ISSN 2229-5518

AEROSTATS- An Insight into the Artificial Eagle Eye in Sky

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Abstract— This paper is intended towards giving an insight into the advent of aerostat which is an artificial eagle eye in the sky. The basic theory, components of an aerostat system, aerostat balloon, the main parameters governing in designing an aerostat and its application are being discussed. This sheds the light on the use of aerostat and it's dominance in coming era due to its low cost, unmanned and it's unique ability to stay aloft days together.

Index Terms— Aerostat, balloon, Co-efficient of drag, Co-efficient of friction, drag, Lighter than air, payload

1 INTRODUCTION

One of the enthusiastic moments for everyone is looking at the sky. A tiddler from small age group would rejoice looking at the balloon floating in the air. One wonders why a balloon floats. It's mainly due to the density difference between the gas filled in the ballon and the surrounding air. Lighter things tend to float in the air due to lift.

Airships also named as lighter than air (LTA) aircrafts which came to light in the nineteenth century. One of the vehicles that are drawing attention and attraction is an Aerostat, which is big in size, low speed airship.

Aerostats are unmanned, aerodynamically shaped blimps that are buoyed aloft, tethered to the ground by a single cable. The aerostat is made of a large single fabric envelope that is filled with lighter than air gases which provides the lifting forces.

These offer the next cutting edge technology of UAVs in lighter than air-aircraft segment. This has stricken a tryst in deploying it for various applications.

2 OUTLINE OF AN AEROSTAT

2.1 Basic Theory of aerostat

An aerostat balloon is an aerodynamically shaped body which is tethered to ground. It is filled with lighter than air gases and thus results in lift due to buoyancy. According to Archimedes principle, the lift F_L is caused by the difference between densities of air ρa and lifting gas ρg,

$$F_L = V*(\rho a - \rho g) = V*\Delta\rho, Kg \quad (1)$$

Where V is volume of gas in aerostat (m^3),
ρa, ρg are density of air and gas (Kg/m^3),
Δρ is specific buoyancy of $1m^3$ of gas.

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The denities of air and gas can be determined by Ideal gas equation given by

$$PV = RT \quad (2)$$

i.e. $P = \rho RT$ (3)

P is atmospheric pressure (Kg/m^2)
ρ is density of gas (Kg/m^3)
T is absolute temperature, K
R is universal gas constant.

In aerostat the buoyancy is produced by gas which has least molecular mass. Air density depending on atmospheric conditions, season and altitude varies. Furthermore as per International Standard Atmosphere, the state of atmospheric is determined by [1]

$$\frac{P}{Po} = \left(1 - \frac{H}{44300}\right)^{5.256} \quad (4)$$

$$\frac{P}{Po} = \left(1 - \frac{H}{44300}\right)^{4.256} \quad (5)$$

2.2 Components of Aerostat

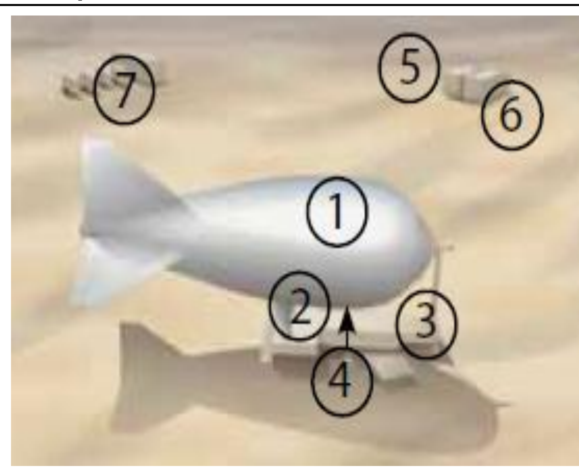

Fig. 1. Components of Aerostat

Fig. 1. Show the various components of an aerostat system. They are: 1. Aerostat 2. Tether 3. Mobile mooring system 4. Mission payloads 5. Ground control station 6. Maintenance and officer station 7. Power generators and site handling equipments.

The aerostat balloon is tethered to a mobile mooring platform via winch mechanism. The payloads are carried by aero-

ISSN 2229-5518

stat balloon. These payloads are communicated to and fro from the ground control station. The maintenance station will play a role of storage and depot/shop replacement of LRUs. The required power is supplied by the power generating station.

2.3 Aerostat balloon

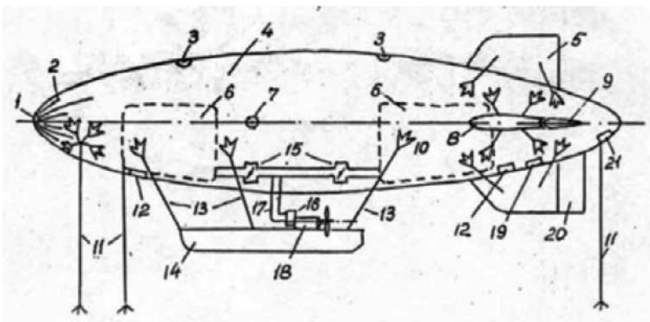

Fig. 2. Aerostat Balloon

Aerostat balloon is an important component which carries payload filled with 'Lighter than air' gas and generates lift due to buoyancy. The main requirements of an aerostat balloon are high payload capacity, low blow-by, sufficient stability and fast response to winds. The total lift that is produced by buoyancy and aerodynamic forces is balanced by the weight of the aerostat, the tether force and payload. The buoyancy solely depends on the volume of LTA gas contained in the envelope.

The weight of the envelope depends on its total surface area and the density of the material that is used for manufacturing the balloon. Thus, to reduce the weight of the aerostat, its surface area should be reduced.

Fig. 2. Depicts the various parts of an aerostat balloon. The parts are as follows: 1. Mooring Point, 2. Bow stiffening, 3. Rip panel, 4. Flexible envelope, 5. Fin, 6. Ballonets, 7. Controlled valves, 8. Stabilizer, 9. Elevators, 10. Mounting foot, 11. Mooring lines, 12. Safety valves, 13. Cords, 14. Gondola, 15. Valve, 16. Fan, 17. Air duct, 18. Power plant, 19. Safety valve, 20. Rudder, 21. Appendix.[1,2,5]

2.4 Main parameters governing aerostat balloon design

An aerostat is in flight due to the generation of aerodynamic lift and drag. The drag consists of three components: 1. The pressure drag, 2. The friction drag, 3. The induced drag.

The pressure drag is due to the air displaced as the wind rushes past the aerostat balloon. The friction drag is due to no-slip condition in the boundary layer of the flow around the aerostat. The induced drag is very small and can be neglected.

The co-efficient of friction is given by:

$$Cf = 0.043 / \mathrm{Re}^{1/6} \qquad (6)$$

The friction drag is given by:

$$Df = 1/2 * \rho * V^2 * Swetted \qquad (7)$$

Where Swetted = 2.33*d*l,
d= diameter of oblong aerostat balloon in m,
l= length of the aerostat balloon in m,
ρ = density of air in kg/m³,
V = Wind velocity in m/s.

The pressure drag is governed by the shape of the aerostat. Co-efficient of drag Cd is given by:

(8)

$$Cd = (0.172 * (l/d)^{1/3} + 0.252 * (d/l)^{1.2} + 1.032 * (d/l)^{2.7}) / \mathrm{Re}^{1/6}$$

The pressure drag is given by:

$$Dp = 1/2 * \rho * V^2 * Volume^{2/3} \qquad (9)$$

Volume of oblong ellipsoid of revolution is given by:

Volume = (4/3)*π*(l/2)*(d/2)² (10)

Let us consider an aerostat, i.e. Akron aerostat from Lockheed Martin. Where d=40.5m and l=238.95m.

Therefore volume = 205571.3433 m³.

The density of air, ρ = 1.1839 Kg/m³ at 25⁰C.

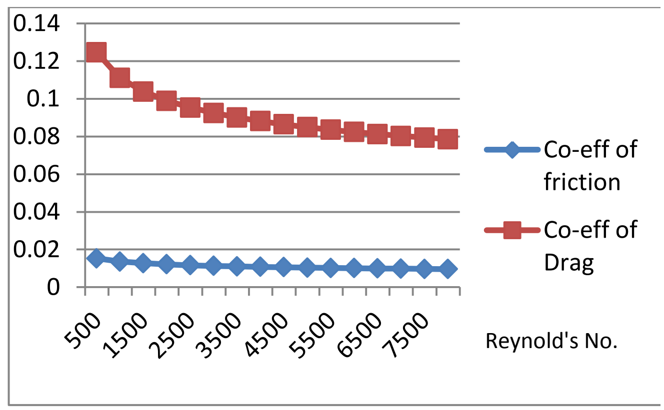

Fig. 3. Co-efficient of Friction and drag vs Reynold's number for Akron aerostat.

The co-efficient of friction and drag depends on the geometric parameters of the aerostat and the reynold's number. The fig. 3. shows the variation of co-efficient of friction and drag versus the reynold's number. The co-efficient stabilizes as the reynold's number increases. It can be observed that the co-efficient of drag is greater than the co-efficient of friction thus attributing that drag plays a vital role.[3,4,6,7]

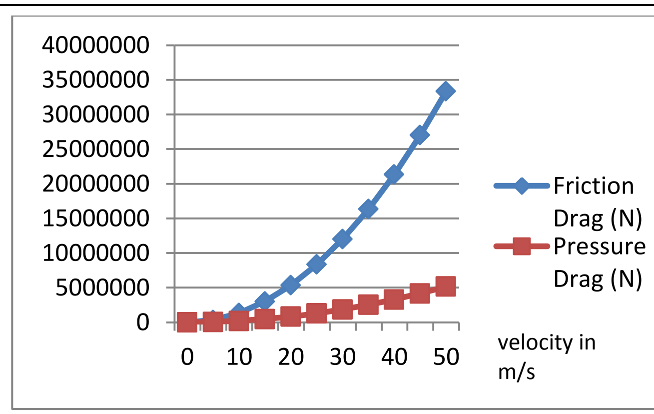

Fig. 4. Drag Forces vs Wind velocity

The drag forces due to friction and pressure are depended on the wind velocity and the geometric parameters of aerostat. The fig. 4. Shows the variation of drag force in Newton versus the wind velocity in m/s. As the wind velocity increases, due to no-slip at the boundary condition the drag force due to friction is higher than the pressure drag. This shows that the drag force due to friction has to be reduced by optimizing the shape of the balloon to achieve greater lift. As the lift forces increases, the aerostat can attain higher altitudes during flight. During this optimization, care has to be taken to optimize the weight of the aerostat including payload to withstand the wind blow-down.

3 APPLICATIONS

The most efficient means to meet the needs of airborne application is a low cost, mobile and flexible system. Mobile towers are one of the means to fulfill these needs. But these are height limited, providing only short range coverage.

To fulfill all these needs and overcome the shortcoming posed by the mobile system, aerostats are best employed and utilized to overcome all issues. Here are few applications explained below:

1. Air sampling and research: An aerostat is used to setup a research instrument that is designed to collect and store air sample, transmit and record pertinent data and provide a secure and sustainable research platform for atmospheric research.

This is to achiev an autonomous, wireless, mobile, reliable and precise air sampling and data collection. [8]

2. Radio Communication: An aerostat acts as a tall antenna tower for radio communications over long distances and rugged terrain. The payloads are used for tactical communication, emergency communication and disaster recovery communications. The system connects antennas on an aerostat to multiple radios on the ground. This system connects distant antennas to radios inside a secure compartmented information facility. This type of system enables persistent, inexpensive wide area radio communications. [3]

3. Disaster Relief: During the times of earthquake, floods etc. The transportation systems to the affected areas are accesible. This leads to the use of other means, to supply basic necessities for people. Aerostat's play a vital role in manuevering along the blocked paths and roadways to rescue people, reduce casualities and losses. It helps in supplying water, medicines, equipment and supplies needed by relief workers.

These also act as surveillance means which stays over a long period of time as compared to that of helicopter. [9]

4. Construction: Aerostat can also be used as construction equipment. The stability of flight provided by aerostats allows them to move and deliver construction components for more maneuverability and efficiency for construction.

5. Aerial Early Warning: Aerostat assures crucial airspace dominance, providing early warning and airspace control. It generates high quality air picture including timely full and accurate data with the help of payloads. [9]

6. Anti-terror/ Homeland Security: Aerostats enhances homeland security against acts of mass terror. It provides improved airspace coverage. It helps in building up database over time for identification of irregular events. It also provides increased co-ordination betweeen surveillance and response units.

7. Border and Maritime surveillance: Aerostats are biggest asset in this application as they provide cost effective solutions for wide area surveillance and detection. It helps in monitoring border areas and maritime surveillance.

8. Military Intelligence: It supports collection and interception of a variety of data types and wavelength. Helps in building up of intelligence database to support tactical and strategic decisions.

Other applications include up-to-the minute aerial updates of a disaster scene for emergency responders, detection of nuclear radiation and chemical agent, oil spills, forest fires, crash sites, crowds, well equipped for night vision and stealth surveillance.

4 CONCLUSION

Aerostats are lowest total cost of ownership of any alternative airborne surveillance method. It involves lower capital investment, less personnel required to operate,, less cost to maintain and operate. It involves very few mechanical parts, low fuel requirements.

It has longest duration and loiter time than any other type of platform. Aerostats are easier and less costly to train and operate than UAVs, fixed wing or rotary wing aircraft. It has less risk of public damage or civilian injury from a system failure.

Aerostats are like an artificial eagle eye in sky and most environmental friendly method of aerial surveillance. It is one of the mobile and flexible systems with quick deployment, long mission duration with wide applications.

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