International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

Vol. 38 No. 2 May 2023, pp. 390-396

Model Airship As A Transportation Mode In Jabodetabek To Overcome Congestion Using CFD

Shidqi Divreda Sulaeman[1], Sovian Aritonang[2], Sjafrie Sjamsoeddin[3] , Gita Amperiawan[4] Imanuel Dindin[5]

Republic Indonesia of Defence University

RIDU

Jakarta, Indonesia

[1]shidqi.sulaeman@tp.idu.ac.id

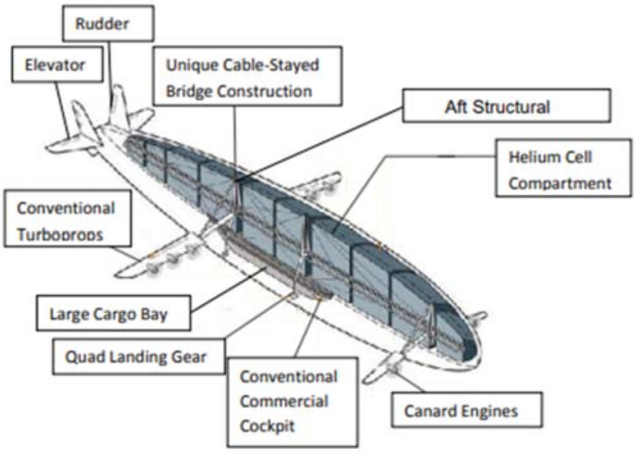
[2]sovian.aritonang@idu.ac.id

Abstract – This research is motivated by the traffic congestion problem in Indonesia, specifically in Jakarta. According to data from the Central Statistics Agency (BPS), the population of Jakarta as of September 2021 is estimated to be 10.61 million people per year. This is an increase of 0.45% compared to the previous year, which had a population of 10.56 million. Road users in Jakarta are divided into four types of motor vehicles: passenger cars, buses, trucks, and motorcycles. According to data collected by the BPS, there are 21.7 million vehicles in Jakarta. Referring to previous research titled "The Potential of Using Airships to Support Development in an Efficient and Environmentally Friendly Manner" (Subagyo, 2011), the authors aim to explore the potential of using airships as a solution to mass transportation congestion. Currently, researchers are looking for solutions to the congestion in Jakarta. In this paper, the authors aim to contribute to finding the best solution to the current problem by providing input on the use of air accommodation using balloons. Specifically, the authors are using the Airlander 10 type balloon being developed in Hamburg. In order to achieve this goal, this research aims to conduct an analysis of the aerodynamics of the platform design using computational fluid dynamics. In order to achieve this goal, this research uses a quantitative method as a calculation of the aerodynamics of the airship combined with the Parent Design Approach method. This approach produces the characteristics of the airship currently in operation. Therefore, the authors would like to present this research to the city of Jakarta as an alternative solution to the traffic congestion problem itself.

Keywords – Aerodynamics, Airship, Computational Fludia Design

I. INTRODUCTION

This research is motivated by the problem of congestion that occurs in Indonesia, especially Jakarta. According to BPS data, having conducted a population census in 2021, the population of DKI Jakarta in September 2021 was 10.6 million people. Can be estimated every year Referring to data from the Central Statistics Agency (BPS), the population of Jakarta will reach 10.61 million people in 2021. This number has increased by 0.45% compared to the previous year of 10.56 million. Road users in Jakarta according to their type are divided into 4 motorized vehicles including; passenger cars, buses, trucks, motorbikes. According to data collected by BPS, according to the type of unit, there are 21.7 million vehicles in Jakarta. the factors that cause congestion, namely the causes of flooding in Jakarta are (1) the high use of private vehicles in Jakarta; (2) the high use of two-wheeled motorbikes in Jakarta; (3) the vehicle volume is not proportional to the road capacity; (4) undisciplined road users comply with traffic rules; (5) infrastructure development (Sitanggang and Saribanon, 2018). Airship Technology for Dynamic Purposes For various purposes with airships that are more mobile or dynamic, the appropriate technology for these purposes is to use semi-rigid airship technology which is designed by combining airship technology and aircraft technology. The combination of airship and aircraft technology provides a higher speed. This airship is designed with lift in mind in addition to using buoyancy assisted by wings that generate lift.



Picture 1 : Hybrid Technology A Combination Of Airship Technology And Aircraft
Source : Subagyo, 2011

The picture above shows a combined hybrid technology between airship technology and aircraft capable of reaching high enough speeds10). The combined technology in the form of a hybrid airship has been developed by an American-based Ohio airship maker. Referring to the research conducted previously, the author aims to try to answer the problem by applying the technology currently being developed, namely Airship. Today, researchers are looking for solutions to traffic jams in Jakarta. In this paper the author aims to contribute to participate in finding the best solution to the problems that are currently being faced. The author wants to contribute in providing input on the use of accommodation by air. That is using a hot air balloon that is being developed in Hamburg with the type name Airlander 10.

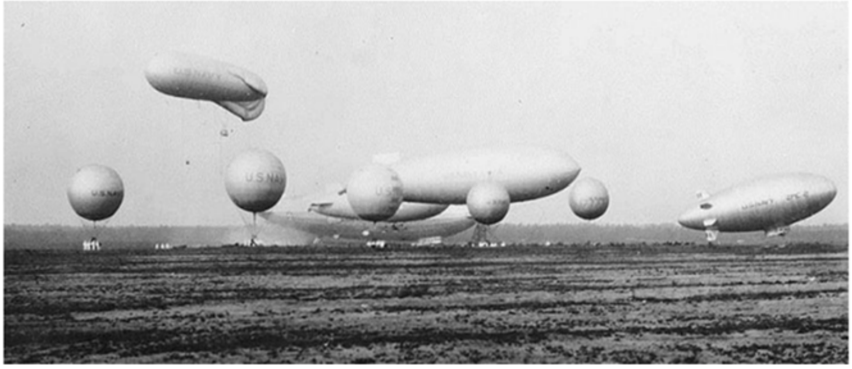
II. Research Methods

Airships originally had the concept of a balloon with combined propulsion and rudder systems. Hot air balloon depends on the pressure of the lifting gas used, namely helium. Hot air balloons have the ability to maintain their shape with excess pressure. Changes in the volume of the lift gas occur due to changes in temperature or changes in altitude which are compensated for by pumping air into the ballonets to maintain excess pressure. Without sufficient overpressure, the balloon loses pilotability and is slowed due to increased drag and distortion.

Development of Airships.

The origins of modern airships can be traced back many centuries. Before fixed wing planes penetrated the sky, humans had flown by airships. Manned flights began with Lighter-than-Air (LTA) aircraft in 1783 when the hot air balloon was invented. The flying ability of a balloon depends on the lift generated through buoyancy, which is created by heating the air inside the balloon. Balloons allowed humans to achieve the first flight. The LTA's advancement came in the 19th century when a propulsion system was incorporated into the balloon to provide propulsion. Controlling these powered balloons required designers to introduce rudders and flaps to the aircraft. During this time the shape of the balloon also began to change. The envelope changed from a spheroid to an ellipsoid design creating a more streamlined body and with it the birth of the airplane.

These components still form the basis of modern aircraft. Today, objects such as balloons and airplanes that rely on buoyancy to generate lift are often found referred to as aerostats. Aircraft functionality was enhanced when internal combustion engines were introduced to efficiently replace human-powered propulsion. The 20th century saw a boom in the industry thanks to these new designs. Airships were soon used for military and commercial applications. The eruption of the first world war caused several countries to use airships for reconnaissance and bombing missions. They proved somewhat ineffective in the latter but their monitoring and communication successes were evident. Continued use after the war.



Picture 2 : US Navy Aerostat during the Demonstration of the year in 1931
Source : Kevin Shields,"CFD applications in airship design", 2010

The image above shows some US Navy aerostats during the Demonstrations of 1931. The first commercially available transatlantic flights were in 3 airships. Many were also found used for expeditions and experiments. Airships returned to significant military use during the second world war. The US Navy operates a fleet of 168 airships in the anti-submarine warfare role to escort ships. Of the 89,000 ships escorted none were sunk, and only one plane would be lost to enemy fire. Aircraft flights continued to decline after World War II as many countries discontinued their use.

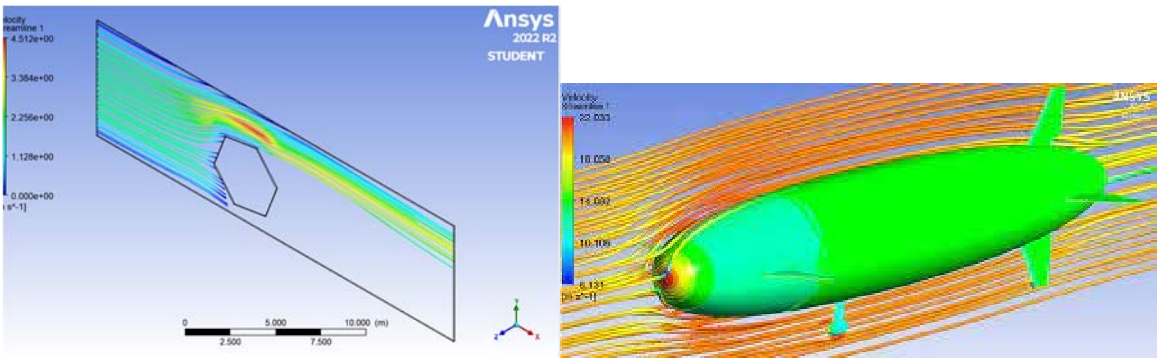
The decline continued and in 1961 the Navy discontinued its LTA program, putting the aircraft's future with the US military in jeopardy. Its use in other fields is also reduced. Over the next four decades, most of the remaining airship operations would serve the advertising industry.

Aerodynamics with a numerical study approach was carried out due to the limitations of measuring instruments and demands for detailed visualization of the resistance flow characteristics across the Airlander 10 airship design platform. dynamic. In order to achieve this goal, this research uses a quantitative method approach combined with the Parent Design Approach or commonly known as the Parent Design Approach and assisted by the Ansys R2 2022 application to analyze fluid flow in airship design.

The parent design approach is a method of designing ships by way of comparison or comparison, namely by taking an airship as a reference for a comparison airship that has the same characteristics as the airship to be designed. In this case the designer already has a reference ship that is the same as the airship to be designed, and it is proven to have good performance. The advantages of the parent design approach are:

- Can design airships more quickly, because there are already ship references, so modifications are enough;
- The ship's performance has been tested in terms of stability, motion and resistance.

Pendekatan tersebut menghasilkan karakteristik Airship yang beroperasi saat ini. Dalam analisa aerodinamika design platform airship ini menggunakan metode numerik computational fluid dynamic menggunakan software ANSYS FLUENT 2022



Picture 3 : : 2022, Ansys Fluent Student R2

Aerodynamics is a fluid movement of air or other gases, which has a force with relative motion to the fluid the Airship is an aerostat that is equipped with propulsion and systems by controlling the direction of motion. Airship movement When the power plant is not operating it will act as a blimp. The aerodynamics of an airship simply consists of magnus lift. This force acts in a direction perpendicular to the direction of motion and the axis of rotation. The magnus force acts vertically upwards to allow it to travel longer distances than in a vacuum [4]. The aerodynamic drag equation can be shown as follows [5].

$$D = \frac{1}{2}\, u^2\, V_{ext}^{2/3}\, C_{D,V} \qquad (1)$$

and aerodynamic lift can be shown as follows [5].

$$L' = \frac{1}{2}\, u^2\, V^{2/3} C_{L,V} \qquad (2)$$

The process of lift on an airship is fundamentally influenced by lift, buoyancy, and the effect of its loading or gravity. The use of lift using gas is based on the principle of Archimedes' law and can be defined as the lift principle. Lift occurs because of the difference in density between gas and air. The Principile Lift (PL) equation is shown as follows:

$$PL = V(\rho_A - \rho_B) = V\Delta\rho,\ \ kg \qquad (3)$$

V is the volume of air gas contained in the airship in m3 units, ρ_A,ρ_B is the density of air and gas in m3 units, Δρ is the specific buoyancy for 1 m3 gas. Then the volume of gas and air can theoretically be determined by the Clapeyron equation for an ideal gas.

$$pv = RT\ ; v = \frac{RT}{P} = \frac{1}{\rho}\ ;\ \rho = \frac{P}{RT} \qquad (4)$$

where, v is the specific gas value in units of m3/kg m, R is the gas constant in units of kg.m/kg°C with 29.27 for air, 424 for hydrogen, and 212 for helium, T is the absolute temperature, °K, p pressure atmosphere in kg/m2.

The working force component consists of a vertical component and a horizontal component, the vertical component consists of lift (Flift) in an upward direction, gravity (W), and drag (Fdv). Meanwhile, the horizontal component consists of thrust (F) and drag (Fdh) which are in the opposite direction to the object's movement [6]. The vertical direction can be viewed using Archimedes' law, with the magnitude of the buoyant force on an object in a fluid proportional to the weight of the displaced fluid.

$$F_y = \Delta\rho . V . g = P_L . g \qquad (5)$$

Airships can rise to the top if the buoyant force is greater than the total load of the airship plus the frictional forces it experiences. The frictional force (Fd) is proportional to the speed (v) and the frontal area of the airship (A). This frontal plane is an elliptical plane with diagonal radii a and b. The drag coefficient can be calculated based on the Squire-Young equation and the airship configuration can be calculated using the non-circulate coupling method [7]. which apply to the calculation of the drag coefficient on airships [8]. The inhibition coefficient equation based on the Squire-Young equation [9] is as follows.

$$C_{dv} = \frac{Fd}{\frac{1}{2}\rho U_\infty^2 v^{2/3}} = \frac{4\pi}{V^{2/3}} r\theta U_e^{(H+5)/2} \qquad (6)$$

where Fd is the drag force, ρ is the density of the atmosphere, U_∞ is the velocity at the infitity, V is the volume of the airship hull, and r is the radius of the generatrix. Drag force can be formulated as follows.

$$F_d = \frac{1}{2} . \rho_h . v^2 . C_d . A. \qquad (7)$$

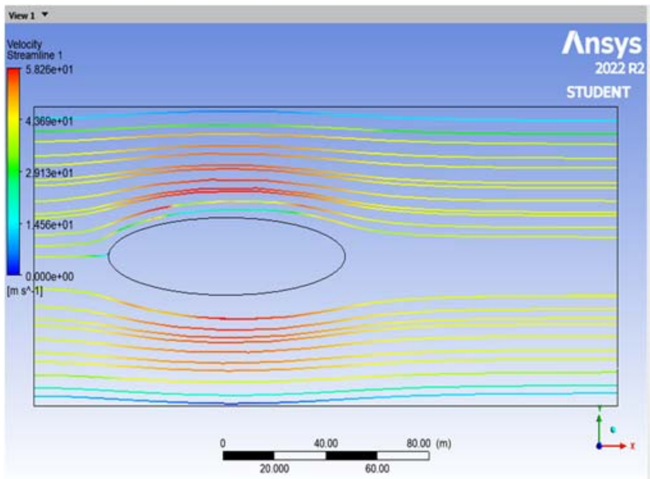
The area of the frontal plane with the vertical resistance component is an ellipse with the radius of the diagonal area of the ellipse, which is shown in the following picture.

Picture 4 : : The shape of the frontal plane is an ellipse and viewed from the vertical, it is a circle. Source: Author, 2022.

Calculation of drag on airships according to Lutz and Wegner [10] and Nakayama and Patelt [11] is determined by four steps namely, the distribution of velocity on the hull surface is calculated by assuming an incompressible and non-viscous flow with potential flow theory, thickness The laminar boundary is calculated using the equations from the first step, the laminar flow turning point is determined, and the boundary layer thickness and momentum loss is calculated by the turbulent flow boundary layer model in the region after the laminar flow transition point. Whereas the horizontal component consists of thrust or the presence of an external tensile force Fx which is given minus the drag Fdx. In the horizontal component, the following equation can be used. After calculating the 2-dimensional airship based on these dimensions, an analysis was carried out using computational design using CFD on the Ansys R2 2022 application.

III. Results And Discussion

Based on the results of the aerodynamic analysis approach, the authors carried out modeling in computational fluid dynamics which answered that the modeling made from the calculations carried out, the airship can pass through the obstacles according to the following picture.



Picture 5 : : 2022, Ansys Fluent Student R2

This study examines the basic aerodynamic response of the model during several flight conditions. Several follow-up and investigative studies may be conducted to further this work. If the Defense University Airship is to be further developed, the study should examine a wider range of flight conditions. The analysis should be extended to additional aircraft features, i.e. fins, control cars, engines etc. The analysis should also include non-linear dynamics such as added mass to fully investigate stability. Research can be continued to provide improvements in the learning process of modeling. One might examine variations in modeling parameters and design changes. Future work should involve more complex turbulent models as computational performance permits increase. Alternative models may also be included such as the LES or the hybrid turbulent model. It may be necessary that any refinement, or agreement, of universal guidelines for verification and validation re-examine these methods, especially if a higher degree of accuracy is desired in future work. In addition, these results can be further verified as data from flight tests on future flights. The analysis should be extended to additional aircraft features, i.e. fins, control cars, engines etc.

The analysis should also include non-linear dynamics such as added mass to fully investigate stability. Research can be continued to provide improvements in the learning process of modeling. One might examine variations in modeling parameters and design changes. Future work should involve more complex turbulent models as computational performance permits increase. Alternative models may also be included such as the LES or the hybrid turbulent model. It may be necessary that any refinement, or agreement, of universal guidelines for verification and validation re-examine these methods, especially if a higher degree of accuracy is desired in future work. In addition, these results can be further verified as data from future flight tests.

CFD As A Design Tool For Airships

Numerical analysis has developed in recent decades pioneered by the emerging field of CFD (Computational Fluid Dynamics). The exponential growth of computing power has propelled analysis from simple two-dimensional laminar flows to turbulent three-dimensional flows with separation. The combination of today's computing power with modern CFD software offers powerful tools for thorough analysis. The more modeling ability, the greater the potential for errors. The success of the simulation and the accuracy of the conclusions drawn depend on the CFD user. Errors can be minimized by specifying appropriate conditions, appropriate models and networks, algorithms, and other input by the user. CFD is still growing and there is no one set of universal modeling procedures yet. There are various guides and procedures available depending on the desired level of accuracy. However, detailed assessments should include comparisons with theory and experiments for verification and validation where possible.

Airship design includes aerodynamic, fabrication, and structural considerations. CFD analysis has been applied to some of these aspects. Aircraft covers are the largest and most important component and receive the greatest attention. In general, most studies analyze the aerodynamic drag coefficient to evaluate design potential. This research has briefly explored the potential of CFD as an airship design tool. The results show that the force coefficient is generated with an acceptable level of accuracy using numerical analysis. In contrast to most wind tunnel tests, numerical modeling can provide specific details about the flow and at each location in the flow plane. Under certain circumstances, the computational model can easily be modified to evaluate different designs or flight conditions. In addition, the computer is not physically limited by the dimensions of the model, so analysis can be performed on a full-scale design.

IV. Conclusion

The use of airship for mass transportation purposes in Jabodetabek there are several possibilities that performance and efficiency can be reduced due to complicated wind flow as a consequence of having a haphazard building orientation in our urban areas. To find a solution for this complex flow field, it is necessary to pay attention to the wind flow pattern around the airship design. CFD simulation and experimental results are very similar to experimental studies. The accuracy of the results also depends on properly scaling the model, properly fitting the model geometry and determining the physical property values exactly under realistic conditions.

The wind flow rate appears to be very influential with the structure of the airship with the speed at various patterns and levels being responsible for increasing or decreasing the performance of the wind turbines installed in these areas. The angle of incidence of wind in all cases has shown a remarkable effect on wind flow around the building. In the case of group buildings extensive wind tunnel testing considering the interference effects of wind required to accurately estimate before installing and designing domestic wind turbines. Many complicated and complex models can be examined with the help of CFD analysis and the wind turbine system design criteria in each flow field can be standardized. In addition to wind tunnel studies, a full-scale model of the physical problem needs to be modeled and analyzed with this numerical simulation for a better understanding of the wind flow field[12].

References

[1] De YOUNG, B. . (1939). The Calculation of the Total and Skin Friction Drags of Bodies of Revolution at Zero Incidence. 51–70

[2] BPS Jumlah Kendaraan Bermotor Menurut Jenis Kendaraan (unit) di Provinsi DKI Jakarta 2019- 2021. (2021). BPS Provinsi DKI Jakarta.

[3] Cross, R. (2007). Aerodynamics of a Party Balloon. The Physics Teacher, 45(6), 334–336. https://doi.org/10.1119/1.2768686

[4] Lutz, T., & Wagner, S. (1997). DRAG REDUCTION AND SHAPE. 1–11

[5] Michele, T., Emilia, R., Di, S. M. I., Emilia, R., Antonio, D., Emilia, R., Di, S. M. I., Emilia, R., Emilia, R., Di, S. M. I., & Emilia, R. (2013). CONSTRUCTAL DESIGN FOR EFFICIENCY : THE CASE OF AIRSHIP DESIGN. 1–12

[6] Nakayama, A., & Patelt, V. C. (1974). Calculation of the Viscous Resistance of Bodies of Revolution. 8(4), 154–162

[7] Ping, L., & Wang, X. L. (2018). Aerodynamic characteristics of airship Zhiyuan-1 Aerodynamic Characteristics of Airship Zhiyuan-1. December 2013. https://doi.org/10.1007/s12204-013-1443-9

[8] Purwadi, P., Sunarto, F., Muttaqin, A., & Seto, T. H. (2014). Aplikasi Mobile Zappeline Sebagai Media Teknologi Modifikasi Cuaca (Tmc) Dan Penipisan Polutan Udara (Asap). Jurnal Sains & Teknologi Modifikasi Cuaca, 15(2), 57. https://doi.org/10.29122/jstmc.v15i2.2671

[9] Rehan, M. H., Hamza, A., Qaisar, A., & Rehman, A. (2021). CFD Analysis of Automobile for Efficient Aerodynamic Design using ANSYS. June. https://doi.org/10.13140/RG.2.2.22560.30729

[10] Roy, A. K., & Bhargava, P. K. (2012). CFD Modelling of Wind Flow around Buildings for Wind Energy Conversion. National Conference on Emerging Trends of Energy Conservation in Buildings, November 2012, 370–379.

[11] Subagyo. (2011). Potensi Penggunaan Airship Untuk Mendukung Pembangunan. 404–412.

[12] Wang, Q., Chen, J., Fu, G., & Duan, D. (2009). An approach for shape optimization of stratosphere airships based on multidisciplinary design optimization *. 10(11), 1609–1616. https://doi.org/10.1631/jzus.A082081