A Review on Technical Development of Airships and its Application

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Abstract- *The research and development of distinct types of airship are mentioned in this paper. The major constructional details of non-rigid, semi-rigid and rigid airships are initially introduced. It is followed by the description of unconventional airship shape with lifting capacity, operation mode and shape. The early history from airship's origin to recent advance airship structural technology and its historical achievements are represented in details, along with their use during World War I. The application of airship in agriculture, food transportation, military application, communication, cargo transportation and advertising are then reviewed.*

Keywords- Airship, structural development, historical achievements, simulation techniques, Cargo application.

I. INTRODUCTION

Airship is lighter than air aerial vehicle which is first invented by Henry Giffard in 1852, the basic principle behind airship is Archimedes principle of floatation in which the lift force is obtains by expansion of lighter than air gases in airship envelopes. Depending upon the structural arrangement airship is classified in two different types that are conventional and un-conventional. The airships differ from the hot air balloons due to ability of controlling the flight which is emerged due to means of powered propulsive system. Airship can perform in very wider range of applications such as cargo transportation, military applications, wireless remote sensing, and communication field with very massive reduction in cost and energy consumption. Conventionally airships are classified as rigid, non-rigid and semi-rigid types which are having stream line axisymmetric bodies which generate lift. The unconventional airship shapes differ from conventional stream line bodies and allow variation in shapes and configuration which will result into higher payload capacity and ability to work in variety of situations.

II. STRUCTURAL DEVELOPMENT

2.1 Classification of Airships

2.1.1 Conventional Airships: A. Non rigid:

Non-rigid airships are classified on the bases of their structure. The non-rigid airship utilizes gas pressure inside the balloon to maintain its structure and shape. They provide comparatively less dead weight due to absence of any fixed supporting structure. Now-a-day various industries as Goodyear and many others are using non-rigid airship for passenger transport and advertising. They give higher payload capacity than rigid airship. The first non-rigid airship was developed by Santos-Dumont, which uses hydrogen as its lifting gas. The main care to be taken of non-rigid airship, it requires to maintain its inner ballonet as its shape contract due to decrease in temperature or absence of sunlight. Some of non-rigid airship models are TC-3, G class Blimp, P-1791, Sky ship 600, SVAM CA-80, etc. [1].

B. Semi-rigid airship:

Semi-rigid airship comprises of the solid keel which covers the entire length of airship body. Any payload or operating equipment are mounted on the keel it acts as the single supporting member to the entire load on the airship. The very important factor of non-rigid airship design is the attachments of airship balloon to the keel. Any slight mistakes in attachment may result into total unbalance of airship, so very precise practices are required to produce the semi-rigid airship. It provides comparatively higher payload carrying capacity rather than same sized rigid airship due to, less self-weight and absence of rigid exoskeleton. Some of Semi-rigid airship models are Zeppelin NT-07, Grob-Basenach Airship, Luftschiff, etc. [11].

C. Rigid airship:

Rigid airship consists of rigid structure maintaining its shape using its external structure and the balloon being located inside the structure. The rigid airship has very good aerodynamics properties due to its constant shape maintained. Rigid airships were used during World War I by many countries for military application. Later, the Germen Company Graff-Zeppelin uses the Hydrogen filled airship for passenger transport. The Hindenberg airship sizing 245 m in length, 41.2 in diameter and 200,000 cubic meters gas capacity of 36 passengers and 61 crew members [12]. It was used for luxurious intercontinental passenger transport between Europe and America.

2.1.2 Unconventional Airship:

The shapes of unconventional airship are different from conventional stream line axisymmetric shape. The hybrid design of unconventional airships enables it to carry large payload over very large distances. Some of the unconventional airships are introduce below.

A. Solar ship:

It is a semi-rigid type of airship model which has aerofoil cross-section, and approximately triangular top view. It uses helium gas for generating static lift, and its unique aerodynamic shape along with rear flaps for aerodynamic lift. It is a combination of an airship and a bush plane which uses of both static and aerodynamic lift. So we can get a bush plane with large payload capacity. Solarship.inc company is developing such advanced airship models for cargo transportation in remote areas, as solar ship requires very less infrastructure and has an ability to land even on water makes it very cost effective and sophisticated mode of transportation.
The upper surface of airship is completely covered with the solar panels, which generates electricity and provides it, the independence on conventional fossil fuels [9].

B. Lenticular Airship:

Lenticular shape can be obtained from spherical shape just by reducing vertical axial length of sphere. These are full rigid type of airship. It can use helium as well as hydrogen gas for generation of static lift. It has large surface area so it produces comparatively high amount of drag force than other aerodynamic shapes. The lenticular shape has less stability during mooring process, so it is required to attach additional wings or stabilizer to get better stability. It has less coefficient of drag than spherical shape and slightly high coefficient than aerofoil shape. The Russian military is using such lenticular airships equipped with various tracking and surveillance equipment for border patrolling [12].

2.2 Effect of envelope shape on airship's payload capacity and drag coefficient:

The selection airship envelope shape plays very crucial role in deciding payload capacity of an airship. It also affects the drag coefficient of an aerostat envelope. Some of the methods to improve airship's payload capacity are reducing the coefficient of drag and dead weight of airship. The author carried out the experimentation on four different shape profile and multiple fabrics. The two fabric configuration found to be very much effective due to increase in breaking strength and reduction in self weight. It results into improved payload capacity. Four profiles in GNVR shape were taken with slight variation in occupied volume, fin weight, envelope fabric weight and tether forces of single fabric configuration. Finally the 2nd shape profile with payload of 242.5 kg, fin weight 102.1 kg, envelope fabric weight 310.5 kg and tether forces 734.7 kg is selected because of its maximum payload capacity least envelope weight and low surface area which also reduces force required to lift the airship and drag on the shape [3].

III. TURBULENT MODEL SELECTION FOR CFD VALIDATION OF AIRSHIP MODEL

Computational fluid dynamics technique has very wide range of application in model simulation for airship. Multiple turbulent models are available for simulation depending upon various fluid mechanics considerations. The available turbulent models are-

i. Standard Spalart-Almaras turbulence model:

It is first invented by Spalart and Almaras in 1992. It is a single equation model which is design for external flows and therefore, suitable for airships.

ii. SST K-Omega turbulence model:

SST K-Omega model is invented by Menter and it is used when there is variable pressure gradient.

iii. Realizable K-Epsilon turbulence model:

Initially the K-Epsilon turbulence models were developed by Launder and Spalding. These models can be used for low Reynolds number and has very large application in CFD industry.

All above mentioned turbulence models are analysed for multi-body advanced airship for transportation at various angle of attack and different results are obtain based on those results Spalart-Almaras turbulence model is found to be accurate. It requires comparatively less processing time as it is a single equation model. The test conditions are maintained as pressure is 12112 Pascal and air density 0.19 kg/m3 and dynamic viscosity is 1.4216*10-5. The accuracy values for SST K-Omega turbulence model is higher than other two models but due to much less CPU time and comparatively low error than SST K-Omega turbulence model, Spalart-Almaras turbulence model is the best choice for airship CFD simulation [4].

IV. EFFECTS OF PROPELLER ARRANGEMENT ON AIRSHIP DRAG REDUCTION

Airships are buoyancy driven vehicles so they required occupying maximum volume which differs it from conventional aerofoil shape. The aerofoil shapes has minimum drag force value but as airship are bluff bodies the amount of drag force acting on it is significantly high. The proper propeller arrangement has significant impact on reduction of drag force. Multiple methods analysed by the author are stagnation point injection without propellers, inner flow with injection, outer flow with injection and it is found that the value of drag coefficient for inner flow with injection are minimum. The second method adopted by the author is varying the position propellers on airship body. The various positons consider are 78.5%, 58.4% and 19.3% on the airship length. The propellers flow away the vortex. The arrangement of propellers at the point where the vortex are produced results into gradually attach flow over the airship body which causes reduction in drag force and it is found that the position of propellers at 58.4% of the length of airship is most suitable for drag reduction [5].

V. EXPERIMENTATION ON CONVENTIONAL AIRSHIP MODEL OF ELLIPSOIDAL SHAPE

Various experimentation methods are available for design radiation of airship such as wind tunnel testing, water towing tank etc. Wind tunnel testing method uses air as fluid and require very high velocity air for scaled model validation changing fluid during testing may result into reduction in required velocity and sizing. Author carried out experimentation on ellipsoid shape airship with two horizontal stabilizers at various Reynolds number. As the value of Reynolds number increases the flow separation occurs frequently and there is increase in the drag force value. At various flow types such as laminar, turbulent and transient the value of Reynolds number is varied from 78000 to 705000 and yaw angle from 0 to 6°. The force component at yaw angle 2° is larger than 0 ° due to sudden flow separation. The flow visualization over the airship body concluded that during lower Reynolds number the flow is attached to the airship body and very smaller vortex is generated at the end. As the Reynolds number value increases the flow separates earlier and vortex formation also increases and the axial position is minimum in laminar flow, intermediated in transient and maximum in turbulent flow [2].

VI. APPLICATION

i. Advertising:

As airship consist of gas rather than wings and engine as that in aeroplane, and hence can fly without utilization of fuel. Since they can stay aloft anywhere in air for hours to days than airplanes or helicopter, so it is easy for advertising hence used as primary command, control and communication platform [11].

ii. Military Applications:

As airship can stay aloft and fly at high altitude they used to detect miles clearly and enemy movements and insurgents by using radar cameras. Airships were slow and fly at high altitude so it was difficult to enemy to find the target at night, since army can travel their destination easily. Airships were used as anti-submarine warfare, as from inside the water they were invisible and the enemy cloud not detect them [9].

iii. Agriculture:

Airship is used for transporting chemical scattering equipment as they are heavy and cannot be transported by other medium. Airships can be used to monitor crop conditions and helps to gather continuous information about crop condition which will be helpful for the farmers to improve crop quality and production rate [7].

iv. Communication Sector:

An airship has an ability to endure for long time periods. These features enable it to perform as an aerial platform for communication equipment. Many countries are carrying out research on using airship as a stratospheric platform which can replace satellites and the costing required for such operations is found to be very much cheaper than launching a satellite in earth's orbit. Airship is capable of carrying tethering hotspot like devices to provide the internet facilities in rural areas where today's cellular technology fails [8].

v. Passenger and Cargo Transportation:

Airships have combined features of aero-plane as well as helicopters. Its aerodynamic shape gives it an advantage of getting aerodynamic lift and static lifting ability enables it to hover like a helicopter. The payload capacity of airship can be varied just by changing its occupied volume so that it makes it sophisticated for carrying huge cargos along long distances without getting significant effect on environment. Airships were used by European countries for passenger transport in early 90's due to its stability and vertical take-off and landing facilities [10].

VIII. SUMMARY

Airships are introduced initially with its history and development. The various types of airship depending upon its structure are then investigated for their payload capacity and it is found that the blimps can carry large payloads than other types of airships. For the turbulent analysis of airships using CFD spallart-alamras model is proved to be most efficient for CFD analysis of airship because it gives minimum computing time and gives sufficiently accurate results. The drag reduction techniques with proper arrangement of propellers are then analyzed and the propeller locations at the point where the whirls are generated is found to be most suitable and reduces the maximum drag force just by taking away the whirls and attaching the flow to the airship body. It is followed by the experimental analysis of a spheroidal shape model using water towing tank and it shows the variation in fluid flows as per the increase in Reynold number value. The application of airship in transportation, communication, advertising, agriculture, and military applications etc. are also described.

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