Morden glider developments: technological advances and environmental challenges

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Abstract. Gliders are improving performance and efficiency by using lightweight, high-strength composite materials in the application of materials technology. These materials not only reduce the weight of gliders and improve flight performance but also increase durability and safety. However, environmental challenges arise, mainly in the production and recycling of the materials. The production of traditional materials often consumes large amounts of resources and generates waste, while the recycling of composites still faces technical challenges. To address these challenges, sustainable materials and green production processes are being actively explored within the industry, to reduce environmental impact and advance the ultimate development of glider technology. These efforts not only provide new ideas for environmentally friendly processes in aviation but also lay the foundation for future glider innovations.

Keywords: Gliders, materials, composites.

1. Introduction

A glider is an unpowered aircraft that relies primarily on aerodynamic principles to fly with long and wide wings. It is usually made of lightweight materials, has a streamlined fuselage and wide-spread wings, and is designed to achieve gliding flight through a balance of lift and gravity. The operating principle of a glider is based on the design of the wing, which creates a pressure difference between the above and below surfaces of the airflow, thus creating lift. Gliders utilise natural air currents such as thermal liquid, dihedral and wave currents to extend flight time and distance. The history of glider planes was a captivating chronicle that shows humanity's enduring fascination with flying and the unremitting pursuit of the aerodynamic industry. From ancient yearning to modern-day innovations, the glider plane represents a pure form of aviation, that depends solely on natural forces to achieve flight. As the using of gliding planes for entertainment uses has increased a lot so far. The research on them has also increased. The evolution of some new glider technology is driven by several different factors. Innovations in aviation power systems have led to more fast and powerful engines, enhancing glider performance and improving their operational range. Concurrently, the development of lightweight materials and advanced manufacturing techniques has disrupted glider plane designs, resulting in improved aerodynamics and flight capabilities. Apart from this, the push for greater environmental sustainability comes up with new challenges, as the aviation industry faces increasing pressure to reduce its ecological footprint. This paper will focus more on the improvements which sailplanes have taken. Additionally, the prospects will be given out in this passage. Analysing the technological progress and environmental dilemmas associated with modern gliders [1].

Deeply search the evolutionary process, the process of the materials and the structural design optimization. These aim to provide a comprehensive understanding of the current state of glider plane technologies and their future morphology. The problems sailplanes face now are weather dependency, safety, maintenance and costs and technological advancements. Despite improvements in technology, glider drivers are still facing risks associated with in-flight emergencies, like equipment failure or sudden climate changes. Make sure that sailplanes are equipped with modern safety features and that drivers are well-trained and own licences to establish. As air traffic develops and regulations become more stricter, glider pilots must navigate increasingly complicated airspace management systems. This can become a new challenge, particularly in busy or legal airspace parts. Coming up with up-to-date technology can be an opportunity. While modern avionics and instruments can enhance safety and performance, they also require investment and professional training. Nowadays, the latest gliders may include automatic systems for tasks such as flight control weather data processing or auto landing. Balancing the advantages of automation with the need for pilot intervention can be challenging. According to Bernoulli's principle, as the speed of the airflow increases, the pressure decreases. The upper surface of a glider's wing is more curved relative to the lower surface, and the airflow passes over it faster, creating a low-pressure area, while the airflow underneath is slower, creating a high-pressure area. This pressure difference creates lift. At the same time, we have to introduce an important theory which is called attack angle. The angle of attack is the angle at which the wing is tilted relative to the airflow. One proper of angle of attack maximises the upward force, but too much angle of attack can lead to a stall.

1.1. Recent use of electronics in gliders

Modern gliders are often equipped with plenty of sensors for real-time monitoring of flight status and climate changes. These sensors measure information such as flow speed, pressure, temperature and the attitude of the gliders, helping drivers to react quickly in complex airflows. By integrating these data, the pilot can better judge the airflow conditions and flight status, thus optimising the glider's flight strategies. This dynamic monitoring not only improved flight safety but also enhanced the pilot's sensitivity and resilience to atmospheric conditions. One of the goals of a glider is to maximise the ratio of lift to drag, known as the glide ratio. A good aerodynamic shape can effectively increase lift while reducing induced drag, resulting in a higher glide ratio. Modern gliders often use slender, streamlined wing designs to improve flying performance. In the contemporary world, more high-tech materials are carried out to improve aviation and flight efficiency. Self-launch sailplanes utilising electric-driven propulsion were also researched. The project requirements for an electric-powered self-launching aircraft are broken into the subcategories of performance, design, manufacturing, and operations. The requirements for this design were selected from the 2023-2024 AIAA Electric Training Sailplane RFP, but not all requirements from the RFP are being applied [2].

2.2.1. Practical use of new composite materials in the aerospace industry and excellent response received

In the contemporary world, more high-tech materials are carried out to improve aviation and flight efficiency. One such example is the use of carbon fibre composites on the Boeing 787 Dreamliner. The company which developed this kind of composite carbon fibre is ‘TORY’ (top 50 global chemical companies, Toray is now one of the few manufacturers in the world to provide both acetate and polyamide composite membranes). Boeing used 50% of New Composite Materials,20% of aluminium,15% of titanium and 10% of steel. This makes 787 offer significantly better performance, with fuel consumption typically in the range of 4,900 to 5,600 litres per hour. On long-haul flights, the Boeing 777-300ER has a fuel consumption rate of 2.9 litres per 100km per seat. In comparison, the Boeing 787-10 achieves more efficient performance, consuming 2.27 litres per 100km of fuel. Within the comparison, we can notice that composite materials lead to higher fuel efficiency and lower weight. Generally, materials are always playing an important role in aircraft manufacturing. This concept is also reflected in the production of gliders. Those gliders which can fly farther means they have higher performance. Using carbon fibre is becoming more common on sailplanes rather than using aluminium. Lighter fuselage makes gliders fly smoother and more manoeuvrable. Benefiting from the higher hardness and better tear resistance of carbon fibre, these gliders will have longer service time and inspire better performance during flying.

2.2.2. Effect of composite materials on aerodynamics in gliders

Alexander Schleicher (one of the most famous sailplane manufacturers) is seen as a milestone in the development of gliders and has set several world records. In 1963, Gerhard Waibel started the development of glass fibre-reinforced composite aircraft. Martin Heide joined the company in 1981 as an aircraft designer. Design flexibility is one of the parts which is considered while designing sailplanes. Carbon fibre is easier to cut and more malleable. They also have excellent precision.

According to the research, the density of carbon fibre and composite materials is 50% lower than aluminium. The shortcomings of aluminium consist mainly of metal fatigue. Metal fatigue refers to the progressive and localized structural damage that occurs when a material is subjected to cyclic use and loading. This phenomenon is recurrent findings in fields like aerospace, automotive, and mechanic engineering.$4Al(s) + 3O_2(l) \rightarrow 2Al_2O_3(s)$. Based on the above reaction formula equation, we could find out that aluminium is easy to react with oxygen and form metal oxide (Aluminium oxide). Metal oxides are weak and the oxide film formed naturally by aluminium in air is amorphous, thin and porous, with poor corrosion resistance. During prolonged and intense uses, carbon fibre is not susceptible to corrosion, which reduces the need for protective coatings and lowers maintenance requirements. In the area of glider planes, they rely on wind and constantly be bent and squeezed. Carbon fibre defuses these problems. Combined with efficient aerodynamic design and lightweight materials, modern gliders offer a significant increase in endurance. Here are some examples of the uses of new materials in gliders of some well-known brands. The ASH 30 Mi is a two-seat glider that uses a variety of composite materials, particularly carbon and glass fibre. Its use of composites allows the glider to achieve an ideal balance of weight and strength, which enhances the overall flight performance. The ASH 30 Mi has also been designed with aerodynamic optimisation in mind, ensuring that it maintains its efficient gliding capability over long periods of flight. The ANTARES 20E is an electronic motorised glider with highly integrated composite technology. Special to the ANTARES 20E is a wing and fuselage design that combines advanced aerodynamic simulations with composite materials to ensure an excellent glide ratio and high performance. Fig.1 shows typical properties of strength, E-modulus and density for some materials frequently used in sailplanes and light aircraft [3].

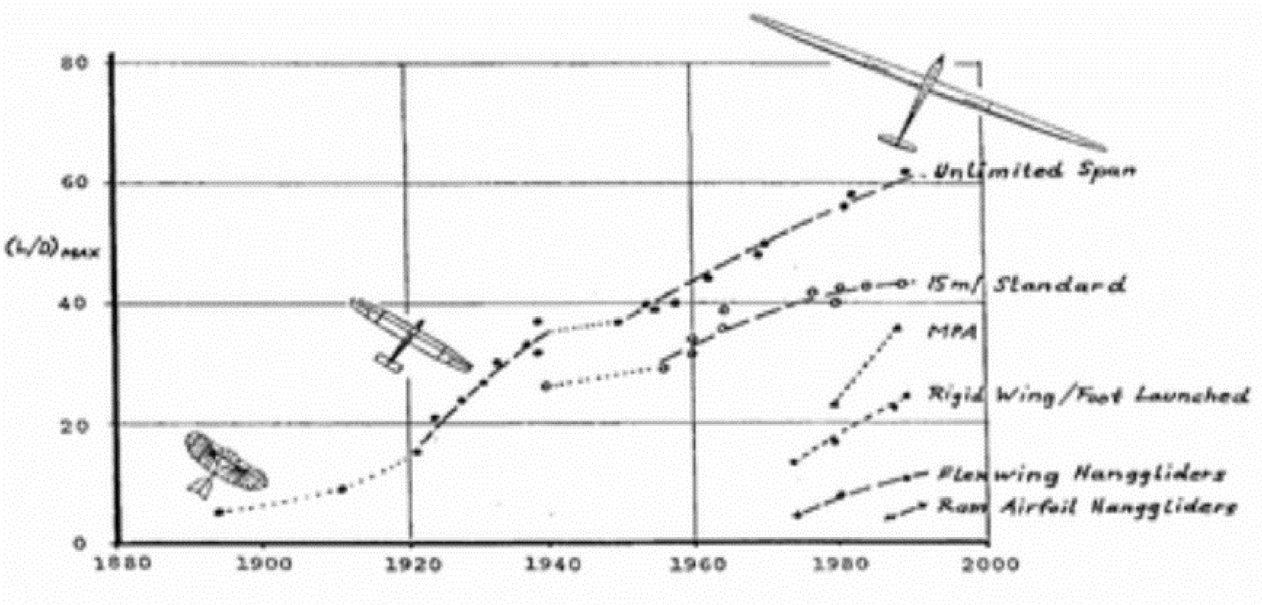

Fig. 1 Typical properties of strength

2.2.3. Technology use and environmental challenges of modern aircraft

Especially in flight, the wing design allows the glider to glide efficiently using smaller updrafts, demonstrating the unique advantages of composites in terms of energy efficiency. We can find that a lot of aircraft manufacturing companies are obsessed with using winglets. One of the most famous uses of winglets is AIRBUS A350. According to Airbus, the A350 Family benefits from cutting-edge aerodynamics that provide a smooth ride for passengers and increased efficiency for airline operators. Its airframe uses more than 70% advanced materials such as composites, titanium, and modern aluminium alloys to create a lighter and more cost-efficient aircraft while increasing resistance to corrosion and reducing maintenance. Besides, the wing-edge winglets make it recognizable and favoured by flying enthusiasts. A successful design can not only improve the performance but also make it artistic and beautiful.

2. Future perspectives

2.1. Computer simulation

In the future, with the growing interest in flight sports, gliders are expected to attract more enthusiasts and participants as a safe and low-cost way to fly. In Microsoft Flight Simulation 2024, gliders were added to the group and a new map of sailplanes was also carried out. More and more flight schools and training companies are focusing on glider training. Glider flight training is relatively simple and helps to train a new generation of pilots. Additionally, gliders can be used as effective platforms for scientific research, in fields such as meteorology and environmental monitoring. They can collect data at high altitudes to support scientific research and continuously improve the level and height of human research through the interconnection between different science fields. Nowadays, CFD is used in the development of high-performance sailplane analysis. This system was first applied to unsteady flow over three-cylinder cases. Two circular cylinders at Re = 200 and Re = 3.6 × 106 and a square cylinder at Re = 2.2 × 104 [4].

3.2.1. Difficulties gliders are now facing

To tackle such obstacles comprehensively, this study employs a combination of experimental and computational fluid dynamics (CFD) approaches to analyse these crucial aerodynamic variables. This study illustrates that optimizing aspect ratios and aerofoil shapes, particularly through the utilization of high aspect ratio cambered aerofoils like the NACA 4412, can substantially improve glider performance. [5] However, gliders are still facing problems and difficulties. For example, the flight safety of gliders may be challenging in certain situations, especially in the operations of new pilots. The lack of power systems in gliders may make it difficult for pilots to cope in the event of sudden climate change or other emergencies. Although flight training and experience can improve flight safety, there are still certain risks. Moreover, the unpredictability of airflow when the glider is flying at high altitude may cause the pilot to lose control, which may lead to accidents. Despite gliders' long history in air sports, gliders are still relatively poorly recognised by consumers. Many people lack an understanding of the capabilities and appeal of gliders and believe that they are only suitable for professional competitions or specific flying activities. This perceived limitation has led to constraints on the promotion of gliders in the recreational aviation market. Therefore, raising public awareness of gliders, as well as increasing their use in areas such as recreation, education and research, will help to improve the market. The updating of new designs requires a sustained financial investment and is very expensive, and although many glider manufacturers are working on the development of new materials and technologies, the high cost and length of research and development can lead to financial pressures for some manufacturers. More importantly, technology renewal is not limited to materials and design but also includes electronics, flight control systems, etc. This kind of investment may not be friendly to some infant companies and makes them much more difficult to develop. The cost of trial and error in the development of new materials is extremely high.

3.2.2. Gliders' lack of utility and feasibility

Therefore, the development and advocacy of gliders have slowed down. The lack of infrastructure for gliders to fly is a serious problem. Gliders' take-off, taxi and landing depend highly on specific infrastructure, such as gliding airfields and landing strips. However, in many areas, especially resource-limited loca, these infrastructures are inadequate or non-existent. This limits the popularity and use of gliders and reduces many opportunities for flying enthusiasts to be able to glide easily. Fixing composite materials requires specialised techniques and equipment. Common repair methods are the use of adhesives, heat curing and fibre reinforcement, processes that often involve precise handling and control. The repair process is not only time-consuming, but also labour-intensive and, most importantly, expensive. Fracture of the carbon fibre material means that this whole piece of material needed to be replaced.

3. Summary

While flying a glider, the pilot maintains the balance between lift and gravity by controlling the angle of attack. The aerodynamic design of gliders continues to advance with the aim of maximising lift force and minimising the drag force. The modern glider uses automatic fluid dynamics techniques for simulation and design optimisation to make the shape of the wings and fuselage more consistent with the specificities of the airflow. New wing designs, reduce vortices and drag and improve the glider's glide ratio effectively. This efficient aerodynamic design allows gliders to better use of airflow during ascent and cruise, resulting in longer flying times and distances. Because they do not rely on engines, gliders are quieter and more environmentally friendly during flight. Gliding is not only a competitive activity but also an important way for aviation enthusiasts and flight training, helping pilots to improve their manoeuvring skills and understanding of airflow. The development of gliders will not die out with the development of society, and as the demand for recreation and utility continues to rise, the use of gliders will become even more widespread. Some of the new materials will also be released to glider manufacturing as they are developed by large-scale aircraft manufacturers. This also makes the development of the glider industry less hindered.

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