A PROJECT REPORT

ON

DESIGN AND DEVELOPMENT OF AN INDOOR AIRSHIP (DESIGN AND FABRICATION OF TAIL FIN)

Submitted by

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In partial fulfilment for the award of the Degree

of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

Under the Guidance

of

Prof. Nawaz Motiwala

DEPARTMENT OF MECHANICAL ENGINEERING

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KALSEKAR TECHNICAL CAMPUS NEW PANVEL,

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CERTIFICATE

This is to certify that the project entitled

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfilment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

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APPROVAL OF DISSERTATION

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AE/RSP/2015/Certi/AIKTC/230415/03 **23rd April 2015**

CERTIFICATE

This is to certify that Mr. Syed Mujtaba, Mr. Shaikh Shahrukh Hussain, Mr. Advit Ghogale, and Ms. Aisha Shaikh, students of Bachelors of Engineering 2014- 2015 batch in Anjuman – I – Islam's Kalsekar Technical Campus, New Panvel have carried out sizing and fabrication of fins as part of the project titled *Design and Development of Indoor Airship*. I have regularly reviewed their progress, and they have completed this task to my satisfaction.

(Rajkumar S. Pant)

Declaration

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

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ABSTRACT

Tail fins are basically needed for providing stability and achieving manoeuvrability. The present investigation deals in finding alternatives for the ways the fin will be mounted on airship to facilitate on site attachment. There needs to be improvement in the alignment mechanism to minimise bending under aerodynamic forces. Designing the fin for portability is the new concept of research. We as a part of curriculum has to undergo the project thesis work. We have to design appropriately sized tail fin considering all the design parameters like weight, cost and strength fulfilling the requirement of a fully functional airship.

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ABBREVIATIONS

AGL	Above Ground Level
AMSL	Above Mean Sea Level
AURORA	Autonomous Unmanned Remote monitoring Robotic Airship
BHP	Brake Horse Power
ESC	Electronic Speed Controller
GNVR	G.N.V. Rao envelop Profile for airship
GSM	Gram per Mean Square
GUI	Graphical User Interface
HTA	Heavier Than Air
LTA	Lower Than Air
IC	Internal Combustion
ISA	International Standard Atmosphere
LiPo	Lithium Polymer
KARI	Korea Aerospace Research Institute
NASA	National Aeronautics and Space Administration
NPL	National Physics Laboratory
PADD	Program on Airship Design and Development
PVC	Poly Vinyl Chloride
RC	Remotely Controlled
RF	Radio Frequency
SL	Sea Level

CHAPTER 1

INTRODUCTION

1.1 Background

An Airship is a type of aerostat which can navigate through the air under its own power. They get their lift using gases which are lighter than air . Airships are the most suitable aerial platforms for advertising and surveillance, as they offer advantages such as of long endurance; ability to hover with low noise and vibrations levels and low fuel consumption [1].while most of the energy used by an airship is to propel it forward. Airships were widely used in the first half of the 20th century, for a variety of purposes, but the speed, power and glamour of conventional aircraft eclipsed the benefits of LTA vehicles for many years. Several studies are being carried out all over the world related to design, development and flight testing of unmanned, remotely operated and autonomous *airships. The proposed objective of an airship varies from their use as high altitude* platforms for the next generation of wireless communications system to transportation of large volumes over long distances. For better and safety flight many investigations have been launched worldwide to study the issues related to provision of operation capability to unmanned airships. The objective of this project is to design and fabricate a remotely controlled indoor airship that could be used for camera surveillance, security and also can be used in opening ceremony to spray flowers, chocolate etc. In the following subsections the classification, applications, and various components of an airship are explained in detail.

1.1.1 Classification of airship

There are four categories of airships i.e., Rigid, Semi-Rigid, Non-Rigid and Hot Air Airships.

Rigid Airships

As the name implies, rigid airships have an internal frame as shown in Fig1. The Zeppelins and the USS Akron and Macron are famous rigid airships[2]. The rigid structure, traditionally an aluminium alloy, holds up the form of airship. In general, rigid airships are only efficient when they are longer than 120 meters because a good weight to volume ratio is only achievable for large airships. For a small airship the solid frame would be too heavy. Use of composite materials may change this difficulty too.

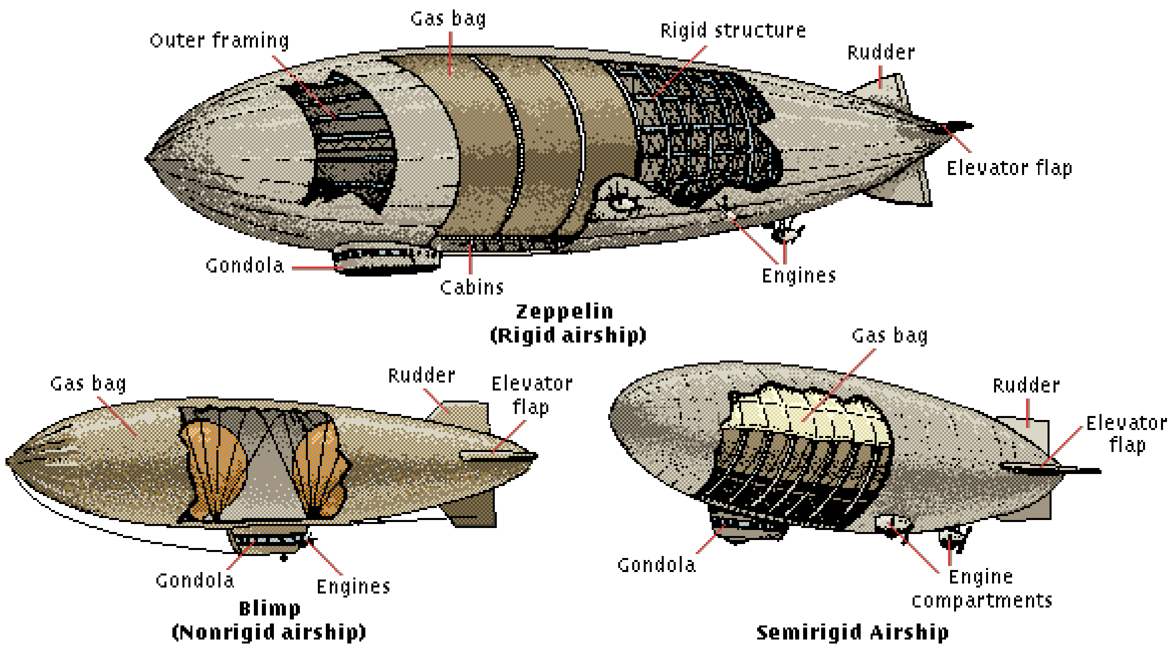

Figure 1.1 Classfiction of airships [2]

Semi Rigid Airships

Semi rigid airships are comprised of a rigid lower keel construction and a pressurized envelope above that as shown in Fig1 The rigid keel can be attached directly to the envelope or hung underneath it. The airship of Brazilian aeronaut Alberto Santos-Dumont was semi rigid [2]. One of the most famous representations of this type was Italia, the airship which General Umberto Nobile used on his attempt to reach the North Pole [2].

Non Rigid Airships or Blimps

Non Rigid airships, also known as blimps are basically large gas balloons as shown in Fig 1.1. Their shape is maintained by their internal gas pressure. The only solid part is the passenger car and the tail fins. All the airships currently flying for publicity use are of this type; the Goodyear Blimps, MetLife blimps in U.S.A, the Fuji Blimp in Europe and the Vodafone blimp in India [2]. The main advantage of this type it is very easy for transportation.

Hot Air Airships

Hot air airships, also known as thermal airships, though technically are a part of non-rigid category, are counted as fourth type. Hot air airships are derived from traditional hot air balloons. Early models were almost like balloons with an engine and tail fins added. Very soon envelopes were lengthened and the tail fins and rudder were pressurized by air from the wash of propeller. Newer hot air airships maintain their shape with internal pressure in the envelope.

1.1.2 Applications of airship

Following are the applications of airship

I. Advertising

The visual appearance of airship has always attracted the attention and the imagination of general public. This fascination with helium- filled airships creates the ultimate advertising vehicle and generates huge amount of money in revenue. As an eye in the sky, the airship provides good camera footage of outdoor events. Under special arrangements with T.V networks and cables, blimps carry the aerial camera without charge and reciprocally receive on air publicity at no cost [1].

Figure 1.2- Advertising airships [4]

II. Tourism

Figure 1.3- Airships tourism [5]

One of the most profitable and growing segments of the market where the need for the airship is more acute is tourism. There is an emerging demand to develop such an airship transport system in the commercial sector and it is considered that such a system could, in many ways, be utilized to stimulate interest in tourism and travel via lighter- than-air vehicles [1].

It can be used for scenic excursions exclusively or it can include transportation element, such as flying passengers to many attractive destinations or it could serve as inter island tourist routes, for example between the Hawaiian and Caribbean Islands without affecting the local environment. The impact of this type of travel transcends imagination [1].

Passengers in helicopters or aircrafts may enjoy comparable views but they will never experience the gentle pace of the airship, nor its spaciousness. Flight characteristics are smooth and unlikely to upset the passengers. Another surprise is the sound, or rather the lack of it. Engines can be cut for gentle and smooth ballooning over special scenic spots [1].

III. Other Civil Applications

- Aerial photography
- Forest Management
- Urban Energy Monitoring
- Hazard and Disaster Monitoring
- Industrial Heat Loss Monitoring
- Urban Planning
- Wildlife Studies
- Fire Spotting
- Soil Survey
- Pollution Monitoring
- Traffic Monitoring
- Resource Explorations

IV. Military Application

The need for improved surveillance techniques for military, government and scientific applications have increasingly led to the use of airships to meet specialized needs. Examples of operational duties performed by airships include:

- Command, control and communication Platform
- Precisely locate friendly and enemy forces
- Detect targets of an extended battlefield at minimal exposure to the enemy forces

- Real time targeting
- Navigation assistance
- Battle management
- Monitor radio conversations
- Maritime surveillance
- Border patrol /Law enforcement
- Mines detection

1.1.3 Components of airship

The major components of airship are as follows:

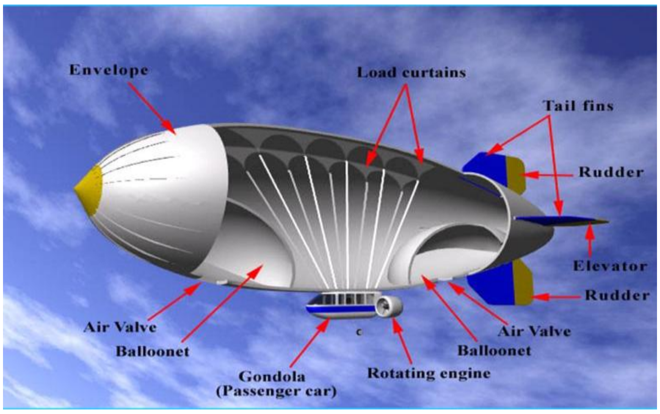

Figure 1.4 Components of Airship [6]

(a)Envelope

The envelope is the most crucial component of the airship and it integrates the aspects of aerodynamics, stability and payload. The envelope material has to be appropriately chosen to ensure adequate strength, durability, as well as low weight and ease for fabrication. There are various shapes of envelopes such as GNVR shape, a range of shapes given by NPL and Zhiyuan. It is basically a bag which holds the lighter than air gas.

(b)Gondola

It is also known as fuselage of airship. The gondola carries the airship payload and also houses the propulsion system. It is sized and designed such that it accommodates the receiver, battery package, fuel tank, engine and payload. The location for the attachment of gondola on airship must be carefully determined so as to keep the airship stable. The gondola may be an Open structure or a closed one but the design should be such that it must be as light as possible so that it does not reduce the payload capacity of the airship.

(c)Fin

Tail fins are basically lifting surfaces which provide us with the ability to steer and stabilize the motion of airship. They are the bodies of airship which helps it to be manoeuvrable. They are generally attached at the stern end of airship. They are different kinds of fins of various sizes n shapes depending upon the type of airship and requirement. Airship tail fins deflect under excessive load on axii to protect the airship hull and also reduce angles of attack to disturbing airflow. A yaw motor may be mounted to the tail fin structure to manage steering. A longitudinally elongated roller may be mounted to the lower tail fin to act as landing gear.Tail fins used may vary in number as per requirement. They may be four for outdoor airships or even one is sufficient to serve the purpose for indoor airship. There are various types of configuration of tail fins in a pattern in which the tail fin is attached on envelope.viz, plus configuration, cross configuration, inverted y configuration etc. Construction of fins may be a solid structure for big commercial airships or may be a skeleton covered with doped fabric for small indoor ships. Tail fins are generally attached on envelope on site of flight for airship after the envelope is being inflated. So the tail fins are needed to have on site attachment arrangement. While designing tail fin various parameters are to be taken into account like strength, weight, cost and reliability. The fin should have optimum strength and low weight to have high payload capacity.

(d) Propulsion System

Propulsion systems are used in airship to provide the upward, forward and side thrust to the airship. Propulsion system of the airships are housed in gondola itself, except, in some of the cases where yaw motor is used to give the direct side thrust force is attached on the fin. There are some cases in which there is only one system which gives the action of both upward and forward thrust by swiveling the motors as required through thrust vectoring mechanisms as shown in Fig1.5 while

Figure 1.5- Thrust vectoring [7]

Yaw motion of airship is achieved through the use of control surfaces on the fins as shown in Fig 1.6 or attaching a motor on the fin as depicted in Fig 1.7, which provide the direct thrust force instead of depending on aerodynamic forces.

Figure 1.6 Control surfaces fin [8]

Figure 1.7 fin with yaw motor [8]

(e) Surveillance Systems

Airships have been considered to be a highly viable airborne platform for aerial surveillance. The onboard surveillance equipment suite has to steadily focus on the desired area on the ground, from a particular altitude. The quality of the surveillance is directly related to the level of stability that the platform can offer. Hence the airborne platform must be able to hover at an altitude and stay steady without causing serious fluctuations to the dynamic surveillance data collection. The platform should be considerably inert to disturbances like crosswind, gust, wavering of the payload surveillance equipment due to maneuvering and induced vibrations by the platform itself.

(f) Power Source

Power Plant is of prime concern in the design of non-rigid airships. Design of power plant for non-rigid airship is affected by many parameters. Its sizing is primarily driven by the desired performance parameters such as max propeller speed, operating altitude, range and endurance. Other factors that affect the power plant design are engine location, symmetry of thrust, noise level, noise isolation, vibration isolation, fuel tank location. Aesthetics and ergonomics also play important role in the design process and lead to several compromises [9] The power plant may be an engine may most probably an internal combustion engine or it may be battery operated, depending upon applications and various other factors listed above.

1.2 Aim and Objective

The aim of the study is to design and fabricate indoor airship, an unmanned vehicle which could be remotely controlled. The following are the objectives which should be achieved:

- T o have an innovative design.
- To build a strong airship with light weight.
- Easy attachment and removal of gondola and fins.
- To achieve good controlling range.

1.3 Problem Definition

- To design fin for light weight.
- To develop fin to accelerate on -site attachment.
- To build mechanism to fix the alignment of fin.

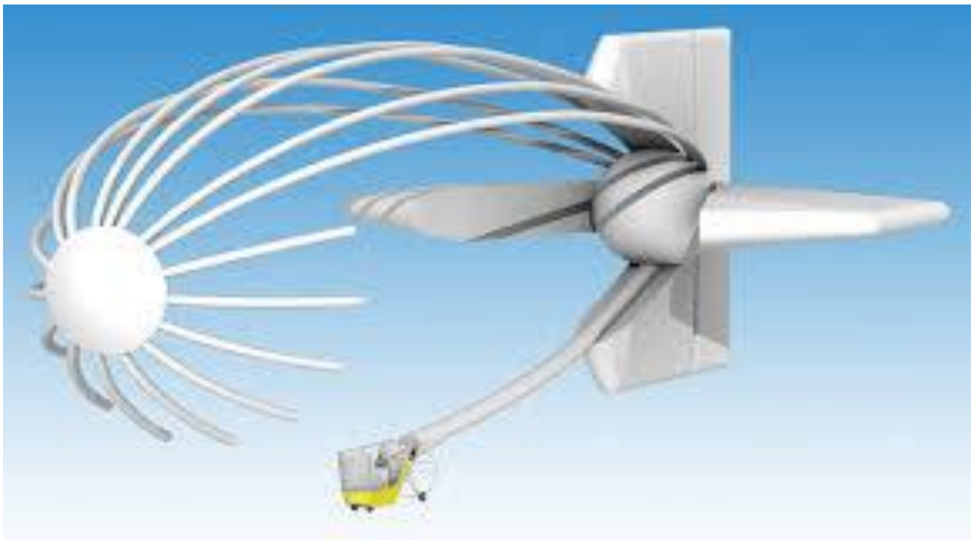

Figure 1.8 Tail Fin [13]

1.4 Scope

Scope of our present work includes :

(a) Investigating the fabrication methods of various components of existing indoor airships.

(b) Devising new methodology for providing ease in calculation for designing of various parts and manufacturing methods.

(c) Designing and fabricating the airship, at the smaller scale and thereafter at full scale.

(d) Obtaining an insight into issues related to operational capabilities and limitations.

(e) Improving on the limitations.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Review

Till now very few researchers have carried out their work in the area of design of airships. The papers which deal with the present study of interest are discussed below.

Since more than a decade, several airships have been designed, fabricated and field tested by researchers in Lighter-Than-Air systems Laboratory in Aerospace Engineering Department at IIT Bombay under PADD (Program on Airship Design and Development). Three remotely controlled airship developed here, viz.; *Micro*, *Mini* and *Macro* are shown in Fig 1.8- 1.10 respectively. A brief description of these airships is provided in the sub-sections that follow:

(a) *Micro* Airship

Gawale et al [2] gave the details of the envelope material to be selected along with the stress analysis and the fabrication of the same. *Micro* is non-rigid, Helium filled experimental aerial vehicle with envelope volume of 6.64 m^3.

Figure 2.1 Micro Airship [10]

The basic purpose of developing the *Micro* airship was to provide a first-hand exposure to issues related to airship design fabrication and operation. It also act flying platform for generation of airship design data and experimentation. The envelope material along with stress analysis and fabrication procedure for the same was considered. The design requirements specified for the *Micro* airship were very modest; it was required to have a payload capacity of 1.0 kg, while operating at a maximum speed of 30 kmph for 20 minutes, using an existing OSMG1415 IC engine, developing 0.41 BHP with a displacement of 2.49 cc. Due to constraints on storage space, it was required to be less than 5.00 m in length.

(b) *Mini* Airship

Subsequent to the successful development and flight demonstrations of *Micro* airship, the PADD team was invited by the Government of India to showcase their technology to the scientific community of India at a national science congress, and the PADD team developed the *Mini* airship for this purpose, which had an envelope volume of 8.64 m3, resulting in a payload capacity of 3.0 kg, and hence was capable of carrying out various missions, such as aerial surveillance. This airship was subsequently demonstrated at several other places.

Figure 2.2 Mini airships [10]

(c) *Macro* Airship

Vishal Chaughle et al [8] describes the methodology followed for sizing of the envelope and various key components of airships and the procedure followed for in house fabrication and testing. They also highlighted the major issues that cropped up during the operation of airship in harsh environmental conditions of rain and mild snow as well as at night time. The *Macro* airship was designed and fabricated for flight demonstration at an international symposium on Snow and Avalanches, held at Manali, India in 2009. Also validation of airship design code and testing of video downlink for the recorded video of airship was done for the same.

Figure 2.3 Macro airships [8]

A comparison of the key features of these three airships is provided in Table 2.1

Table 2.1 Comparison of mini, micro and macro airship

Parameter	Micro	Mini	Macro
Length(m)	4.99	6.42	8.0
Envelope Volume(m^3)	6.8	8.6	26.6
Payload(kg)	1.0	3.0	6.0
Endurance(min)	17	18	25
Max Speed(m/min)	7.0	10	12
Engine Power(HP)	0.41	0.6	2.0

Rajkumar S. Pant [11] has presented a methodology for arriving at the base specifications of non-rigid airship of conventional configuration. The methodology presented calculates the volume required to carry a user specified payload and also arrives at the mass breakdown. Also the Sensitivity of parameters such as pressure altitude, ambient temperature, cruising speed, helium purity level, engine power, envelope length to diameter ratio etc. to the payload available or envelope volume required using the above methodology is presented.

Gawale et al [12] presented a brief description of a methodology for sizing and baseline design calculations of an RC airship meeting some user specified requirements. The section on design in the paper provides details of the standard envelope profiles for RC airships, types of materials use for envelope and fins and their properties, basic buoyancy and aerodynamic calculations, followed by stabilizer and fin sizing, and description of the propulsion system. The section on fabrication describes the Radio Frequency (RF) sealing method for realizing the envelope and fins, and discusses important issues related to the system integration and testing.

CHAPTER 3

BASICS OF TAIL FIN

3.1Function of Tail Fin

Tail fin is a stabilizer that controls the yaw motion of airship. They deflect under excessive load on axii to protect the airship hull and also reduce angle of attack of disturbing airflow.

3.2 Terminologies of Tail Fin

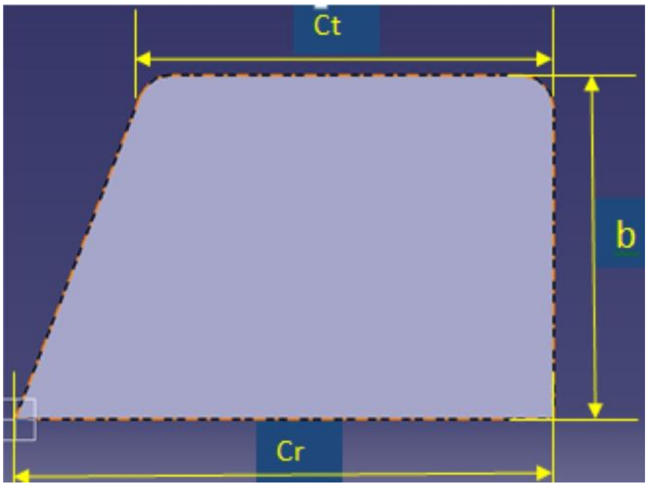

Figure 3.1 Standard Fin [14]

Before calculating the dimensions we need to first go through the terminologies of a tail fin. Above diagram demonstrates the terminologies of a tail fin.

3.2.1 Root chord (Cr): This is the base length of the fin. The fin is fixed to the envelope along its root chord.

3.2.2 Tip chord (Ct): This is the top length of the fin. Tip chord is always smaller in length than root chord.

3.2.3 Height (b): This is the vertical length of the fin and kept perpendicular to root chord.

3.2.4 Surface Area (Sf): It is the surface area of the fin. This is the most important parameter as the entire methodology of designing the fin depends on surface are of fin.

3.2.5. Fin location Length (Ls): The length at which the fin should be fixed from the nose end of envelope is the fin location length.

3.2.6. Envelope Length (L): This is the length of the envelope.

3.2.7. Surface area (Se): This is the surface area of the envelope.

3.3 Forces acting on Tail Fin

During flight an airship has to cut through air. So there are number of forces which act on the fin. The following are the two major forces acting on tail fin:

3.3.1 Aerodynamic Force

Aerodynamics forces occur when a body moves relative to air in which it is immersed. These forces are classified as steady when they are invariant with time or transient when they are not. The steady forces arise, for example, when a body is in uniform motion in a still atmosphere. Transient forces occur during maneuvers or owing to turbulence in the atmosphere. Aerodynamic forces and moments arise from local surfaces pressure, which, when integrated over the whole body, give the overall forces and moments. It is therefore necessary to determine the local pressures. The force on a very small area δA of a body is given by the product of the static pressure and δA. The application **of Newton's Law to the motion of the fluid leads to Bernoulli's equation. For a non- viscous, incompressible fluid in steady motion this takes the form:**

$$P_S + (\frac{1}{2}\rho V_S{}^2) = P_a + \frac{1}{2}\rho V^2 \qquad (3.1)$$

where, Pa is the local static pressure, Ps is the static pressure, V is the local velocity at point under investigation, Vs is velocity of the fluid far removed from the body and ρ is density of the fluid everywhere.

3.3.2 Drag

It is a force opposing the motion of the airship. In order for airship to move, it should overcome the drag force. Drag is therefore of primary importance. Also the selection of the power plant is dependent on amount of drag.

3.4 Configuration

In an airship a single fin may serve the purpose but when more number of fins is used there is a way in which they are attached. The fashions in which the fins are attached are known as its configuration. The following are few types of configuration:-

3.4.1 Plus configuration

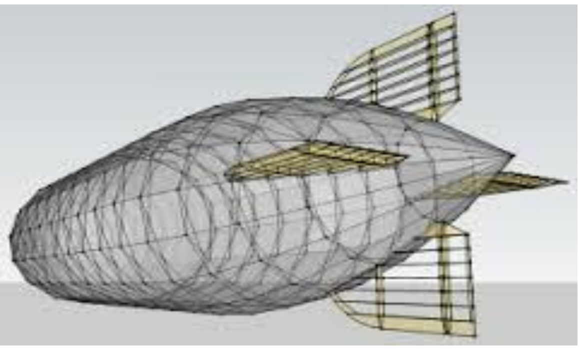

Figure 3.2 Plus Configuration [15]

3.4.2.Cross Configuration

Figure 3.3 Cross Configuration [16]

3.4.3 Y Configuration

Figure 3.4 Y Configuration [17]

For our airship we have proposed cruciform configuration i.e., plus configuration for the following reasons:-

1.Highly effective in slow speed applications: Unlike rudder and elevator construction which are ineffective in slow speed application plus type of fins uses yaw motor which enables fins to be functional at slow speeds.

2. Independent of Aerodynamic forces: Use of propeller in fins instead of control surfaces makes it independent of aerodynamic forces .Thus operation of fins completely relies on yaw motor.

3. Simple concept: It is quite easy to implement plus type of configuration as no cables or wires are tied to fins as in case of rudders n elevators. Moreover design calculations are reduced and complexities are eliminated.

CHAPTER 4

DESIGN OF FIN

4.1 Design Considerations

Before designing any engineering structure there are certain design considerations which should be listed. The structure is to be so designed to fulfil all the design aspects. The following are the few design parameters which should be considered while designing a Tail Fin:-

4.1.1 Maneuverable: The fins should be such designed that the airship can be easily steered in all directions. A controller must find easy to control the airship thus keeping simplicity in design.

4.1.2 Shape & Size: The Size and dimensions of fin depends on the surface area of the envelope. So based on statistics and size ratios fin should be appropriately sized and shaped to fulfil the purpose. The shape can be varied from triangle to any quadrilateral depending on the requirements.

4.1.3 Rigid: The fin has face to face various drag forces and bending forces. It has to bear a velocity of about 5 to 10 m/s. Thus fin should be designed to withstand these pressures. It should have enough rigidity without compromising the weight factor

4.1.4 Light weight: Increase in weight of airship components ddirectly affects the payload capacity. Thus fin should be designed for light weight selecting the lightest material considering strength.

4.1.5 Asthetics: The fin designed should be aesthetically appealing. The fin should not be dull in colour and should not have rough edges or surfaces. Smooth finished design is moat appealing.

4.2 Materials

Tail fin of airship is needed to be rigid and light weight. So as a compromise between weight and strength appropriate material must be selected. Other factor which a material must possess is its availability. A material must be easily available in the market. Material should be such selected such that it gives ease in fabrication. Material should also be classified based on cost. The cheapest material serving all the above mentioned parameters is to be chosen. The following materials were listed for our tail fins fabrication:-

4.2.1 Beech wood: This material was selected based on its strength giving the highest rigidity among all the materials. Beech wood is commonly known an ice cream sticks.

4.2.2 Polypropylene sheets: corrugated polypropylene sheets were considered because of its light weight and availability. These sheets can be easily fabricated and even gives aesthetic value.

4.2.3 Polystyrene: commonly known as thermacol which is light in weight but low strength was listed as it was cheap and available. Thermacol gave ease of fabrication and two or more sheet bounded together gave enough strength for fin.

4.2.4 PVC strips: polyvinyl chloride strips were considered for its strength.

4.2.5 Steel: light weight steel strips for skeleton of fin was proposed. Steel strips had enough strength and was reliable.

***4.2.6* Polyurethane**: polyurethane cloth for covering skeleton of fin was proposed.

4.3 Design Procedure of fin

There is no specific methodology for design of fin due to lack of availability of data. However design of fin needs control analysis which is difficult. So we need to design the fin by scaling the dimension of previously build airship's fin into ratios. The following table show the ratios as per the statistics of previously build airships:

Table 4.1 Ratios for Dimensions of Fin [14]

Parameter	Formula	Value
Tail Area Ratio	Sf/Se	0.055
Fin Aspect Ratio	b^2/Sf	0.8
Fin Taper Ratio	Ct/Cr	0.75
Span to Root Chord Ratio	b/Cr	0.62
Fin Location Ratio	Ls/L	0.78

4.3.1Design Calculations

With help of statistical values given in table no.3 an example of designing procedure is given below:

1. Tail Area ratio = Sf/ Se =0.055 (Se=13.102sqm given)

0.055 = Sf/ 13.102

Sf=0.72061sq.m

2. Fin Aspect Ratio = b^2/Sf = 0.8

0.8 = b^2/ 0.7206

b =0.7594 m

3. Span to root chord Ratio = b/ Cr =0.62

0.62= 0.7594/Cr

Cr= 1.22m

4. Fin Taper Ratio = Ct/Cr =0.75

0.75=Ct/1.22

Ct=0.915m

5. Fin Location Ratio = Ls/L = 0.78

0.78= Ls/4

Ls= 3.12m

4.4 Prototypes

To check the viability of the materials various test were conducted. Under these tests various prototypes were made and tested. The following are the prototypes of fin of different materials, size and shape:-

4.4.1 Beechwood fin

Figure 4.1 Beechwood Fin

Skeleton of tail fin was made of beech wood i.e., ice cream sticks as shown in the above diagram. The idea behind this was to build a rigid structure and cover this skeleton with cloth or paper of different material such as polyurethane or kite paper. The fin was checked for weight where it weighed 80 Gms. The fin proved stable under forces with slight buckling which was negligible.

4.4.2 Polystyrene fin

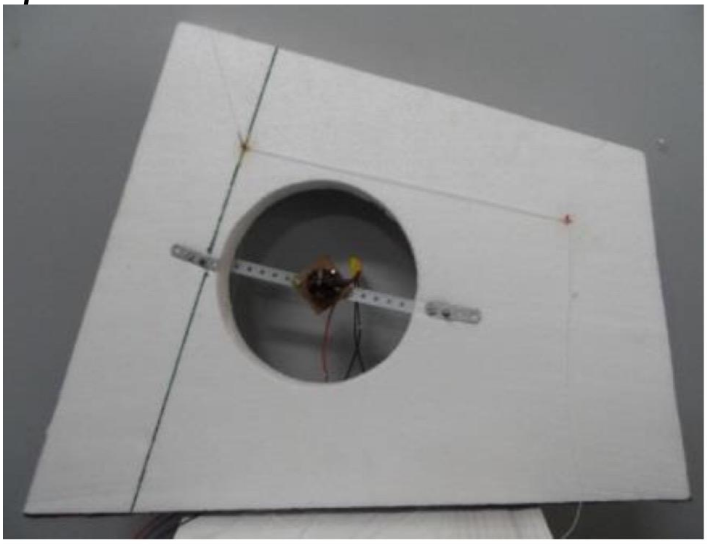

Figure 4.2 Polystyrene Fin

Entire fin structure was made of thermacol sheet. This fin was the lightest less than 50 Gms but was not reliable under forces and bending. However this fin proved useful where the incorporation of yaw motor was a task. A small hole could be made in the polystyrene sheet to fix the yaw motor. Major problem associated with thermacol fin was its transport. The fin is needed to be handled with care as there are chances of breakage.

4.4.3 Straw fin

Figure 4.3 Straw Fin

A series of polypropylene straws were woven together to have a strong rigid structure of fin. The advantage of this fin was the cylindrical shape of straw as cylindrical surfaces can stand high forces. This fin weighed more than 100gms so the weight factor of this fin was a major concern. Moreover reliability was less and to introduce yaw motor was a difficult job.

4.4.4 Pvc fin

Figure 4.4 PVC Fin

PVC strips were used to build the skeleton of fin which was to be further covered by kite plastic. Under test the fin faced buckling and failed to stand forces. Moreover the weight of the structure crossed 90gms.

4.4.5 Beech wood fin in triangular form

Figure 4.5 Triangular Fin

Considering the weight factor of previous fin, experiment was made to change the shape of fin giving the skeleton a triangular truss. The fin was equilateral triangle having triangular trusses inside. The fin deflected under force tests but weighed 70gms which was a good outcome of change in shape.

4.4.6 Polypropylene fin

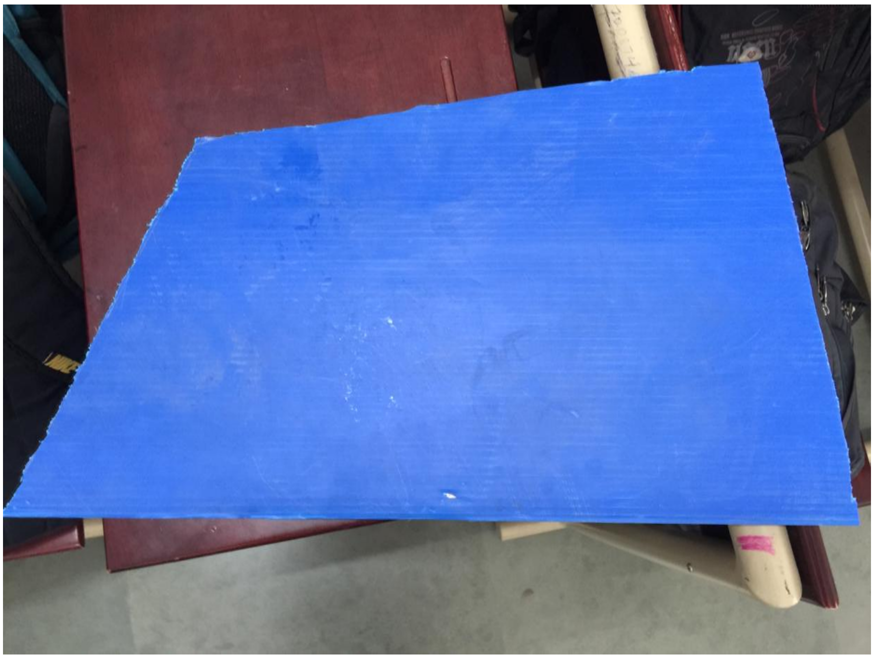

Figure 4.6 Polypropylene Fin

A polypropylene corrugated sheet was used to make fin. Corrugation gave cushioning effect which proved useful as the fin could take the forces easily. The fin was rigid enough and could be easily transported on site. The fin weighed 90gms which was acceptable based on other favourable factors.

4.4.7 Polypropylene fin (portable type)

Figure 4.7 Portable Fin

The entire fin was made from corrugated sheet then the fin was cut into vertical parts as shown in diagram. A thread was passed through these each parts through the corrugation. When the thread was pulled the parts used to get self aligned resembling the original fin. The idea was to make the fin portable so that it could be easily transported on site.

Table 4.2 Comparison of prototypes

No.	Type of Fin	Weight (gms)	Strength
1	Beechwood Fin	80	High
2	Polystyrene Fin	45	Low
3	Straw Fin	104	Medium
4	PVC fin	98	Low
5	Triangular Fin	70	Medium
6	Polypropylene Fin	90	High
7	Portable Fin	96	Medium

4.5 Attachment mechanism

Designing the fin is the initial job but to place that fin on the envelope of airship is a major job. Mechanisms are to be build to mount the fin on airship. The attachment mechanism must be light in weight and reliable. It must hold the fin strongly and should not affect the alignmnet.The mechanism should facilitate the onsite attachment of fin thus saving time. Various types of attachments are discussed further:-

4.5.1Male female steel strips type attachment

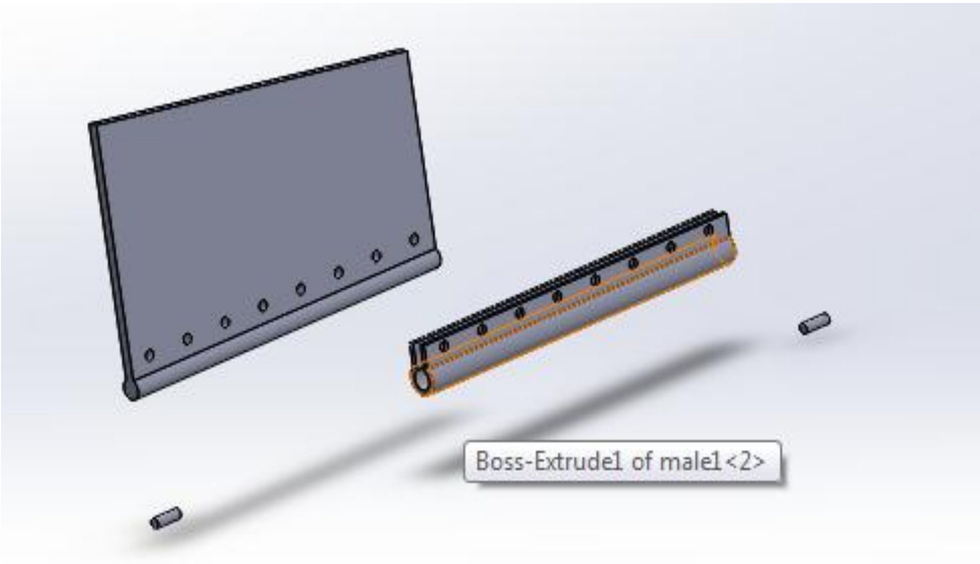

Figure 4.8 Male Female Type

In this type of attachment the female part which is steel strips will be fixed on the envelope whereas the fin which is a male part itself will have holes at its base. The fin will be placed on the female part and they will be locked with help of locking pin. After placing the fin on female part the holes of both the parts will coincide and then the locking pin will be passed through the holes.

4.5.2 Lock type attachment

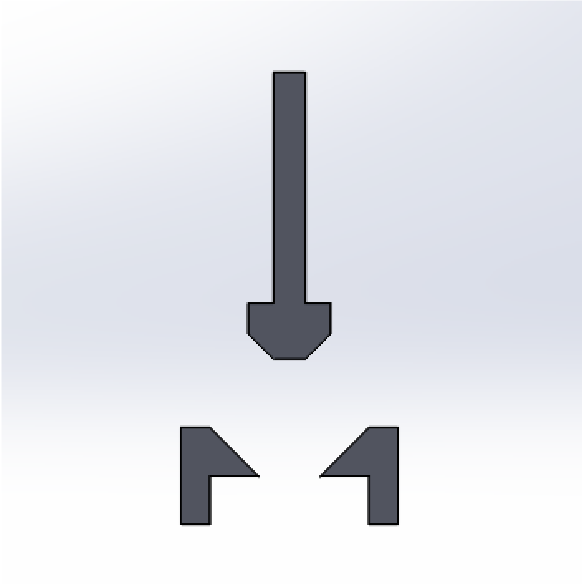

Figure 4.9 Lock Type

In this type of attachment, there is locking mechanism on the envelope. The base of the fin will be thick as shown in diagram. When the fin will be press fitted in the attachment on envelope it will get locked.

4.5.3Straw attachment

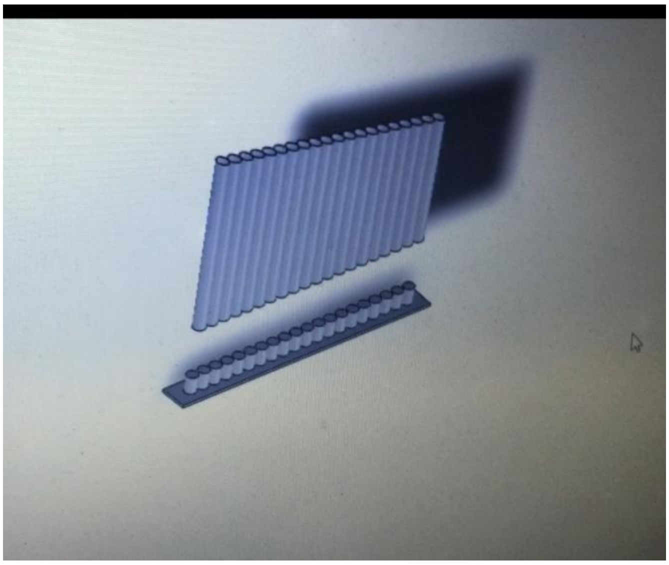

Figure 4.10 Straw attachment

This attachment was specially built for straw fin in which there would be cylindrical projections on envelope. This series of projections will go inside the hollow series of straws and will get fixed.

4.5.4 Velcro type attachment

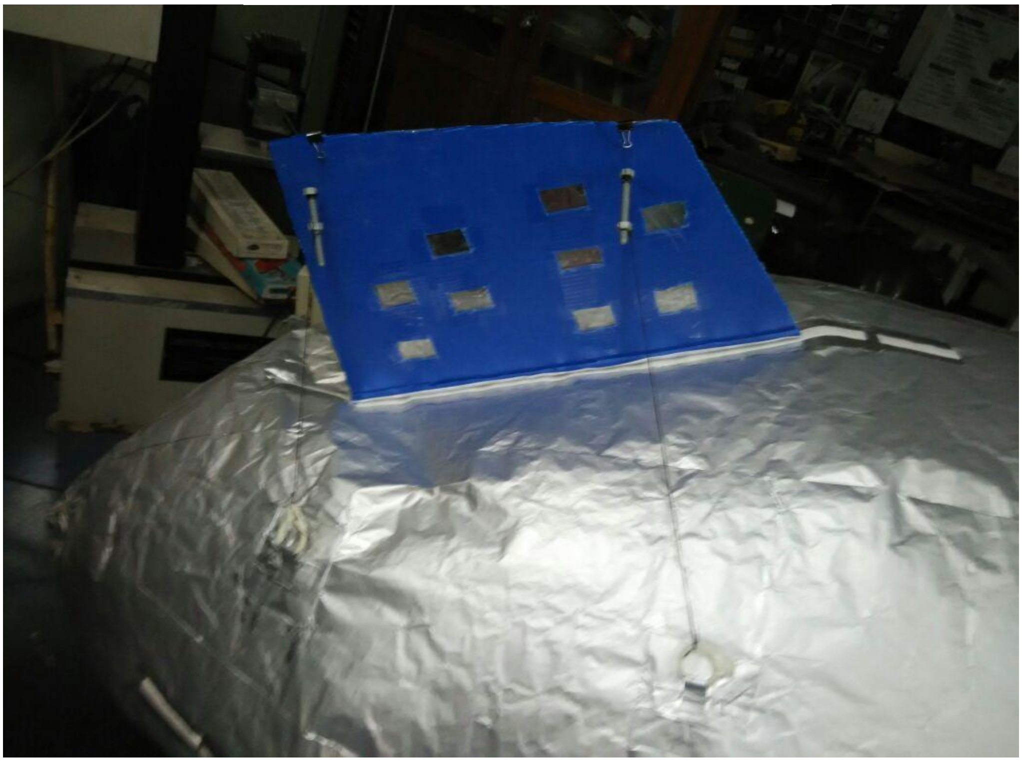

Figure 4.11 Velcro Attachment

In this type of attachment one part of Velcro will be stitched on a patch of material which would be further RF welded on envelope. The other part of Velcro will be glued to base of fin. The fin then will be gently placed on the envelope by sticking of Velcro this fulfilling the purpose. This attachment is most reliable and easy having lightest weight than all other attachments.

4.6 Innovation

It is often seen that after attachment of fin on the envelope the fin experiences bending even though it may be rigid and strong. It is thus difficult to maintain alignment of fin. So presently engineers tie strings from both sides of fin tangentially to the envelope. However it is difficult to maintain tension in the string. It takes lot of time on site to align fin with help of strings so as to maintain correct tension. Our group have come up with a solution to this problem by introducing a nut bolt arrangement in between the strings. We have used a long bolt which will have string tied to it at its head. The other end of string will be tied to the fin

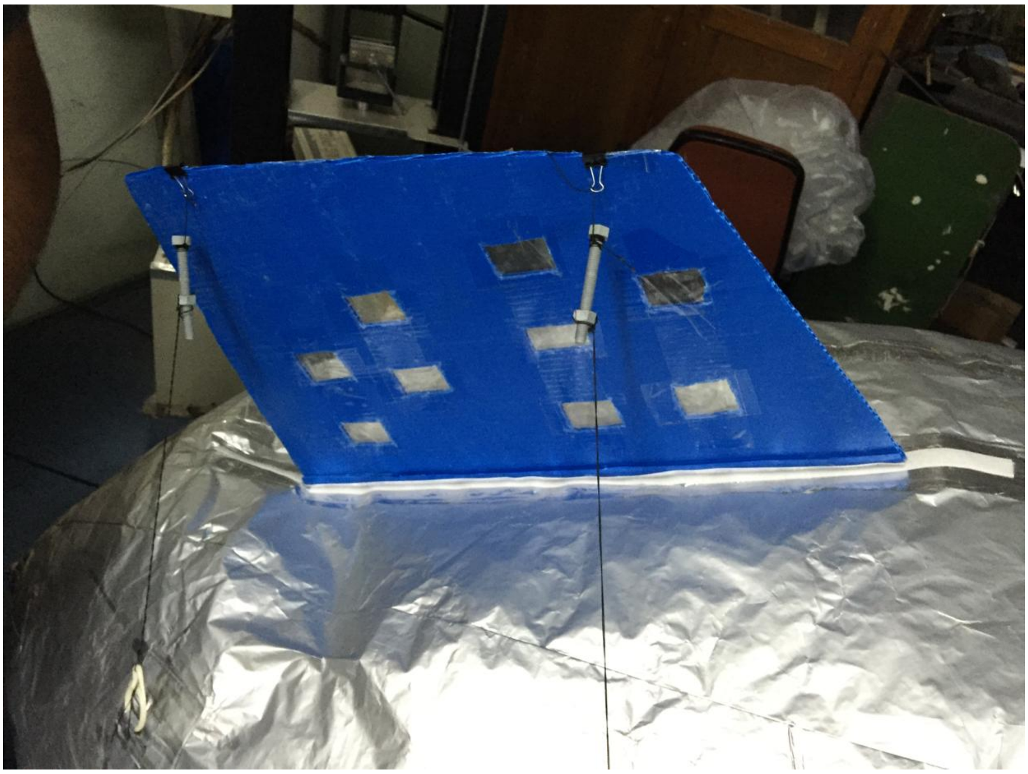

Figure 4.12 Nut Bolt arrangement for alignment

with help of clips mounted on fin. Nut tied with string will be placed at the base threads of bolt while the other side of string will be tied to the envelope with suitable arrangement. Movement of nut on bolt will help to bring tension in the spring thus aligning the fin with respect to horizontal or vertical axis.

4.7 Yaw Motor

One of the basic functions of fin is to control yaw motion of airship. Thus the steering of the airship is done by means of yaw motor. This yaw motor is fitted on the lower vertical fin at an offset from the centroid horizontally. Yaw motor is generally a brushless dc motor which works bidirectionally. Blades are provided which are later fitted on the yaw motor and the entire assembly is then fitted on the gondola. Varying the speed of the motor in clockwise or anticlockwise direction directs the airship in particular direction. The motor gets its power from the battery placed in the gondola. The speed controller of the motor is also placed with battery in the gondola and a long wire connection is made from gondola to fin.

Figure 4.13 Yaw Motor in Air Fin [14]

CHAPTER 5

FABRICATION

5.1 Fabrication of fin

After several tests on the prototypes and considering the requirements of the tail fin design we have selected propylene fin of corrugated sheet to go with for fabrication. This fin had the most simplicity in design and fabrication. It was the most successful in strength and rigidity test. We further worked on the fin for lowering its weight for which we created rectangular slots in the fin by cutting out from the fin. This helped us to reduce the fins weight by around 10-12 gms .As we needed plus configuration of fins in our airship we were supposed to fabricate four fins of which three fins were simple and the fourth one was suppose to have a 8 inch circular hole to accommodate the yaw motor. We calculated the dimensions of the fins based on the methodology discussed further. As per the dimensions we cut out the fin from the polypropylene sheets. The fin was ready in shape and size. Further we needed to fix Velcro on the fin whose size was 1inch but the width of the fin was 1.5cm. Thus we had to make the base of the fin wide for this purpose we glued two long strips 1 inch in height along the base of the fin. Eventually we glued the one side of Velcro on the base of the fin as shown in figure.

Figure 5.1 Fin selected for fabrication

5.2 Development of Attachment

We needed to have a strong attachment which will hold on the fin even under strong aerodynamic forces. We wanted an easy mechanism which will facilitate on site mounting of fin for this purpose we chose Velcro attachment as it was most simple and catered all the requirements. The Velcro was supposed to be fixed on the envelope at the right position so that when the fin is brought on it the Velcro gets adhered to the other part of it on the fin thus holding the fin. To fix the Velcro on the envelope is a difficult task. It was not advised to fix the Velcro directly on the envelope as the envelope material is very delicate and carelessness in fixing the Velcro may cause pores on the envelope resulting in leakage. Thus we stitched the Velcro on the long patch of same material as that of the envelope leaving clearance of both side of the Velcro. We further welded the patch on the envelope by RF heating. In this way the attachment was ready as shown in the figure.

Figure 5.2 Attachment Mechanism with Velcro on envelope and fin

5.3Alignment Mechanism

After fixing the fin on the envelope with help of attachment it is seen that the fin suffers bending. So to align the fin and prevent bending we have to tie string to the fins from both sides of the fin to the envelope tangentially. To tie string to the envelope some provision should be there on the envelope. In our case we fixed plastic rings on the envelope of 1inch size. Initially we welded the ring on the patch which was further RF heated on the envelope. To tie string on the fin we needed a light weight arrangement on the fin so we used plastic clips which were fixed on the fin. When fin was aligned by string tied to the envelope, we faced the difficulty in maintaining the tension in the string. For this purpose we introduced a nut bolt arrangement between the strings. By tightening the nut on the bolt the tension in the string could be maintained thus giving proper alignment of fin.

Figure 5.3 Plastic nut -bolt

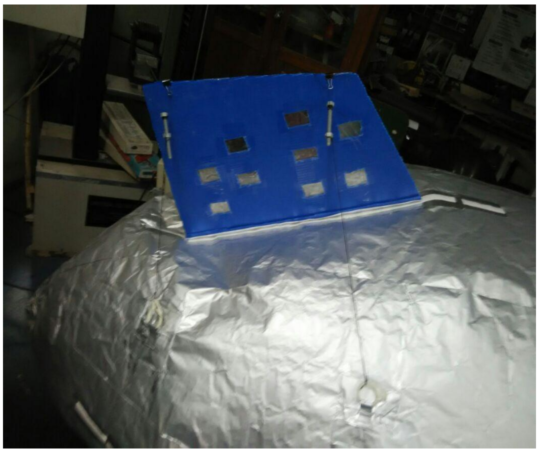

Figure 5.4 View of alignment mechanism

5.4 Assembly and Working

On- site before flight at the time of assembly, initially we have to place the fin on the envelope at the point where the other side of Velcro is fixed. The fin should be carefully adhered to the envelope. Further we have to tie string containing nut to the ring fixed on the envelope. The string containing bolt should be tied to the clip on the fin. Further the nut should be screwed on the bolt. The nut should be rotated on the bolt until tension is achieved in the fin. Such strings should be tied on both side of the fin. Each fin should have four strings two on each side, in all four strings to get strong alignment. Wire connections should be carefully done from yaw motor of fin to the batteries in gondola. The yaw motor along with blades should be fixed on the fin by small screws and nut.

At the time of flight during operation, the yaw motor is controlled by a remote controller which has a provision of rotating the motor in both directions. When the rotor moves anticlockwise it generates force perpendicular to the direction of rotation. This force yaws the airship which results in left or right turn. The intensity of force controls the angle of steer. Force is varied with help of speed controller.

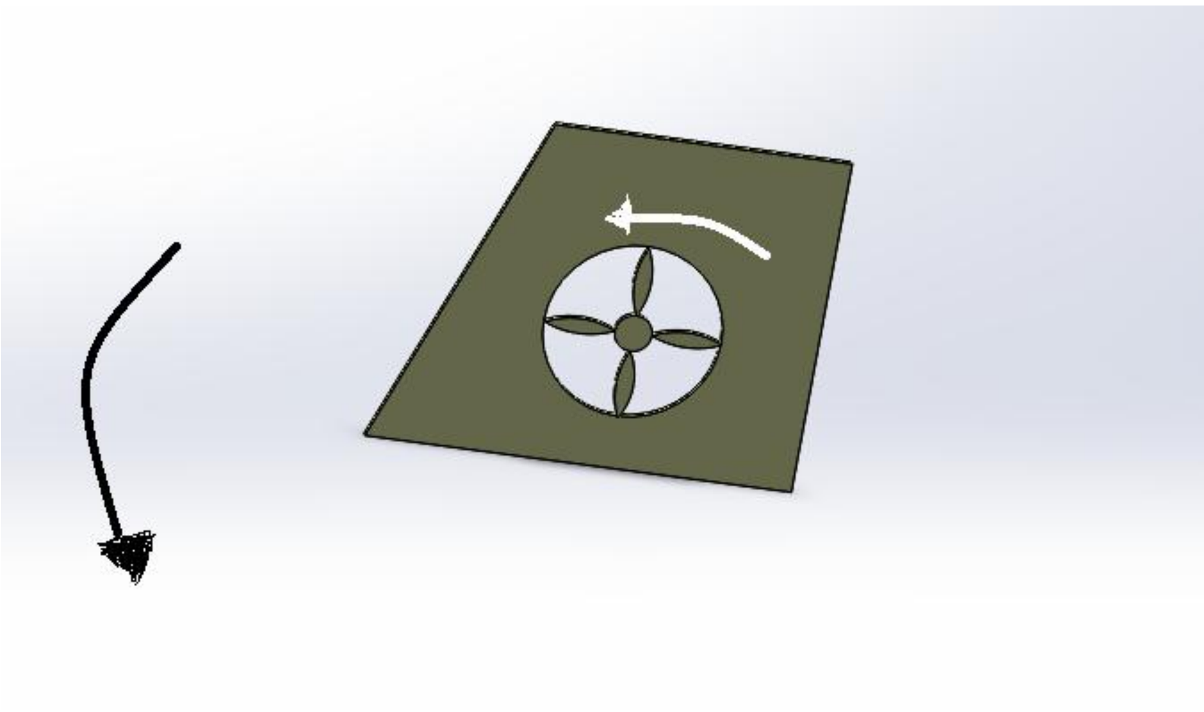

Figure 5.5 Steering Mechanism

CHAPTER 6

VALIDATION

6.1Finite Element analysis

To check the reliability and feasibility of our design we checked the fin virtually by finite element analysis. For this purpose we used the analysis and modelling software AutoCAD Inventor 2015. We modelled the fin as per our dimensions on the software and analysed it for bending to check the effect of drag force on the fin. The results obtained are shown in the following diagram.

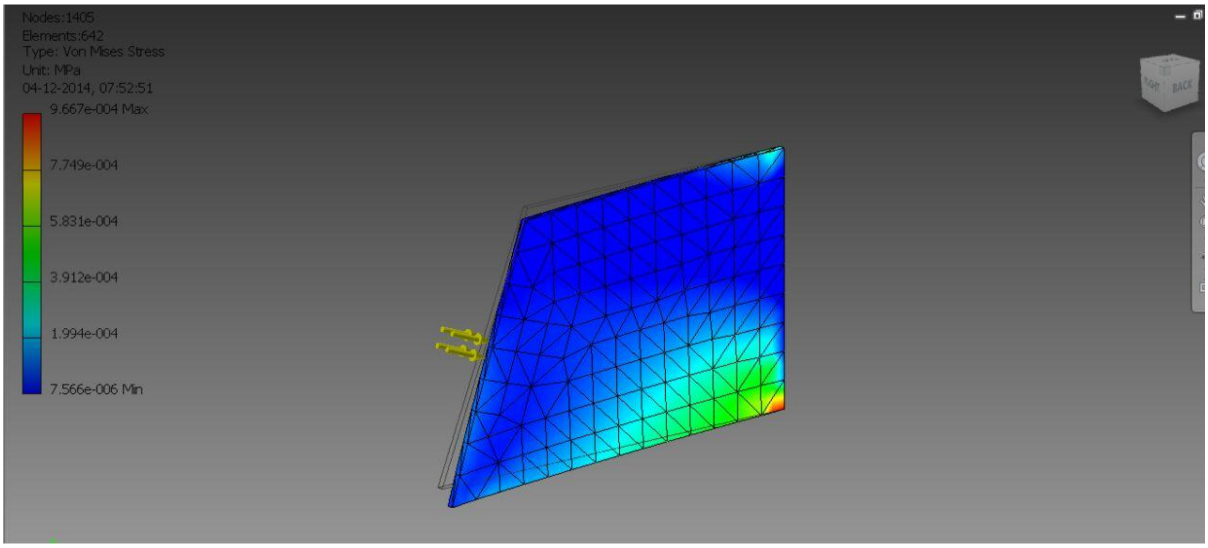

Figure 6.1 Von Mises stress

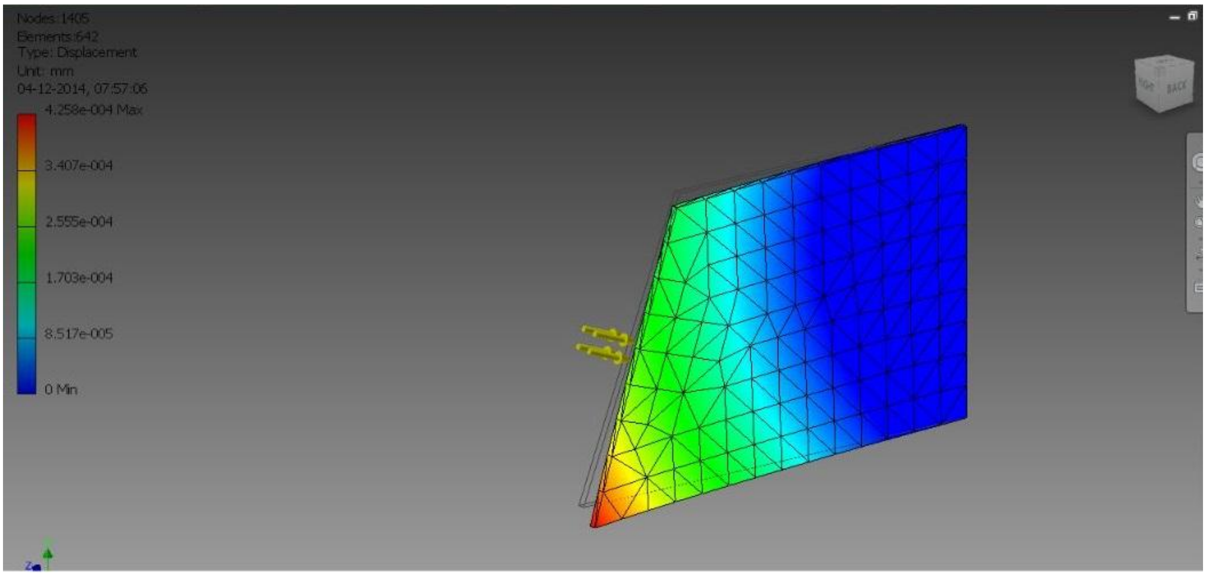

Figure 6.2 Displacement analysis

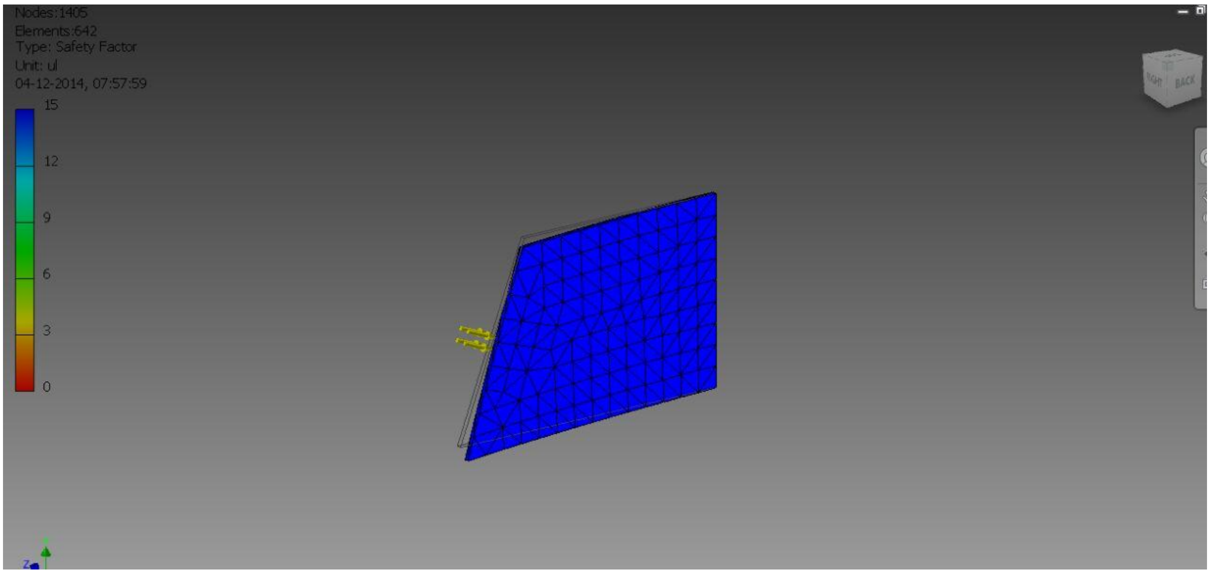

Figure 6.3 Factor of safety

The design was found to be safe in finite element analysis with induced stress of 0.000774MPa. The results were confirmed true with the success of flight test.

CHAPTER 7

CONCLUSION AND RESULT

7.1 Flight Test

After the completion of the design and fabrication, the next objective is the fight testing of airship. The location chosen for flight testing is Structures Laboratory in IIT Bombay. The airship is steered in all directions for about 30 minutes in order to check its maneuvering capabilities as shown in Fig 7.1. The maximum speed achieved is estimated to be 2 to 5 m/s. The detailed specifications of the airship are listed in Table 7.1, while the weight breakdown is given in Table 7.2.

Table 7.1 Indoor Airship Details

Parameter	Specification
Length[m]	3.8
Diameter[m]	1.3
Volume [m^3]	3.571
Surface Area	13.614
Gross Lift [Kg]	4.374
Net Lift [Kg]	0.666
Fin	'+'type
Gondola Type	Open Structure

Table 7.2 Weight breakdown of indoor airship

Components	Weight(Kg)
Envelope	2.5867
Avionics(Battery Motors, Wires)	0.470
Fins	0.240
Gondola	0.170
Total	3.4567

7.2 Results

- Design and development of airship is done successfully.
- Innovation of nut bolt in aligning mechanism of fin was a success.
- Light weight fins was successfully developed increasing payload capacity.
- Attachment mechanism used resulted in quick attachment and detachment of the fins.

References

[1] Pant, R.S., “Transportation of goods and passengers to remote areas using airships: Two case studies in India”, Proceedings of 6th International Forum on Air Transport for Remote Regions, Bergen, Norway, 27-30 April 2009

[2] Web Link: http://www.airship.com.au/services/powered_airships.html

[3] Web Link: http://nbnl.globalwhelming.com/wp-content/uploads/2008/07/airship-2.jpg

[4] Web Link: http://www.airforce-technology.com/projects/mineseeker/

[5] Web Link: http://www.aero.iitb.ac.in/~airships/gallery/airship16.jpg

[6] Web Link : http://www.aero.iitb.ac.in/~ltasys/airship2.html

[7] Gawale, A. C. and Pant, R. S., “Design, Fabrication And Flight Testing Of Remotely Controlled Airship”, National Conference on LTA Technologies, Aerial Delivery R&D Establishment, Agra, India, October 2002.

[8] Web Link : http://i271.photobucket.com/albums/jj154/phillyblizzard/AkronZRS.jpg

[9] Gawale, A, and Pant, R.S., “Design Studies of a Powerplant System of Non-Rigid Airship”,Proceedings of the 5th International Convention of the Airship Association, Oxford, England,Aug 2004.

[10] Pant, R. S., “A Methodology for Determination of Baseline Specifications of a Non-rigid Airship”, AIAA-2003-6830, Proceedings of the 3rd Annual Aviation Technology, Integration,and Operations (ATIO) Conference, 17-19 Nov. 2003, Denver, Colorado, USA.

[11] Pant, R. S., Gawale Amol, Amool Raina, Jahagirdar, Y. P., “Design Fabrication and Testing of Remotely Controlled Airships in India”, ICES-2008, Proceedings of the 26th International Congress of the Aeronautical Sciences, 14-19 Sep. 2008, Anchorage, Alaska, USA.

[12] Lee, G-Y., Kim, D-M., and Yeom, C-H., “Development of Korean high altitude platform systems”, International Journal of Wireless Information Networks, Vol. 13, No. 1, pp.31–42, January 2006.

[13] Web Link : http//www.apexballoons.com/airships.html

[14] Nawaz Motiwala, Irshad Ahmed Khan, Nilesh P. Yelve , Balkrishna Narkhede , Rajkumar Pant, ‘‘Conceptual Approach for Design, Fabrication and Testing of Indoor Remotely Controlled Airship”,Journal of Advance Material Reasearch Vols 690-693 (2013) pp 3390-3395.

[15]Web Link: http://aviationweek.com/blog/airship-programs-so-buoyant-says-gao.html

[16] Web Link :http://modelairship.wordpress.com/2010/12/09/redesigned-airship-tail-fins.html

[17] Web Link : http//homemadedefence.blogspot.com/2010/09/airship-drones.html