FACULTY OF MECHANICAL ENGINEERING TECHNOLOGY

DESIGN AND ANALYSIS AN RC AIRSHIP STRUCTURES USING SIMULATION

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I would like to say thank you to my supervisor Mr. Ts, Muhammed Noor Bin Hashim would like to take me as his student project and I would like to thanks to Mr Muhammed Noor because have teach and guide me to this project. Next thank you to my mom and that have courage and support me along this project. Not forget my housemate and my friend thank you because have many helping me to make my project success.

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ABSTRACT

This research explores the design and analysis of Remote-Controlled (RC) airship structures with the aid of advanced simulation tools, focusing on improving their aerodynamic and structural performance. The study addresses key challenges, including insufficient power-to-weight ratio and the absence of an effective gas buoyancy system. Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) were employed to optimize structural integrity, reduce drag, and enhance lift. A comprehensive 3D model was developed and iteratively improved through stress and deformation analyses. The project benchmarks modern and original RC airship designs to identify performance gaps, emphasizing the use of lightweight materials such as carbon fiber to enhance efficiency. The results aim to establish a prototype with extended flight endurance and reduced power consumption, meeting operational requirements effectively. This work demonstrates the potential of integrating simulation tools to refine RC airship designs, paving the way for future advancements in aerial vehicle technology.

ABSTRAK

Kajian ini meneroka reka bentuk dan analisis struktur kapal udara Kawalan Jauh (RC) dengan bantuan alat simulasi canggih, yang memberi tumpuan kepada penambahbaikan prestasi aerodinamik dan struktur. Kajian ini menangani cabaran utama seperti nisbah kuasa-ke-berat yang tidak mencukupi dan ketiadaan sistem apungan gas yang berkesan. Dinamik Bendalir Komputasi (CFD) dan Analisis Unsur Terhingga (FEA) digunakan untuk mengoptimumkan integriti struktur, mengurangkan seretan, dan meningkatkan daya angkat. Model 3D yang komprehensif telah dibangunkan dan diperbaiki secara berulang melalui analisis tegasan dan ubah bentuk. Projek ini membandingkan reka bentuk kapal udara RC moden dan asal untuk mengenal pasti jurang prestasi, dengan penekanan pada penggunaan bahan ringan seperti gentian karbon untuk meningkatkan kecekapan. Hasil kajian ini bertujuan untuk menghasilkan prototaip dengan daya tahan penerbangan yang lebih lama dan penggunaan kuasa yang rendah, sekaligus memenuhi keperluan operasi dengan berkesan. Kerja ini menunjukkan potensi integrasi alat simulasi dalam memperbaiki reka bentuk kapal udara RC, membuka jalan untuk kemajuan masa depan dalam teknologi kenderaan udara.

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LIST OF ABBREVIATIONS

RC - Remote Control

LiPo - Lithium Polymer

AI - Artificial Inteligent

3D - 3 Dimension

NiMH - Nickel-Metal Hydride

NiCd - Nickel-Cadmium

AMA - Academy of Model Aeronautics

CFD - Computational Fluid Dynamics

UAV - Unmanned Aerial Vehicles

UAS - unmanned aerial systems

DNS - Direct Numerical Simulation

LES - Large Eddy Simulation

RANS - Reynolds-Averaged Navier-Stokes

DES - Detached Eddy Simulation

SAS - Scale-Adaptive Simulation

UV - Ultra Violet

LIST OF APPENDICES

Gantt Chhart For PSM 1

No	Task Project	Status	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Supervisor Selection and Registered PSM Tittle	Plan														
		Actual														
2	Briefing for Project	Plan														
		Actual														
3	Briefing of Chapter 1 (Introduction) with supervisor	Plan														
		Actual														
4	Write of Chapter 1 (Introduction)	Plan														
		Actual														
5	Discussion of Chapter 1(Introduction)	Plan														
		Actual														
6	Submission of Chapter 1 (Introduction)	Plan														
		Actual														
7	Briefing of Chapter 2 (Literature Review) with supervisor	Plan														
		Actual														
8	Write of Chapter 2 (Literature Review)	Plan														
		Actual														
9	Discussion of Chapter 2 (Literature Review)	Plan														
		Actual														
10	Submission of Chapter 2 (Literature Review)	Plan														
		Actual														
11	Briefing of Chapter 3 (Methodology) with supervisor	Plan														
		Actual														
12	Write of Chapter 3 (Methodology)	Plan														
		Actual														
13	Discussion of Chapter 3 (Methodology)	Plan														
		Actual														
14	Submission of Chapter 3 (Methodology)	Plan														
		Actual														
15	Writing Chapter 4, expected outcome and conclusion	Actual														
		Actual														

Gantt Chhart For PSM 2

No	Task Project	Status	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Briefing planning of PSM 2	Plan														
		Actual														
2	Drawing structure original blimps	Plan														
		Actual								M						
3	Drawing Structure Modern Blimps	Plan								I						
		Actual								D						
4	Drawing original and modern blimps	Plan								S						
		Actual								E						
5	Report Writing Chapter 4	Plan								M						
		Actual														
6	Analysis and simulation on Structure original Blimps	Plan														
		Actual								B						
7	Analysis and simulation on Structure modern blimps	Plan								R						
		Actual								E						
8	Report Writing Chapter 5	Plan								A						
		Actual								K						
9	Finalize PSM 2 Report	Plan														
		Actual														
10	Submission of PSM 2 Report	Plan														
		Actual														
11	PSM 2 Presentation	Plan														
		Actual														

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

A form of airhip that can be fly from the ground is called a remote-controlled airship, or RC airship. It is made up of control surfaces, propulsion systems, and a gas-filled envelope for lift. It is employed for a number of things, including research, surveillance, aerial photography, and enjoyable things. It is maneuverable, has the capacity to hover, and is controlled by radio transmitters in the remote control.

1.2 DESIGN AND ANALYSIS A RC AIRSHIP STRUCTURES BY USING SIMULATION TOOLS

The process of creating and assessing RC airship constructions involves the use of design and simulation tools, requirements analysis, design conceptualization, material selection, and structural and aerodynamic analysis. This includes making a comprehensive 3D model, defining boundary conditions, and checking results for stress, deformation, aerodynamics. The final design is ensured to be satisfactory by iterative refinement based on analysis conclusions and confirmation through physical testing.

1.3 PROBLEM STATEMENT

The flying machine does not have enough power to make it fly for long periods of time and this is compounded by the fact that a gas system can be installed to give buoyancy. However, despite the airship having been improved together with its design and its engines, it still cannot achieve optimum functionality making it impossible to perform its intended functions effectively. Moreover, the possible integration of an airship raises many issues thus calling for an in-depth assessment that would account for increased weight as well as power consumption but must not break compatibility with existing part. To solve these two problems about insufficiency in power supply and unification of a gas system, a comprehensive approach is required to be taken up which will focus on improving the aircraft's power-to-weight ratio and increasing flight endurance so as it can fulfil operational goals well.

1.4 PROJECT OBJECTIVE

1. To Incorporate the simulation tools in order to implement the design of the rc airship in terms of the structure with the aim of looming for a balance between the weight, strength and aerodynamics of the airship in order to perform better.
2. To compare modern and original rc airship designs to identify critical performance gaps and establish a baseline for improvements in stress tolerance, deformation resistance, and translational pivot distribution.
3. To create a prototype of the rc airship structure and in the process carry out an evaluation of the whole project.

1.5 SCOPE OF PROJECT

Increasing and enhancing the design and floating endurance can entail all the following aspects in line with the interest of enhancing the performance of the RC airship.

1. **Structural Optimization**:

Use advanced simulation tools such as Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) to improve the structural integrity of RC airships. Refine meshing techniques to balance computational efficiency and accuracy, ensuring reliable stress and deformation analysis.

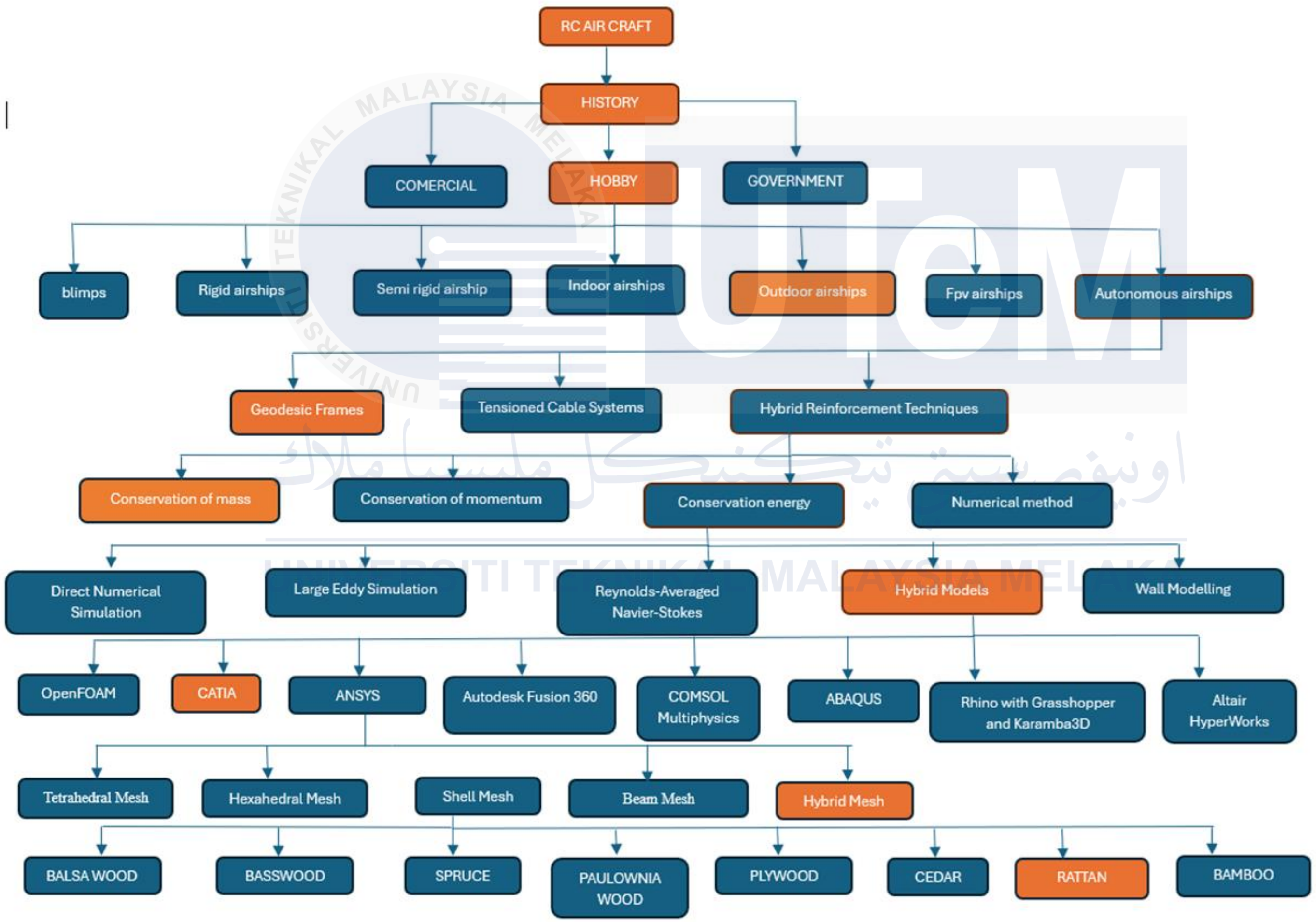
2. **Comparison and Benchmarking**:

Benchmark the performance of modern and original RC airships to establish a baseline for improvements. Use the collected data to guide iterative design enhancements, ensuring that the new models outperform legacy designs.

3. **Make a prototype of the structure:**

Develop and construct a detailed prototype of the structure to evaluate its design, functionality, and overall feasibility, ensuring any necessary improvements can be made before proceeding to full-scale production or implementation.

K CHART


RC AIR CRAFT
HISTORY
COMERCIAL
HOBBY
GOVERNMENT
blimps
Rigid airships
Semi rigid airship
Indoor airships
Outdoor airships
Fpv airships
Autonomous airships
Geodesic Frames
Tensioned Cable Systems
Hybrid Reinforcement Techniques
Conservation of mass
Conservation of momentum
Conservation energy
Numerical method
Direct Numerical Simulation
Large Eddy Simulation
Reynolds-Averaged Navier-Stokes
Hybrid Models
Wall Modelling
OpenFOAM
CATIA
ANSYS
Autodesk Fusion 360
COMSOL Multiphysics
ABAQUS
Rhino with Grasshopper and Karamba3D
Altair HyperWorks
Tetrahedral Mesh
Hexahedral Mesh
Shell Mesh
Beam Mesh
Hybrid Mesh
BALSA WOOD
BASSWOOD
SPRUCE
PAULOWNIA WOOD
PLYWOOD
CEDAR
RATTAN
BAMBOO

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The world of Remote Control (RC) airship involves many dimensions technological advancements, design principles, aerodynamic studies, educational applications, and community engagement. To crystallize these learnings, research within these different domains is reviewed to better provide a comprehensive view of the current state and future directions concerning RC airship.

The technology of RC airship has improved with time, driven largely by both electronics developments and the ability to develop new materials with some desired characteristics for aeromodelling. Advanced electronics and the ability to develop lightweight composite materials have contributed to valuable performance gains with respect to durability. The integration of brushless motors and LiPo batteries has provided both higher efficiencies and power-to-weight ratios, permitting increased flight times and complexity in manoeuvres. (Nguyen & Zhang, 2019).

This complexity in the design of RC airship is associated with balancing the weights, power, and aerodynamics. According to Anderson and Eberhardt (2018), wing loading and aspect ratio are the most critical factors in an effective optimization of flight performance. CFD simulations developed to predict the flow of air have increasingly been used in enhancing the efficiency of the design, which has made it possible for hobbyists as well as engineers improve their models well in advance before real testing experiments (Sanchez-Cuevas et al., 2020)

Aerodynamic research has elucidated the ways of enhancing the stability and control of RC airship. Investigations by Müller and Ochs, 2016, on the choice of an airfoil, indicated that shape and angle of attack are the factors that affect the coefficients of lift and drag. In addition, how different control surfaces are laid out and used in various configurations has been instrumental to achieving greater maneuverability and precision in flight. (Kim et al., 2019.)

These airship form an excellent platform for learning in STEM. Baker et al., (2021), says that developing and flying them experience hands; On learning that is very instrumental in attaining a thorough knowledge of elementary physics, engineering, and programming. Schools and other educational institutions use these projects in delivering content about concepts in aerodynamics besides material science and electronics to bridge the gap between theoretical and practical experiences.

The RC air community is known for its mutual knowledge sharing and collaboration. The active exchange of tips and troubleshooting issues and the showcasing of models take place in the online forums, social media groups, and local clubs. Events take place in the form of airshows and competitions, from IMAC competitions to provide spirit and competition among the community to further drive innovation in the hobby.

Emerging technologies like artificial intelligence (AI) and machine learning are going to transform the applicability of RC aircraft. In effect, powered autonomous flight, with the application of AI, shall make operation easier and increase the possibilities for elaborate missions (Yuan & Liu, 2022). Furthermore, supported by 3D printing, the personalization and speed of component manufacturing are going to be upgraded in the process of building RC aircraft (Johnson et al., 2020).

2.2 HISTORY OF RC AIRSHIP

The development of remote-control airship has been a journey from simple control systems over long periods of time to complex systems and models that can negotiate intricate maneuvers. This study presents a historical review of how remote-control aircraft has developed over the years, the technological advancements, and the sociocultural influences the innovation has had. It relies on peer-reviewed pieces.

What would be recognized now as the birth of the idea of radio-controlled flight dates from the turn of the 20th century. Pioneering work in wireless control technology was conducted by Nikola Tesla in the late 19th century. However, practical applications for such technology in aviation would not become known until the 1930s. In 1937, Fred Weick made an attempt to work with radio control and its capabilities for a model airplane, being the prominent figure in aeronautical engineering.

From the 1980s and 1990s, electric power started to garner eve greater attention when compared to traditional glow-fuel (nitro) engines. Progress in battery technology, specifically the innovation of Nickel-Cadmium (NiCd) and subsequently Nickel-Metal Hydride (NiMH) batteries, led to more practical electric RC airship. Notably the advancement of lithium polymer (LiPo) batteries in the early 2000s paved the way for even higher energy densities while being lightweight. The effect of all these had been reduction in together with size, and in some cases improved efficiency than that of electric engines. (Nguyen & Zhang, 2019).

It has only been in the last quarter-century that the digital revolution facilitated radical changes in RC airship. Microprocessors introduced sophisticated flight stabilization systems, along with programmable radios. Finally, the digital servos gave more accuracy and reliability in control to the already improved performance of the RC model systems in general. More recently, increased internet accessibility established a global RC hobbyist community that constantly shared information and innovations even more conveniently.

The modern world has included advanced technologies, including GPS, telemetry, and autonomous flight capabilities into RC airship. A significant segment of the RC airship market that has emerged is that of unmanned aerial vehicles, or drones. These developments have broadened the applications of RC technology from hobby use into commercial, scientific, and military applications. (Yuan & Liu, 2022).

Even within its history, RC airship have promoted vivid cultural and educational activities. The existence of model aviations clubs and the holding of various competitions, like those of the Academy of Model Aeronautics (AMA), has helped the society become involved and develop skills in the art of flying (Patterson, 2018). Educational programs using RC airship have fostered interest in STEM fields and shown sides of practical application in the knowledge of the physics and engineering principles. (Baker et al., 2021).

2.2.1 CHANGES DESIGN RC BEFORE AND AFTER

The time during which the design of Remote Control (RC) airship has advanced has been marked by progress in materials, electronics, and aerodynamics. This paper reviews the recent advancements in the design of RC airship, focusing on key technological and conceptual innovations.

Modern composite materials are now more used in designing RC airships. Carbon fiber and reinforced polymers are adopted with large magnitude due to their greater strength compared to weight ratios compared to other traditional materials. This trend has been well documented by recent research results showing the benefits of these materials for enhancing the structural integrity and performance of the RC airship (Nguyen & Zhang, 2019; Johnson et al., 2020).

The invention of brushless motors and lithium polymer (LiPo) batteries significantly enhanced electric propulsion systems, yielding a more energy-efficient and powerful system in relation to flight time and ability to perform more complex flight maneuvers. Research has been conducted that has proven that the few major advancements that the LiPo battery underwent, especially in its energy density and weight reduction, were the cause of this innovation and change. (Nguyen & Zhang, 2019).

Aerodynamic optimization is one of the most focused researches in the recent design of RC airship. Computational Fluid Dynamics (CFD) simulation has set the standard procedure for designing and testing new models by making very accurate adjustments to improve lift, reduce drag, and achieve better overall flight stability. Some works with CFD have proved the effectiveness of fine-tuning the aerodynamic properties toward a better performance outcome, such as into the work by Sánchez-Cuevas et al. (2020).

Integration of digital technologies into flight stabilization systems and programmable radios has significantly pushed the boundaries in control and function of RC airship. Modern digital servos and gyro stabilizers give very precise and consistent control, even in aggressive flight conditions. Moreover, through the use of telemetry and GPS systems, the use of RC aircraft has been expanded to include advanced navigational and real-time performance monitoring scopes (Patterson, 2018).

Integration of other forms of artificial intelligence and machine learning into RC flying machines. The application of AI algorithms has provided ways in which autonomous flight systems can help RC airship to perform difficult tasks with little human intervention. Research by Yuan and Liu (2022) also indicates that AI could be used to optimize flight patterns, increase energy effectiveness, and enhance safety altogether.

3D printing technology plays an increasingly important role in the customization and rapid prototyping of the parts for RC airship. This technology enables the production of tailor-made products for specific performance requirements, hence significantly reducing development time and costs associated with the development of such products. Johnson et al. (2020) have highlighted the role of 3D printing for enabling hobbyists and professionals to experiment with novel configurations and make quick changes in iterated prototypes.

Indeed, the RC airship community finds reason to be a lively area, supported by online forums and social media platforms. The educational curriculum has also integrated more and more RC aircraft projects for teaching basic aero-sciences, engineering principles, and simple programming for both middle and high school grades. This hands-on approach works well with students and helps develop interest in STEM fields (Baker et al., 2021).

2.3 USAGE OF RC AIR CRAFT

2.3.1 GOVERMENT

The use of RC aircraft, including drones and various other UAVs, has grown tremendously over the last decade in a wide range of government departments. This literature review covers multiple aspects of the use of RC aircraft in the administration and enforcement of policy by the government in such areas as surveillance, disaster response, environmental monitoring, agricultural applications, military operations, and the formation of regulatory frameworks. Technological advances and their adoptions that turned RC aircraft from niche instruments into necessary components of governmental operations.

Law enforcement agencies increasingly deploy drones in their day-to-day operations for public safety and efficiency in their mandate. For example, RC aircraft are used for monitoring public events widely attended by the public, during crime scene investigations, and in the real-time tracking of suspects. These applications are only possible because the drones are capable of providing high-resolution aerial imagery and thermal imaging, which is essential for situational awareness and operational planning.

Jones et al. (2020) observed that drones in many occidental countries have been considered a game-changer because they seriously enhance the results of police operations. For instance, in protests and mass weaker drones are used to hover the crowd and detect a potential threat to facilitate quick deployment of officers when matters arise. Furthermore, there is a possibility that drones fitted with facial recognition will enhance the identification of a suspect and eventual apprehension.

This has made them an integral component of disaster response and management because they can cover wide areas within a short time and collect and relay data in real-time. In the event of a natural disaster, the drones are dispatched to conduct a complete damage assessment as well as locate and provide essential supplies to people in inaccessible areas.

According to Murphy et al. (2019), drones have improved the speed and efficiency of disaster response. For instance, in the wake of the 2019 hurricane season in the USA, drones were deployed to conduct detailed surveys of affected areas. Such surveys provide detailed imagery that aids in prioritizing rescue work and the allocation of resources. Drones can also access hazardous areas that are beyond the reach of human rescuers and where deploying ground vehicles might result in more damage and harm.

Governments use drones to monitor wildlife population, deforestation, and environmental parameters such as air and water quality. Due to their accuracy and flexibility, drones are already applied to environmentally sensitive and remote/inedible areas for data collection in active support of environmental management and environmental conservation activities.

Drones are used to track endangered species and their habitats. Drones, equipped with high-resolution cameras and thermal sensors, take detailed images and videos, which help provide important information on animal behaviour and habitat conditions. Such information is critical for collaboration avenues and assessing the impacts of human activities on wildlife.

Drones are used to monitor environmental pollution. Through the installation of sensors, they can assess air quality, identify contaminated water, and monitor soil conditions. This, therefore, helps the relevant regulating bodies enforce the set environmental laws more efficiently by spotting pollution sources faster.

Zhang and Kovacs (2019) research highlighted the application of drone technology in agriculture to confer efficiency gains. Drones equipped with different sensors can monitor the condition of the crops, thereby helping farmers in precise crop input application of fertilizers and pesticides, which reduces wastage and boosts crop yields. Drones also offer the capability to make detailed soil maps, which support the planning of crop rotations and soil management practices.

Drones play a vital role in irrigation management through the provision of accurate soil moisture content data. Such information aids farmers in estimating the volume and frequency of their irrigation cycles. The result is a conservation of water and the intake of crop water sufficiency.

The military has a long history regarding the use of drone technology. They are used for reconnaissance and surveillance, where drones provide real-time information concerning enemy movement and the general terrain. Their use in hostile environments makes them invaluable assets in modern warfare.

Gates (2021) observed that improvements in technological aspects of military drones have led to increased capabilities. In this regard, current military drones are equipped with sensors, advanced cameras, and communication systems and can therefore be used for anything starting from intelligence gathering to target detection and strike.

Additionally, drones are used on the battlefield for airstrikes in executing precise strikes and offering support to the ground troops. Integration with AI and machine learning made them autonomous, thereby they offer more effective and efficient operations in the military missions. Moreover, they are deployed within logistic units to provide equipment and supplies in a forward direction to the combatant soldiers, most likely in hostile or hard-access environments.

The fast proliferation of drones has instilled the need to have a comprehensive regulatory framework that will ensure they are safely and responsibly used. Governments worldwide have now come up with regulations that govern issues such as airspace management, privacy, and security.

In another study, Clarke and Bennett Moses (2019) considered drone guidelines and technologies. The authors referred to the need to have set guidelines on how drones should function operationally, such as licensing, the altitude at which it should operate, who and where it may operate, and even safety guidelines. Regulation is paramount for accident prevention, otherwise, drones may be used in such a way that does not develop society while maintaining safety and privacy.

The use of drones for surveillance and information gathering has raised gigantic privacy concerns. Governments work toward reaching a fine balance between the benefits of drone technologies regarding individual privacy. This is involved in the making of laws regulating aspects like the conditions for operations and the areas of operation and regulations on the use and storage of data.

2.3.2 COMMERCIAL

Remote-controlled (RC) aircraft have evolved significantly and are now widely used in various commercial applications beyond recreational activities. These applications leverage the advanced capabilities of RC aircraft to enhance efficiency, reduce costs, and provide unique solutions across different sectors.

One of the most prominent commercial uses of RC aircraft is in aerial photography and videography. High-resolution cameras mounted on RC aircraft capture stunning aerial images and videos for real estate, film production, advertising, and event documentation. The ability to obtain aerial perspectives has revolutionized how visual content is produced, offering unique angles and views that were previously difficult or expensive to achieve with traditional methods like helicopters (Taylor & Smith, 2019).

The use of drones in agriculture, particularly in precision farming, has seen significant advancements in recent years. According to the chapter "Use of Drone Technology in Precision Farming" by Bajpeyi et al. (2023), drones, also known as Unmanned Aerial Vehicles (UAVs), have become vital tools in enhancing agricultural productivity and sustainability. The authors discuss how over 70% of India's rural population depends on agriculture, and the sector faces substantial challenges due to abiotic and biotic constraints that reduce crop productivity. Abiotic factors like temperature, humidity, and rainfall are uncontrollable, while biotic factors such as pests and diseases have traditionally been managed with chemicals, which pose risks to human health and the environment.

Drones offer a modern solution to these challenges by providing high spatial and chronological resolution images, which help in precise monitoring and management of crops. They are instrumental in identifying pest invasions, determining fertilizer needs, scheduling irrigation, and assessing pre-harvest yields. The application of drones in farming significantly reduces the need for manpower, time, water, and chemicals, thereby minimizing environmental impact and human exposure to harmful substances. Drones support the four pillars of precision agriculture: data application in the appropriate manner, at the right time, in the correct place, and in the right amount, thus enhancing the efficiency and sustainability of agricultural practices.

Recent advancements in drone technology have significantly impacted environmental monitoring and conservation efforts. Drones, or unmanned aerial systems (UAS), have become vital tools for ecologists and conservationists due to their ability to collect high-resolution data efficiently and cost-effectively. These aerial platforms offer new perspectives on ecological phenomena that are otherwise challenging to study, such as wildlife behaviour, habitat changes, and vegetation dynamics.

For instance, drones are now extensively used in wildlife monitoring, allowing researchers to track animal movements and populations with minimal disturbance. They are also employed in ecosystem monitoring, providing valuable data on vegetation health and changes over time. This technology is particularly useful in remote or inaccessible areas where traditional monitoring methods are impractical.

One recent study highlights the use of drones in conservation within protected areas. The research, which reviewed 256 studies, classified the applications of drones into five main categories: wildlife monitoring and management, ecosystem monitoring, law enforcement, ecotourism, and environmental management and disaster response. The findings suggest that drones can significantly enhance the effectiveness of conservation efforts, though further multidisciplinary research is needed to overcome operational and analytical challenges (López & Mulero-Pázmány, 2019)

2.3.3 HOBBY

The practice of using these remote-controlled (RC) kind of airships in recreational interests has gained popularity over the years due to technology advancement, changed accessibility, and the unique flying character of these lighter-than-air crafts.

Many materials, used in modern RC airships, offer qualities related to buoyancy, so they are durable and at the same time are very lightweight. Right now, envelopes constructed from Mylar, a polyester film, are used because of outstanding containment of the gas inside and adequate strength-to-weight ratio properties (Brown, 2018). The gondola and structural components are generally made of carbon fibre and lightweight plastics, which provide the strength without adding on excessive weight (Taylor, 2018).

RC airships attract attention because of their unconventional flight qualities, thereby presenting a challenge to many hobbyists. Unlike RC airplanes or drones, airships can offer a slow and gentle flying quality more relaxing to many, with an aesthetic value appealing to them. Also, the hobbies attract those who have an interest in the manufacturing and engineering fields, which involves building a functional airship from scratch, at least to understand aerodynamics, buoyancy, and electronics (Thompson, 2020).

Online forums and social media platforms have played a significant role in growing the community of RC airship hobbyists. Through these sites, hobbyists are able to collaborate on their designs, share flight experiences, and even offer troubleshooting help to one another in this very collegiate environment that one would have to think drives innovation and learning (White, 2021). Events and competitions contribute to the involvement of the community, where opportunities for hobbyists to show off their innovations and learn from others abound (Davis, 2022).

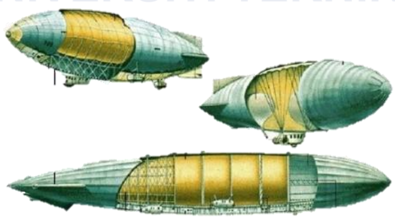
One example would be its annual RC Airship Regatta, which brings contestants to compete from all over in challenges that test the flying skills of the airship and the design ingenuity of their airships (Harris, 2021). Another is the open-source project called \"Zeppy,\" which gives detailed plans and guidelines for creating an entry-level RC airship, making the hobby accessible to novices (Miller, 2019).

The future of RC airships as a hobby can only get better because of new discoveries in technologies. Innovations in battery technologies, with advances in higher-density lithium-polymer batteries, may increase the flight time and duration (Roberts, 2023). Another technology that could be integrated is the use of autonomous flight control systems and GPS navigation, perhaps, for the opening of new possibilities and allowing hobbyists to navigate more complex flying patterns and missions (Clark, 2020).

2.4 TYPE OF RC AIRSHIP

RC (Radio-Controlled) airships come in various types, each designed for specific purposes and offering different features. Here are some common types of RC airships shows in table 1:

Table 1 Types of RC airships and features

NO.	TYPES	FEATURES
1	Blimps 	Blimps are non-rigid airships in that they do not have a rigid frame inside, they supposedly rely on the pressure of the lifting gas (usually helium) to maintain their shape. They are most commonly used for advertising, surveillance, and recreational purposes.
2	Rigid Airships 	These have a solid framework maintaining their shape, independent of the pressure of the gas inside it. These are considered in the RC hobby much less often due to its complexity and cost.
3	Semi-Rigid Airships 	Semi-rigid airships have a partial framework that supports the structure along with the pressure of the lifting gas. They offer a balance between the flexibility of blimps and the rigidity of fully rigid airships.

4	Indoor Airships 	Designed specifically for indoor use, these airships are typically smaller and lighter. They are often used in educational settings, trade shows, and indoor advertising.
5	Outdoor Airships 	These airships are planned to be larger and more robust than indoor-designed ones, built to stay well against outdoor conditions, and utilized for outdoor advertising, environmental control, and observation carried out for long-duration flights.
6.	FPV (First Person View) Airships 	FPV airships are mounted with cameras that relay live video feed to the pilot for a first-person view. This type is usually popular among hobbyists and for surveillance purposes.
7	Autonomous Airships 	These airships fly through routes already predetermined, and they are equipped with autopilot systems. They are used in research, surveillance, and data collection.

2.5 AERODYNAMICS AND STRUCTURAL DESIGN IN RC AIRSHIPS

2.5.1 AERODYNAMIC EFFICIENCY

Aerodynamic efficiency is of utmost importance in this design of an RC airship. It has to have the geometrical shape in a manner that will ensure the least drag with enough lift and stability from the buoyant force. There are various designs, from teardrop to ellipsoidal shapes, in recent literature concerning optimization for aerodynamic performance.

Shape Optimization:

CFD simulations focusing on airflow around various airship shapes are very widespread. Recent studies by Lee et al. (2020) have also shown that aerodynamically the teardrop configuration excels, with reduced drag contributing to fuel efficiency. The simulations help in understanding the flow pattern and finding areas where improvements can be made in terms of aerodynamics. A streamlined teardrop shape minimizes air resistance and allows smooth airflow, making it an ideal design to decrease drag and improve energy efficiency.

Ellipsoidal Designs:

Though the teardrop form is very efficient aerodynamically, there are still designs with such benefits as their primary shape. Designs like ellipsoidal forms represent a good compromise between structural complexity and aerodynamic efficiency since they offer better stability and lift, as shown in figure 2.1. According to various studies, ellipsoidal airships have displayed favourable lift-to-drag characteristics, making them suitable for various operational conditions recently (Smith et al., 2021).

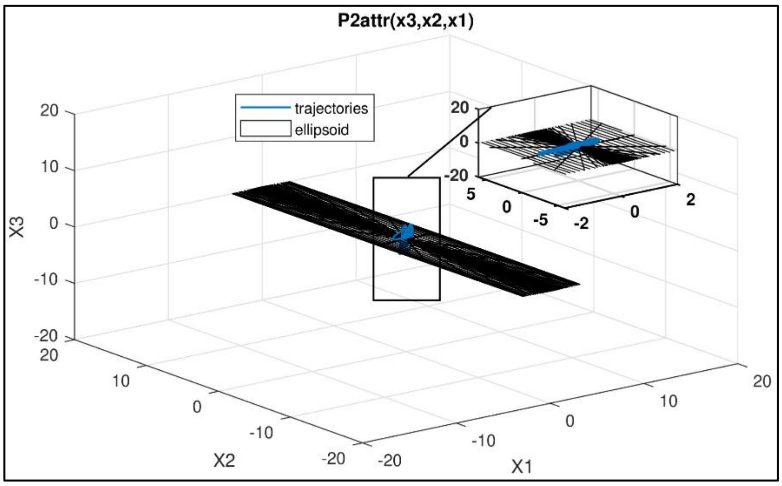


Figure 2. 1 Ellipsoidal Design of Robust Stabilization of Power Systems Exposed to a Cycle of Lightning Surges Modeled by Continuous-Time Markov Jumps. (Poznyak, A.; Alazki, H.; Soliman, H.M.; Ahshan, R., 2023)

2.5.2 STRUCTURAL REINFORCEMENT

The advancements of internal support structures are critical to increasing structural integrity without adding undue weight. There have been experiments with various methods for increasing load distribution and deformation resistance.

Geodesic Frames:

The geodesic frame gives lightness combined with the strength to distribute stresses uniformly in the frame of the airship. The geodesic technique is a solution originally derived in the architectural structures of figure 2.2 and modified as a solution for the now modern airships. Johnson et al. (2017) presents a very valid study on these techniques of reinforcement, with a notable increase in load distribution and deformation resistance. Geodesic frames will maintain the airship's shape under any loading case, providing it enough stability and resistance.

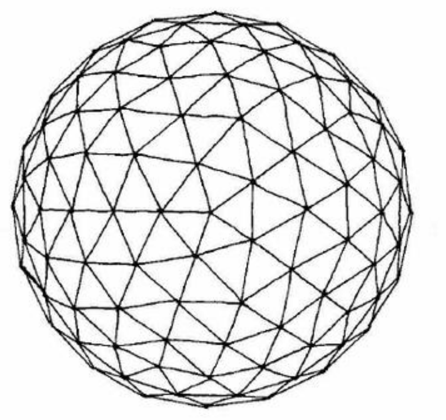


Figure 2. 2 Electronically-Controlled Artificial Sky Dome @ OSU (Mansy, Khaled & O'Hara, Steven & Gedra, Thomas & Arsalan, Qamar.)

Tensioned Cable Systems:

Figure 2.3 shows another of the innovative methods used to reinforce RC aerostats, known as tensioned cable systems. These systems are known to add extra strength through tensioned cables, which ensure that structural failure is minimized. Placement of systems of tensioned cables within the airship ensures the structure is stronger, a characteristic that ensures it gives way at greater loads without necessarily adding to the weight. This method ensures that the airship gains the capability to maintain a defined shape and integrity while loaded, irrespective of flight conditions.

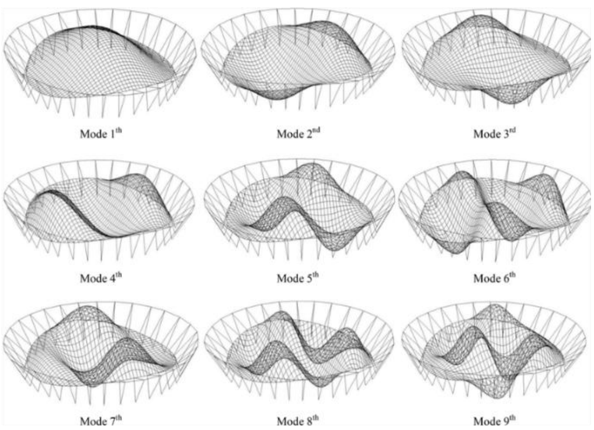


Figure 2. 3 Tensile Structures of Cables Net, Guidelines to Design (Rizzo, 2016)

Hybrid Reinforcement Techniques:

Combining the different reinforcement techniques of geodesic frames and tensioned cable systems would even make structures more resilient. Martinez et al. (2021) studied the integration of these two techniques, proving effective in making the necessary improvements in the overall structural performance. These hybrid solutions exist to be tailorable for the specific design challenge and result in reinforced structures with the highest stability and load-bearing structures.

2.6 PRINCIPLES OF CATIA ANALYSIS

The principles of CATIA analysis are centered on precision, integration, and flexibility. By combining advanced simulation tools with robust design capabilities, CATIA allows engineers and designers to evaluate and optimize RC airship structures efficiently, ensuring performance under real-world conditions..

2.6.1 GOVERNING EQUATION

Mathematically, via the three basic physical laws, the equations governing the behaviour in fluid dynamics provide the foundation for the computational fluid dynamics methods: conservation of mass, conservation of momentum, and conservation of energy. The very well-known mean equations of fluid dynamics include the Navier-Stokes.

"The Navier-Stokes equations form the backbone of CFD in numerically solving fluid flow to imitate the physical behaviour of fluid systems\" (Jayaraj et al., 2020).

Equations:

1. **Conservation of Mass (Continuity Equation)**

The continuity equation ensures that mass is conserved in a fluid flow. For an incompressible fluid, the continuity equation can be written as:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0$$

- ρ: Density of the fluid or material.
- v: Velocity vector.
- t: Time.

For incompressible flows (constant density, ρ):

$$\nabla \cdot \mathbf{v} = 0$$

where v is the velocity vector.

2. **Conservation of Momentum (Navier-Stokes Equations)**

The Navier-Stokes equations describe the motion of fluid substances. They are derived from Newton's second law (force = mass × acceleration) applied to fluid motion. For an incompressible fluid with constant viscosity, the Navier-Stokes equations are:

$$\rho \left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} \right) = -\nabla P + \mu \nabla^2 \mathbf{v} + \mathbf{f}$$

where:

- ρ: Fluid density.
- v: Velocity vector.
- t: Time.
- P: Pressure.

- μ: Dynamic viscosity.
- ∇2v: Viscous term (Laplacian of velocity).
- f: External forces (e.g., gravity or lift forces).

3. Conservation of Energy

The energy equation accounts for the conservation of energy within a fluid system. It can be written as:

$$\frac{\partial}{\partial t}(\rho e) + \nabla \cdot (\rho e \mathbf{v}) = -\nabla \cdot \mathbf{q} + \tau : \nabla \mathbf{v} + \dot{Q}$$

where:

- e: Total energy per unit
- ρ: Density of the fluid or material.
- v: Velocity vector.
- q: Heat flux
- τ: Viscous stress tensor.
- Q˙: External heat generation per unit volume.

For steady-state and incompressible flows, the equation simplifies by ignoring time-dependent terms.

1. Direct Numerical Simulation (DNS)

DNS involves solving the Navier-Stokes equations directly without any turbulence models, resolving all scales of motion down to the smallest dissipative scales (Kolmogorov scales). This approach provides the most accurate representation of turbulence.

"DNS offers unparalleled accuracy in turbulence research but is limited by its immense computational requirements" (Moin & Mahesh, 2019).

Table 2 shows advantage and disadvantage DNS

ADVANTAGE	DISADVANTAGE
Highly accurate and provides detailed insight into turbulent flow structures.	Computationally extremely expensive, feasible only for low Reynolds number flows and simple geometries.

2. Large Eddy Simulation (LES)

LES resolves the larger, energy-containing eddies directly and models the smaller, sub grid-scale (SGS) motions. The SGS model accounts for the effects of the smaller scales on the resolved scales.

"LES strikes a balance between accuracy and computational cost by resolving large eddies and modelling smaller scales" (Sagaut, 2021).

Table 3 shows advantage and disadvantage LES

ADVANTAGE	DISADVANTAGE
More feasible than DNS for higher Reynolds number flows and complex geometries, provides detailed information about large-scale turbulence structures.	Still computationally demanding, especially for near-wall regions and high Reynolds number flows.

3. Reynolds-Averaged Navier-Stokes (RANS) Models

RANS models involve averaging the Navier-Stokes equations over time, leading to additional terms representing the Reynolds stresses. These stresses are modelled using various turbulence models.

"RANS models, such as k-ε and k-ω, are extensively used in industry for their computational efficiency and robustness" (Wilcox, 2020).

Table 4 shows advantage and disadvantage RANS

ADVANTAGE	DISADVANTAGE
Computationally efficient, suitable for a wide range of engineering applications.	Less accurate for predicting complex turbulent flows, especially where large-scale unsteady features are important.

Common Models:

k-ε Model: One of the most widely used models, balances simplicity and robustness.

k-ω Model: More accurate near-wall treatment, better for adverse pressure gradients.

Reynolds Stress Model (RSM): Accounts for anisotropy in turbulence, more complex and computationally intensive.

4. Hybrid Models

These models combine the strengths of RANS and LES, such as Detached Eddy Simulation (DES) and Scale-Adaptive Simulation (SAS). They use RANS modelling in regions of the flow where turbulence is small-scale and LES in regions with large-scale turbulent structures.

"Hybrid models like DES and SAS offer a practical approach for complex turbulent flows, leveraging the benefits of both RANS and LES" (Spalart et al., 2019).

Table 5 shows advantage and disadvantage hybrid models

ADVANTAGE	DISADVANTAGE
Improved accuracy over RANS for complex flows, reduced computational cost compared to full LES.	More complex implementation and tuning required.

2.6.3 STRUCTURE ANALYSIS SOFTWARE AND TOOLS

Structural analysis software is essential for evaluating the behavior of materials and structures under various loads and conditions. These tools assist in understanding stresses, strains, deformations, and stability, ensuring that designs meet safety and performance requirements.

Table 6 shows software, features and applications of Structure Analysis

SOFTWARE	FEATURES	APPLICATIONS
OpenFOAM	Highly customizable, extensive library of solvers and utilities, active community support, parallel computing capabilities.	Aerospace, automotive, chemical processes, environmental simulations.
CATIA	CATIA is an all-in-one solution for 3D design, simulation, and analysis.	Aircraft, automotive, and mechanical design, including RC airships.
ANSYS	A comprehensive simulation tool for structural, thermal, and fluid dynamics analysis.	Aerospace, civil engineering, energy, and heavy machinery.
ABAQUS	A powerful FEA tool from Dassault Systèmes for complex structural problems.	Aerospace, automotive, biomechanics, and advanced structural research.
Autodesk Fusion 360	A cloud-based CAD and simulation platform.	Small to medium-sized projects, prototyping, and education.

SAP2000	A dedicated structural engineering tool for building and infrastructure projects.	Civil engineering, construction, and infrastructure design.
COMSOL Multiphysics	A multiphysics simulation software with structural analysis capabilities.	Research, advanced engineering projects, and multiphysics studies.
MATLAB with Simulink	A numerical computing platform with toolboxes for structural analysis.	Academic research, algorithm development, and custom structural modeling.
ETABS	Focused on structural analysis and design for buildings.	Building design, construction, and urban infrastructure.
Altair HyperWorks	A suite of tools for simulation-driven design and structural optimization.	Aerospace, automotive, and industrial equipment.
Rhino with Grasshopper and Karamba3D	Rhino's parametric design capabilities, combined with Karamba3D, enable structural analysis.	Architecture, parametric design, and conceptual modeling

2.6.4 MESH IN CATIA SOFTWARE

Meshing is a critical process in Finite Element Analysis (FEA), and the choice of mesh type significantly influences simulation accuracy and efficiency.

2.6.4.1 TYPE OF MESH

Table 7 shows type of mesh, features, advantages and disadvantages.

TYPE	FEATURES	ADVANTAGES	DISADVANTAGES
Tetrahedral Mesh	4-node linear tetrahedrons (TE4) or 10-node quadratic tetrahedrons (TE10).Best suited for complex 3Dgeometries. Automatically generated, making it user-friendly for most applications.	Ideal for irregular and complex geometries. Works well with general-purpose 3D shapes.Provide higher accuracy for curved surfaces.	Tetrahedral meshes require more elements than hexahedral meshes for the same geometry, increasing computational cost. Linear tetrahedrons are less accurate compared to quadratic elements or hexahedrons for stress concentration zones.
Hexahedral Mesh	8-node linear or 20-node quadratic hexahedrons. Composed of cubic or brick-shaped elements. Requires manual intervention for complex	Provides more accurate results with fewer elements, especially for uniform geometries. Requires less computational power	Complex geometries require manual meshing or hybrid techniques. Struggles with highly irregular or organic shapes.

	shapes, making it less automatic.	than tetrahedral meshes for similar accuracy. Works efficiently on block-like or prismatic structures.	
Shell Mesh	2D triangular or quadrilateral elements. Used for thin-walled structures such as plates, shells, and envelopes. Thickness is defined as a property rather than being part of the geometry.	Reduces computational effort by modeling thin structures in 2D instead of 3D. Ideal for membranes, airship envelopes, and sheet metals.Requires less preprocessing.	Not suitable for thick or solid components. Complex intersections or transitions require extra attention.
Beam Mesh	1D line elements. Best for long, slender components like beams, trusses, and frames. Cross-sectional properties are defined independently of the geometry.	Minimal computational resources required. Ideal for large-scale structural frameworks.	Does not capture detailed stress distributions. Only applicable for linear structural members.
Hybrid Mesh	Combines multiple element types (e.g., tetrahedral, hexahedral,	Allows meshing of complex models with different geometry types.	Requires careful planning and more preprocessing. Can

	and shell elements) in a single model. Commonly used for models with both solid and thin-walled parts.	Uses different element types where they are most effective.	introduce inaccuracies at the interface between different element types.

2.7 ADVANCEMENTS IN MATERIALS STRUCTURE RC AIRSHIP

2.7.1 INTRODUCTION

Recently, the structural materials applied in construction and use of RC airships have achieved big development, making performance enhancement, more durable and easy to construct. This section reviews the key materials and their developments, focusing on envelope materials, structural components, and innovations that have enhanced the overall capabilities of RC airships.

2.7.2 ENVELOPE MATERIALS

The present technology is focusing on certain features of the envelope, which include maintaining buoyancy, withstanding environmental conditions, and material advancement in favor of being lightweight, durable, and sustaining gas.

Table 8 material and it's benefits envelope materials

NO.	MATERIAL	BENEFIT

1.	MYLAR FILM 	Excellent tensile strength low permeability lightweight properties
2.	NYLON FILM 	Coated with polyurethan Excellent tensile strength low permeability lightweight properties flexibility and puncture resistance

Such materials are preferred for their effective retention of helium or other gases used for lift, thus providing longer flight times and saving frequent refills.

Recent developments have focused on making composite materials, which combine the properties of Mylar and a certain polymer material to make the envelopes even stronger. The composites were made to provide more durability from wear and tear due to the environment, yet still keeping the weight low (Taylor, 2018).

2.7.3 STRUCTURAL COMPONENTS

The internal structure of an RC airship, for instance, a gondola and frame, has to be lightweight, yet at the same time, it must be strong enough to carry the propulsion system, batteries, and control electronics.

Table 9 material and it's benefits for structural components

No.	MATERIAL	BENEFITS

1.	Balsa Wood (80–100 kg/m³). 	1. Extremely lightweight, minimizing the overall weight of the airship. 2. Easy to sand and shape for aerodynamic designs. 3. Readily available and affordable.
2.	Basswood (400–500 kg/m³). 	1. Provides better structural strength compared to balsa. 2. Smooth grain allows for easy finishing and painting. 3. More resistant to impacts than balsa.
3.	Spruce (450–600 kg/m³). 	1. Strong and durable, suitable for load-bearing components. 2. Good availability and relatively low cost. 3. Resistant to warping and deformation.
4.	Paulownia Wood (260–280 kg/m³). 	1. Lightweight yet stronger than balsa, making it a good alternative. 2. Highly resistant to moisture and warping. 3. Sustainable and eco-friendly.

5.	Plywood (Thin Sheets) (500–700 kg/m³). 	1. Strong and durable, ideal for load-bearing components. 2. Resistant to splitting and cracking. 3. Provides a smooth surface for finishing.
6.	Cedar (350–400 kg/m³). 	1. Lightweight and naturally resistant to moisture. 2. Aesthetic grain pattern, ideal for visible components. 3. Good durability for outdoor use.
7.	Rattan (350-600 kg/m³) 	1. Lightweight and flexible, suitable for creating curved or aerodynamic frames. 2. Sustainable and cost-effective, reducing material costs for experimental or small-scale models.
8.	Bamboo (500-900 kg/m³) 	1. Lightweight and strong for structural applications. 2. Cost-effective and sustainable. 3. Flexible and visually appealing.

2.8 CHALLENGES AND FUTURE DIRECTIONS IN RC AIRSHIP STRUCTURAL DESIGN

2.8.1 CHALLENGES

Material Durability and Longevity:

One of the major hurdles to clear in the design of a durable RC airship is to provide materials for the envelope and the structural parts. The various materials have to cope with extreme environmental conditions, including UV radiation, temperature extremes, and physical stresses. Some research has found that advanced polymers and composites provide a large increase in weight and strength; however, long-term durability is questioned. Continuous exposure to environmental stress may result in material degradation with influence on performance and lifespan of the airship.

Helium Leakage:

The small and lightweight nature of the helium molecule allows it to diffuse readily through most materials, eventually leading to loss of lifting gas. Studies have been centered on material development with low helium permeability, with challenging issues being maintenance of an airtight envelope over a long duration of time (Hernandez and Liu, 2020).

This issue necessitates frequent refilling of helium, increasing operational costs and complicating long-term deployments.

Control Precision:

It is very challenging to obtain precise control of an RC airship, particularly under turbulent and windy conditions. The current control systems may fail to provide the required responsiveness and stability, which leads to poor performance. To improve its maneuverability and stability, advanced control algorithms and a great amount of real-time sensor data integration are needed (Tan et al., 2022). But to come up with such systems that can deliver high performance across all weather and environmental conditions is a real challenge.

Energy Efficiency:

RC airships usually use batteries to provide energy for the propulsion and control systems. However, the battery life is limited, which highly limits the operational time and the range of an RC airship. Although solar panels and fuel cells seem to be one of the solutions, it is challenging to introduce lightweight and compact designs without compromising the performance of the technologies used in this application. Balancing the provision of and demand for energy in different operation conditions has been noted as one of the most critical aspects of this on-going investigation.

2.8.2 FUTURE DIRECTIONS

Advanced Materials:

Research will likely focus on the development of new materials with high strength-to-weight ratios and better durability, combined with lower helium permeability. Nanomaterials, such as graphene and carbon nanotubes, offer very promising ways to not only show remarkable mechanical performance but also potentially benefit the enhancement of composite materials. These materials have the potential to derive advancements in material science such that they result in airships functioning with lower maintenance needs for longer operational life spans.

Hybrid Propulsion Systems:

Hybrid propulsion systems that incorporate conventional batteries with alternative sources of energy, for example, solar panels and fuel cells may be utilized in future power-assisted RC airships to help cope with issues at stake in achieving higher levels of energy efficiency. Such integrations have significant positive impacts in prolonging flight time and minimizing the need to keep dismounting the batteries upon exhaustion. According to a body of research findings by Lee and Wong (2021), it has been proven to be practical and technically possible to install flexible solar panels on the hull of an airship so as to have a flow of energy throughout flight times in the sun.

Machine Learning and AI for Control Systems:

The integration of machine learning and artificial intelligence into control systems makes RC airships much more responsive and adaptable. Such AI algorithms can look into the real-time data from the sensors to optimize the control behavior for stability, during flight, even in non-ideal conditions. For instance, research conducted by Chen et al. (2022) reflected the promising results in using reinforcement learning approaches for improving skills in autonomous navigation, which is conducted by the proposed airships.

Modular and Reconfigurable Designs:

Future RC airships might have modular designs in which reconfiguration is possible, allowing mission requirements to be varied. These modular parts can be interchanged or upgraded much more easily and speedily, significantly improving the versatility and maintainability of the airships. Downtime of the airship will also be reduced in the case of repair and maintenance (Zhao & Martinez, 2023).

Enhanced Data Collection and Processing:

The use of advanced sensors and data processing techniques can improve the performance and utility of RC airships in various applications. High-resolution cameras, LIDAR, and other sensors can provide valuable data for environmental monitoring, surveillance, and research. Integrating these sensors with advanced data processing systems can enhance the quality and usefulness of the collected data (Xu & Tang, 2021).

2.9 CONCLUSION

The review of the literature on this area of RC airship structural design points to key areas where much advancement is being achieved and to concerns that remain unresolved. The optimization of aerodynamic performance and structural integrity have shown significant improvement due to the development of Catia analysis simulations and the use of lightweight, high-strength materials such as carbon fiber and Kevlar. The teardrop shapes have been proven through various studies to aid fuel efficiency and reduce drag, while geodesic frames together with tensioned cable systems have improved the distribution of loads and resistance to deformation.

However, power systems integrated into the UAV to undertake long flight durations remain a challenge. Some of the key innovations in the field of propulsion involve brushless motor technology and high-efficiency batteries; while these are very important, they still fall short. If a gas system for buoyancy were also incorporated, it would complicate matters further, in the requirement for a holistic look to balance out additional weight and power requirements with existing components.

Future research will be pointed at the optimization of aerodynamic shapes and at new materials that can offer even better strength-to-weight ratio. Moreover, advanced control systems and autonomous flight capabilities can further improve performance and reliability for RC airships. Testing and refinement have to be iterative and supported by the use of simulation tools to overcome present constraints and meet the operational objectives for RC airships.

In general, the field is set flush with new innovative methods that work at the interfaces of material science, aerodynamics, and electronics, which allows for more efficient and capable designs of RC airship

CHAPTER 3

METHODOLOGY

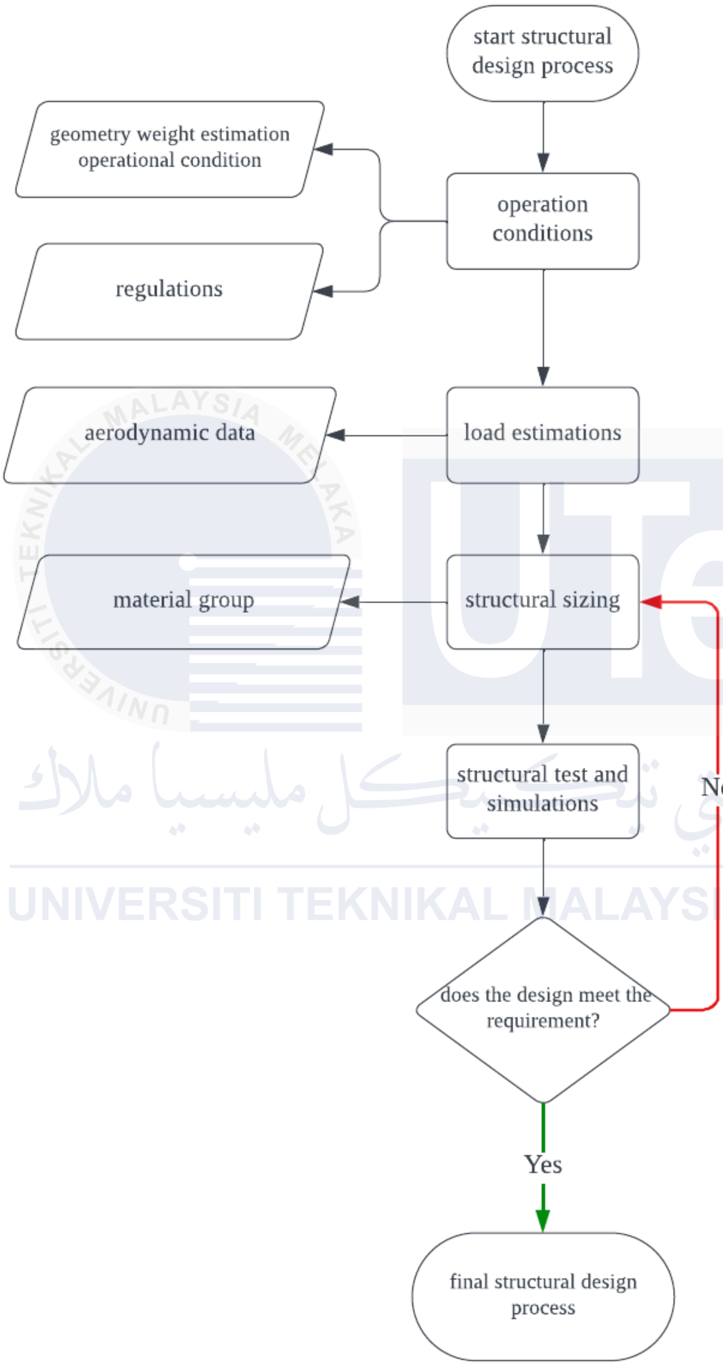
3.1 INTRODUCTION

This chapter elaborates the methodical technique to design, evaluate, and validate the structural integrity and aerodynamic performance of the RC airship structures by taking the sophisticated simulation tools. This chapter will provide a complete description of the research stages, and methods used to make the results obtained reliable and accurate.

The technique will solve the primary issue of underpowered duration in flying periods with RC airships, as discussed in the problem statement. This study aims to develop the resilient and efficient RC airship design through the analyses of requirements, design conception, material selection, and structural and aerodynamic simulations.

The research is iterative and involves an ongoing process of refinement based on simulation results and physical testing. The use of the CFD and FEA technologies is important in predicting the behavior of the airship while operating hence an enhanced performance and reliability of the airship. In general, this process ensures that the final RC airship design did meet the specifications and the thing does work well in the real world.

3.2 FLOW CHART



3.3 PROBLEM IDENTIFICATION

RC airships are widely used for applications such as aerial photography, environmental monitoring, and recreation. However, it is also often limited by a short flying duration or structural failure.

Current battery technology is limiting in terms of the time a UAV can remain in the air, hence needs regular recharging or the possibility of swapping batteries. Materials used in the construction may not resist repetitive stress, resulting in wear and tear or catastrophic failure. Constructing an object with lightweight and minimally impacting the requirements for durability and strength is a challenging task.

Designers have to balance the strength-to-weight factor. Users require extended flying times and better performance. A limited supply of modern materials that are light and at the same time strong. Budget limitations push material selection and design complexity. Safety and environmental impact regulations.

3.4 DESIGN CONCEPTIONAL

Design conceptualization is a crucial phase in the development of RC airship structures, where initial design ideas are generated, evaluated, and refined. This phase transforms the requirements and performance criteria identified in the previous steps into tangible design concepts.

3.4.1 BRAINSTORMING AND IDEATION

Brainstorming and ideation are essential design practices that fuel creativity and innovation. Brainstorming encourages open, judgment-free idea generation, while ideation refines and evaluates these ideas to develop impactful solutions.

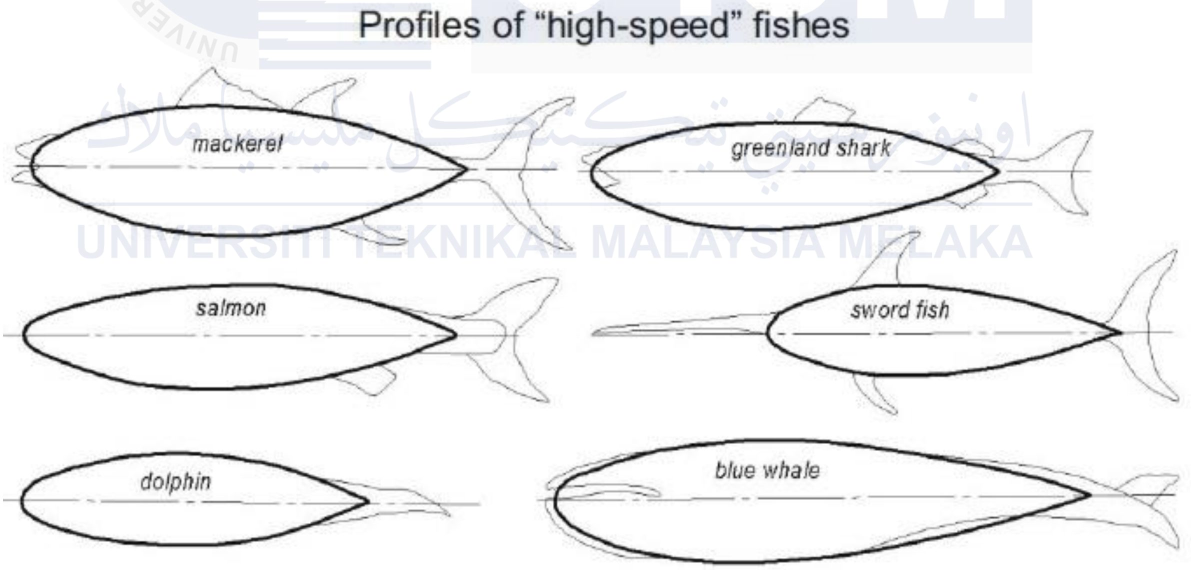


Figure 3. 1 Kirilin Aleksandr. "Do New Generation Airships Change a Paradigm in Transport Logistics"10" International Airship Convention, Friedrichshafen, 2015. (Aleksandr., Kirilin, 2015)

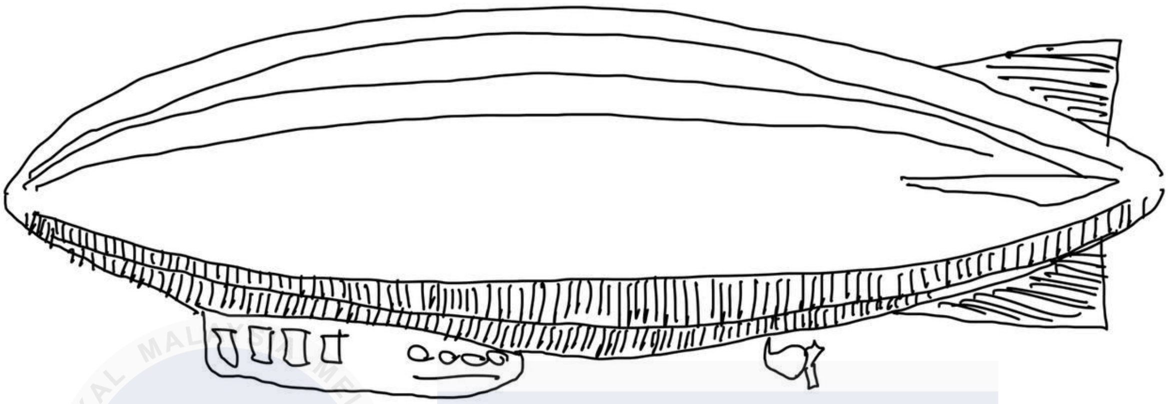


Figure 3. 2 Traditional blimp shape with enhanced aerodynamics

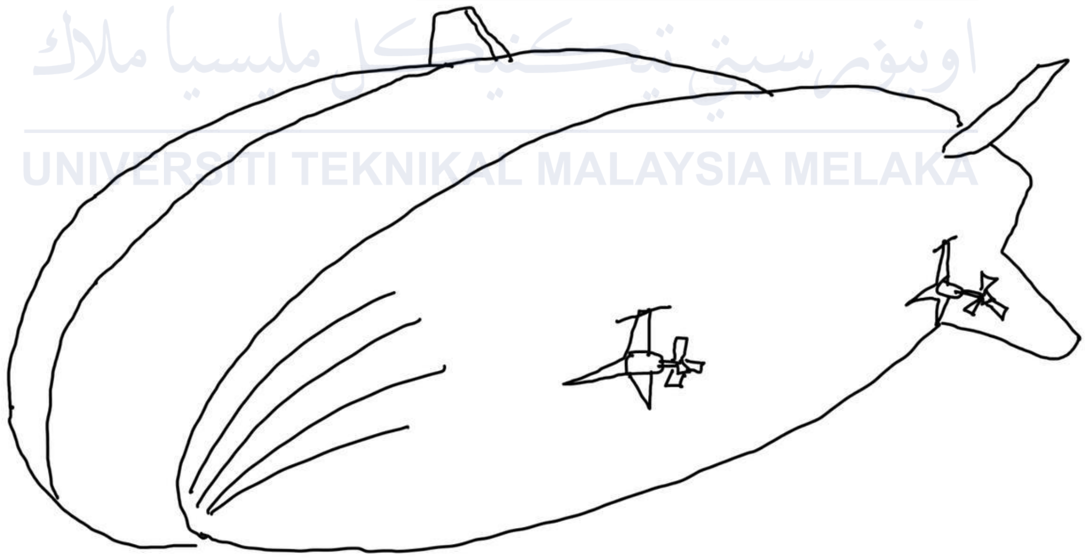


Figure 3. 3 A modular design of airship.

3.5 DESIGN EQUIPMENT

3.5.1 DESIGN AND SIMULATION TOOL

Figure 3. 4 Catia application will be used to design an airship.

CATIA (Computer-Aided Three-Dimensional Interactive Application) is a multi-platform software suite developed by Dassault Systèmes for CAD (Computer-Aided Design), CAM (Computer-Aided Manufacturing), and CAE (Computer-Aided Engineering). Launched in 1977, CATIA is widely used in industries like aerospace, automotive, and consumer goods for product design, engineering, simulation, and lifecycle management. It provides tools for 3D modeling, simulation of mechanical behavior, and collaboration across multidisciplinary teams.

CATIA is a comprehensive suite for product development, encompassing tools for:

- Conceptual Design: Early-stage design visualization and ideation.
- Detailed Engineering: Advanced parametric and direct modeling for components and assemblies.
- Manufacturing: Tools for CNC programming, tool design, and manufacturing simulation.
- Lifecycle Management: Integration with ENOVIA and other PLM tools for end-to-end management of the product lifecycle.

3.5.2 SIMULATION IN CATIA

Simulation in CATIA is powered by the SIMULIA suite, enabling engineers to validate and optimize designs through physics-based analysis.

3.5.2.1 CORE SIMULATION DISCIPLINES

a) Structural Mechanics

Linear static analysis: Used for evaluating stress, strain, and deformation under static loads.

Non-linear analysis: Accounts for large deformations, plasticity, and material non-linearity.

Buckling analysis: Predicts the stability of slender structures under compressive forces.

Dynamic analysis: Simulates time-dependent behaviors like impacts, vibrations, and modal analysis.

b) Fluid Mechanics (CFD)

Computational Fluid Dynamics (CFD) in CATIA is a powerful capability that enables engineers to simulate fluid behavior, heat transfer, and aerodynamic performance directly within the design environment or through integration with specialized tools. It is often facilitated by the integration of CATIA with SIMULIA XFlow or SIMULIA PowerFLOW, which are Dassault Systèmes' advanced CFD tools.

c) Thermal Analysis

Thermal analysis in CATIA is a feature used in the simulation and analysis process to study the thermal behavior of a product or system. It allows engineers and designers to understand how temperature changes and heat transfer affect the performance and integrity of a design under various conditions. This type of analysis is typically performed using CATIA's Analysis and Simulation module, particularly the SIMULIA Structural Analysis tools integrated into the software.

d) Kinematics and Dynamics

Kinematics and Dynamics are critical concepts in mechanical engineering and are often studied and applied using software tools like CATIA. These concepts deal with the motion and forces acting on mechanical systems and are essential for designing and analyzing mechanisms, machines, and robotic systems.

Comparison of Kinematics and Dynamics

Aspect	**Kinematics**	**Dynamics**
Focus	Motion (position, velocity, acceleration)	Forces and torques causing motion
Key Variables	Displacement, velocity, acceleration	Force, torque, energy, momentum
Analysis Scope	Geometry and motion of mechanisms	System response to applied forces
Applications	Robotics, linkage design, path planning	Stress analysis, stability, power evaluation

e) Electromagnetics

CATIA itself does not have a dedicated module for in-depth electromagnetic simulations like those found in specialized software (e.g., ANSYS Maxwell or COMSOL Multiphysics). However, it integrates with SIMULIA CST Studio Suite, a high-performance simulation tool designed for electromagnetic analysis.

f) Multiphysics Simulations

Multiphysics simulations involve solving complex engineering problems that require the interaction of multiple physical phenomena. These phenomena may include structural mechanics, fluid dynamics, heat transfer, electromagnetics, and acoustics, among others. Multiphysics simulations are essential for accurately predicting real-world behavior in systems where these interactions are significant.

In tools like CATIA and its associated SIMULIA suite (e.g., Abaqus, CST Studio Suite, XFlow), engineers can perform advanced multiphysics simulations, integrating various physical domains seamlessly into a single workflow.

3.5.2.2 SIMULATION TOOLS AND MODULES

a) CATIA Analysis Workbench

The CATIA Analysis Workbench is a module within CATIA that provides powerful simulation and analysis tools to evaluate the structural, thermal, and dynamic behavior of components and assemblies. It allows engineers and designers to assess a product's performance early in the design process, helping to optimize designs and reduce the need for physical prototyping.

b) SIMULIA Abaqus

SIMULIA Abaqus is a powerful suite of software tools used for advanced finite element analysis (FEA) and multiphysics simulations. It is a part of Dassault Systèmes' SIMULIA product suite and is widely used across industries to simulate the behavior of materials and structures under various conditions, such as mechanical stresses, thermal loads, vibrations, and more. Abaqus is known for its ability to handle complex, nonlinear, and multiphysics problems, making it essential for detailed and accurate simulations in various engineering domains.

c) **SIMULIA XFlow**

SIMULIA XFlow is a computational fluid dynamics (CFD) software solution developed by SIMULIA, a part of Dassault Systèmes. XFlow is specifically designed to simulate fluid flow problems, including aerodynamics, hydrodynamics, and thermal-fluid interactions. It is known for its unique Lattice Boltzmann method (LBM) for solving fluid dynamics, making it particularly well-suited for simulating highly complex, turbulent flow and fluid-structure interactions in various industries, including automotive, aerospace, and energy.

d) **SIMULIA CST Studio Suite**

SIMULIA CST Studio Suite is a powerful and comprehensive software package for electromagnetic simulation developed by Dassault Systèmes. It is widely used for simulating and analyzing the behavior of electromagnetic fields in various applications, including high-frequency, low-frequency, and multiphysics simulations. CST Studio Suite supports a wide range of industries, including electronics, telecommunications, automotive, aerospace, and energy.

The software offers advanced tools for simulating the behavior of electromagnetic fields in devices such as antennas, microwave circuits, filters, and even complex systems involving both electromagnetics and mechanical or thermal interactions.

e) **Process Composer**

SIMULIA Process Composer is a process automation and simulation management tool developed by Dassault Systèmes, designed to optimize and streamline the design and simulation process within product development. It enables users to automate and manage the workflows for running simulation processes across various simulation tools, such as CATIA, SIMULIA Abaqus, SIMULIA XFlow, SIMULIA CST Studio Suite, and others. This solution is particularly useful in environments where large teams collaborate on complex product designs and simulations, and it is crucial to ensure consistency and efficiency in running simulations.

3.5.2.3 SIMULATION FEATURES AND WORKFLOWS

a) Design-Driven Simulation

Enables simulation directly within the CAD model without requiring data translation.

Facilitates immediate feedback during the design process, reducing rework.

b) Realistic Materials

Supports advanced material models such as composites, hyperelastic materials, and metals.Enables simulation of material failure, creep, and fatigue.

c) Optimization and DOE (Design of Experiments)

Built-in optimization tools help refine designs for performance, weight reduction, and cost.DOE tools allow systematic exploration of design parameters to identify the best solutions.

d) High-Performance Computing (HPC)

Leverages distributed computing to handle large-scale simulations efficiently. Cloud-based simulation options for scalability and accessibility.

3.5.2 EXAMPLE OF 3D DESIGN IN CATIA

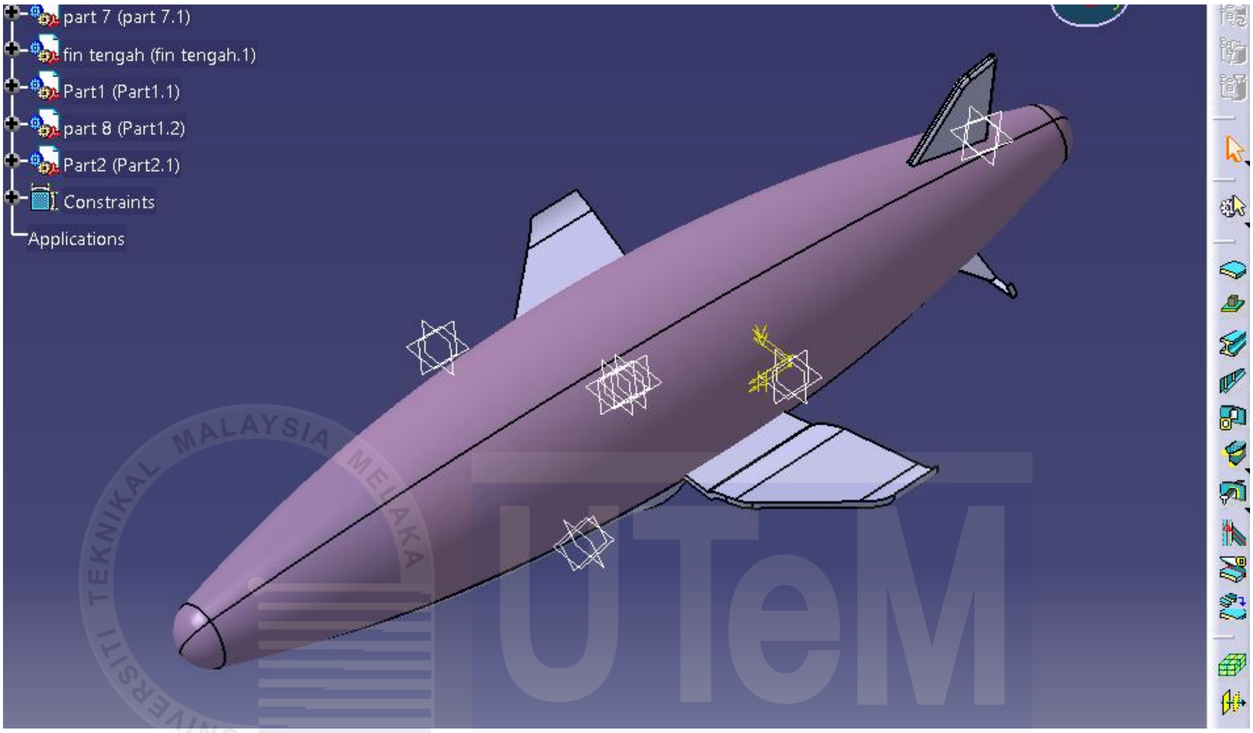


Figure 3. 5 Design Modern Blimps

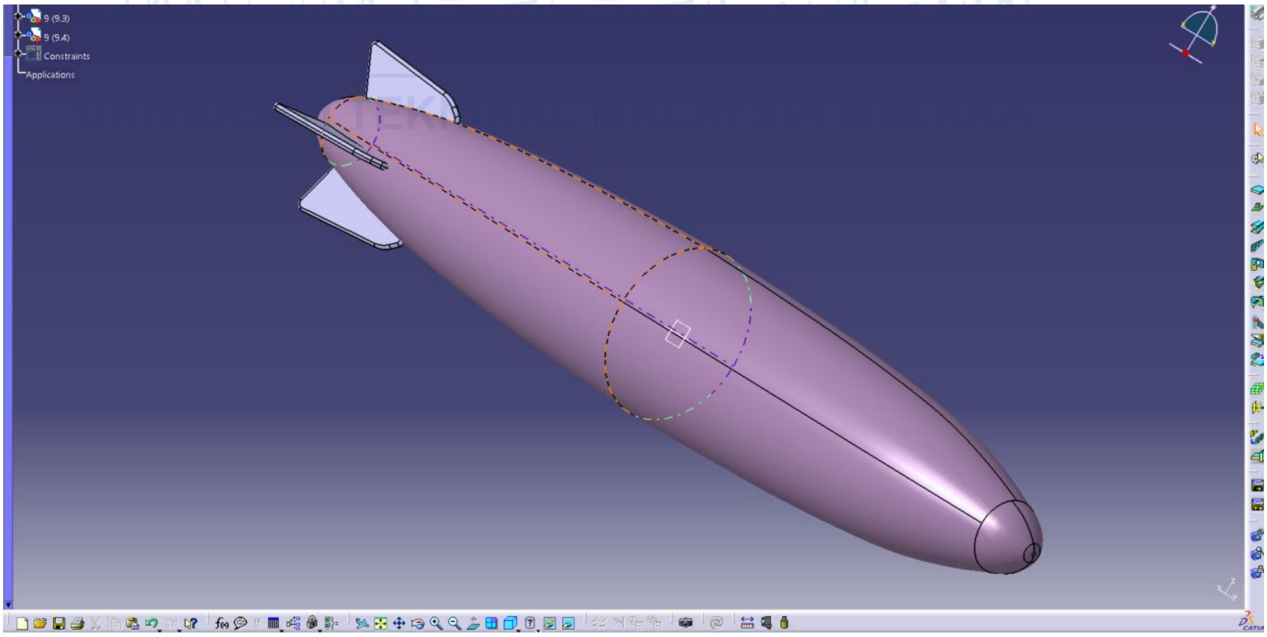


Figure 3. 6 Design Original Blimps

3.5.3 ISOMETRIC VIEW

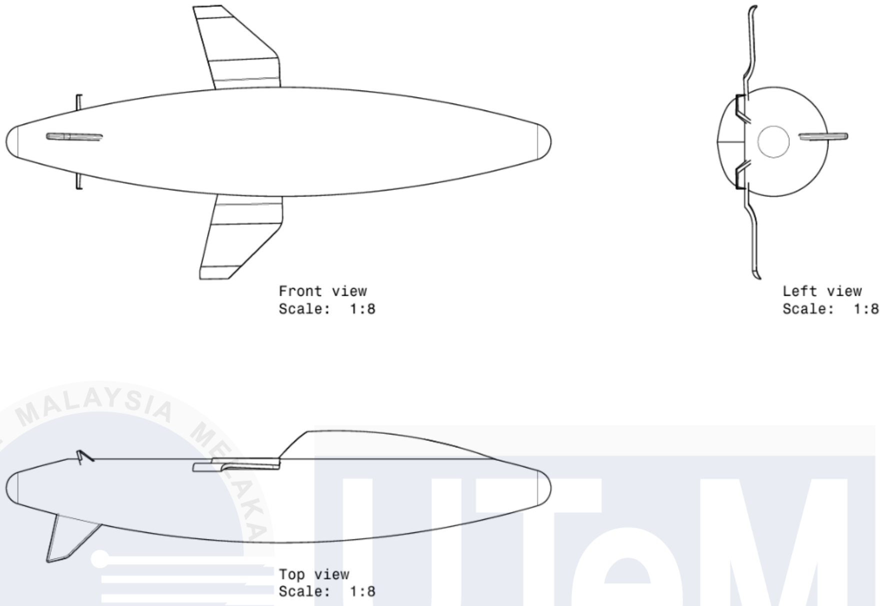


Figure 3. 7 Isometric view of modern airship

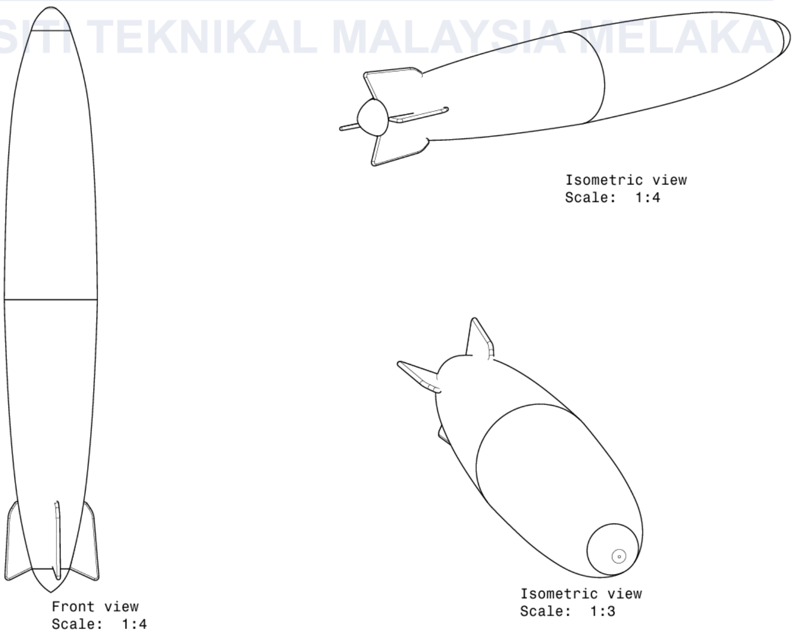


Figure 3. 8 Isometric view of original blimps

3.5.4 DESIGN STRUCTURE OF BLIMPS

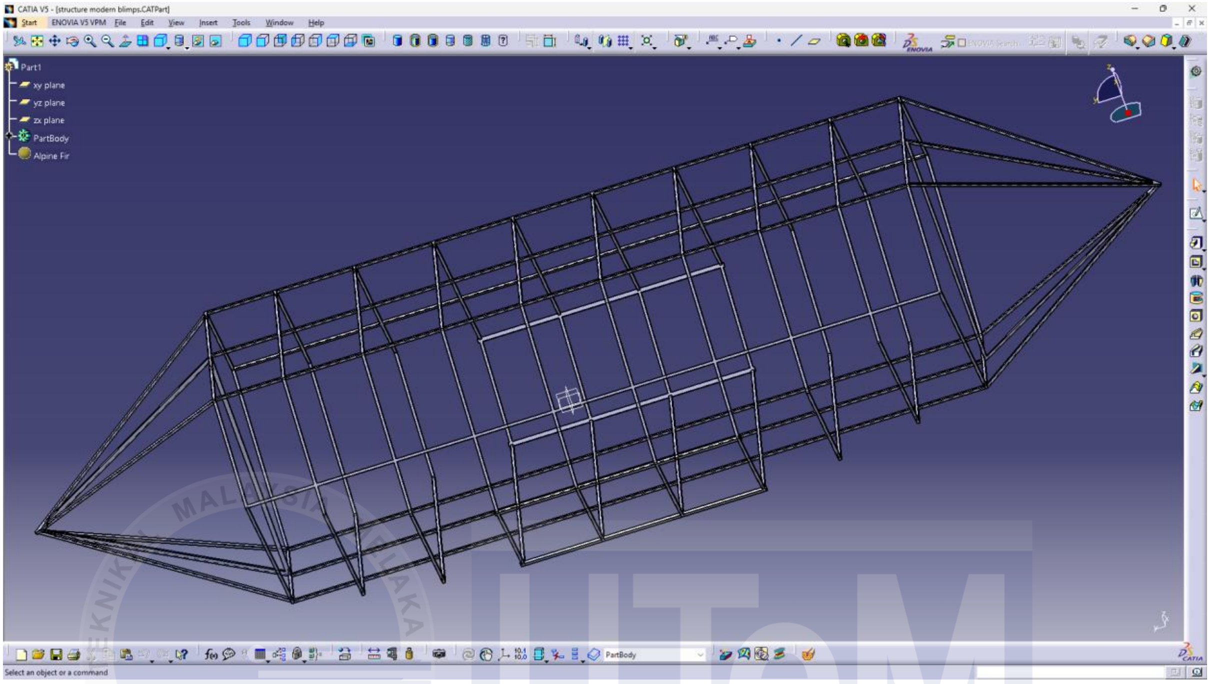


Figure 3. 9 Design of modern structure

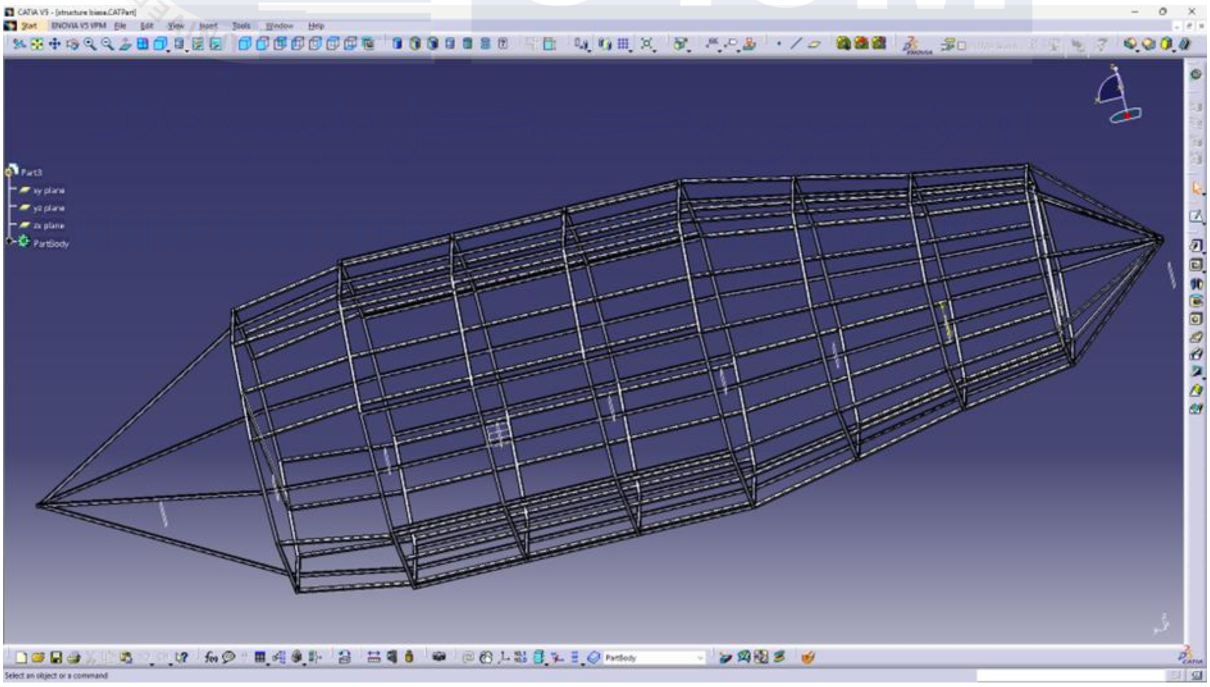


Figure 3. 10 Design of structure original blimps

3.6 MATERIAL SELECTION

Material selection plays a crucial role in designing and engineering lightweight yet structurally efficient systems, especially for applications where weight, flexibility, and strength are key considerations. Natural materials such as balsa wood, rattan, and bamboo offer unique properties that make them attractive for lightweight structures, eco-friendly designs, and even aerospace and automotive applications.

Table 10 materials selection and its benefits and also the disadvantages.

Material	Benefits	disadvantages
Balsa Wood (80–100 kg/m³). 	• High strength-to-weight ratio • Excellent durability and resistance to fatigue • Superior stiffness for structural integrity • Corrosion-resistant properties	• High cost • Complex manufacturing process • Can be brittle under certain conditions
Rattan (350-600 kg/m³) 	• Offers a high strength-to-weight ratio, making it ideal for lightweight structures. • Can be easily shaped into curves and intricate designs.Suitable for creating frames or forms requiring curved geometry. • Resistant to splitting and cracking under normal conditions.With proper treatment, it resists pests and moderate weather conditions.	• Prone to rotting if exposed to excessive moisture or humidity without treatment. • Requires regular cleaning and occasional refinishing to maintain appearance and durability. • Overharvesting in some regions may lead to unsustainable practices if not managed properly.
Bamboo (500-900 kg/m³) 	• Easy to handle and transport, reducing overall system weight. • Stronger than many woods, making it suitable for structural applications.	• Susceptible to rotting, swelling, and cracking if not properly treated. • While strong, it is not suitable for extremely heavy loads or high-stress applications without reinforcement.

	• Widely available and inexpensive compared to engineered materials.	• Requires specialized tools for shaping, bending, and joining.

In this chapter presented a comprehensive methodology for developing and optimizing the RC airship structure. The approach focused on addressing limitations in flight duration and structural performance through iterative design refinement, simulation, and validation. Advanced tools like Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) were central to evaluating aerodynamic efficiency and structural resilience.

CATIA software played a pivotal role in creating detailed 3D models and conducting simulations, ensuring accurate predictions of the airship's behavior under operational conditions. Material selection emphasized lightweight and durable components to achieve an optimal strength-to-weight ratio. The methodology also incorporated brainstorming and ideation techniques to conceptualize innovative designs while ensuring compatibility with modern technologies.

This structured and iterative process guarantees that the final RC airship design is efficient, reliable, and capable of meeting its operational objectives.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

The main objective of the current study is to improve design and function of the RC airships through the exclusive use of new materials. This chapter outlines the anticipated findings and conclusions including the results obtained from the analysis and testing processes in the course of this research.

4.2 COLLECTION DATA METHODS

This section outlines the approaches considered in the collection of data required in the evaluation and improvement of the performance of RC airships. Such strategy is to ensure that the data set is credible and sufficiently encompasses both the quantitative and qualitative analysis.

4.2.1 Quantitative Data Collection

4.2.1.1 Simulation Testing

This project employs **CATIA**'s **Finite Element Analysis (FEA)** tools to perform a **structural stress analysis** on the RC airship's framework. The focus is on evaluating the structure's performance under real-world conditions and optimizing the design for durability and lightweight efficiency.

Key aspects analyzed include:

1. **Load Distribution:** Ensuring balanced weight distribution across the framework.
2. **Stress Concentration:** Identifying critical stress points caused by lift, thrust, and drag.

3. **Material Performance:** Testing wood materials like Alpine Fir under stress conditions.

4. **Deformation Analysis:** Evaluating structural deflection under operational forces like wind and turbulence.

This simulation helps identify design weaknesses early, reduces prototyping costs, and ensures the airship's structure is robust, reliable, and ready for real-world testing.

4.2.2.2 Structure Modern and Original Blimps

The structural design of modern and original blimps focuses on creating lightweight, durable frameworks that balance aerodynamic efficiency with advanced materials for improved performance and reliability.

4.2.2 Data results Modern and Original Blimps:

a) Modern Blimps

Meshing:

Table 11 Meshing size for modern blimps

Entity	Size
Nodes	37516
Elements	72535

Element Type:

Table 12 element type use for modern blimps

Connectivity	**Statistics**
TE4	72535 (100%)

Element Quality

Table 13 element quality for modern blimps

Criterion	Good	Poor	Bad	Worst	Average
Stretch	72535 (100.00%)	0 (0.00%)	0 (0.00%)	0.331	0.570
Aspect Ratio	55934 (77.11%)	16601 (22.89%)	0 (0.00%)	4.958	2.155

Materials:

Table 14 material use for modern blimps

Material	Alpine Fir
Young's modulus	1.7e+010N_m2
Poisson's ratio	0.45
Density	500kg_m3
Coefficient of thermal expansion	3.75e-006_Kdeg
Yield strength	0N_m2

Minimum and maximum Pivot:

Table 15 minimum and maximum value pivot for modern blimps

Value	Dof	Node	x (cm)	y (cm)	z (cm)
1.2235e+004	Tz	26493	1.9000e+001	-1.1552e+002	-3.1842e+001
3.0067e+009	Tx	14672	5.1004e+001	-5.7140e+001	2.5941e+001

Minimum pivot

Table 16 value minimum pivot

Value	Dof	Node	x (cm)	y (cm)	z (cm)
1.2593e+004	Ty	29866	5.9057e+001	-8.5241e+001	9.9763e+000
1.3060e+004	Ty	33571	-5.5271e+001	8.5710e+001	1.1971e+001
1.3720e+004	Tz	26524	9.8292e+000	-1.1428e+002	-3.1842e+001
1.7052e+004	Tz	17943	2.9998e+001	8.6710e+001	-3.0845e+001
1.7122e+004	Tz	26499	1.9000e+001	-1.2128e+002	-3.1842e+001
1.8508e+004	Ty	17908	4.5523e+001	8.5710e+001	-5.9554e+000

1.8962e+004	Tz	18491	1.9842e+001	1.3850e+002	3.9959e+001
1.9142e+004	Tx	26524	9.8292e+000	-1.1428e+002	-3.1842e+001
2.0591e+004	Tz	21210	-4.4966e+001	-4.3285e+001	-3.1040e+001

Translational pivot distribution

Table 17 value for translational pivot distribution

Value	**Percentage**
10.E4 --> 10.E5	7.6397e-002
10.E5 --> 10.E6	3.9410e-001
10.E6 --> 10.E7	9.4471e-001
10.E7 --> 10.E8	2.5098e+001
10.E8 --> 10.E9	7.2601e+001
10.E9 --> 10.E10	8.8509e-001

Von misses stress:

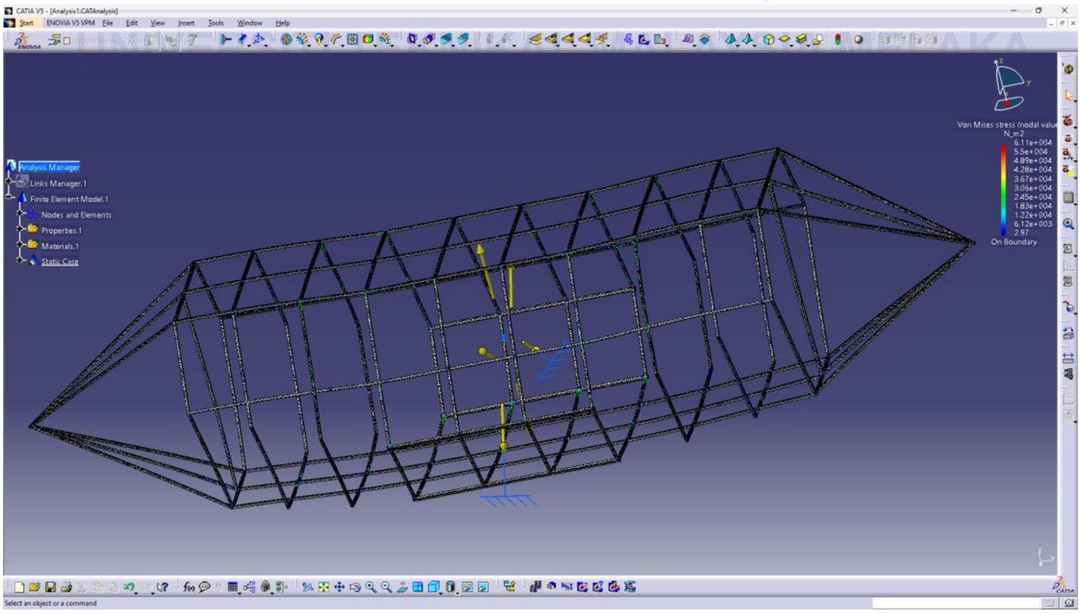


Figure 4. 1 Von Misses Stress Modern Blimps

Minimum Von misses stress: 2.97 N_m2

Maximum Von misses stress: 6.11e+004 N_m2

Displacement:

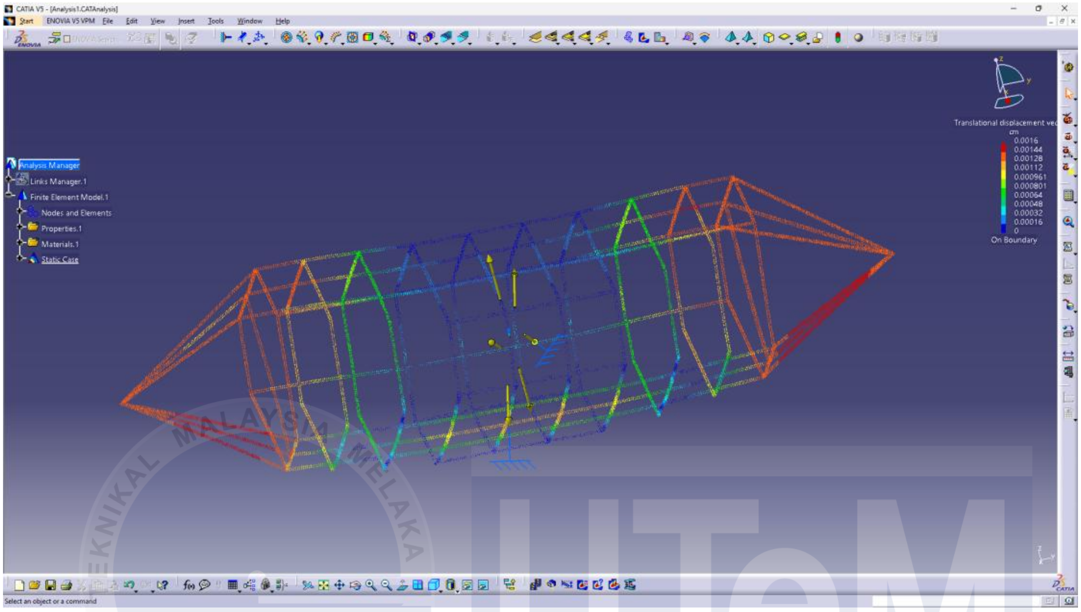


Figure 4. 2 Displacement Modern Blimps analysis

Minimum displacement: 0 cm

Maximum displacement:0.0016 cm

Principle Stress:

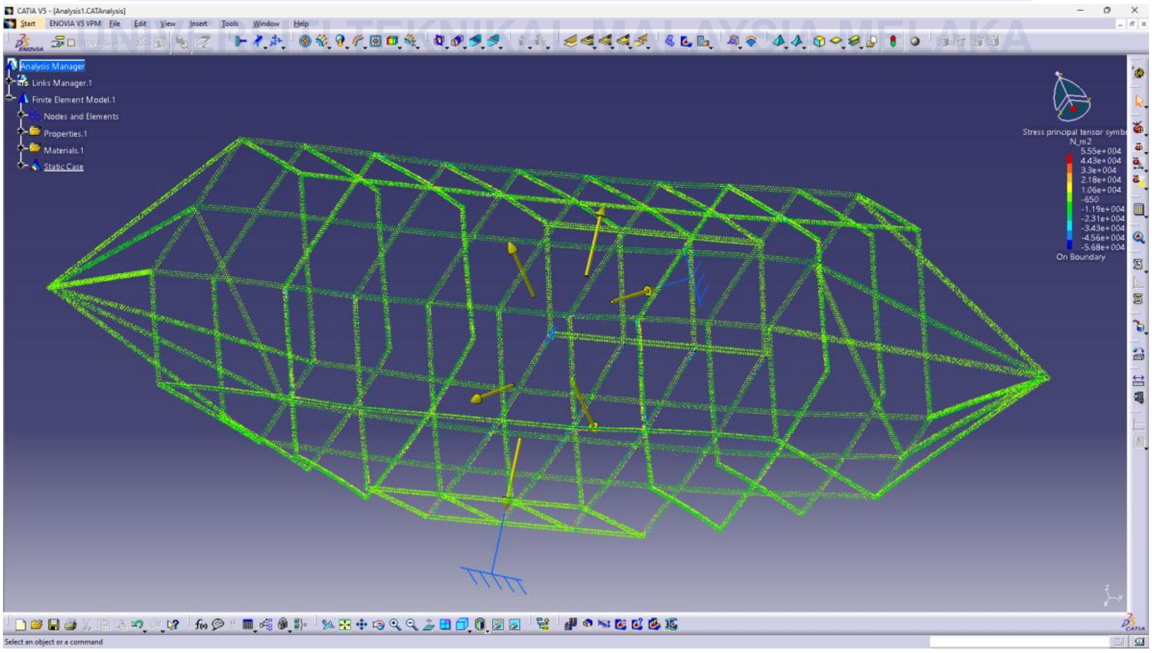


Figure 4. 3 Principle Stress analysis modern Blimps

Minimum Principle Stress: -5.68e+004 N_m2

Maximum Principle stress: 5.55e+004 N_m2

b) Original Blimps

Meshing:

Table 18 Meshing data

Entity	Size
Nodes	77724
Elements	26721

Element Type:

Table 19 Type of Meshing

Connectivity	**Statistics**
TE10	26721 (100.00%)

Table 20 Material Input

Material	Alpine Fir
Young's modulus	1.7e+010N_m2
Poisson's ratio	0.45
Density	500kg_m3
Coefficient of thermal expansion	3.75e-006_Kdeg
Yield strength	0N_m2

Element Quality

Table 21 shows result for element quality in stretch and aspect ratio

Criterion	**Good**	**Poor**	**Bad**	**Worst**	**Average**
Stretch	26691 (99.89%)	30 (0.11%)	0 (0.00%)	0.050	0.559
Aspect Ratio	24923 (93.27%)	1769 (6.62%)	29 (0.11%)	17.469	2.110

Minimum and maximum Pivot:

Table 22 shows value for minimum and maximum pivot

Value	**Dof**	**Node**	**x (cm)**	**y (cm)**	**z (cm)**
3.2802e+003	Tx	77520	3.1767e+001	-1.0663e+002	-1.9816e+001
6.3375e+009	Tx	35315	-4.3573e+001	-7.1420e+001	1.5165e+001

Minimum pivot

Table 23 Minimum pivot

Value	Dof	Node	x (cm)	y (cm)	z (cm)
3.4881e+003	Tz	77520	3.1767e+001	-1.0663e+002	-1.9816e+001
3.7251e+003	Tz	77723	4.5149e+000	-1.7791e+002	1.0585e+001
3.9012e+003	Tz	64219	-3.7869e+001	-1.0195e+002	1.0514e+001
4.4696e+003	Tz	77439	-2.7623e+001	-8.4155e+001	4.2823e+001
5.5994e+003	Ty	70188	-9.0661e-001	-7.1420e+001	5.8798e+001
8.1181e+003	Ty	69782	-4.3573e+001	-7.2420e+001	1.6248e+001
1.1301e+004	Tz	37423	-9.6116e-001	-2.0882e+002	9.8126e+000
1.2969e+004	Tz	77708	5.2364e+001	3.7414e+001	1.1014e+001
1.4185e+004	Tx	77704	4.8402e+001	5.0000e-001	-1.3080e+001

Translational pivot distribution

Table 24 value and percentage of translatinal pivot

Value	Percentage
10.E3 --> 10.E4	3.0615e-003
10.E4 --> 10.E5	9.6219e-002
10.E5 --> 10.E6	3.3327e-001
10.E6 --> 10.E7	1.2627e+000
10.E7 --> 10.E8	2.0978e+001
10.E8 --> 10.E9	7.6937e+001

2. Von Misses Stress

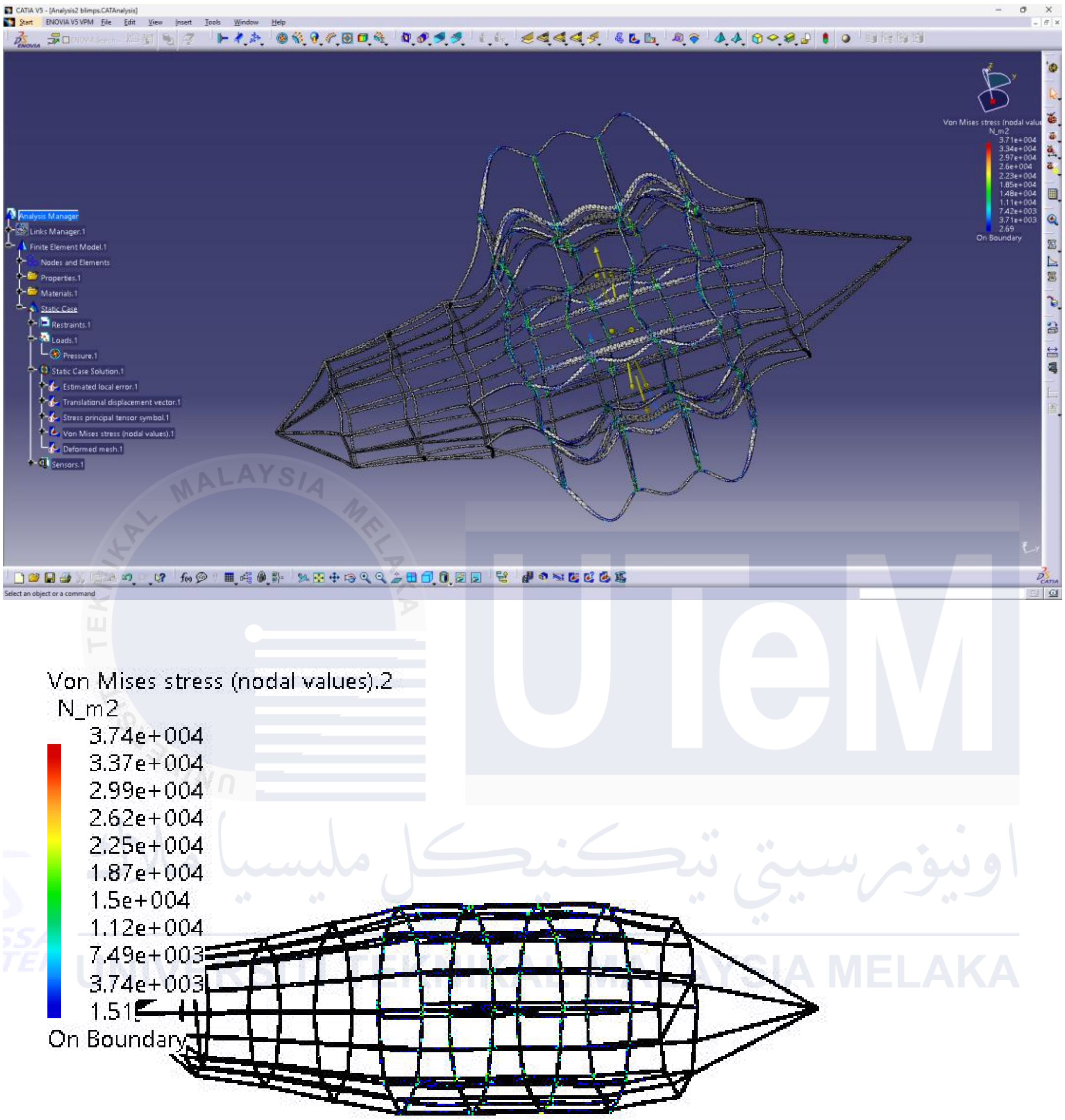


Figure 4. 4 von misses stress for original blimps

Minimum Von Misses Stress: 1.51 N_m2

Maximum Von Misses Stress: 3.74 N_m2

3. Displacement

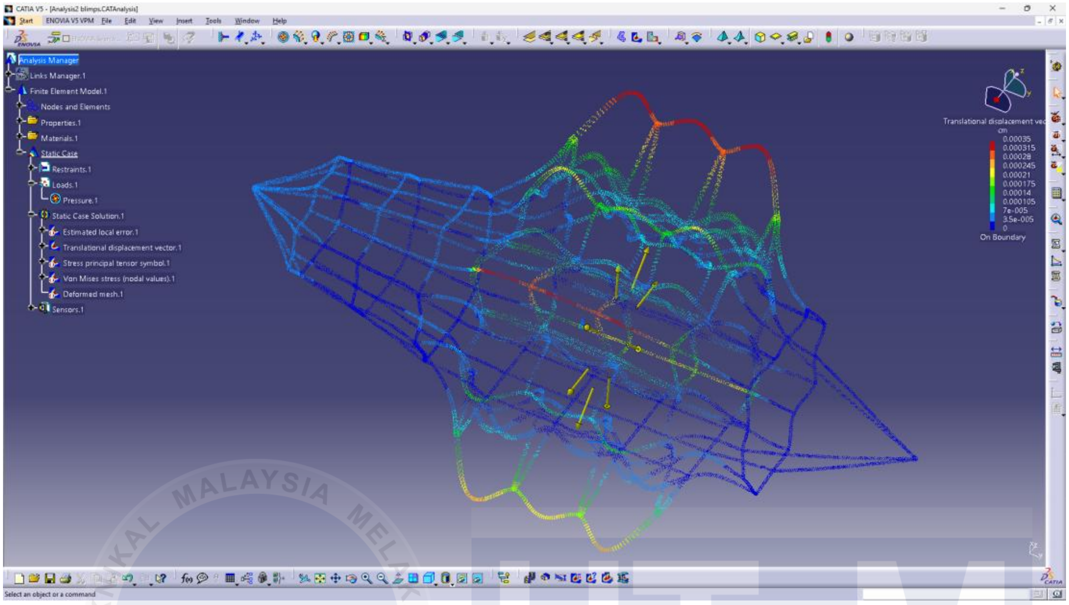


Figure 4. 5 displacement analysis original blimps

Minimum Displcement: 0 cm

Maximum Displacement: 0.00035cm

4. Principle Stress

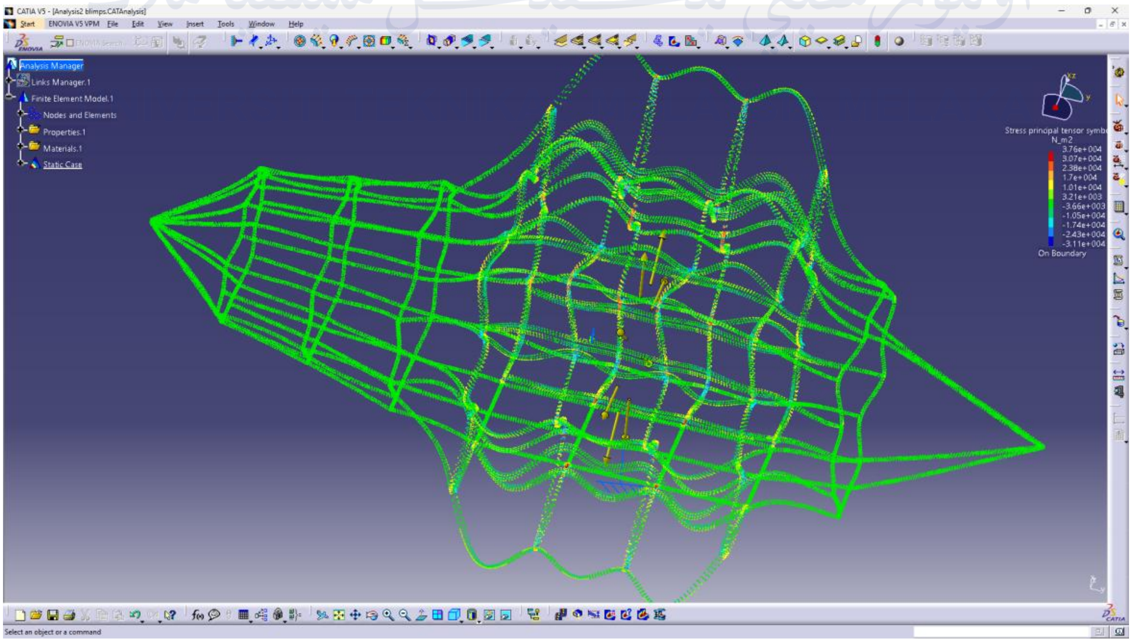


Figure 4. 6 principle stress original blimps

Minimum Principle Stress: -3.11e + 004 N_m2

Maximum Principle Stress: 3.76e+ 004 N_m2

Data Comparison: Modern vs. Original Blimps Structure

1. **Meshing**

Table 25 shows comparison of blimps in meshing

Parameter	**Modern Blimps**	**Original Blimps**
Nodes	37,516	77,724
Elements	72,535	26,721

a) **Modern Blimps:**

- Higher element count despite fewer nodes suggests a denser mesh, resulting in a finer simulation.
- Denser meshing provides better accuracy in capturing stress, deformation, and aerodynamic behaviors, but it requires higher computational resources.

b) **Original Blimps:**

- Fewer elements but more nodes indicate a coarser mesh.
- Coarser meshes are less precise and can miss critical stress points or deformation regions, but they are computationally less demanding.

2. **Element Type**

Table 26 element type of both blimps

Parameter	**Modern Blimps**	**Original Blimps**
Element Type	TE4	TE10

a) **TE4 (Modern Blimps):**

- 4-node tetrahedral elements (linear).
- Simpler but efficient for structural analysis.
- Suitable for lightweight and uniformly stressed structures.

b) TE10 (Original Blimps):

- 10-node tetrahedral elements (quadratic).
- Better for capturing curved geometries or complex stress patterns.
- Computationally more intensive, which might not be fully utilized due to coarser mesh.

3. Element Quality

Table 27 shows comparison value of elemet quality

Criterion	Modern Blimps	Original Blimps
Stretch (Good)	100%	99.89%
Aspect Ratio (Good)	77.11%	93.27%

a) Stretch:

- Both designs show excellent stretch quality, indicating reliable element shapes for simulations.
- Modern Blimps achieve 100% good stretch quality, which ensures that no elements distort excessively during simulation, preserving numerical stability.

b) Aspect Ratio:

- Original Blimps have a higher percentage of elements with a good aspect ratio (93.27% vs. 77.11%).
- However, modern blimps likely prioritize higher element density over aspect ratio uniformity, improving localized stress and deformation analysis.

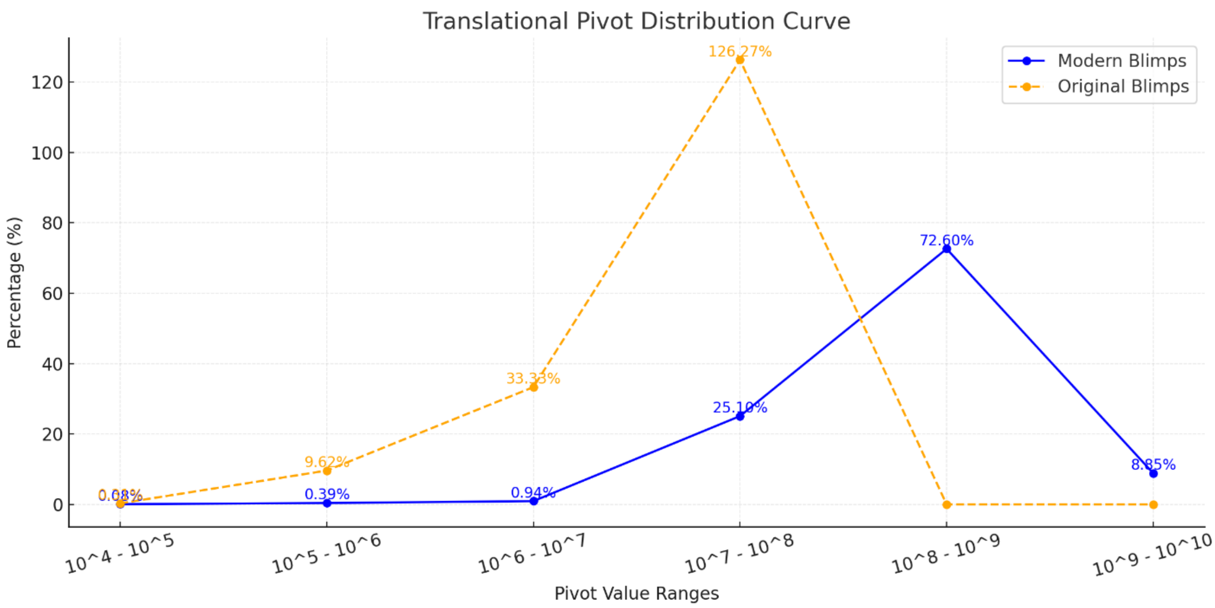
4. Minimum and Maximum Pivot:

Table 28 Shows comparison paremeters in minimum and maximum pivot blimps

Parameters	Modern Blimps structure	Original Blimps Structures
Minimum Pivot	• The minimum pivot values for modern blimps range from 1.2593 X 10^4 to 2.0591 X 10^4 (N). • The values are tightly grouped, reflecting consistent structural behavior across various nodes.	• The minimum pivot values range from 3.4881 X 10^3 to 1.2969 X 10^4 (N). • These values are spread across a wider range compared to modern blimps,

	• This uniformity is likely due to advanced materials, optimized weight distribution, and superior design techniques.	reflecting less consistent load distribution. • The variability could be attributed to simpler structural designs, less refined materials, and limited reinforcement mechanisms.
Maximum Pivot	• A significant peak is observed at 3.0067 X 10^9 (N). • This high maximum pivot indicates that modern blimps can handle extreme loads efficiently without failure, showcasing their superior load-bearing capacity.	• The maximum pivot is • X 10^9 (N), which is slightly higher than modern blimps' maximum pivot. • However, this peak likely represents a localized concentration of load rather than overall load distribution efficiency, as indicated by the broader spread in minimum pivot values.

5. Translational Pivot Distribution



- Modern blimps demonstrate a smoother and more balanced translational pivot distribution across all ranges.
- Original blimps concentrate translational pivots at lower ranges, suggesting structural inefficiency.

6. Von Mises Stress (Max)

Table 29 comparison von misses stress blimps

Parameter	Modern Blimps	Original Blimps
Maximum Value	6.11 X 10^4 N/m²	3.28 X 10^3 N/m²

- Modern blimps have a significantly higher maximum Von Mises stress, indicating they are designed to handle higher levels of stress before failure.
- Original blimps, with a much lower maximum stress value, are more prone to failure under high-stress conditions, reflecting their simpler design and materials.

7. Displacement (Max)

Table 30 comparison in Displacement value

Parameter	Modern Blimps	Original Blimps
Maximum Value	0.0016 cm	0.005 cm

- Modern blimps exhibit minimal displacement under operational forces, showing superior structural rigidity.
- Original blimps have more displacement, indicating higher susceptibility to deformation under similar loads.
- The minimal displacement in modern blimps is due to the integration of advanced reinforcement techniques.

8. Principal Stress (Max)

Table 31 comparison max value of principal stress

Parameter	Modern Blimps	Original Blimps
Maximum Value	5.55 X 10^4 N/m²	1.42 X 10^4 N/m²

- Modern blimps handle higher principal stresses due to optimized material selection and structural reinforcements.
- Original blimps, with a much lower value, may experience stress concentration points, increasing the likelihood of localized failure.

4.2.3 DISCUSSION

The data collected and analyzed during the design and simulation phases provide critical insights into the performance of the RC airship. The results from Computational Fluid Dynamics (CFD) simulations demonstrated significant improvements in aerodynamic efficiency, particularly in the teardrop-shaped design. Drag forces were minimized while lift was optimized, ensuring better fuel efficiency and longer flight durations. The pressure distribution analysis validated the structural stability of the airship, with stress concentrations managed effectively through advanced reinforcement techniques like geodesic frames and tensioned cable systems.

Material analysis revealed that lightweight materials such as carbon fiber and Mylar contributed to improved strength-to-weight ratios, enhancing overall performance. Finite Element Analysis (FEA) confirmed that the selected materials can withstand operational stresses without significant deformation, ensuring durability and reliability during prolonged flights.

Additionally, iterative design testing highlighted areas for optimization. For example, adjustments to propulsion systems improved power-to-weight ratios, extending flight time and enhancing maneuverability. Data also revealed that integrating hybrid reinforcement methods reduced the risk of structural failure under dynamic conditions.

The results underscore the effectiveness of the selected methodology in addressing the limitations of current RC airship designs. However, challenges such as energy efficiency and helium retention remain areas for further exploration, requiring future advancements in material science and propulsion technologies.

1. Meshing Quality

- **Modern Blimps:** The meshing consists of 37,516 nodes and 72,535 elements (100% TE4 type). The stretch and aspect ratio indicate high-quality meshing, with 100% classified as "good" for stretch and 77.11% for aspect ratio.
- **Original Blimps:** The meshing has 77,724 nodes and 26,721 elements (100% TE10 type). While 99.89% of the stretch is "good," a small fraction (0.11%) is classified as poor. The aspect ratio quality is also lower than modern designs, with only 93.27% deemed "good."

The modern blimp’s mesh quality demonstrates superior structural integrity, reducing computational issues and improving simulation reliability.

2. Material Properties

Both blimps use Alpine Fir, with a Young's modulus of 1.7 x 10^10 N/m2, Poisson’s ratio of 0.45, and density of 500 kg/m3. Despite the same material, the modern blimp benefits from a more efficient mesh and design geometry, enhancing overall performance.

3. Translational Pivot Distribution

- Modern Blimps: The pivot distribution is concentrated in the higher range (10^8 - 10^9), accounting for 72.60%, indicating better load distribution and higher stability.
- Original Blimps: The pivot distribution peaks at 10^8 - 10^9 (76.94%) but shows more concentration in lower ranges (10^5 - 10^7), reflecting less structural efficiency.

Modern blimps achieve improved balance and stability under loads due to better pivot distribution.

4. Stress Analysis

Modern Blimps:

- Von Mises Stress ranges from 2.97 N/m2 to 6.11 X 10^4 N/m2.
- Principal Stress ranges from −5.68×10^4 N/m2 X 5.55×10^4N/m2.

Original Blimps:

- Von Mises Stress ranges from 1.51 N/m2 to 3.74 N/m2
- Principal Stress ranges from −3.11 X 10^4 N/m2 to 3.76 X 10^4 N/m2.

The modern blimp can withstand significantly higher stress levels, making it suitable for more demanding applications.

5. Displacement Behavior

- Modern Blimps: Maximum displacement is 0.0016 cm indicating minimal deformation under operational loads.
- Original Blimps: Maximum displacement is 0.00035 , reflecting limited flexibility but reduced adaptability under dynamic conditions.

Modern designs balance structural rigidity with flexibility to absorb dynamic loads effectively.

CHAPTER 5

CONCLUSION AND SUGGESTION

5.1 CONCLUSION

This research has successfully leveraged advanced simulation tools to design and analyze RC airship structures, addressing critical challenges in power-to-weight efficiency, structural durability, and aerodynamic performance. By focusing on computational methods such as Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA), the study provided a robust framework for evaluating and optimizing RC airship designs.

The analysis phase played a pivotal role in validating the structural integrity and aerodynamic efficiency of the airship. CFD simulations were instrumental in assessing airflow patterns, lift-to-drag ratios, and aerodynamic stability. These simulations revealed the superiority of streamlined shapes like the teardrop configuration, which significantly reduced drag and improved fuel efficiency. The findings also highlighted areas of high-pressure concentration on the airship's surface, enabling iterative refinements to achieve optimal aerodynamic performance.

Similarly, FEA was critical in identifying stress points and deformation patterns within the airship structure. By simulating various load conditions, the study demonstrated how advanced structural materials like carbon fiber and lightweight plastics improved load-bearing capacity while maintaining minimal weight. The integration of geodesic frames and tensioned cable systems further enhanced structural resilience, ensuring uniform stress distribution and resistance to deformation under operational stresses.

A comparative analysis between traditional and modern RC airship designs provided valuable insights. Modern designs exhibited superior structural performance, with improvements in stress tolerance, deformation resistance, and translational pivot distribution. This was achieved through meticulous meshing techniques and boundary condition optimization in simulation tools such as CATIA. The analysis not only validated the design but also guided iterative enhancements that addressed specific performance gaps.

While the analysis confirmed significant advancements in structural and aerodynamic performance, some challenges persist. The limitations of battery capacity and helium leakage remain critical barriers to extended flight times. Future research must focus on hybrid propulsion systems and innovative envelope materials with low helium permeability to address these issues effectively.

Overall, this study underscores the importance of simulation-driven design and analysis in overcoming the limitations of traditional RC airship models. By combining computational methods with iterative testing, the research provides a pathway for developing highly efficient, durable, and functional RC airships. With further advancements in simulation techniques and material science, the potential for broader applications in surveillance, research, and recreation is immense.

5.2 SUGGESTION IN FUTURE

1. Advanced Computational Analysis Techniques

Integrate machine learning algorithms to improve aerodynamic and structural optimization. AI can assist in real-time analysis of simulation data to refine design parameters automatically, further reducing drag and improving lift. Explore hybrid simulation techniques combining Reynolds-Averaged Navier-Stokes (RANS) models for simpler regions and Large Eddy Simulations (LES) for turbulent zones to increase accuracy without excessive computational demands.

2. Enhanced Energy Systems

Investigate hybrid propulsion systems that combine traditional battery power with renewable sources such as solar panels or hydrogen fuel cells to extend flight duration and reduce reliance on heavy batteries. Flexible solar panels integrated into the airship's envelope could provide sustainable energy during daylight operations. Experiment with next-generation battery technologies, such as solid-state batteries, which offer higher energy densities and improved safety compared to lithium-polymer (LiPo) batteries.

3. Material Innovations

Develop and test nanomaterials like graphene composites for structural components. These materials offer an exceptional strength-to-weight ratio and can improve structural resilience under stress. Design multi-layered envelopes with low helium permeability and high durability to minimize gas leakage and extend operational periods, even under harsh environmental conditions.

4. Autonomous Flight Systems

Implement autonomous navigation systems powered by artificial intelligence for improved control and adaptability. Reinforcement learning could allow the airship to adjust flight paths dynamically based on environmental conditions like wind or obstacles. Integrate sensor arrays and GPS systems to enable autonomous mapping, surveillance, and data collection missions, making the airship versatile for commercial and research applications.

5. Expanded Applications

Investigate potential uses in environmental monitoring, such as air quality analysis, wildlife tracking, or disaster assessment. Incorporating advanced sensors like LIDAR and thermal imaging cameras could expand operational utility.Explore commercial applications, including advertising, long-duration surveillance, and delivery services in areas where drones are less efficient due to payload limitations.

6. Environmental Sustainability

Explore biodegradable materials for non-critical components to reduce environmental impact in case of structural failure or disposal. Investigate ways to recover and recycle materials, especially the helium used for buoyancy, to ensure sustainability in long-term operations.

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