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Aerodynamic investigation of a high altitude airship

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بسم الله الرحمن الرحيم

اللهم اجعل هذا العمل قربة اليك وخيرا للبشرية وعلم ينتفع به بعد موتي

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Abstract

The “TEMO-Leb Airship” is a rigid airship. This purpose is to distribute Internet in the far regions without having to install a complete network. And it will be used for the surveillance of fire in far forests, natural disasters and the surveillance of the traffic jam. It has twenty meters as length and a four meters as diameter. It must reach a height of 7 km.

In order to apply this project, a theoretical study is carried out, focusing on the volume of Helium bags and the materials used: Plexiglas and tissues. Due to the political and regional situation, the implementation of this airship has been delayed.

Instead of these, a test is performed on a smaller airship and at a lower height.

Keywords: Airship; Internet; Surveillance; Helium; Plexiglas; tissues.

Résumé

"TEMO-Leb Airship" est un dirigeable rigide. Leur but est de distribuer de l’Internet dans les régions lointaines sans avoir besoin d’installer un réseau complet. Il sera utilisé aussi pour la surveillance des incendies dans les forêts éloignées, les catastrophes naturelles et la surveillance du trafic. Il possède comme dimensions vingt mètres de longueur et quatre mètres de diamètre. Et il doit atteindre une hauteur de 7 km.

Afin d'appliquer ce projet, une étude théorique est réalisée, tout en intéressant au volume des sacs contenant l'hélium et les matériaux utilisés pour leur fabrication: les plexiglas et les tissus. En raison de la situation politique et régionale, la mise en œuvre de ce dirigeable a été retardée.

Au lieu de cela, un test est effectué sur un dirigeable plus petit et à une hauteur inférieure.

Mots-clés: Dirigeable; Internet; Surveillance ; Hélium; Plexiglas; tissus.

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Introduction

The manufacturing of the airships has been reduced in our times, especially after the accident at Hindenburg, and also because aircraft manufacture became more important.

This project wants to revive the science of airship, this appropriate by using it for contemporary purposes. The airship can used in different fields:

They are shone in science and research applications. By comparing to aircraft, they can stay up in air for extended periods. They are cheaper and more stable.

They have also used for surveillance, if we have fire in far forests, natural disasters and traffic jam. And they have used for tourism, they are very attractive means for transport.

For these purposes, we decide to apply a new project, it is to manufacture an airship which called “TEMO-Leb Airship”. The planned airship has a rigid type. It has a twenty meters as length and four meters as diameter. It must reach an operational height of 7 km. This airship shall will distribute Internet in the far regions without having to install a complete network. It is a solution to the development of low-cost areas. This is a new project to be implemented in Lebanon.

In order to apply this project, a theoretical study is carried out, focusing on the volume of Helium and the materials used: Plexiglas and tissues. Due to the political and regional situation, the implementation of this project has been delayed.

Instead of immediately undergoing the described project, a test is carried out on a smaller airship and at a lower height. The test contains an airship having a 6.8 meters as length and a 1.2 meters as diameter.

At the beginning we had the following working packages:

- Rough modeling of all parts of platform including internet communication payload.
- Computing of total weight to required Helium gas of lifting cells relation.
- Specification of rough design parameters of airship (Length, volume of lifting cells) and altitude.
- Search for the products needed for manufacturing of airship in the Lebanese market.

This memory has formed of five chapters:

In Chapter 1, “State of the art”, we talk about the evolution of airships, their development over the years and the end of the golden epoch of airships. We talk also for the purpose of this project.

In Chapter 2, “Basics”, we talk about Archimedes principle, the types of airships and the difference between them. The operation of the rigid type is explained. We also talk about the gases used inside the dirigible “Helium and Hydrogen” and the characteristics of each gas are cited.

In Chapter 3, “Contribution”, we speak of the aerostatic of airships which is based on the bouncy force. We also talk about the variation of the density, the pressure and the temperature as a function of the altitude. This variation is plotting on the “MATLAB” software. Then, we study the influence of these parameters on the airship.

In this chapter too, we suggested a design of “TEMO-Leb airship” draws on “FreeCAD” (FreeCAD is a software similar to AutoCAD, but it is more complicated and needs more time to do drawing by comparing the AutoCAD. Despite this disadvantage, we obtain the same quality.)

In this chapter, the necessary calculation is made to determine whether the “TEMO-Leb airship” is able to reach the desired altitude. We talk about the problems that confront us and prevents us from applying this theoretical study.

Next, we propose a new conception which has considered as a solution. This design which has a new dimensions, will rise to a lower altitude. It calls “Low altitude test TEMO-Leb Airship”. We expect its implementation.

In Chapter 4,”Results and Discussion”, we put the results obtained by the software “MATLAB” and we put in a table the volume of gas Helium containing in the bags inside the airship, at several altitudes.

Fortunately, we obtain positive results for our theoretical studies. The “TEMO-Leb airship” can reach the desired altitude.

In Chapter 5, “Conclusion and Perspective”, we talk about our work and the result obtained. While proposing several suggestions for developing this project.

1.State of the Art

In this chapter, we talk about the evolution of airships, their development over the years, and the end of the golden epoch of airships. It was caused by the disaster of the airship named Hindenburg when this hydrogen based airship was burned. At the end of this chapter, we talk about this project, which is conform to a new trend to revive airships.

1.1 Evolution of airship

Since the past ages, the high ambition of human promotes him to fly. The science of aviation has developed gradually.

1.1.1 Hot air balloons

The first attempt was based on heating of the air without a motor. The balloon consisted of the envelope, a burner and the gondola.

Figure 1: First ever of hot air balloon

The hot air balloons adopted two principles to work:

- **The principle of cold and of hot air**

The air is composed of the invisible particles: "molecules". When the air is cold, the molecules approach together and take a small volume comparing to the case of hot air where the molecules move away from each other and the volume is larger.

For this reason, the mass of hot air is lighter than cold air. When the molecules of air contained in the envelope is heated, the air in the balloon becomes lighter than the air in the atmosphere, allowing the balloon to lift.

In order to descend the balloon, the air in the envelope must be cooled and it is also possible to open the valve located at the top of the balloon. In this way, the cold air replaces the hot, and the mass of interior air increases. Consequently, the balloon can descent. [1]

- **Principle of Archimedes**

When a body is immersed in a fluid (gas or liquid), it is held up by a force equal to the weight of the displaced fluid.

In order to lift an airship, the bouncy force must be larger than the weight of the displaced air.

Figure 2: Hot air balloons

The manufacturing of hot air balloon has developed and the design of his envelope, his burner and his gondola work out big success.

- **Development of envelope**

By time, the fabrication methods used to produce balloons have changed. The aim was to achieve the following characteristics:

- Flexibility
- Resistance
- Tightness: It is necessary to achieve this characteristic because the gas lighter than air as helium has small molecules which can leak out of the balloon. So to be able to undergo long flights, the balloon cover needs a very good seal.

a. “Baudruche”(Type of tissue)

The “Baudruche” is a membrane made from the intestine of beef and mutton. This tissue is very light and waterproof but it has low durability and high cost.

b. Cotton or Silk

Cotton or silk can provide the mechanical strength. They coated with rubber or vanish to ensure the tightness.

c. Polyamide(Nylon) and Polyester

The polyamide (Nylon) and Polyester have used a lot in this days because they have a light weight and good resistance. They are coated with polyurethane or silicone for protection to the ultraviolet rays. [2]

- **Development of burner**

The burner is the engine of the hot air balloons. It heats and propels the air in the envelope and contributes to lift the balloon.

In the first time, the damp straw and wood were used as fuel in the burner. After that, the coal and the oil derivatives were used.

The current balloons used the propane in the burner. In the basket, many cylinders contain propane. It is highly compressed in canisters and it is entered into the burner in liquid form.

When the burner is started up, the flame burns, the propane heats and transforms from a liquid to a gas. The gas makes for a more powerful flame and an overall more efficient fuel consumption. [3]

- **Development of gondola**

Originally, the gondola or the basket was made of “Wicker” (material was used at the time especially to make baskets).

Since that time, the materials have evolved. “Rattan” is also a material which used after, his advantage is more solid and less susceptible to external elements but that is heavier than “Wicker”.

Both of materials still used, they have more advantages: solidity, lightness and flexibility. [2]

The modern materials used to made baskets are from “Kooboo” and “Palambang” cane. There are many characteristics: sturdy, flexible and relativity light weight. The cane is very strong even more than aluminum or some composite plastics. [2]

1.1.2 Dirigible or Airship

The dirigible is newer than hot air balloon. It contains gas which is lighter than air, this gas is used instead of hot air. Three types of airship existed and they developed gradually:

1. Non-rigid airship(blimp):

It is composed of ballonets, rudders (for directions), elevator flaps, gondola and a small engine.

Figure 3: Blimp (Non rigid airship)

This type developed and had an amelioration, it is named:

2. Semi-rigid airship:

The improvement of this dirigible: instead of the ballonets, it used gas bags, and it used big engine and a keel.

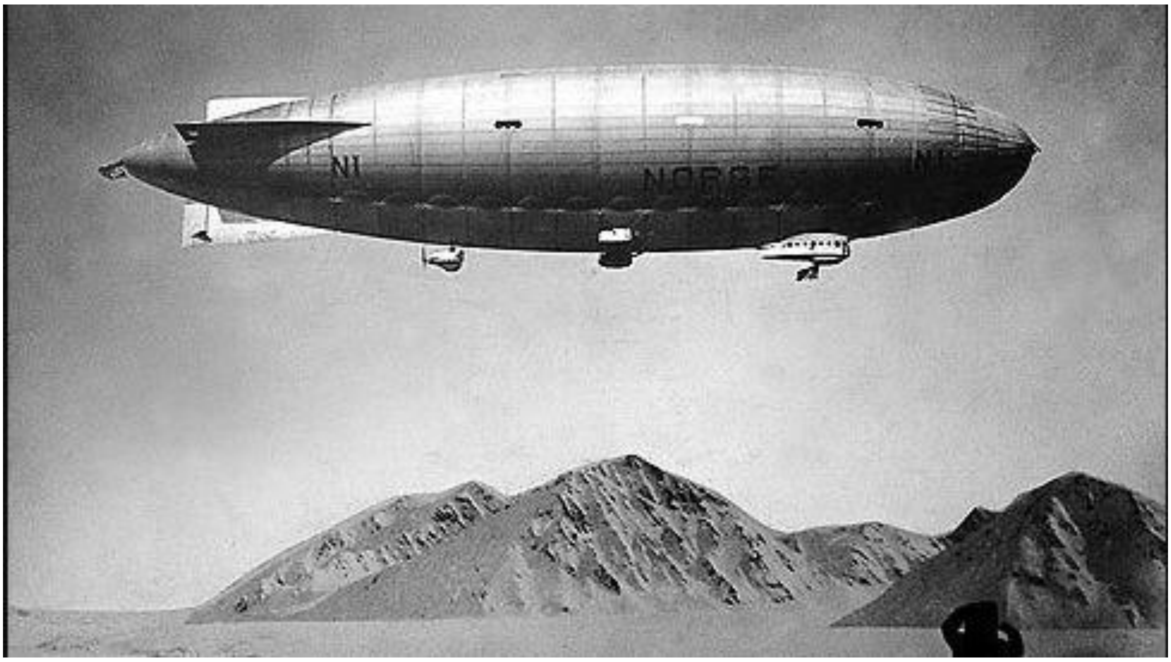


Figure 4: Semi-rigid airship

3. Rigid airship: More than the previous type, it had a rigid structure.

Figure 5: The Graf Zeppelin LZ-127 the most successful rigid airship

1.2 Evolution of the airship industry

In 1784, Jean-Baptiste Meusnier suggested a design for an airship of ellipsoid form. This design consisted from: rudder, elevator and three large aircrews without lightweight powerful engine.

In 1852, Henri Giffard succeeded to apply steam-engine technology to airships. With a single propeller driven by a three horsepower engine, his airship flew 17 miles. [4]

In 1872, Paul Haenlein was powered an aircraft by an internal combustion engine, the first attempt was used such an engine to power an airship. [5]

In 1900, the Zeppelin airships became the most famous dirigible. During World War I, the Germany army was used some of these airships as bombers.

In 1920s and 1930s, the United States and the Britain also were made airships, mostly imitating the original Zeppelin design. [5]

1.3 The end of airship

Series of accidents were happened and ended the golden age of airship. In particularly, the Hindenburg disaster at Lakehurst, New Jersey, 6 May 1937.The burn of this airship named" LZ 129 Hindenburg" was filled hydrogen ,killing 36 persons and becoming the most well-known and widely remembered airships disasters of all time. The public's confidence in capacities of airships was shattered.

The development and application of airplanes has declined also the use of airships. The century of airship finished and start new future of aircraft. [6]

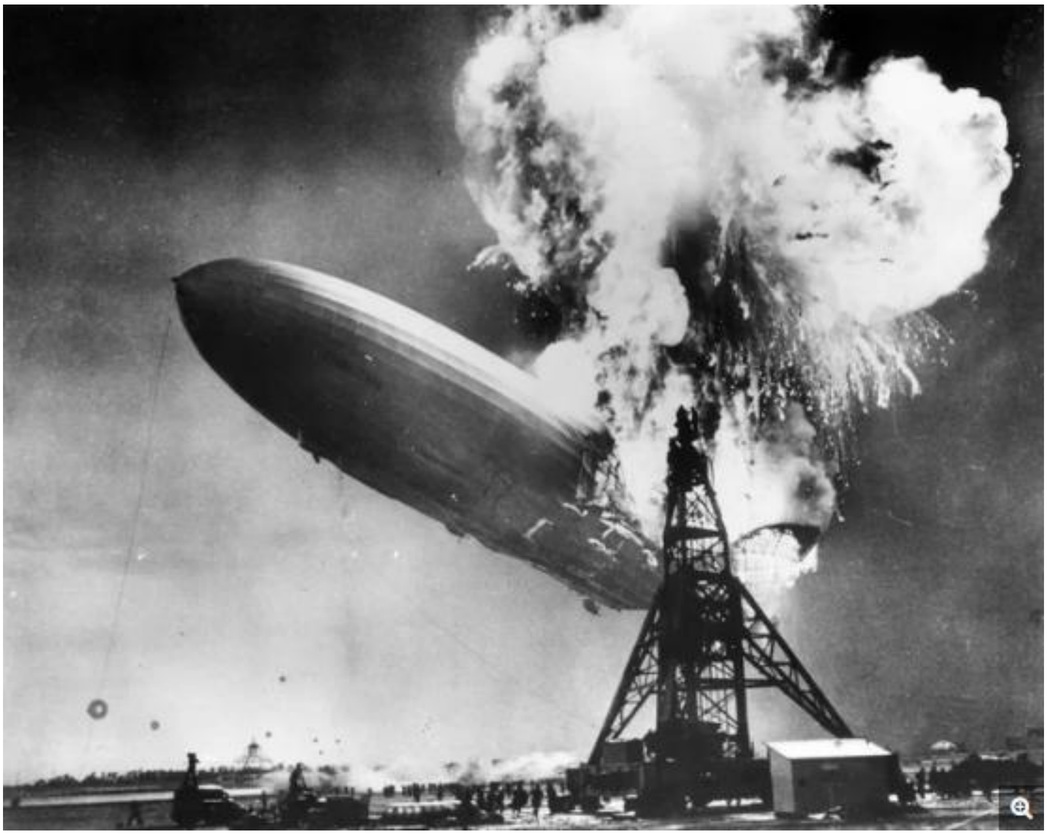


Figure 6: The Hindenburg disaster

1.4 Return of airship

After a pause of about hundred years, the airship returned to life at the end of the twentieth century. Thus the hobby of the airship has aroused the curiosity of many, and has opened up new horizons for this invention to move from sport to a means that allows man to leave the Earth and seek other uses, especially in the science field, such as surveillance and telecommunication.

If we have a traffic jam, we can use the airship as a solution to detect the main point of traffic, using the new technology people receive messages to avoid the busy roads. Consequently, people save their time.

In the far forests, if we have fire or natural disasters, we can use the airship to detect these actions as a satellite.

Also, the airships can used for tourism, they are very attractive means for transport.

Our study concerns to create a design of a rigid airship, its application will be in the field of telecommunications. Indeed, the problem of internet weakness and its high price will be solved by such a project whose objective is to distribute Internet in the far regions without having to install a complete network. Hence the objective of this thesis is to design a rigid airship which can reach a high altitude. To appropriate this design, we need to do a study of aerostatic of airship, to draw the design on “FreeCAD” and to study the all parts of this dirigible.

1.5 TEMO-Leb Airship

After a long absence of the manufacture of the airships, this project made it possible to revive the science of dirigibles. The new proposed project involves using the airship for new objects, making it a contemporary science.

It is a new idea that will be applied in Lebanon and will give our country new advantages, in particular:

- Self-sufficiency
- Local industry
- Distribution of the net in a new way

The airship “TEMO-Leb Airship” is a rigid airship which is wanted to design. It has twenty meters as length and four meters as diameter. It must reach a height of 7 km.

In order to apply this project, a theoretical study is carried out, focusing on the volume of Helium and the materials used: Plexiglas and tissues. Due to the political and regional situation, the implementation of this project has been delayed.

Instead of immediately undergoing the described project, a test is carried out on a smaller airship and at a lower height. The test contains an airship having a 6.8 meters as length and a 1.2 meters as diameter.

2. Basics

In this chapter, we talk about Archimedes principle, the types of airships and the difference between them. The operation of the rigid type is explained. We also talk about the gases used inside the dirigible “Helium and Hydrogen” and the characteristics of each gas are cited.

2.1 Archimedes principle

The main source of lift in an airship is the bouncy force or the static lift. The bouncy force is based on Archimedes principle: if a body is immersed in a fluid, in this case the fluid is the air, it experiences a force proportional to the volume of the displaced air in the opposite direction of its weight. When the density of the gas contained in the airship is less than the air, that force is substantial.

2.2 Types of airships

2.2.1 Non-rigid Airship

The non-rigid airship named also “blimp” maintains his shape and his structural integrity using higher internal pressure from its lifting gases. [4]

When the airship ascends, the lifting gas expands and when it descends, the lifting gas contracts. Then, the envelope would lose shape and become unmanageable. That is happening because this type of airship doesn’t contain a framework.

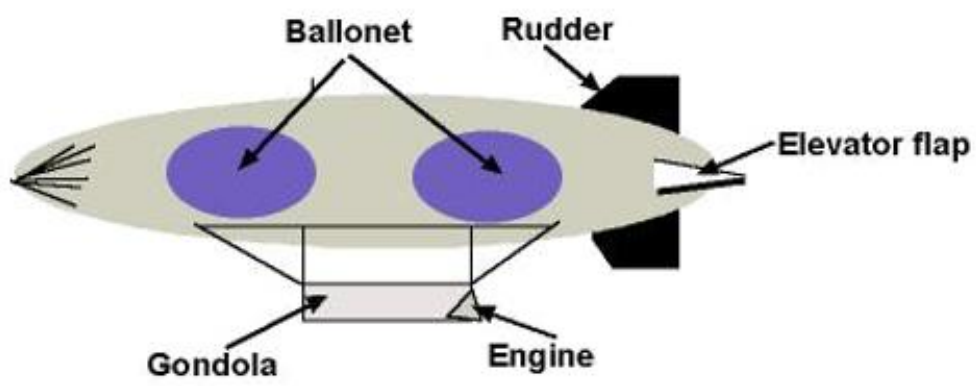


Figure 7: Parts of non-rigid airship

Figure 8: Blimp during filling gas

The development of aeronautic science was emerged a new type of airship:

2.2.2 Semi-rigid airship

Semi-rigid airships are similar to blimps in that they have no internal frame to support their envelopes. They do have, however, rigid objects on them that give them some backbone. A stiff keel runs along the length of the airship for distributing weight and attaching fins and engines. The keel also provides structural integrity during flight maneuvering. Similar to non-rigid airships, the shape of the hull is maintained largely by an overpressure of the lifting gas. Light framework at the nose and the tail may also contribute to the hull's outer shape. [4]

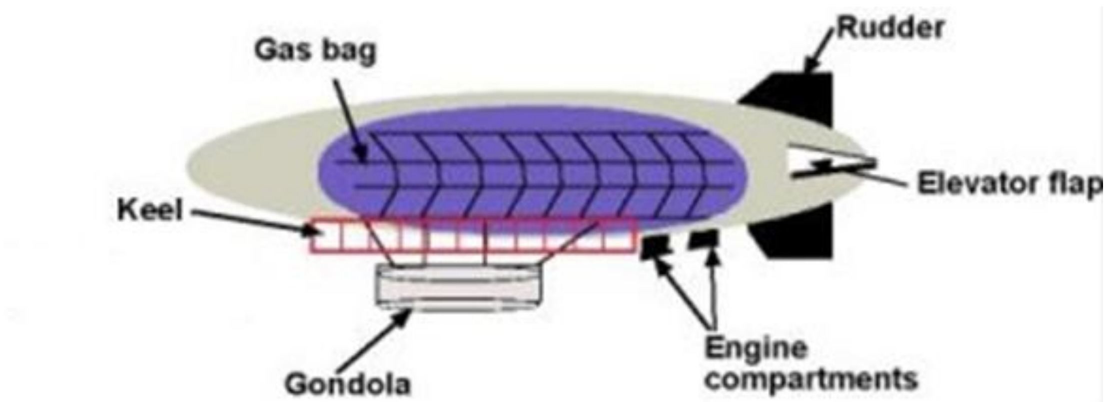


Figure 9: Parts of semi rigid airship

2.2.3 Rigid Airship

Semi-rigid and non-rigid airships maintain their shapes by the internal pressure of lifting gases. But rigid airship is different, it has an internal structure framework which it gives their shape form. It has an outer envelope to recover the framework.

Rigid airships have be built by a size larger than semi-rigid and non-rigid airships because there are no possibility of kinking in the hull due from aerodynamic forces and moments. Multiple gas bags containing the lifting gases are filled inside the internal framework of dirigible.

Splitting the gas in multiple bags instead using a single large bag is more safety and minimizes to happening a catastrophe. [4]

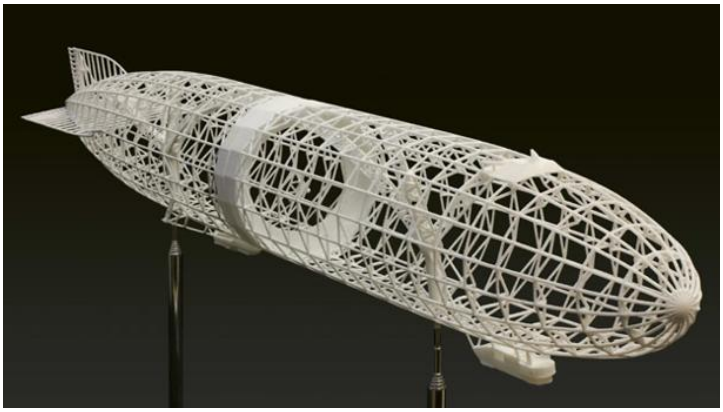


Figure 10: The internal framework of rigid airship

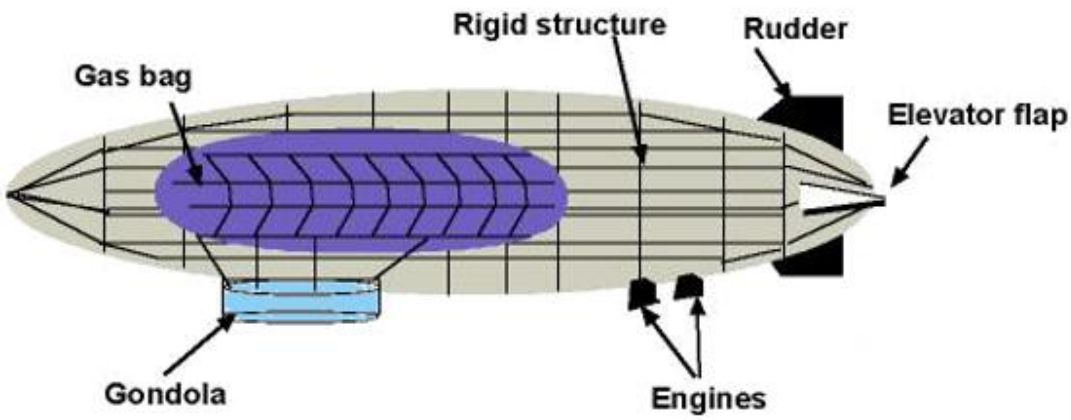


Figure 11: Parts of rigid airship

2.3 How do rigid airship work?

In order to rigid airships get off the ground, fly and descend, different gases are used by rigid airships. Today, to rise the lighter-than-air craft, the helium gas is used instead to hydrogen. Helium is more expensive than hydrogen, but it was adopted because it has more properties. It is inflammable contrary the hydrogen which causes the infamous Hindenburg accident.

The airships, filled by Helium, load ballonets (tanks of air). When the pilot opens the valves of air, a positive bouncy is created, and consequently the dirigible elevates because air is heavier than helium.

The pilot controls the airship in flight by rudders and elevators, when it becomes in the sky, like a submarine under water. The rudders are used to steer the airship and the elevators are used to ascend and descend and throttling the engine to angle it into the wind. The engine provides forward and reserve thrust.

The air pressure outside the lighter-than-air craft deceases, at higher altitudes, consequently the helium in the gasbags expands. The pilot pumps air into ballonets in order to maintain pressure.

To descend the airship, this technique is also employed, the ballonets are filled by air. The air is heavier than Helium. That is created a negatively buoyant and therefore sinks lower in the sky or bring it in to land. [7]

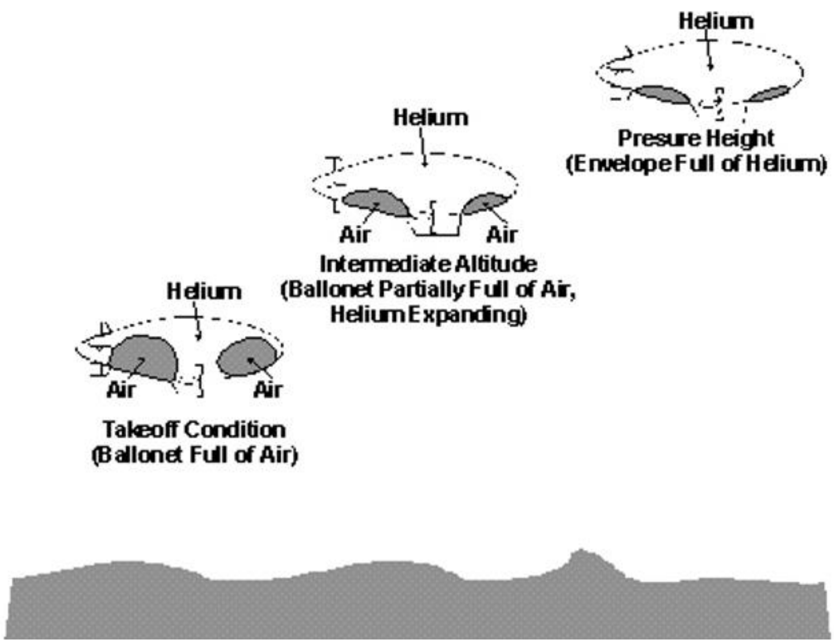


Figure 12: Airship principle of operation

2.4 Why do we use Helium not Hydrogen?

The performance of Helium in airship is better than hydrogen. In order to inflate an airship, the use of Helium instead of hydrogen reduces the cruising range from 30 to 40 % and reduces the total lift from 10 to 15 %. This is a disadvantage for Helium but it be can justified. Helium has absolute safety against the risks of fire that is expected with hydrogen. In the United States, Helium finds in large quantities. It is very expensive, but the price is significantly lowered, because the quantities of production have increased.

- Characteristics of hydrogen and Helium:
- Hydrogen
    - Lightest element in the earth
    - Inexpensively
    - Easily to obtain
    - Flammable. For this disadvantage, it is unacceptable for manned airship operations.
- Helium
    - Scarce
    - Expensive
    - Non-flammable. This advantage makes it the only practical lifting gas for manned airship operations. [8]

2.5 Control of airships

The Control of the airship differs from the aircraft's one. It can be divided into two categories. While the control of airplanes is performed by one pilot; in airships two pilots are utilized, one for direction, one for altitude.

Both pilots must recognize the flight pattern of each and constantly alert each other to mutual assistance; to give an effective performance. The pilot should organize the route to meet the needs of the situation. There are too many coordination cases, but capable pilots have little difficulty in achieving the expected results.

As indicated in the previous paragraph, the pilot is responsible for monitoring the course of the airship in a horizontal plane. On flights throughout the country, his problem is solved with regard to the course required by the mission of the dirigible. Once the course is established, the dirigible will hold its own. But when it is affected by external powers such as gusts, the rudder must work in the opposite direction to overcome it. While flying in a very stormy air, it is impossible to prevent lace, but a good pilot can prevent the amplitude of oscillations from exceeding a few degrees. Then, as the storms also strike on both sides, the average direction of the dirigible will be the desired direction.

It is essential that the pilot has a clear conception of the reaction to control the rudder of the airship at the turn. When you need to move to the right, for example, the rudder is placed to the right. Immediate effect of this rotation is to produce a force to the left acting on the right side of the rudder. This force to the left has a dual effect. In the first place, it gives a moment around the center of gravity inclined to turn the nose to the right. In the second place, it moves the whole airship to the left. When the airship moves to the left, and the nose turns to the right, both motions combine to make the air fall to the left of the envelope and to turn the nose still further to the right.

Once this has been done during a period, the pressure on the left side of the nose becomes equal to that on the right side of the rudder and the resulting total pressure is zero, but as the force is applied to the front, there is a moment of rotation that tends to continue twisting to the right.

As the motion goes further, the force on the left side of the envelope becomes larger than the force on the right side of the rudder, and there is a gravitational force to the right of the skill to begin to scroll to the right. If you leave the rudder hard or if it is rotated to neutral, this turning to the right will continue, to check the cycle, it is necessary to put the rudder on the left side of the envelope.

The shift radius is controlled by instantaneous damping on the envelope, which is more important for the rate of high-speed propagation than those with a low ratio. This should be one of the main concerns of the driver whenever he controls a new type of airship to identify himself with his turn circle. Otherwise, he may try to maneuver when the space limit is insufficient.

The first effect on the rudder mode on the right is to move the airship slightly to the left so that if the airship was stolen near the right side of the wall or any other obstruction, it would not be wise to put the rudder On the right to move to the right and away from the obstacle because the immediate action for such work would be to pay the airship in the wall.

Sometimes, when flying through foggy weather, an obstacle will suddenly loom up in front of the airship. So the pilot must first put the rudder to disperse the nose of the airship and then completely reverse the rudder in order to miss the obstacle.

3. Contribution

In this chapter, we speak of the aerostatic of airships which is based on the bouncy force. We also talk about the variation of the density, the pressure and the temperature as a function of the altitude. This variation is plotting on the “MATLAB” software. Then, we study the influence of these parameters on the airship.

In this chapter too, we suggested a design of “TEMO-Leb airship” draws on “FreeCAD” (FreeCAD is a software similar to AutoCAD, but it is more complicated and needs more time to do drawing by comparing the AutoCAD. Despite this disadvantage, we obtain the same quality.)

In this chapter, the necessary calculation is made to determine whether the “TEMO-Leb airship” is able to reach the desired altitude. We talk about the problems that confront us and prevents us from applying this theoretical study.

Next, we propose a new conception which has considered as a solution. This design which has a new dimensions, will rise to a lower altitude. It calls “Low altitude test TEMO-Leb Airship”. We expect its implementation.

3.1 Aerostatic of airship

To define the buoyant lift capability and to determine the maximum attainable altitude by the airship, it is necessary to calculate the volume of the hull.

Depending on aerostatic principles, we obtain some relations between mass, volume and gas densities.

3.1.1 Bouncy force

The bouncy force (F) generated by an airship is equal to the weight of the displaced air subtracting the weight of the lifting gas (Helium). Noting the volume of displaced air is equal to the volume occupied by the helium.

$$F=V_N*(\rho_{A0}-\rho_{He0})*g \quad \text{Eq.1}$$

V_N: The net volume of displaced air.

ρ_{A0}: The density of air at sea level.

ρ_{He0}: The density of Helium at sea level.

g: The acceleration of gravity.

The amount of lift available to counteract the weight of the airship structure and payload is represented by the bouncy force F.

3.1.2 The relation between altitude and density

The density varies with altitude. The relation is inversely proportional: when the altitude increases, in opposition, the density decreases.

The conventional state of atmosphere is defined by equations of International Standard Atmosphere (ISA). The equation below is suitable until an altitude of 11 000 m:

$$\rho_H/\rho_0 = [1-(H/44\,300)]^{4.256} \qquad \text{Eq.2}$$ [9]

ρ_H : Density of the air as a function of altitude (kg/m³).

ρ_0 : Density of the air as a function of altitude (kg/m³) at sea level, ρ_0=1.205 kg/m³.

H: Altitude (m).

MATLAB is used plotting the variation of density as a function of altitude using Eq.2. This program allows matrix manipulation, plotting of data and functions, creation of user interfaces, implementation of algorithms and interfacing with programs written in others languages, including **"C"** , **"C++"** , **"Fortran"** , **"Java"** and **"Python".**

- ✓ Writing the code in **"MATLAB":**

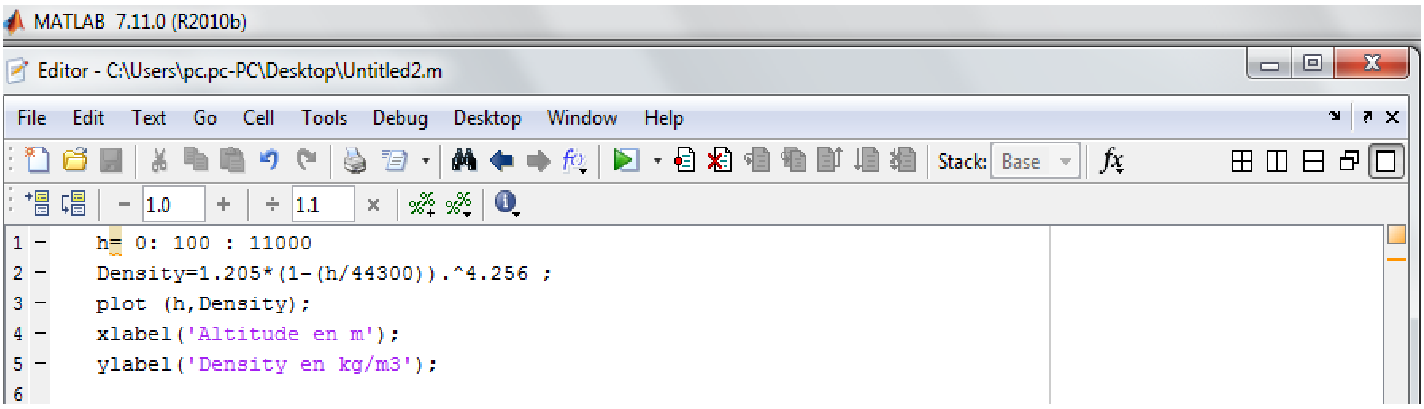


Figure 13: code of Eq.2 in MATLAB

Results and plotting of this function is shown in the next chapter.

3.1.3 The relation between altitude and pressure

The atmospheric pressure decreases rapidly with the altitude. The conventional state of atmosphere is defined by equations of International Standard Atmosphere (ISA). The equation below is available till altitude of 11 000 m:

$$P/P_0 = [1-(H/44\,300)]^{5.256} \qquad \text{Eq.3} \qquad [9]$$

P : Pressure of the air as a function of altitude (Pa).

P_0 : Pressure of the air as a function of altitude (Pa) at sea level, P_0=101 325 Pa.

H: Altitude (m).

MATLAB is used for plotting the variation of pressure as a function of altitude using the equation "Eq.3".

- ✓ Writing the code in **"MATLAB":**

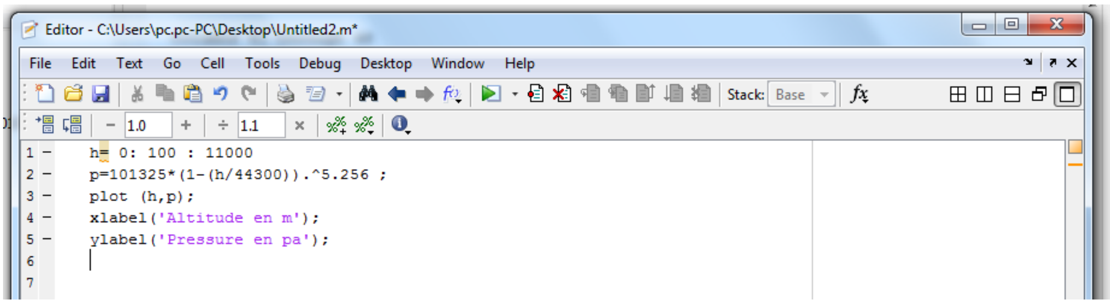


Figure 14: code of Eq.3 in MATLAB

Results and plotting of this function in the next chapter.

3.1.4 The relation between altitude and temperature

The temperature decreases with the altitude. The conventional state of atmosphere is defined by equations of International Standard Atmosphere (ISA). The equation below is available till altitude of 11 000 m:

$$T_H = T_0 - 0.0065*H \qquad \text{Eq.4} \qquad [9]$$

T_H : Temperature as a function of altitude (°c).

T_0 : Temperature as a function of altitude (°c) at sea level, T_0=15°c.

H: Altitude (m).

MATLAB is used for plotting the variation of pressure as a function of altitude using the equation "Eq.4".

✓ Writing the code in **“MATLAB”:**

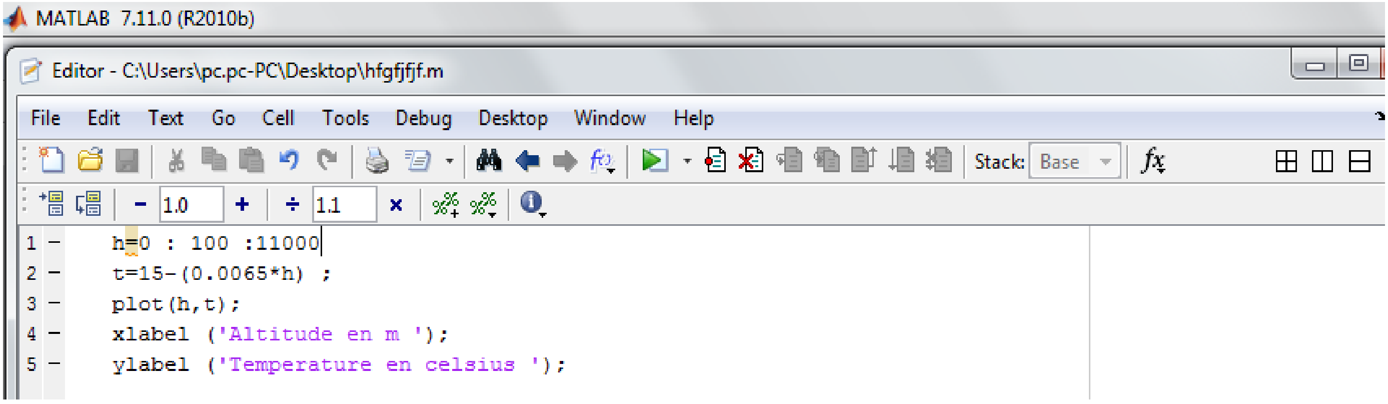


Figure 15: code of Eq.4 in MATLAB

The results and plotting of this function in the next chapter.

3.1.5 Pressure Altitude

It is necessary to define the term **“Pressure Altitude”**. At this point, the net volume is maximum “Vmax” and no further expansion of the lifting gas volume is possible.

3.1.6 Influence of pressure, temperature, density and volume on the airship during its rise

a) Under “Pressure Altitude”

Supposing both gases, air and Helium have the same temperature and pressure, but their densities change with altitude.

A slight pressure differential is necessary, but this difference is very small. For the purposes of this analysis, it is considered null.

When the airship rises, the density of Helium decreases along with the atmospheric density. We know the relationship between density, mass and volume:

$$\rho = m/V \qquad \text{Eq.5}$$

Therefore, since the mass of the Helium remains fixed, the volume V_N must increase. In order to regulate the internal pressure, two ballonets contain air are located inside the hull which expand and contract. By this way, the variation in internal lifting gas volume is achieved.

At the sea level, assume that is the airship’s launch altitude, the value of density is maximum. Also, the volume of ballonets expand to maximum while the net volume is minimum.

When the airship begins to rise, the ambient density and pressure both decrease, and air is automatically ejected from the ballonets to match the falling pressure.

At a given point, the ballonets must be empty completely. At this point, the volume of the lifting gas can't expand. The value of the net volume now is maximum "V_{max}".

By summarizing, under the point **"Pressure Altitude"**, we have:

- The differential of pressure between lifting gas and atmosphere is null: ΔP=0.
- The differential of temperature between lifting gas and atmosphere is null: ΔT=0.
- The density of lifting gas and atmosphere decrease, this variation affects an increase of net volume. The equation Eq.5 is available up to the **"Pressure Altitude"**.

b) Above "Pressure Altitude"

When the airship continue to rise, the density of lifting gas and atmosphere also continue to decrease, but the volume of lifting gas remains constant.

The differential of pressure now isn't null, it starts to increase. An overpressure is created, and consequently the differential of pressure will increase so a rupture will be exist in the exterior structure of airship. The equation Eq.5 becomes unavailable.

3.1.7 Sizing the airship hull

To reach the Equilibrium, the bouncy force must be equal the weight of the airship structure (framework, external fabric and gasbags) and payload (propeller, control system…).

The weight is equal:

$$P= (m_s+m_p)*g \qquad \text{Eq.6}$$

P: The weight of the structure and payload (N/Kg).

m_s: The mass of structure (kg).

m_p: The mass of payload (kg).

g: The acceleration of gravity (N/Kg).

When the airship rise, up to the pressure altitude, the net lift remains constant, because the atmospheric density changes at the same rate as the density of the lifting gas.

The density ratio is equal to:

$$\sigma=\rho_A/\rho_{A0}= \rho_{He}/\rho_{He0} \qquad \text{Eq.7}$$

σ: The density ratio.

ρ_A: The atmospheric density at a given altitude.

ρ_{A0}: The atmospheric density at the sea level.

ρ_{He}: The density of Helium at a given altitude.

ρ_{He0}: The density of Helium at the sea level.

At a given altitude, the Eq.1 will be:

$$F=V_N * \sigma *(\rho_{A0}-\rho_{He0})*g \qquad \text{Eq.8}$$

At the equilibrium and the point **"Pressure Altitude"** ($V_N=V_{max}$), we have:

$$\text{Eq.6} = \text{Eq.8}$$

$$(m_s+m_p)*g= V_{max} * \sigma *(\rho_{A0}-\rho_{He0})*g$$

$$V_{max}= (m_s+m_p)/ \sigma *(\rho_{A0}-\rho_{He0}) \qquad \text{Eq.9}$$

The equation "Eq.9" gives us the maximum volume of the airship hull which is needed to rise the airship. This volume is based upon the ratio of the density which is varied with altitude, mass of the structure and payload.

The mass of structure includes the mass of the gasbags, the mass of the airship framework and the mass of the envelope or the external skin.

3.2 TEMO-Leb Airship

In this project, we suggest an airship called "**TEMO-Leb Airship"**. This airship will distribute Internet between Turkish and Lebanon, at altitude 7 km.

The new idea in this project is that the size of "**TEMO-Leb Airship"** is smaller than other airships which take off at a high altitude.

The "**TEMO-Leb Airship"** dimensions: it length equal to twenty meters and a diameter equal to four meters.

A theoretical study is needed to calculate the volume required for "**TEMO-Leb Airship"** to reach an altitude of 7 km.

a) First, it is important to calculate the volume of the airship based on the proposed dimensions.
b) Secondly, it must be calculate V_{max}.
c) Thirdly, it must be investigated whether this airship is available to reach the altitude 7 km with these dimensions. This is discussed in the next chapter.

To get V_{max}, it is necessary to calculate the mass of structure includes the mass of framework, the mass of external fabric and the mass of the gasbags. It must be know the mass of payload.

Step a) is described in section 3.2.1. Step b) is described in section 3.2.2.

The airship is like an ellipse, so the volume is equal to:

$$V_{TEMOLeb\ Airship} = 4/3*\pi*(L/2)*(D/2)\ \text{^}2$$

$V_{TEMOLeb\ Airship}$: The volume of the airship (m^3).

L: The length of the airship (m).

D: The diameter of the airship (m).

$$V_{TEMOLeb\ Airship} = 4/3*\pi*(20/2)*(4/2)\ \text{^}2=167.55\ m^3.$$

We draw this airship having this dimensions using a free 3D modeling software named **“FreeCAD”.** This program is oriented towards product design and mechanical engineering. It also targets towards architecture or other branches of engineering.

3.2.1 Design of "TEMO-Leb Airship"

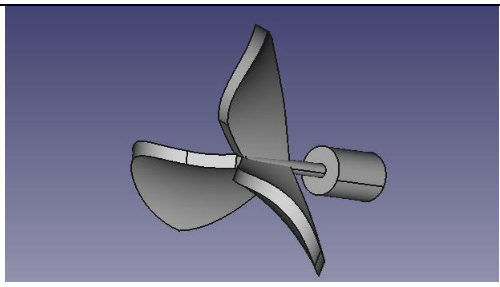
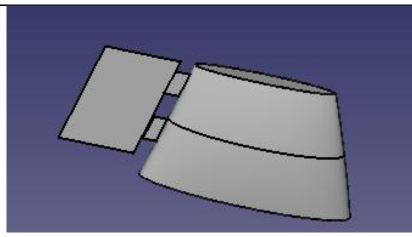
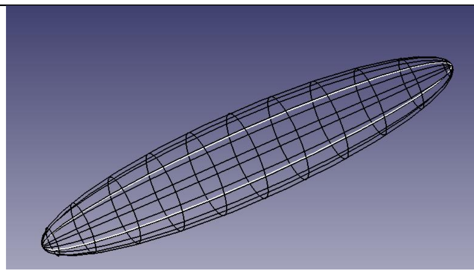
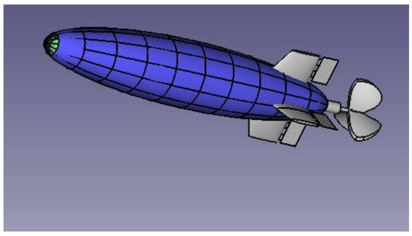
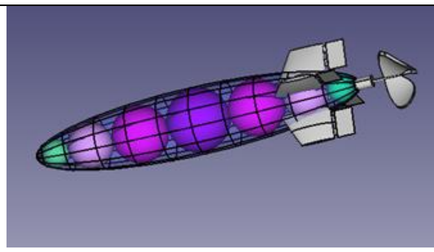
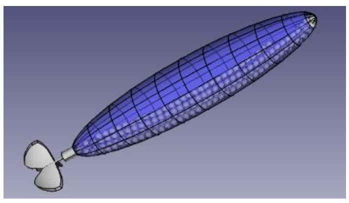
Part and details	Date and Data	Design
Propeller	May/2017 Propeller.Design.FCStd	
Rudder and Elevator	May/2017 Rudder.Elevator.FCStd	
Frame of Airship L=20 m D=4m	April/2017 Frame.of.Airship.FCStd	
Outer Shell of the Airship	April/2017 Outer.Shell.of.airship.FCStd	
Airship with the internal gasbags	April/2017 Airship.with.the.internal.gasbags.FCStd	
Airship With Balloons	29/May/2017 070617_Airship_Gazbags(Balloons).FCStd	

Table 1: All Parts and design of Airship

- **Propeller**

In order to displace the dirigible, we use the propeller. It transmit power by converting the rotational motion and it provides the main thrust. The propeller is also used to provide various speed.

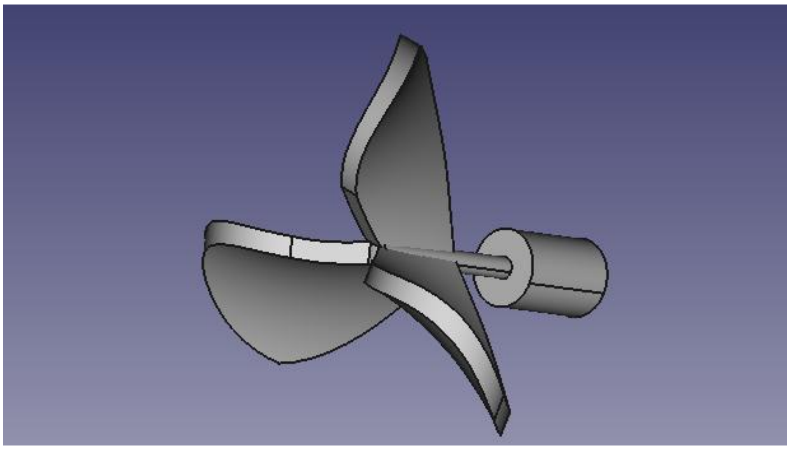


Figure 16: The propeller model drawn with FreeCAD

- **Rudder and Elevator**

To control an airship, we need many instruments, among them: rudders and elevators.

- The rudder is the part of airship which rotates and help to turn right or left.
- The elevator is like the rudder but it leads the dirigible to rise or descend.

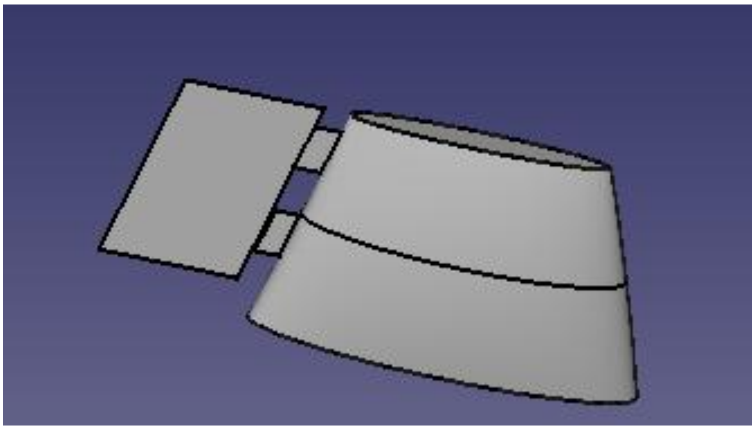


Figure 17: The rudder and the elevator models drawn with FreeCAD

- **Frame of the airship**

The frame is the body of airship, it gives its shapes. Which is main characteristic of rigid airship

It has formed by:

- Six ellipses: The length of the major axis is 20 m and the length of the minor axis is 4 m.

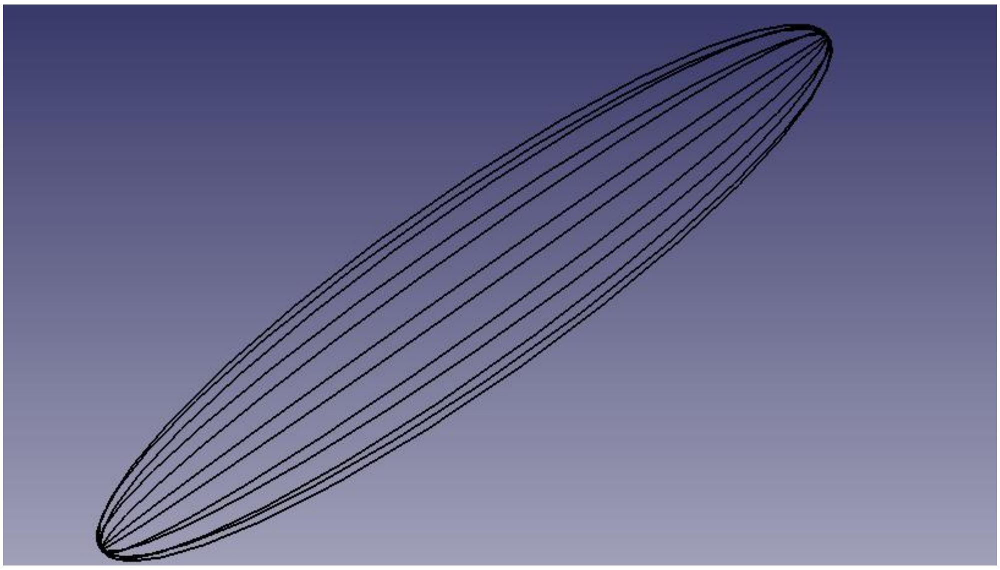


Figure 18: Ellipses of airship are drawn using FreeCAD

- 11 circles: This airship have 11 circles, four of them are symmetrical. Theirs dimensions are given in the table below.

Circle	Radius(m)
Circle 1	2
Circle 2	1.96
Circle 3	1.83
Circle 4	1.56
Circle 5	1.19
Circle 6	0.43
Circle 7	0.66

Table 2: Radius of Circles of the airship

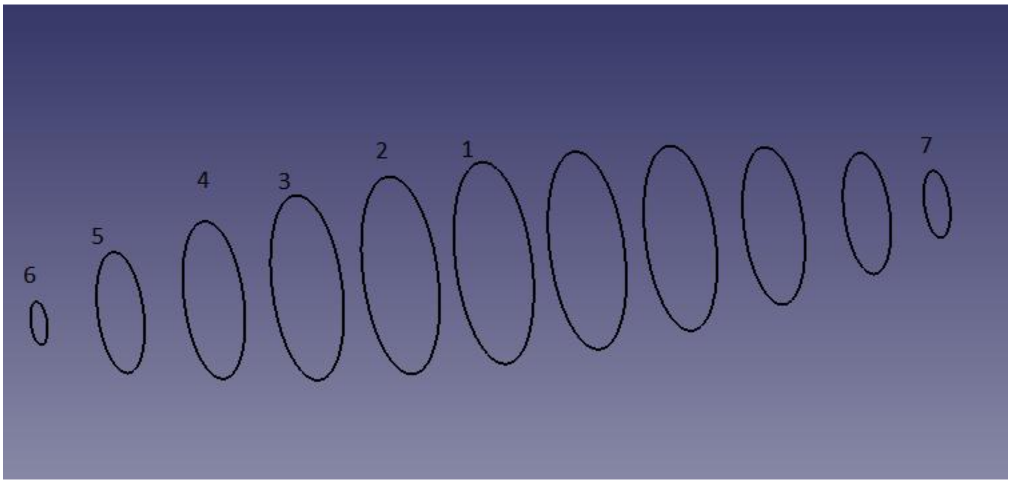


Figure 19: Circles of airship are drawn using FreeCAD

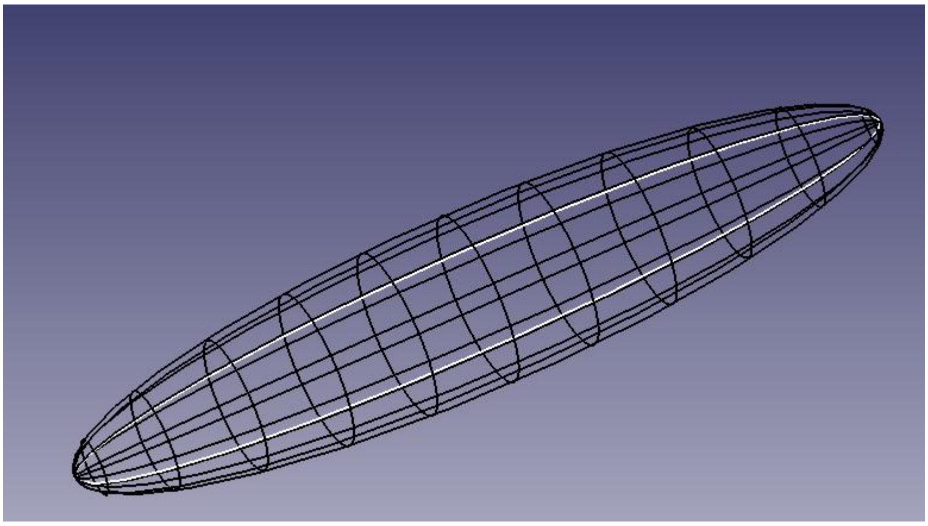


Figure 20: The framework of airship model drawn with FreeCAD

- **Outer shell of the airship**

The outer shell must be light. It covers the whole airship.

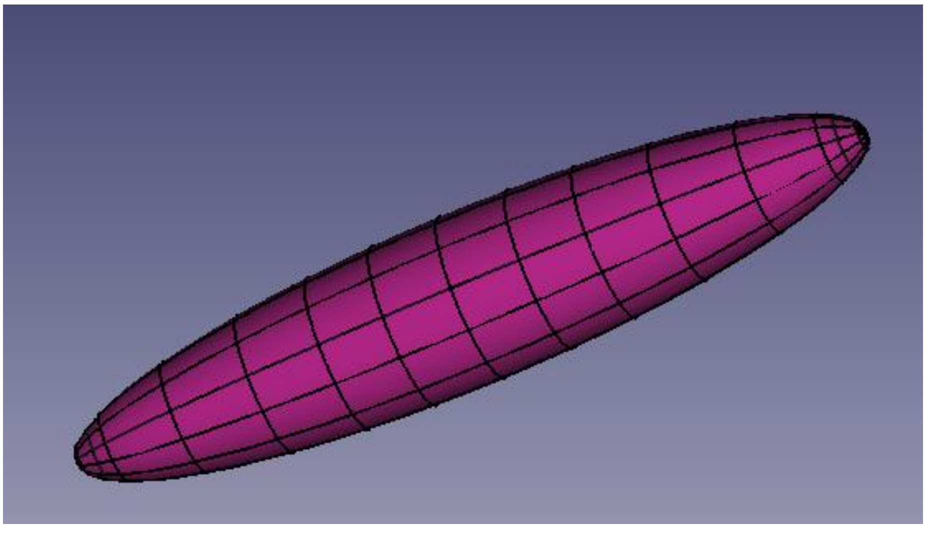


Figure 21: The hull of the airship designed with FreeCAD

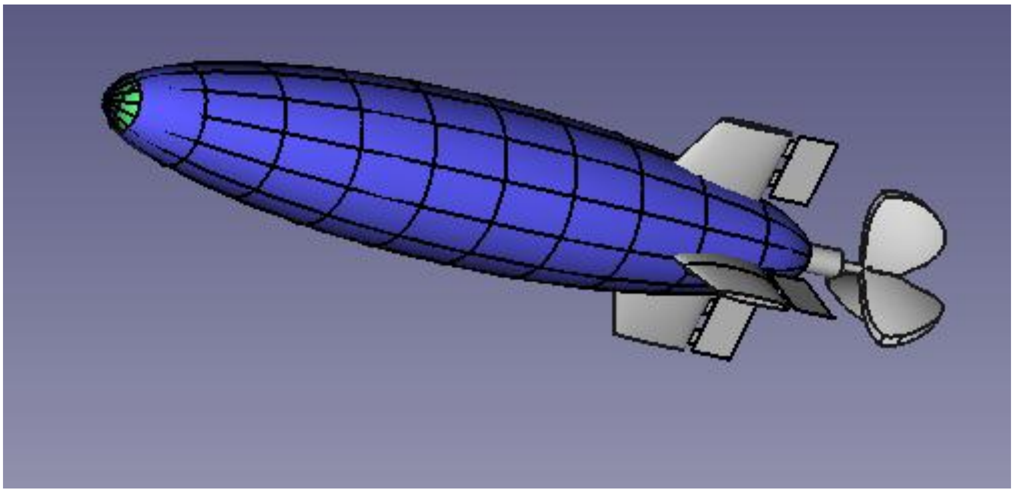


Figure 22: The envelope of airship model drawn with FreeCAD

- **Airship with the internal gasbags**

The internal gasbags contain the lifting gas and are designed with different dimensions.

The gas used is Helium and should choose carefully the envelope of gasbags. We know the atom of Helium is very small so it should not leak from the envelope. It gives greater durability of the airship to stay at the desired altitude.

This airship have 7 bags, three of them are symmetrical. Theirs dimensions are given in the table below.

Bag	Radius(m)
Bag 1	1.9
Bag 2	1.7
Bag 3	1.35
Bag 4	0.83

Table 3: Radius of Bags of the airship

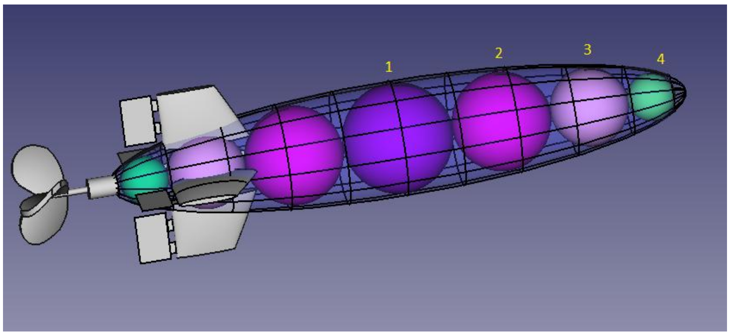


Figure 23: The internal gasbags of the airship

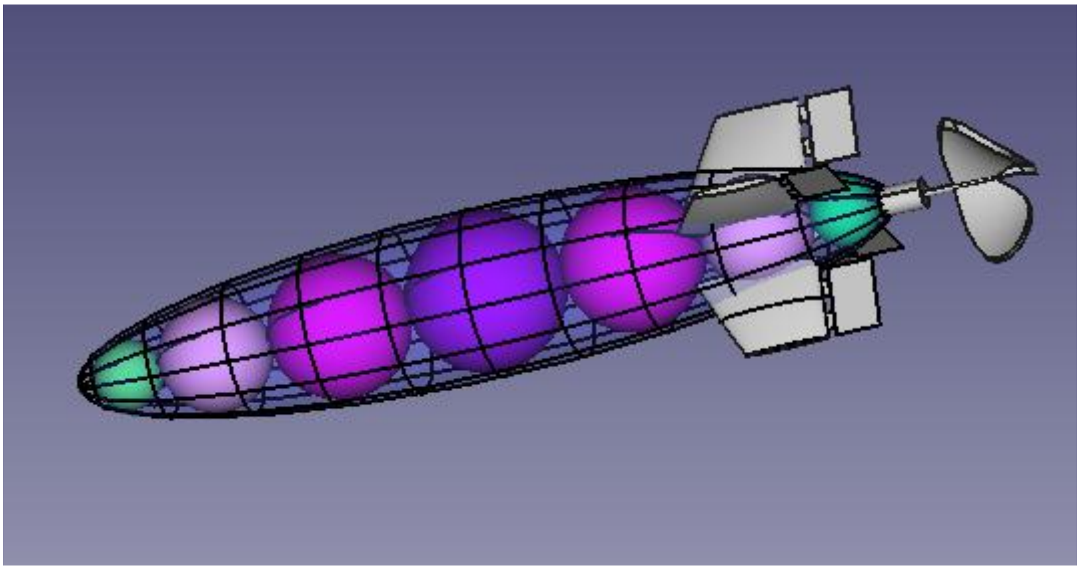


Figure 24: The internal gasbags of airship model draw with FreeCAD

- **Airship with balloons**

After a search in the Lebanese market done to find gasbags with the chosen dimensions, we did not find our requests. That's why we decided to use balloons having a 0.5 m of diameter instead of gasbags.

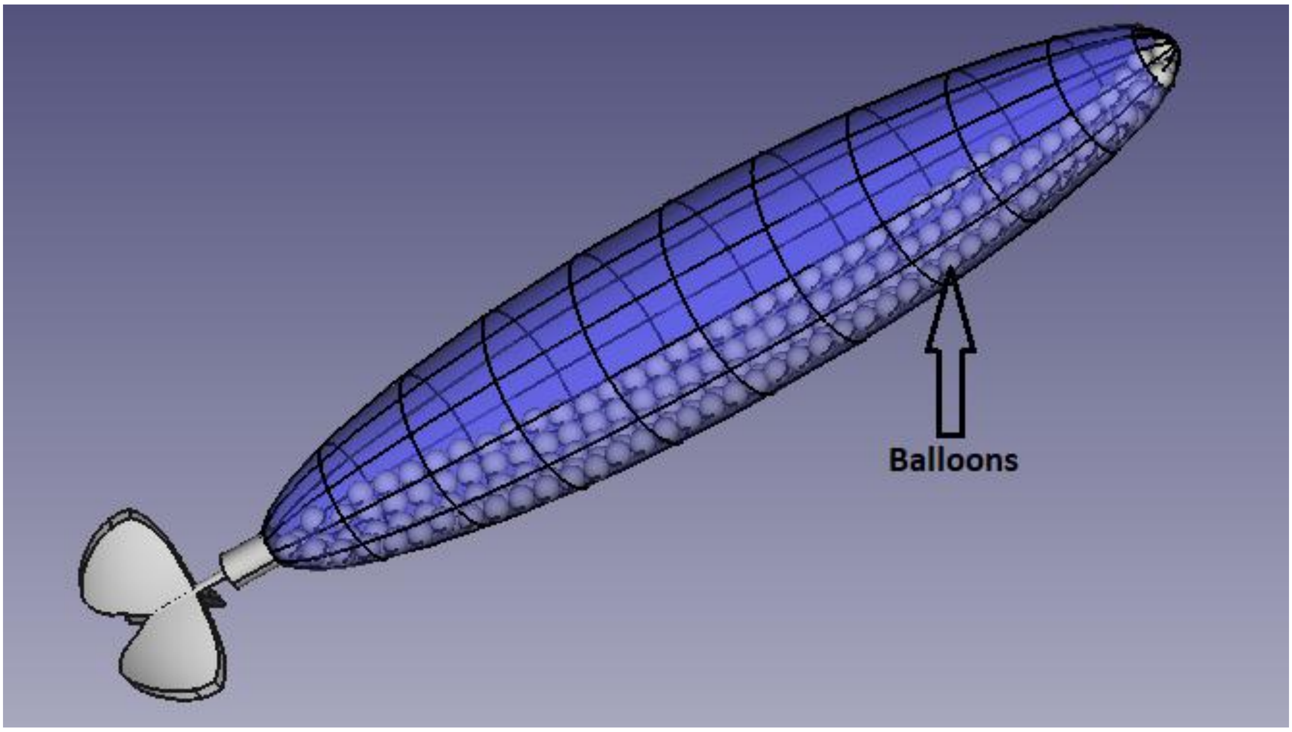


Figure 25: The airship with balloons model draws with FreeCAD

3.2.2 Mass of framework

To obtain the mass of framework, we need to choose the suitable material and to know its characteristics and its density. Then, we calculate the volume of the framework and finally, we use equation Eq.5.

Plexiglas is the suitable material to construct the airship framework. On the Internet, there are many choices. We choose Plexiglas stick, plastic, having a circular section of diameter 6 mm and a length of 1m. [10]

It has also many characteristics:

1. Good mechanical strength
2. Good shock resistance
3. Good dielectric properties
4. Minimal absorption of humidity
5. UV resistance
6. Density= 1180 kg/m^3
7. Elongation at rupture= 4%
8. Compressive strength= 118 N/mm^2
9. Elasticity module= 3140 N/ mm^2
10. Specific Heat= 0.35 cal/g°C
11. Coefficient of linear expansion= 6.8*10^-5 (1/°c)
12. Resistance to cold temperature > -40°C

Figure 26: Stick of Plexiglas

Now, we know the characteristic of Plexiglas, so we can calculate the mass of framework. At the beginning, the volume of the frame must be calculated.

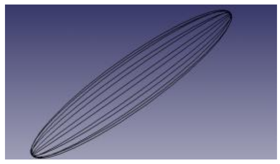
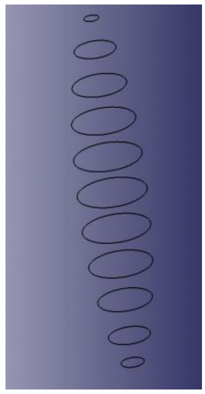
Plexiglas (Material of Structure)			
Volume of structure of ellipses (cm^3)	Ellipse 1	1281	
	Total (6 Ellipses)	7686	
Volume of structure of circles(cm^3)	Circle 1	355	
	Circle 2	76	
	Circle 3	118	
	Circle 4	213	
	Circle 5	213	
	Circle 6	277	
	Circle 7	277	
	Circle 8	326	
	Circle 9	326	
	Circle 10	348	
	Circle 11	348	
	Total	2877	

Table 4: The volume of frame made of **Plexiglas** in cm^3

Volume of ellipse is calculated by this equation:

$$V_{ellipse} = 2 \cdot \pi \cdot ((((\frac{L}{2})^2 + (\frac{D}{2})^2)/2)^{0.5}) \cdot \pi \cdot S^2 \qquad \text{Eq.A}$$

Volume of circle is calculated by this equation:

$$Vcircle = 2 \cdot \pi \cdot (\frac{D}{2}) \cdot \pi \cdot S^2 \qquad \text{Eq.B}$$

S: Demi-Section of circle and ellipse manufactured by Plexiglas.

Using Eq.5, we obtain the mass of frame made of **Plexiglas**:

Total volume of frame : Volume of ellipses + Volume of circles	0.01 m^3
Density of Plexiglas	1180 kg/m^3
Mass of Plexiglas	12.47 kg

Table 5: Mass of **Plexiglas**

3.2.3 Mass of gasbags

We need a specific material when we use Helium. The newly developed envelope is made of high-strength, tear-resistant multi-layer laminates. Even a lighting impact cannot significantly after the flight characteristics. The envelope has a slight overpressure of 5 mbar.

The materials used for this envelope:

- Outer Layer: “Teldar”. It is a film which has a protection from UV rays.
- Intercellular Layer: “Polyester fabric”. It has a snag resistant.
- Internal Layer: “Polyurethane”. It has many characteristic: weldable and waterproof. [11]

This envelope has a density equal to 0.25 kg/m^2 and a force tearing equal to 285 N/cm.

Now, we know the characteristic of the envelope, so we can calculate the mass of gasbags. At the beginning, the surface of the gasbags must be calculated. Eq.5 is not suitable because when we study the tissues, we need to use the surface instead the volume. We calculate the mass using this equation:

$$\text{Surface density } \rho'=m/S \qquad \text{Eq.5'}$$

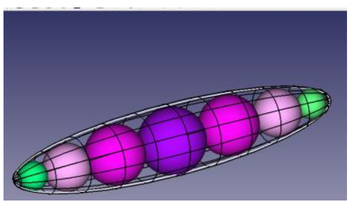
Material of Gasbags			
Surface of Gasbags(m^2)	Bag 1	45.36	
	Bag 2	36.32	
	Bag 3	36.32	
	Bag 4	22.90	
	Bag 5	22.90	
	Bag 6	8.66	
	Bag 7	8.66	
	Total	181.12	

Table 6: The surface of gas bags en m^2

The surface of gasbags is calculated by this equation:

$$S\ sphere= 4*\pi*(D/2)\ ^\wedge 2$$

Total surface of gasbags:	181.12 m^2
Surface Density	0.25 kg/m^2
Mass of gasbags	45.28 kg

Table 7: Mass of gasbags

3.2.4 Mass of external fabric

The tissue used for the external fabric is different from the one that is used in the bags. The envelope of the bags does not leak gas and this is not the status of the outer shell. So another type of tissue is used “Cotton Fabric “has a density of 0.075 kg/m^2.

Surface of external shell	251.33 m^2
Density	0.075 kg/m^2
Mass of external fabric	18.85 kg

Table 8: Mass of external fabric

This theoretical study is difficult to implement now, because, in this project, we want to elevate the airship at high altitude, given that we have become large-scale.

The approval of the Lebanese government must be taken, and it will take a long time. Moreover, the difficult circumstances encountered by neighboring regional states may hinder such approval.

As the aim of the project is to revive the science of airships, we decide to set up a small airship at low altitude, with some modifications to the theoretical study, due to the unavailability of airship manufacturers in the Lebanese market.

3.3 Low altitude test TEMO-Leb Airship

3.3.1 New design with new dimensions of the Low altitude test TEMO-Leb Airship

The new design of the Low altitude test TEMO-Leb Airship has the following dimensions which elevates at a low altitudes. This airship is actually under construction.

Diameter= 1.2 m; Length= 6.4577 m

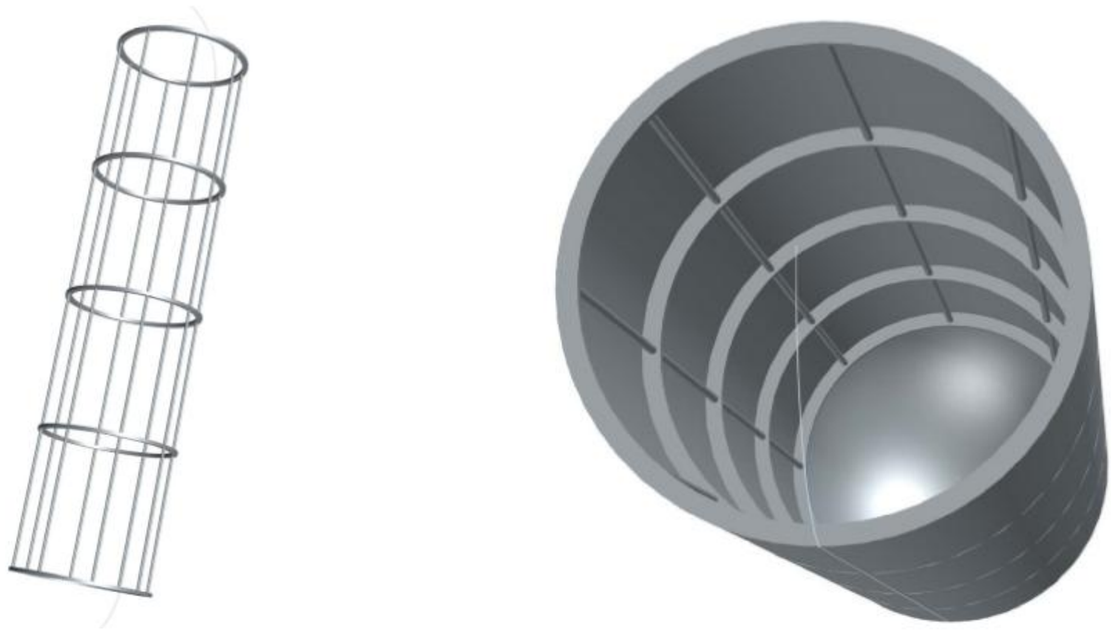


Figure 27: The framework of airship model draws with AutoCAD

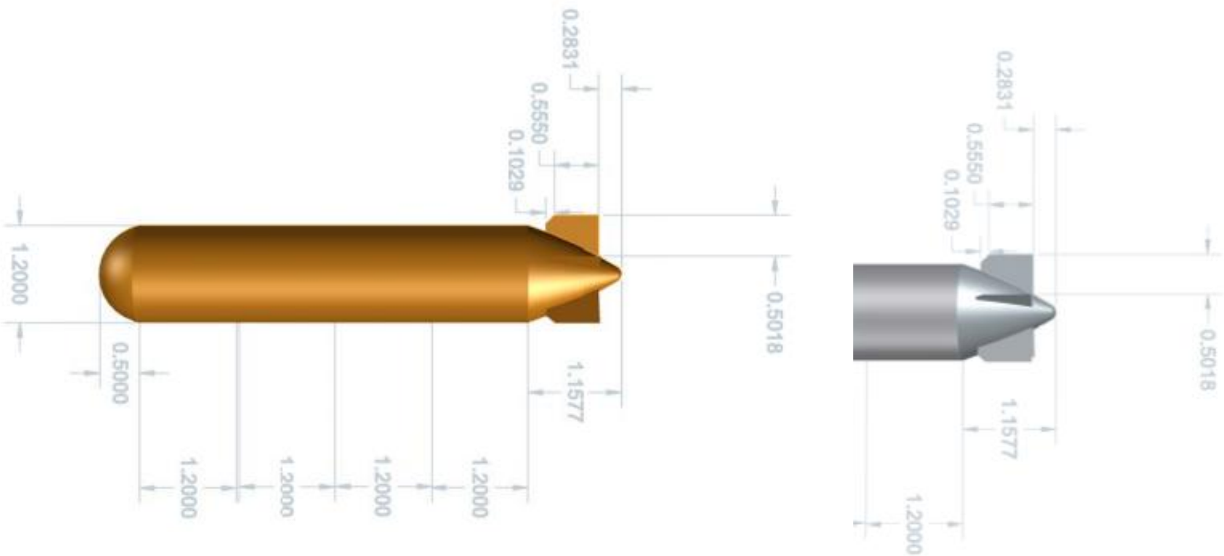


Figure 28: The new design of airship draws with AutoCAD

3.3.2 Materials of the test device for the Low altitude test TEMO-Leb Airship in Lebanese market

1) Balloons filled with Helium

The gasbags are replaced by the balloons, having 1.5 m as a diameter. It is important to know the mass hold by the balloons and the pressure of Helium contained into the balloon. To obtain these parameters, we want to perform this calculation:

Firstly, we calculate the volume of balloon:

$$V_{Balloon} = 4/3*\pi*(D/2)\ \hat{}3 = 4/3*\pi*(1.5/2)\ \hat{}3 = 1.77\ m^3$$

We know the density of Helium at 20°c: ρ_{He}= 0.178 kg/m^3 [14]

By applying Eq.5, we obtain the mass theirs hold by the balloons:

$$m_{hold\ by\ 1\ balloon} = \rho_{He} * V_{Balloon} = 0.178*1.77 = 0.3\ kg$$

$$m_{hold\ by\ balloons} = 4*0.3=1.3\ kg$$

The pressure of Helium into the balloon can be calculate by using the equation:

$$P*V= (m/M)*R*T \qquad Eq.10$$

P: Pressure of Helium into the balloon (Pa)

V: Volume of balloon (m^3)

m: Mass of balloon (kg)

M: Molar mass of Helium (kg/m^3)

R: The universal gas constant = 8.314 $JK^{-1}mol^{-1}$

T: The absolute Temperature of Helium (k)

To obtain the mass, we use Eq.5:

$$\rho=m/V;\ m=0.178*1.77=0.3\ kg/m^3$$

The pressure is:

$$P= ((m/M)*R*T)/V=((0.3/4)*8.314*293.15)/1.77=108457.6\ Pa=1.07\ atm$$

ρ: Density of Helium at 20°c=0.178 kg/m^3

2) Plexiglas

The framework of airship is manufactured by empty tubes of Plexiglas. The section of tube is equal: 6 mm. The mass of framework must be lower than the mass hold by the balloons, in order to rise the airship.

To ensure this calculations, we have to wait for the implementation.

3) External envelope

For the external envelope, a very light type of fabric must be used, because Plexiglas and the balloons cannot sustain an excess weight.

4.Results and Discussion

In this chapter, there are described two results: the results of the theoretical study and the results of the Low altitude test TEMO-Leb airship which is attended to implement.

4.1 Results of theoretical study

4.1.1 Results of "MATLAB"

We use **"MATLAB"** for plotting the variation of density, pressure and temperature as a function of altitude. The results can be found below:

1) **Variation of the density with altitude**

✓ Plotting the function:

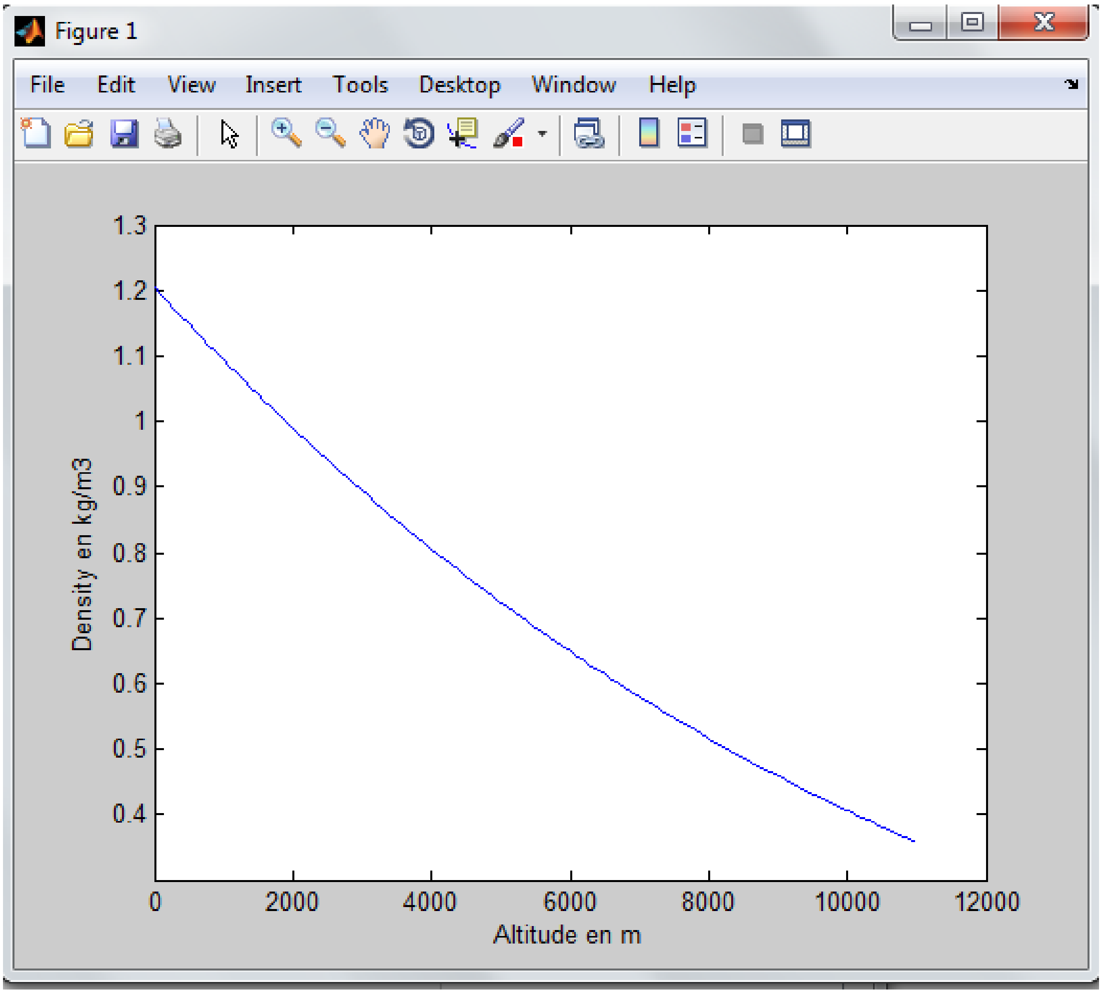


Figure 29: Variation of density (kg/m^3) with altitude (m).

This graph show the variation of the density as a function of altitude along 11 km. we notice that the density decreases with the increase of altitude.

2) Variation of pressure with altitude

✓ Plotting the function:

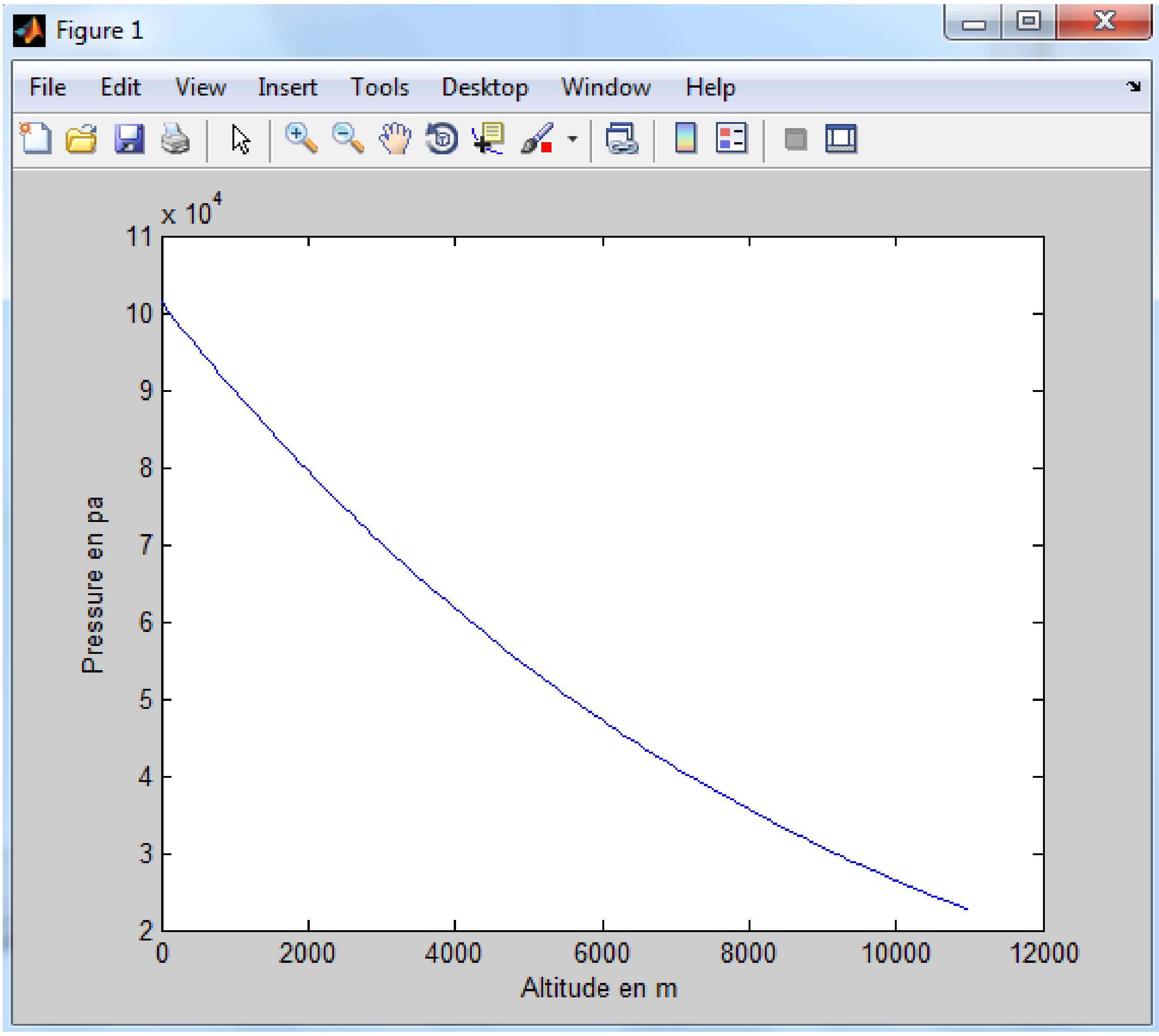


Figure 30: Variation of pressure (pa) with altitude (m) computed for 15°c and 0% relative humidity.

This graph show the variation of the pressure as a function of altitude along 11 km. we notice that the pressure decreases with the increase of altitude.

3) Variation of temperature with altitude

✓ Plotting the function:

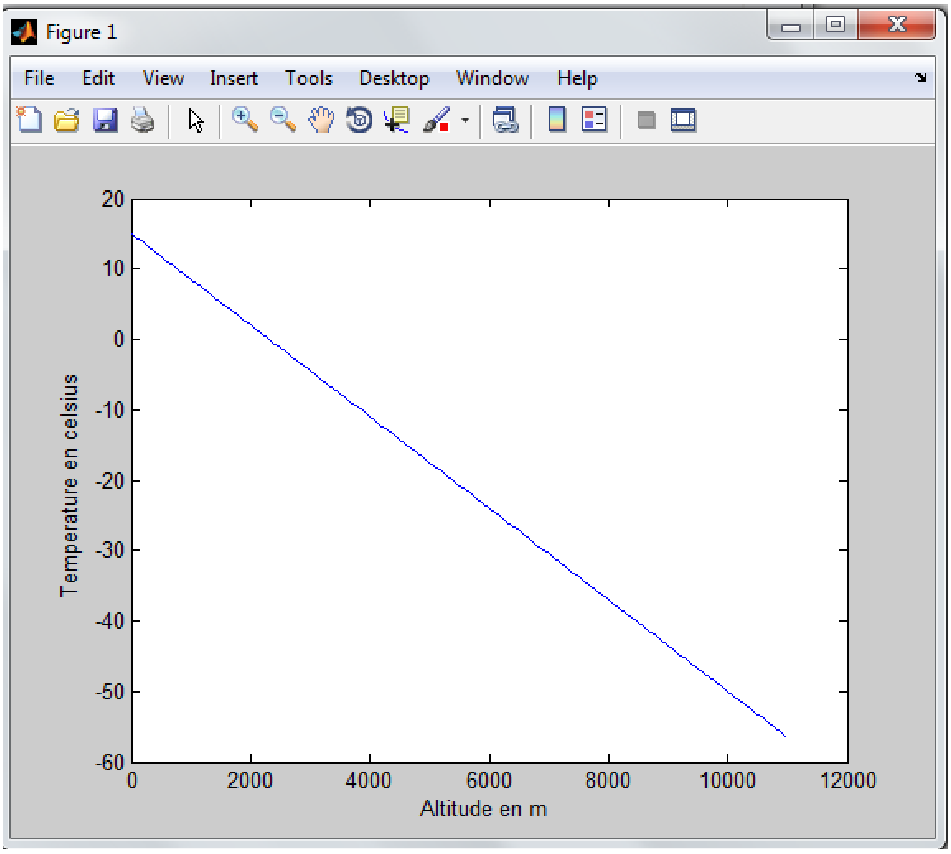


Figure 31: Variation of temperature (°C) with altitude (m).

This graph show the variation of the temperature as a function of altitude along 11 km. we notice that the temperature decreases with the increase of altitude.

4.1.2. $V_{TEMOLeb\ Airship}$ and the V_{max}

We will calculate the maximum volume of Helium contained in the gasbags, and we will check whether the airship able to reach the proposed height.

$$V_{max}= (m_s+m_p)/ \sigma *(\rho_{A0}-\rho_{He0})$$

To obtain the mass of structure, it is necessary to add the mass of framework, the mass of gasbags and the mass of external fabric.

$$m_s = 76.6 \text{ kg}$$

It is assumed that the mass of payload:

$$m_p = 2 \text{ kg}$$

We have the density of air and Helium at 15°c and at sea level:

$$\rho_{A0}= 1.225 \text{ kg/m}^3;\ \rho_{He0}= 0.169 \text{ kg/m}^3$$

The density ratio “σ “is varied with altitude, depending on the below table, we calculate the ratio:

$$\sigma=\rho_A/\rho_{A0}$$

	0	100	200	300	400
-500	1.285	1.273	1.261	1.249	1.237
0	1.225	1.213	1.202	1.190	1.179
500	1.167	1.156	1.145	1.134	1.123
1000	1.112	1.101	1.090	1.079	1.069
1500	1.058	1.048	1.037	1.027	1.017
2000	1.007	0.996	0.986	0.977	0.967
2500	0.957	0.947	0.938	0.928	0.919
3000	0.909	0.900	0.891	0.881	0.872
3500	0.863	0.854	0.845	0.837	0.828
4000	0.819	0.811	0.802	0.794	0.785
4500	0.777	0.769	0.760	0.752	0.744
5000	0.736	0.728	0.720	0.713	0.705
5500	0.697	0.690	0.682	0.675	0.667
6000	0.660	0.652	0.645	0.638	0.631
6500	0.624	0.617	0.610	0.603	0.596
7000	0.590	0.583	0.576	0.570	0.563
7500	0.557	0.550	0.544	0.538	0.531
8000	0.525	0.519	0.513	0.507	0.501
8500	0.495	0.489	0.484	0.478	0.472
9000	0.466	0.461	0.455	0.450	0.444
9500	0.439	0.434	0.428	0.423	0.418
10000	0.413	0.408	0.403	0.398	0.393
10500	0.388	0.383	0.378	0.373	0.369
11000	0.364	0.359	0.355	0.350	0.346
11500	0.341	0.337	0.333	0.328	0.324
12000	0.320	0.316	0.311	0.307	0.303

Table 9: Variation of density of air with altitude

To obtain the density of atmosphere, we use table 9, when we want to obtain the density of 600 km, we see the column in the left: 500 and the line above 100 and we read the density 1.156 kg/m^3.

Altitude (km)	$\sigma*(\rho_{A0}-\rho_{He0})$	V_{max} (m^3)
H=0	1.056	74
H=1	0.959	82
H=2	0.868	91
H=3	0.784	100
H=4	0.706	111
H=5	0.634	124
H=6	0.569	138
H=7	0.508	155
H=8	0.461	170

Table 10: Variation of volume Helium as function of altitude

4.1.3. Positive results

From 0 km to 7 km, we are under the point **“Pressure Altitude”** (explain in Chapter 3).

Under this point, we have:

- The differential of pressure between lifting gas and atmosphere is null: $\Delta P=0$.
- The differential of temperature between lifting gas and atmosphere is null: $\Delta T=0$.
- The density of lifting gas and atmosphere decrease, this variation affects an increase of net volume. The equation Eq.5 is available up to the **"Pressure Altitude"**.

The variation of density and pressure is composed by the volume. When the density and the pressure decrease, the volume of gasbags increases.

At 7 km, this is the proposed altitude to elevate **TEMO-Leb airship**:

$$\mathbf{V_{TEMOLeb\ Airship} > V_{max}}$$

This is a **positive result**, it hasn't any danger to a rupture of airship. The volume of Helium in the gasbags is enough to rise **TEMO-Leb airship**, at **7 km.**

The airship cannot to rise at 8 km, because:

$$V_{TEMOLeb\ Airship} < V_{max}$$

We are now above the point **"Pressure Altitude"** (explain in Chapter 3).

When the airship continue to rise, the density of lifting gas and atmosphere also continue to decrease, but the volume of lifting gas remains constant.

The differential of pressure now isn't null, it starts to increase. The overpressure is created, and consequently, a rupture of the exterior structure of airship can be result if the differential becomes too great.

4.2. Results of the Low altitude test TEMO-Leb airship

We expect the implementation and the experience

5. Conclusion and Perspective

In this chapter, we talk about our work and the result obtained. While proposing several suggestions for developing this project.

After a long absence of the manufacture of the airships, this project made it possible to revive the science of dirigibles. The new proposed project involves using the airship for new objects, making it a contemporary science. It aims to distribute Internet in the far regions without having to install a complete network.

In this memory, we talk about the evolution of airships, their development over the years and the end of the golden epoch of airships. We talk about the principle which is based the airship, the types of airships and the difference between them. We choose the specific gas which uses inside the airship.

We speak of the aerostatic of airships which is based on the bouncy force. We also talk about the variation of the density, the pressure and the temperature as a function of the altitude. This variation is plotting on the "MATLAB" software. Then, we study the influence of these parameters on the airship.

We suggested a design of "TEMO-Leb airship" draws on "FreeCAD" and we calculate the necessary calculation to determine whether the "TEMO-Leb airship" is able to reach the desired altitude.

We talk about the problems that confront us and prevents us from applying this theoretical study.

Next, we propose a new conception which has considered as a solution. This design which has a new dimensions, will rise to a lower altitude. It calls "Low altitude test TEMO-Leb Airship". We expect its implementation.

We put the results obtained by the software "MATLAB" and we put in a table the volume of gas Helium containing in the bags inside the airship, at several altitudes.

Fortunately, we obtain positive results for our theoretical studies. The "TEMO-Leb airship" can reach the desired altitude.

It is a new idea that will be applied in Lebanon and will give our country new advantages, in particular:

- Self-sufficiency
- Local industry
- Distribution of the net in a new way

This project is a solution to many problems, through which we can distribute the Internet in remote cities without having to install a complete network. It is a solution to the development of low-cost areas.

Moreover, we can get Internet from neighboring countries. Thus, the problems that afflict the Internet in Lebanon can solve by this project.

Some suggestions for the development of this project:

- Use an electronic control
- Raise the airship to a height of more than 7 km
- Control the airship in a control room on the ground

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