta = θ
3. Gamma = γ
4. Vertical thrust = L
5. Alpha velocity = $d\varphi/dt = \dot{\varphi}$
6. Beta velocity = $d\theta/dt = \dot{\theta}$
7. Gamma velocity = $d\gamma/dt = \dot{\gamma}$
8. Lift velocity = $dL/dt = \dot{L}$

One of the movements will now be considered, with the outcome extrapolated to the others. Given that yaw is caused by the variation in rotational speeds of the aerial emergency vehicle's rotors at the diagonal ends (a configuration in X or H is considered), the yaw rate can be determined as:

$\dot{\gamma} = k((\omega_1 + \omega_3) - (\omega_2 + \omega_4))$ where k is just a proportionality constant.

The aerial emergency vehicle's movement can be expressed as: If the series of equations is provided in matrix form, and all proportionality constants are considered to be the same for convenience, the aerial emergency vehicle's movement can be expressed as:

In order to achieve stability and stability, the speed of rotation that must be exerted on each rotor in order to attain a certain velocity of displacement along the corresponding axis must be known. The equation can be rewritten by calculating the inverse of the matrix $[k]$ as:

$$\begin{bmatrix} \phi \\ \theta \\ \psi \\ \dot{L} \end{bmatrix} = \begin{bmatrix} K & -K & -K & K \\ K & K & -K & -K \\ K & -K & K & -K \\ K & K & K & K \end{bmatrix} \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} = [k] \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix}$$

This equation has already been graphically translated as follows:

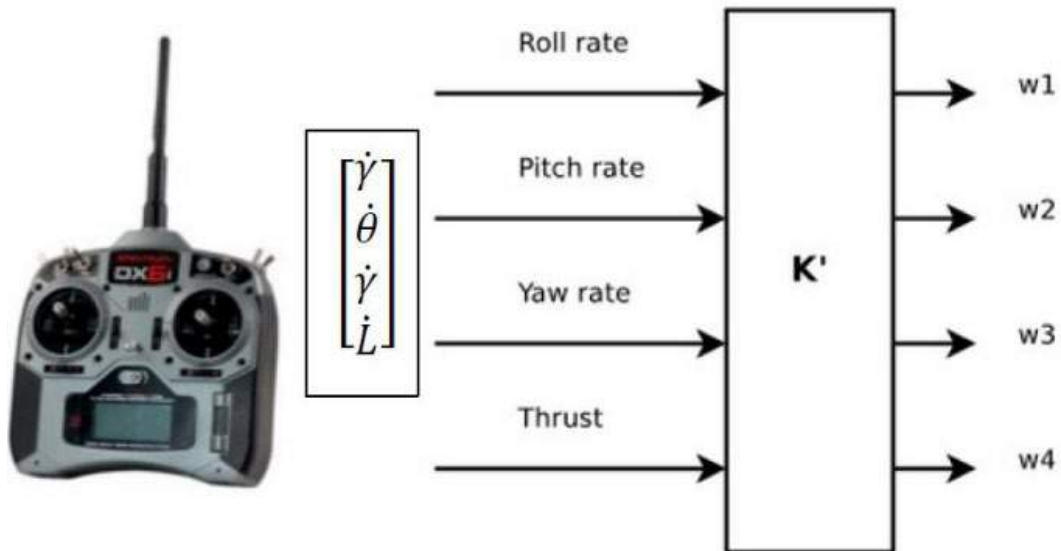


Figure 4.40

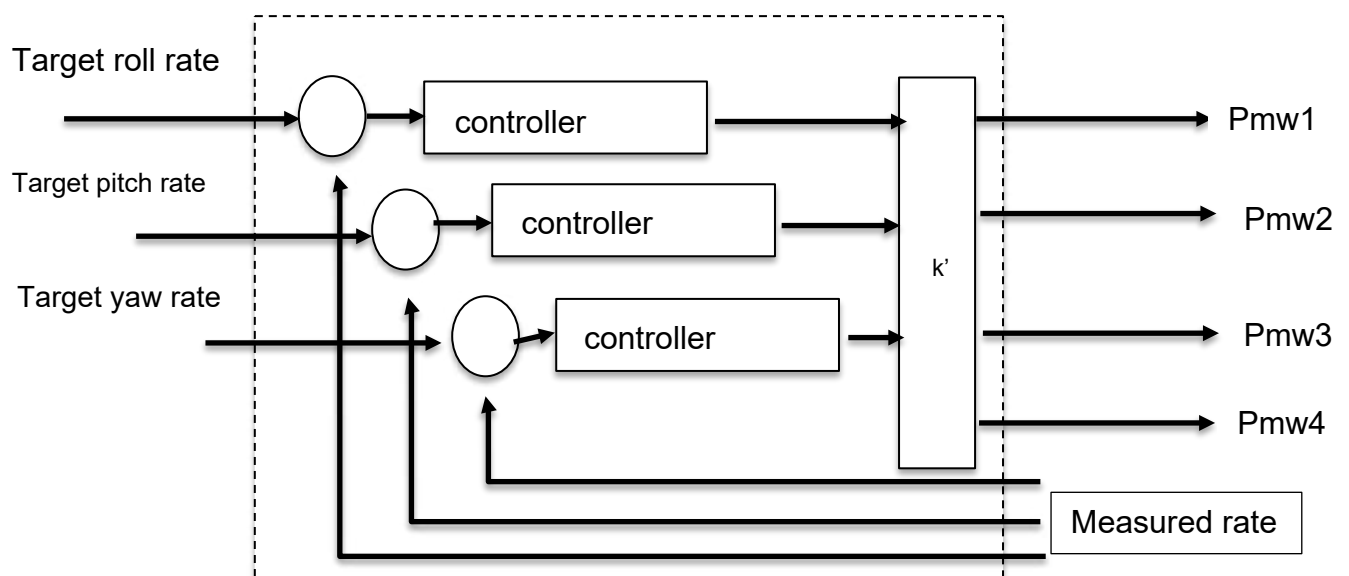
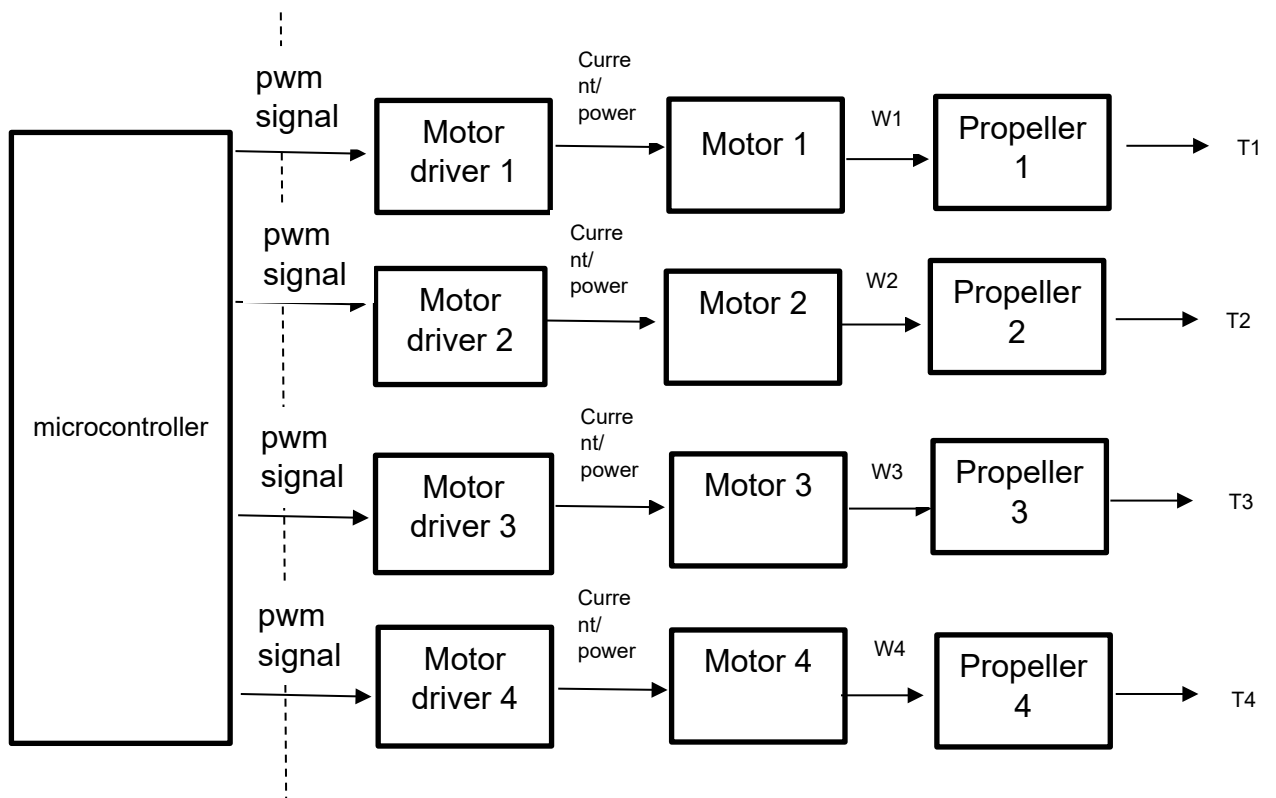
$$\begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} = [k]^{-1} \begin{bmatrix} \emptyset \\ \theta \\ \psi \\ \dot{\varphi} \end{bmatrix}$$

After considering the calculations, we'll move on to developing the factors that force the use of an advanced control scheme in a very intuitive manner.

The hardware scheme for the aerial emergency vehicle is depicted in the diagram below.

Even if all of the machinery has been designed to achieve optimum symmetry, it is obvious that the four assemblies cannot function identically due to minor differences in motor configuration, mechanical construction, and drive reaction. The output of the receiver, and so on. Make it difficult to describe and achieve a clear and accurate relationship between the order signal transmitted by the transmitter and the angular velocity of each of the rotor rotors.

The use of a closed-loop method is the solution to this problem. To do so, the signal obtained from the gyroscopes and solid-state accelerometers in the flight control system is compared to the desired value, indicated by the



Pilot by operating on the station's controls, by obtaining the matrix of ratios of speed of travel according to the three axes. The discrepancy (error)

between the measured and desired variables is the input to a PID controller which is familiar to all engineering students, and its output is the PWM signal that is added to each inverter to set the desired rotation speed in each rotor.

4.18 WEIGHT CALCULATION:

To obtain the mass of the CAD model, it is necessary to assign the materials for each and every part which is about to be 3d printed.

The Real time sized will be equipped with high quality, durable and low weighing materials like fiberglass, duralumin and carbon fibre composites.

The prototype of the vehicle will be 3D printed in plastic materials to cut cost, weight and time. At present materials which are used in rapid prototyping techniques are (ABS), (PLA), Polypropylene (PP) and High-Performance Polymers.

A study on all these materials was taken and classification results are as follows.

ACRYLONITRILE-BUTADLENE-STYRENE (ABS): The most popular 3D printing plastic is ABS filament. It can be found in the bodywork of vehicles, appliances, and cell phone cases. It's a thermoplastic with a foundation of polybutadiene-based elastomers, which makes it more flexible and shock-resistant. ABS is also available in powder form for powder bed processes like SLS, as well as liquid form for SLA and PolyJet. When heated between 230 C and 260C, ABS is used in 3D printing. It's a durable substance that can handle temperatures ranging from -20 to 80 degrees Celsius. It's a reusable material that can also be welded using chemical processes, in addition to its high strength. ABS, on the other hand, is non-

biodegradable and shrinks when exposed to cold, necessitating the use of a heated printing platform to avoid warping.

PLA: Known as polylactic acid, or PLA, this substance, unlike ABS, has the advantage of being biodegradable. PLA is made from corn starch, which is a green raw material. PLA is one of the most straightforward materials to print, but it does shrink slightly after 3D printing. In comparison to ABS, PLA printing does not require a heated base. PLA also prints at a lower temperature than ABS, varying from 190 to 230 degrees Celsius. PLA is more difficult to deal with because of its accelerated cooling and solidification. It's also worth noting that models will deteriorate if they come into contact with water. The stuff, on the other hand, is consistent, easy to work with, and comes in a variety of colours, making it perfect for FDM 3D printing.

Polypropylene (PP): Polypropylene is a thermoplastic that is commonly used in the car industry, technical textiles, and the manufacture of a wide variety of consumer products. PP is known for its abrasion resistance and shock absorption, as well as its relative rigidity and flexibility. However, the material's low temperature tolerance and susceptibility to UV rays, which may cause it to expand, are also disadvantages. As a result, many manufacturers have produced simili-propilenos, a form of PP that is both physically and mechanically stronger.

High Performance Polymers (PEEK, PEKK, ULTEM): The advent of 3D printing technology has resulted in comprehensive material testing, allowing the development of a wide variety of high-performance filaments with mechanical properties close to those of metals. PEEK, PEKK, and ULTEM are examples of high-performance 3D printing plastics. They are grouped by family, such as polyaryletherketones (PAEK) or polyetherimides (PEI). These filaments have a high mechanical and thermal resistance, are exceptionally heavy, and are considerably lighter than metals. These characteristics make them particularly appealing in the aerospace, automobile, and medical industries. High performance polymers cannot be printed on all FDM machines on the market due to their properties. The 3D printer must, in particular, have a heating plate that can exceed 230°C, a

350°C extrusion, and a closed chamber. Approximately 65 percent of these materials are printed using FDM technology today, although they are still available in powder form, which can be used using SLS technology.

Table no: 4.1

	Density (g/cm ³)	Yield Strength (MPa)	Maximum Service Temperature(°C)	Other Significant Properties
ABS	1.04	40	98	Heat and Impact Resistant
PLA	1.24	65	52	Hard
PP	0.9	32	100	Flexible and Soft in Nature
HPP	1.04	32	100	Dissolvable and Impact Resistant

In light of the above information, ABS was chosen as the material for prototyping the vehicle because it is resistant to heat generated by the motors and electronic systems, and it is safe if the prototype launch fails due to its impact resistance. Another thing to consider is that the time it takes to print the model and the cost per kilogram of ABS are both much lower than those of other prototyping products.

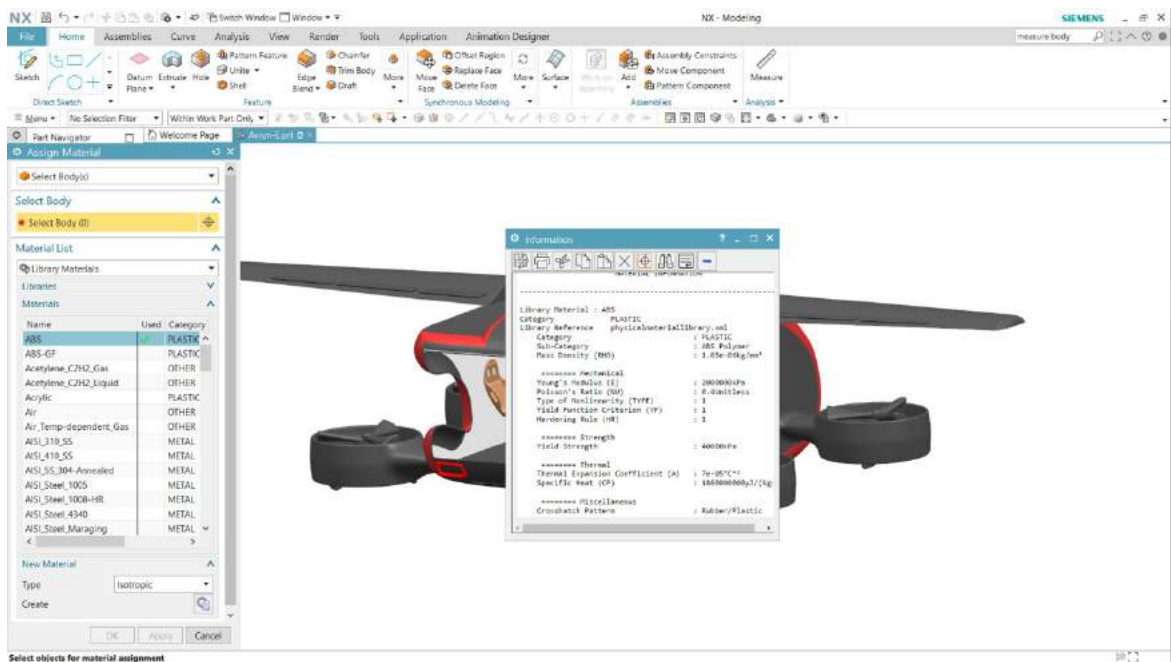


Figure 4.41

By assigning the material and measuring the weight of the model, the obtained result was

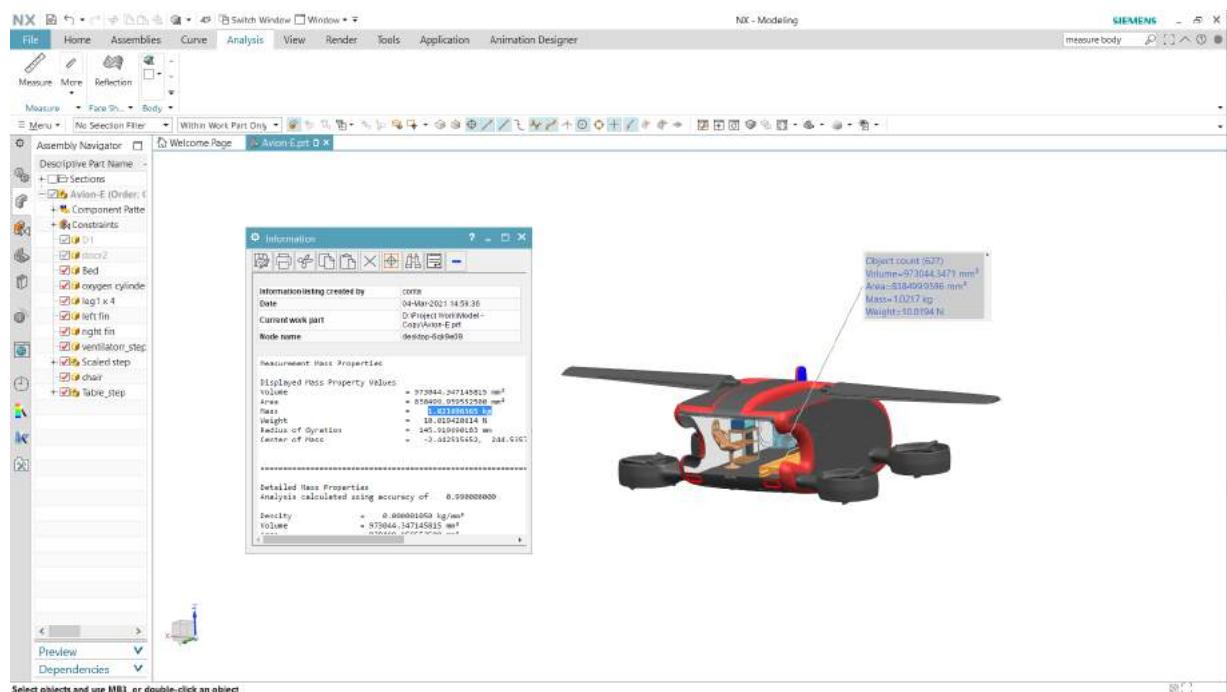


Figure 4.42

Weight = 1.021 kg (1021 gms)

The weight of the 3D model does not include the weights of the battery and the motors, so additionally 1.5 kg is added because a 5200mAh battery would weigh around 500 gm, but if it is equipped with one battery the flight of the vehicle would be around 10-15 minutes. Hence, 2 batteries should be added to test the prototype in real-time conditions. The motor body and the windings would approximately weigh around 500 gms.

Therefore, Total weight of the Prototype = 1021+ 1000 + 500
= 2521 gms.

Thrust Calculation:

The formula to calculate the thrust to be provided by the motors

$$= \frac{2 \times (\text{total weight of the vehicle}) + ((2 \times \text{total weight of the vehicle}) \times 0.20)}{\text{Number of Motors in the vehicle}}$$

$$= \frac{2 \times 2521 + ((2 \times 2521) \times 0.20)}{8}$$

$$= \frac{5042 + (5042 \times 0.20)}{8}$$

$$= \frac{5042 + 1008}{8}$$

$$= \frac{6050}{8} = 756.25$$

= approximately 800 gms of thrust from each motor.

Static thrust measurements are needed to ensure that the correct propellers and motors have been chosen. The amount of thrust generated by

a propeller that is stationary to the earth is known as static thrust. Since quadrotor helicopters are more likely to operate at low speeds compared to the ground, this measurement is especially important for this project. Because of this low-speed performance, static thrust measurements can be extended to a wide variety of flight conditions. It's also worth noting that the final static thrust measurements are averages rather than precise numbers.

Chapter – 5

RESULTS AND DISCUSSION

5.1 FINITE ELEMENT ANALYSIS:

The aerodynamic behaviour of a baseline design is discussed in this paper, at Mach 0.1 and 0.19, the investigation is shown in steady state 3D computational fluid elements (CFD). Lift, Drag, Lift Coefficient (CL), and Drag Coefficient (CD) are all calculated and analyzed separately in this investigation technique. Pressure forms and velocity shapes are plotted, and the Turbulence region is predicted from a streamline view, all of which are not subjected to CFD analysis.

The investigation of a aerial emergency vehicle's computational liquid flow (CFD) plays a crucial role in determining the plane's ideal configuration. The subjective and quantitative depiction of the outline provides useful information for determining and configuring the flying machine before embarking on the time-consuming task of building it.

Aside from its applications, the vehicle domain suffers from a lack of manufacturability due to design constraints and its scale. The Aerial Vehicle's must be energy efficient, cost effective, and meet the desired performance goals. As a result, the work should focus on the aerial vehicle's fuselage, wings, and ailerons, taking into account designable and non-design areas when applying appropriate loads.

5.2 MATHEMATICAL MODEL:

The ANSYS CFX solver is used to do the analysis, which allows for 100 iterations of the turbulence and Navier stroke equation approaches. An upstream velocity of 34.3 m/s and a downstream velocity of 65.17 m/s are defined at the inlet boundary in this analysis. Many other boundary conditions are still unchanged. To calculate the

necessary loads, the vehicle's Mach number, temperature, and velocity must be investigated, as well as a lift and drag measurement.

The Mach number is a dimensionless quantity that describes the ratio of off-low velocity past over a domain boundary to the speed of sound.

$$M = V/a \quad , \text{ where}$$

M= Mach number = Flow velocity over boundaries and

a= Speed of the sound

$$a = \sqrt{\gamma RT} = 340 \text{ m/s} \quad , \text{ where}$$

γ is the density of air 1.4

R is the gas consistent 287J/kgK

T is the temperature of air (25°C) in K

The drag force acting on a body in fluid flow can be expressed as $D = 1/2 C_D \rho V^2 A$

Where,

D=drag force (N), C_D = drag co-efficient, ρ = density of fluid (kg/m³), V = flow velocity (m/s),

A = body area (m²)

Lifting Force

The lifting force acting on a body in a fluid flow can be expressed as $L = 1/2 C_L \rho V^2 A$

Where,

L = lifting force (N),

C_L =lifting co-efficient,

ρ =density of fluid (kg/m³),

V=flow velocity(m/s),

A = body area (m²)

Calculation:

For co-efficient of Drag & Lift on fuselage with velocity-34.3 m/s at Mach no 0.1

$$\text{Drag co. efficient (C}_D\text{)} = \frac{2 \times F_D}{\rho \times V^2 \times A} = \frac{2 \times 14.41}{1.4 \times 34.3^2 \times 1.04}$$

Drag co-efficient (C_D) =0.0168

$$\text{Lift co. efficient (C}_L\text{)} = \frac{2 \times F_L}{\rho \times V^2 \times A} = \frac{2 \times 16.76}{1.4 \times 34.3^2 \times 1.04}$$

Lift co-efficient (C_L) =0.0195

For Drag & Lift co-efficient on fuselage with velocity-65.17m/s at Mach no 0.19

$$\text{Drag co. efficient (C}_D\text{)} = \frac{2 \times F_D}{\rho \times V^2 \times A} = \frac{2 \times 50.69}{1.4 \times 65.17^2 \times 1.04}$$

Drag co-efficient (C_D) =0.0163

$$\text{Lift co. efficient (C}_D\text{)} = \frac{2 \times F_D}{\rho \times V^2 \times A} = \frac{2 \times 60.88}{1.4 \times 65.17^2 \times 1.04}$$

Lift co-efficient (C_L) =0.0196

Computational fluid dynamics is a subset of fluid dynamics that investigates problems using computational strategies and calculations. It's a PC-based instrument for simulating the behaviour of frameworks, such as liquid flow, heat exchange, and other physical processes. It functions by describing the conditions of a liquid stream (in a unique structure) over a hotspot of interest, with predetermined conditions at the area's edge.

Steps in performing the CFD analysis:

The protocol for performing a single CFD replication is divided into four sections:

1. The geometry of a model/Mesh is created using geometry parameters as well as domain form and height.
2. Flow properties, heat transfer, and boundary conditions are all part of defining the model's physics.
3. Iterations and a numerical scheme are used to solve the CFD problem.
4. Contours and streamlines are used to visualise the effects in the post-processor.

5.3 EXTERNAL FLOW ANALYSIS:

A CFD model of the aerial emergency vehicle was created in order to quantify the pressure distributions on the aircraft. This was accomplished simply by uploading the model to the ICEM CFD platform, which serves as a pre-process or for flow analysis.

ANSYS ICEM CFD is a popular proprietary CAD and mesh generation software kit. It can render grids with different cell geometries that are hierarchical, unstructured, multi-block, and hybrid. ANSYS ICEM CFD is built to mesh geometry that has already been created with other CAD packages.

As a result, the geometry modelling tools are specifically for 'cleaning up' an imported CAD model.

The ANSYS workbench stage provides stronger bi-directional relations than other other CAD frameworks, powerful geometry shift and construction software with ANSYS Concept modeller, advanced fitting advances in ANSYS coinciding, and quick step and configure details and results to exchange across applications.

5.4 MESH:

The aerial vehicle's leading edges, such as the wing, fuselage, horizontal and vertical tails, are meshes with a fine surface mesh size of 2 and a mesh scale factor of 0.1. Then a complete mesh of size 15 with a mesh scale factor of 1 is formed. The scale of the stream region is calculated by previous experiments in which the space size was steadily increased until no discernible effect on the airplane's lift and drag was detected. To account for the complexity of the geometry, a small volume and thickness cross section is formed using unstructured tetrahedral cells as part of the region nearly encompassing the flying vehicle, along with a kaleidoscopic limit layer network 6 cells thick on the airplane's wetted surface. The remaining stream Space is then described using ordered hexahedral cells.

5.5 RESULTS:

With 34.3 m/s and 65.17 m/s free stream velocity in the x-direction, a temperature of 298 K, and a pressure of 1 atm as initial conditions. The plots and stream lines for various Mach numbers of 0.1 and 0.19 as shown below.

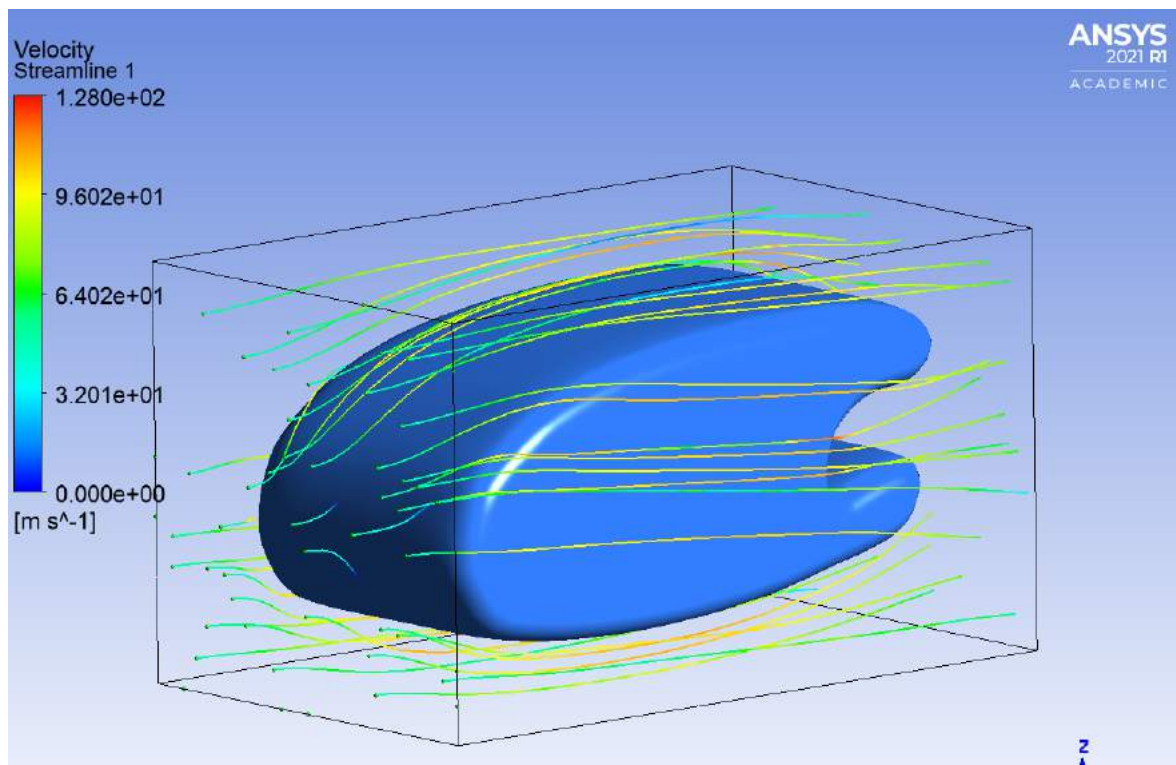


Figure 5.1

The paths travelled by neutrally buoyant particles in equilibrium with fluid motion are known as path lines. Path lines are a perfect way to imagine intricate three-dimensional currents. In this case, path lines would be used to analyse the flow around and behind the vehicle.

A streamline is a way that travels with the movement traced by a massless atom. A streamline can be conveniently visualised if we shift with the body (as opposed to moving with the flow). The figure above indicates the calculated streamlines around a cylindrical air-foil. In both cases, we switch from left to right with the piece. Since a moving particle follows the path, the speed on the track is tangent at all points along the track. Since the path does not have a normal speed portion, mass cannot cross a streamline. There is also the same mass in the flow-field between two streamlines. We may use the equation of Bernoulli to connect pressure and speed along the streamline. The object's surface is smooth since no mass moves through the air-foil (or cylinders).

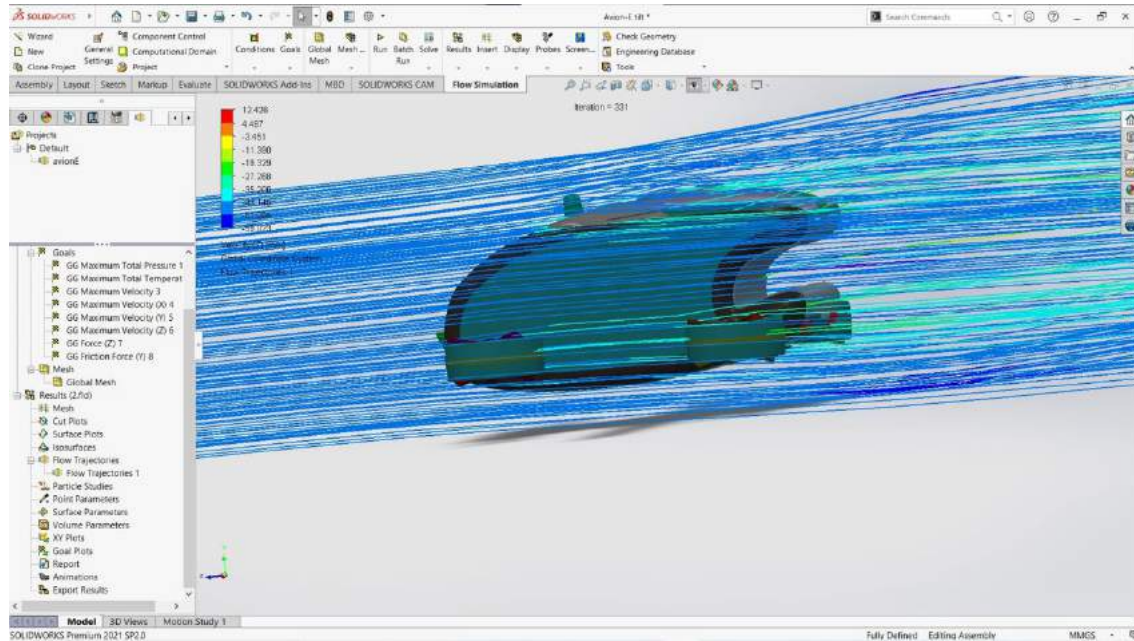


Figure 5.2

Aircraft travel almost quietly in air, but we build and measure them with wind tunnels in which the model of the aircraft is set, and the air moves behind the model. It might be a little confusing to think of keeping the air-foil fixed and passing the airflow. However, every day you face the same thing! If you stand at the corner and watch a car passing by, the air is relatively quiet around you. There are aerodynamic forces while the vehicle is going through the air. Now you can imagine that the aerodynamic force is on your side while you are in your car and place your hand out of the windshield. It sounds like the air passes your hand as quickly as the vehicle moves. Now that's the same with aircraft. The powers are exactly the same, regardless of

whether the aircraft travels in the air or the air flows around the plane.

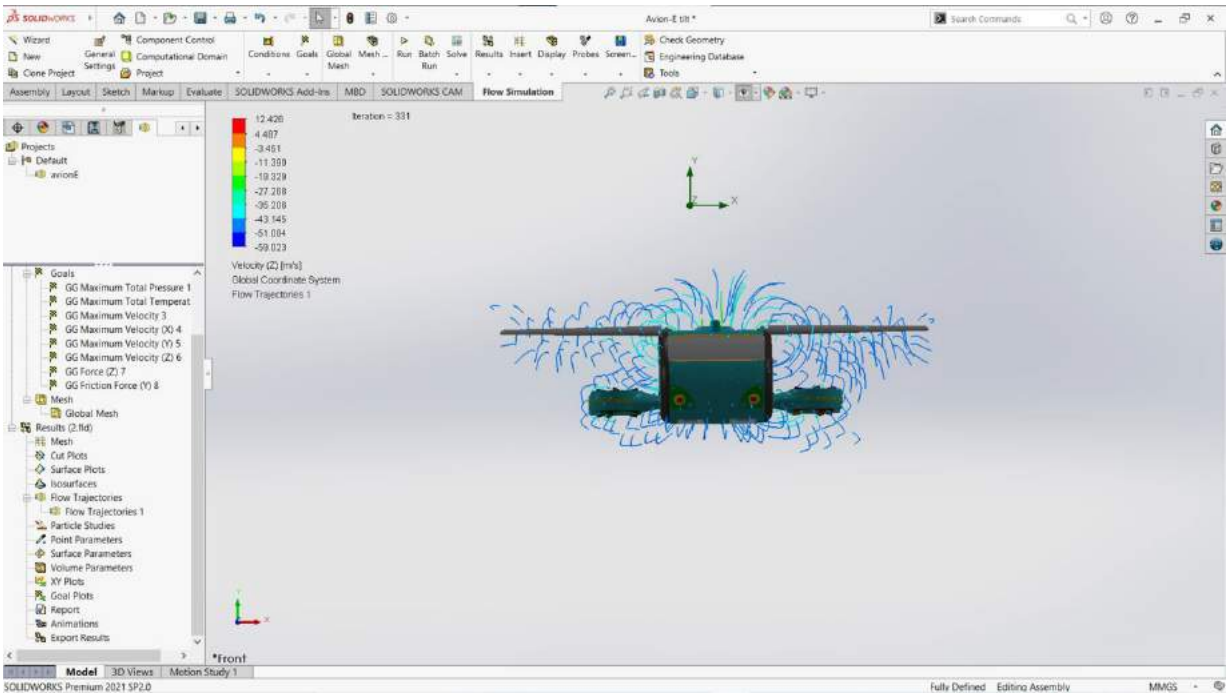


Figure 5.3

Either you stand on the corner or drive in the taxi, the strength on the car is the same. Now that's the same with aircraft.

Testing aircraft in a wind tunnel before attempting to fly is generally faster, cheaper and (in some cases) less hazardous.

The prototype model is analysed with the virtual environment like in the real time.

Table 5.1

Air flow speed	34.3 m/s
Element size	15 mm
Type of meshing	Tetrahedral mesh
Assigned Material	ABS Plastic

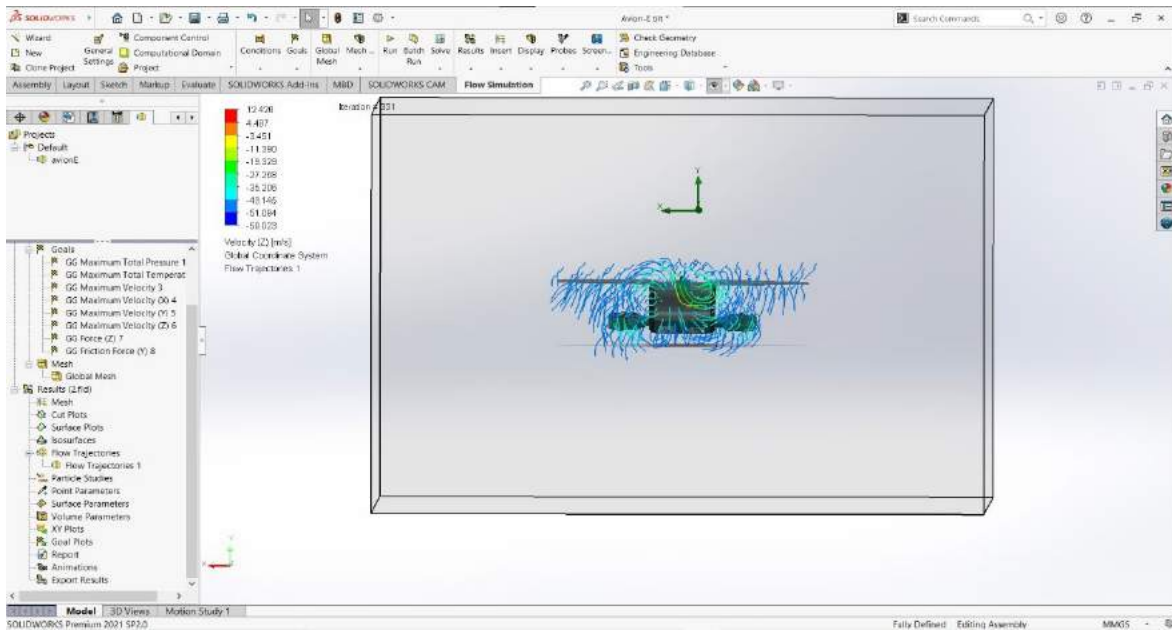


Figure 5.4

5.5.1 ANALYSIS OF THE WING:

The most famous finite element groups are 4-noded tetrahedra and 8-noded hexahedra. Tetrahedral mesh generators are a typical feature in Computer-Aided Engineering (CAE) software. The Delaunay triangulation method, modified-octree technique, and advancing front technique are among the techniques and optimization schemes they employ. Automated (with the requisite analyst's feedback, usually limited to the parameters defining the element size, mesh density, and element quality) discretization of artefacts evaluated in engineering applications is made possible by tetrahedral mesh generators available in commercial CAE packages.

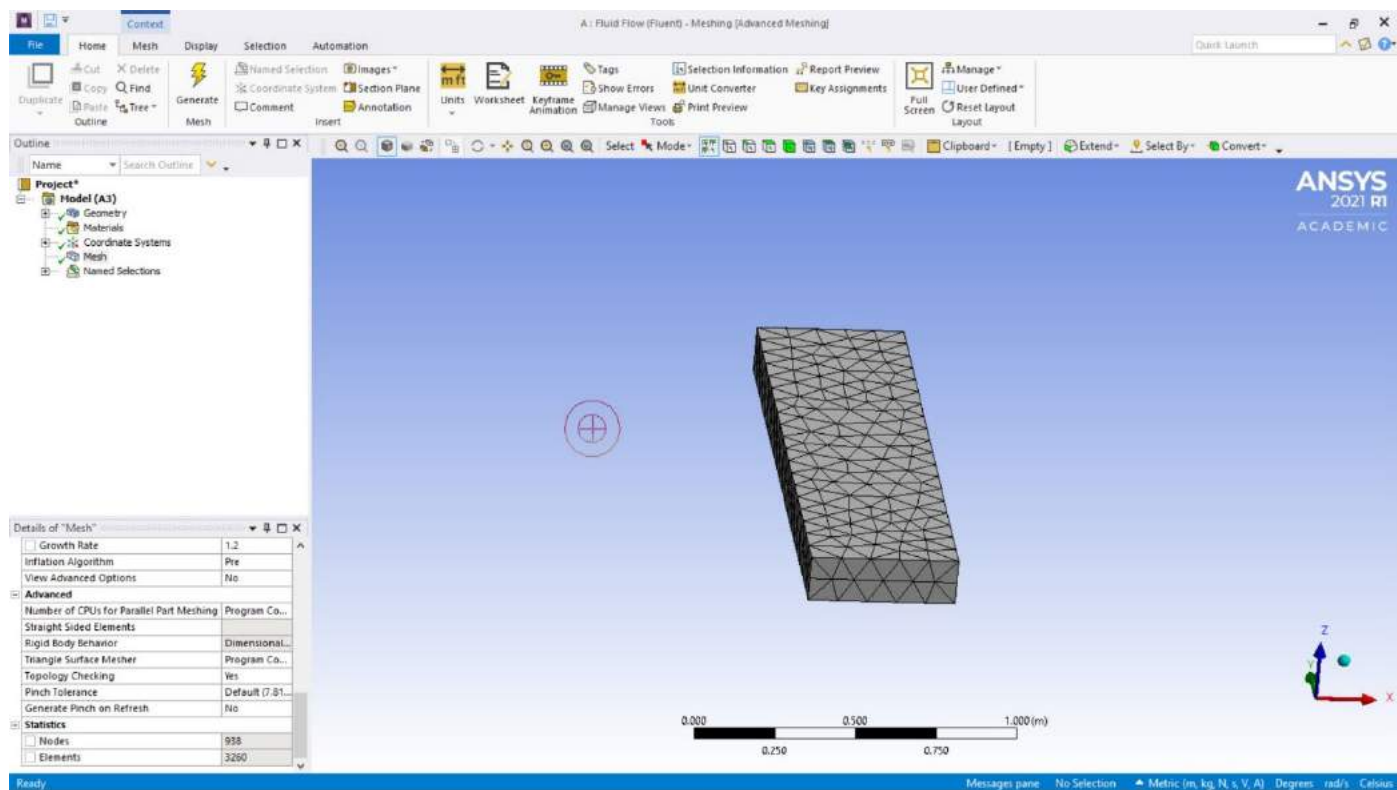


Figure 5.5

Meshing of the wing

Table 5.2

Nodes	938
Elements	3260
Element size	15 mm

5.5.2. PRESSURE DISTRIBUTION RESULTS:

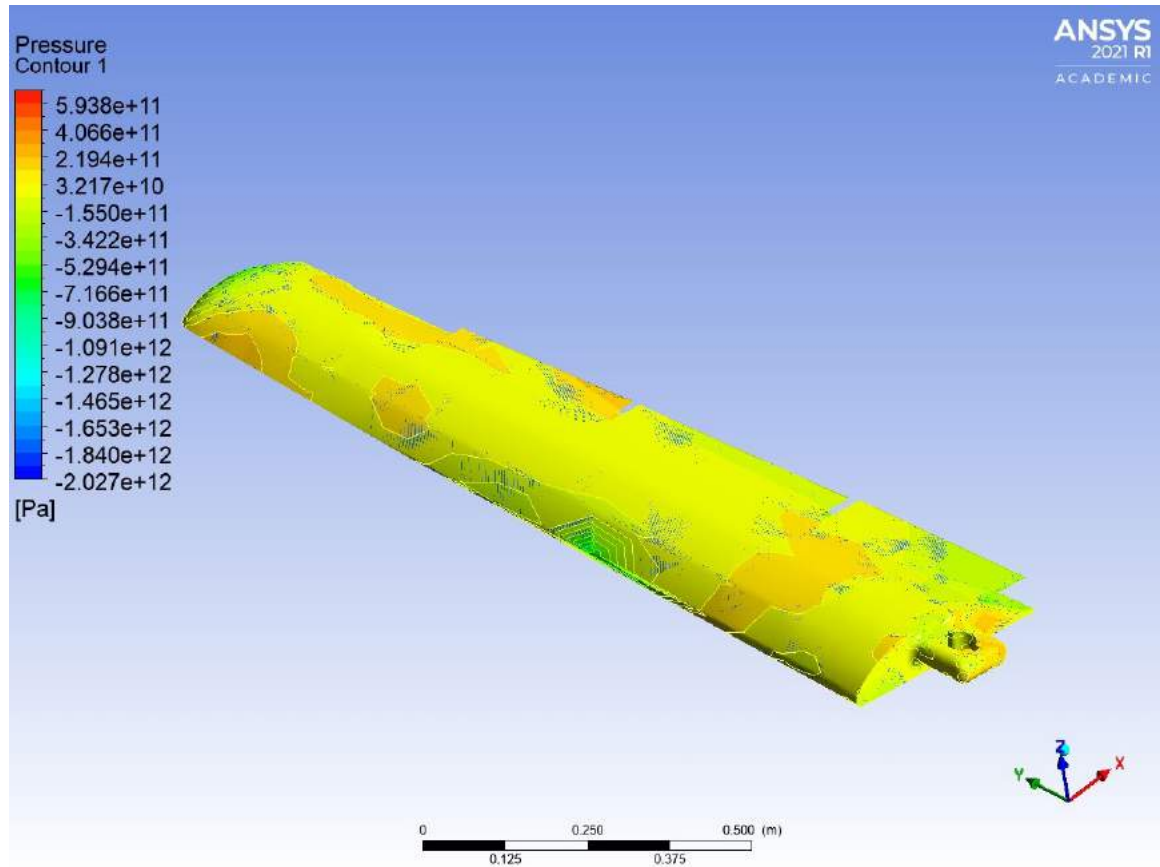


Figure 5.6

The pressure distributed to the wings while in mid-air is tolerable by the above analysis done. The project is good to go with the pressure details obtained.

5.5.3 VELOCITY FLOW ANALYSIS:

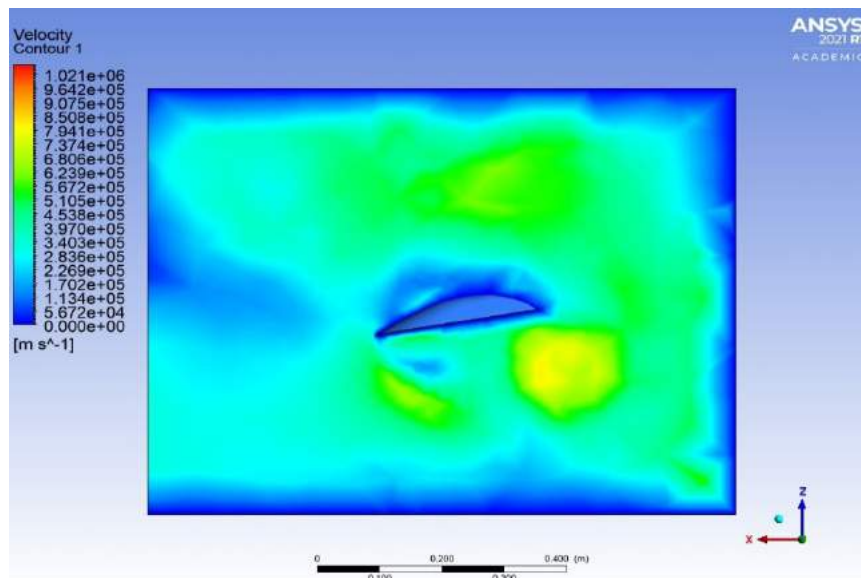


Figure 5.7

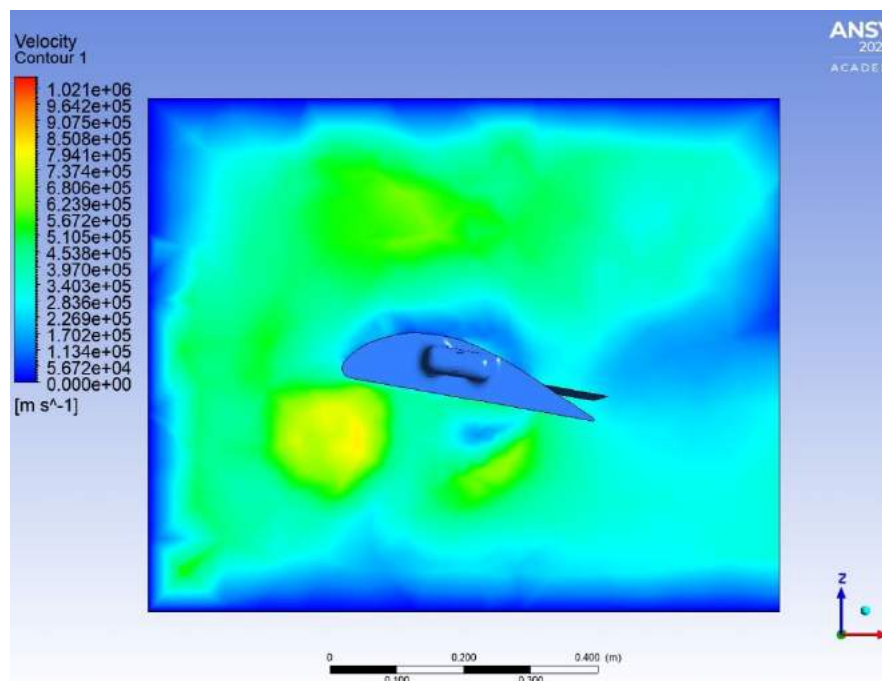


Figure 5.8

As seen on the analysis above the air flow over the wing is distributed efficiently to provide lift for the vehicle.

5.5.4 STRESS DISTRIBUTION:

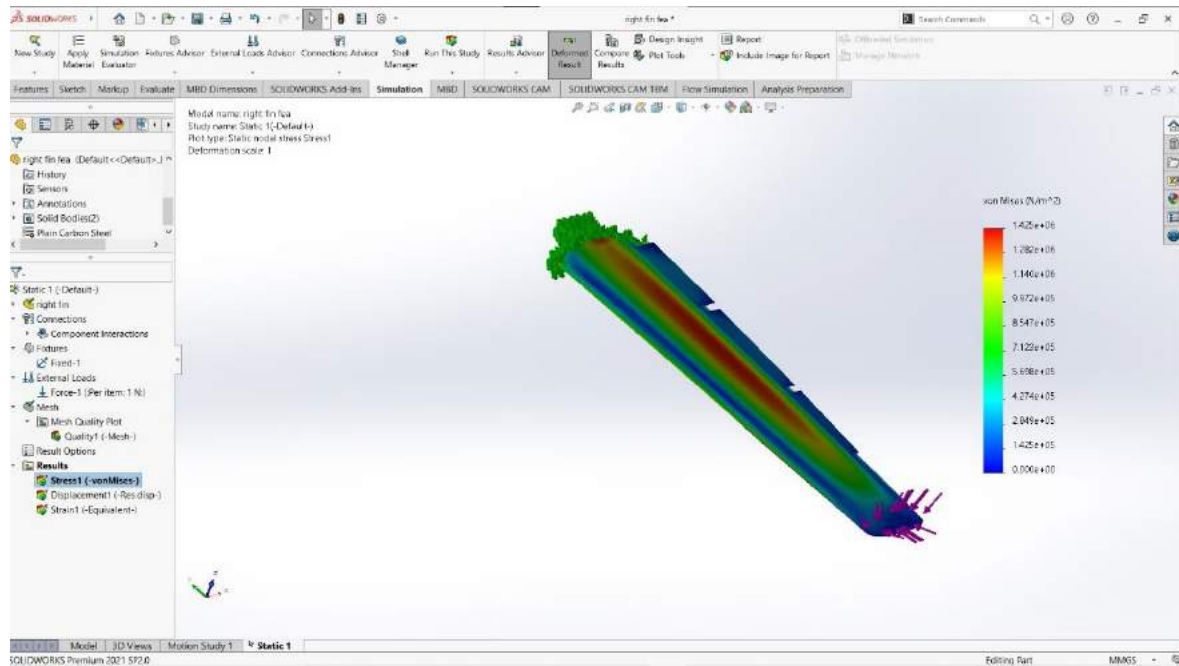


Figure 5.9

Material at the centre is higher and the structure is strong enough to withstand the stress distributed.

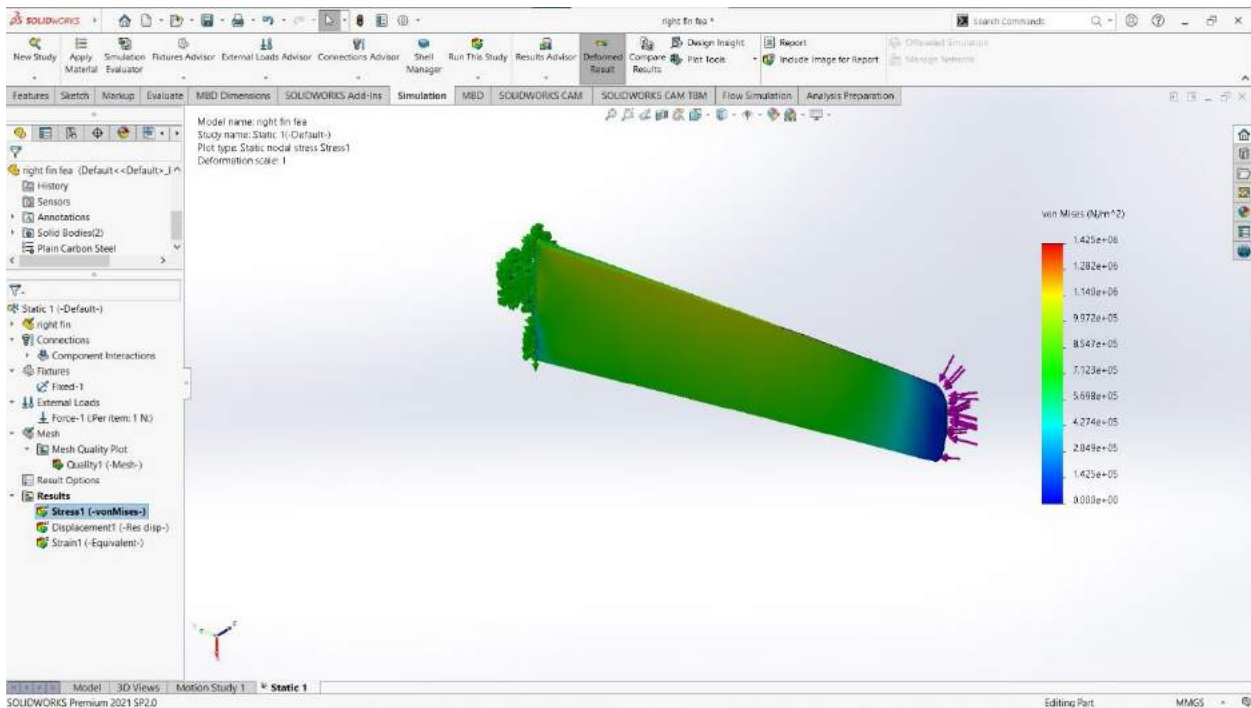


Figure 5.10

5.5.5 STRUCTURAL DISPLACEMENT:

When the vehicle is to be moved under air pressure, the wings tend to absorb force and have deformation,

The limit of that is analysed.

Force acting = gravitational + air drag

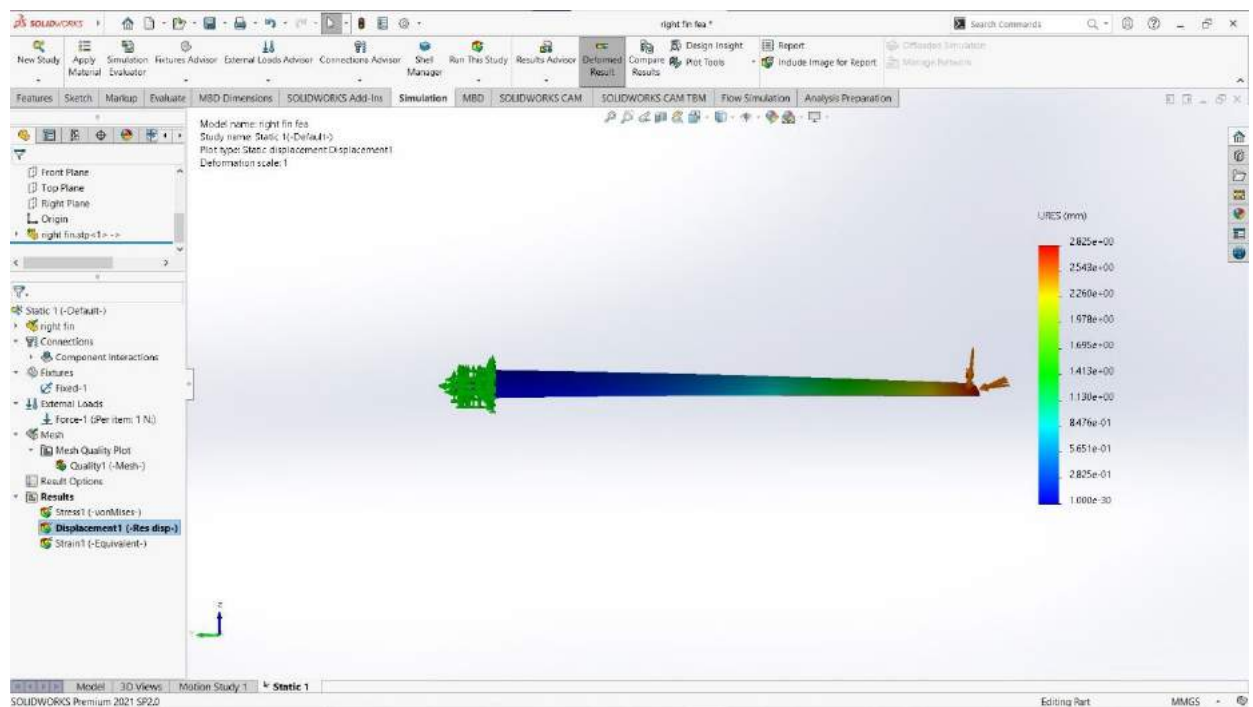


Figure 5.11

5.5.6 STRAIN ACROSS THE WING:

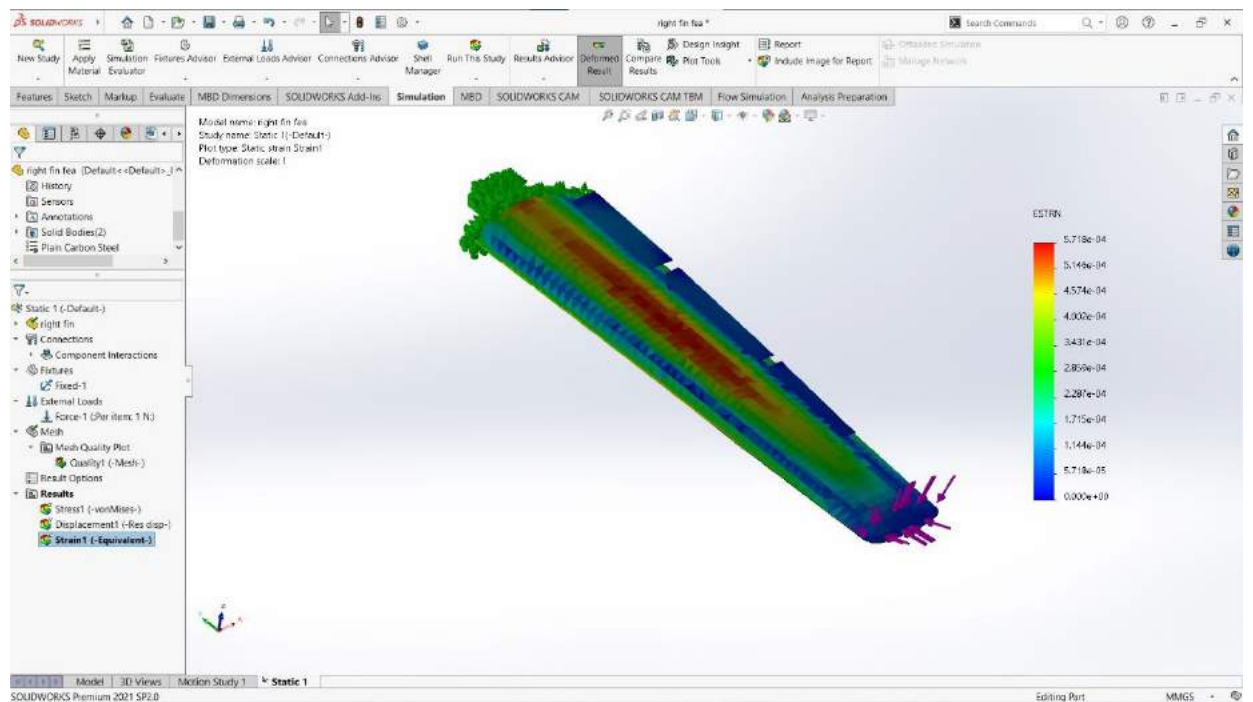


Figure 5.12

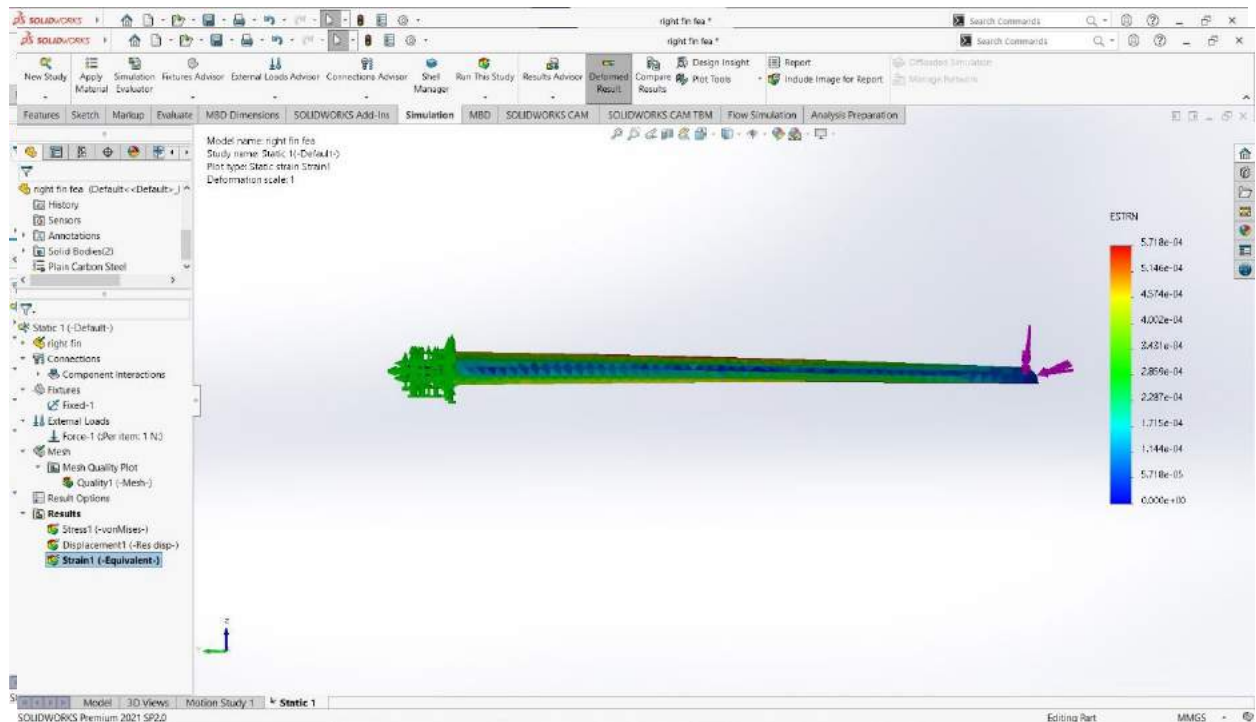


Figure 5.14

5.5.7 RENDERING:

The CAD model of the vehicle was rendered using key shot to have a realistic view of the vehicle. To achieve this real time textures and views, materials for each and every part of the model was assigned with their respective colours. Then the environment settings and using High Dynamic Range Imaging (HDRI) editor lightings and models looks will be altered to have the shadows and textures look amazingly real time. The obtained renders are as follows:

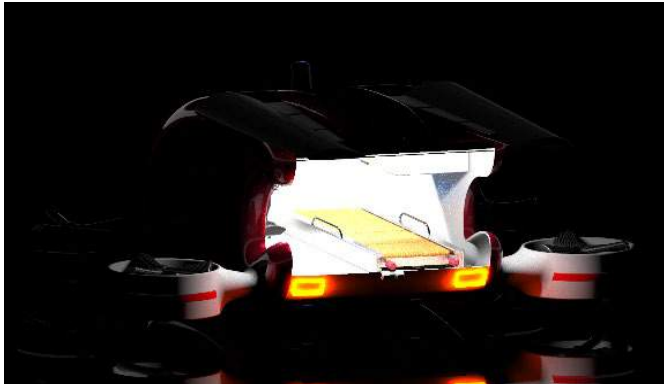


Figure 5.15



Figure 5.16



Figure 5.17



Figure 5.18



Figure 5.19



Figure 5.20



Figure 5.21



Figure 5.22



Figure 5.23 – Isometric View



Figure 5.24 – Front View



Figure 5.25 – Top View

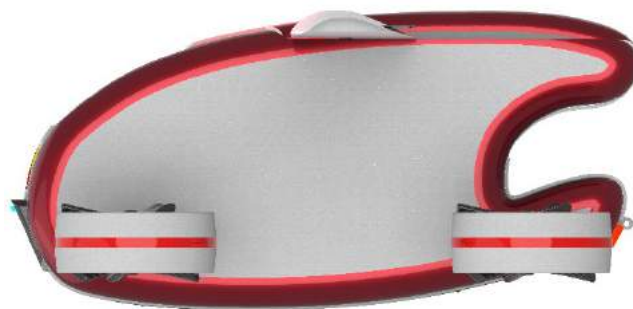


Figure 5.26 – Side View



Figure 5.27 – Back View

CHAPTER 6

CONCLUSION

Main aim of this project was to develop a develop aerial emergency vehicle which can be used in several emergency services and help getting road accident injured patients to hospitals faster. For controlling the aerial vehicle, a pilot is appointed who can fly the vehicle with easy with the user interface. The original model is designed to be developed as a prototype by reducing its scale by 100x and the prototype model is to be powered with receiver, microcontroller, electronic speed controller, brushless DC motor and servo motor have been used. SOLIDWORKS®/ANSYS®/NX® has been used to developed the PROTOTYPE lift, drag, structural analysis and system simulation. The proportional, integral controller action shows the better performance of controlling the roll, pitch and yaw of the to be developed prototype. analysis shows the successful operation of prototype structurer and FEA analysis

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25. Lilium Jet - Lilium is developing a revolutionary on-demand air taxi service (source: Regional Air Mobility – Lilium <https://lilium.com/>)
26. Gravity Industries - Gravity Industries Ltd in March 2017, the company behind the Daedalus Mark 1, a jet pack that uses several miniature jet engines to achieve vertical flight. (source: Gravity - Gravity Industries <https://gravity.co/ries>)
27. PAL-V –A Dutch company that is involved in the development of the first commercial flying car, the PAL-V Liberty. It is a compact two-person aircraft that can travel on public roads. (source: Flying Car: Personal Air Land Vehicle | PAL-V (pal-v.com))
28. SkyDrive - Develop “flying car” from Japan. SkyDrive Inc. is a company with such passions. It is a start-up that started with engineers in the fields of aircraft, drone, and automobile. It was founded mainly by members of the voluntary group, “CARTIVATOR” established in 2012. (source: SkyDrive Inc. -Flying car- | SkyDrive Inc. (skydrive2020.com))
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APPENDIX

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Head) at SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in MECHANICAL ENGINEERING. DATE: PLACE: SIGNATURE OF THE

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APPENDIX ABSTRACT Avion-e is a manned emergency flying vehicle, which is a
replacement to ambulances used these days.

In short it is an ambulance which flies. It will be ergonomically designed to carry an operator, a medical representative and the patient. The goal of this design is to reach the emergency spots at the shortest time possible, and the easiest way to do it is to avoid road traffic and taking air routes. After boarding on the vehicle, the