GLIDER WING MODEL MADE OF COMPOSITE POLYMERIC MATERIAL

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Summary:

This project was made to experiment with a construction method for the glider wing. In this paper, we will explain the principles of building a glider wing and all the phenomena necessary to understand this process. As part of the work, an experimental model of a glider wing was created at a scale of 1:450, made by 3D printing from UV resin and covered with glass fiber. In the physical model, you can see the structure of the wing and the materials used.

In the introduction, we will explain the principle of flight of an aircraft to better understand the importance of the materials used in the aeronautical field and the shapes chosen for the wing geometry. The experiment looks at the strength of such a wing in flight, tested in specialized programs, as well as the ease of its design, also analyzed in programs such as SolidWorks and XFLR5. Next, we will explain the physical construction process and the steps taken to obtain the final object.

1. Introduction

The glider is a heavier-than-air flying device, not equipped with a propulsion unit and which, by launching at a certain height, will fly with a continuous downward slope. There are four main forces that act on a glider and help it move along its path and stay in the air. First, the weight of the glider pulls it toward Earth with the help of gravity and gives it a natural tendency to descend. This force must be countered by other forces to allow it to fly. Thus, the concept of lift force comes into play. In the direction of travel, we encounter two other forces: the resistance to the forward movement and the traction force.

Flight is based on the lift force created by the wings of the airplane. The wings are designed to produce a low-pressure zone above them and a high-pressure zone below them, creating a lift force that keeps the airplane in the air. This effect is produced by the flow of air streams along the wings.

As the airplane moves through the air, the air streams that flow over the wings are directed towards the back of the wings, where they expand and slow down. This leads to a decrease in the air pressure above the wings, while the air pressure below the wings remains constant. This phenomenon is based on Bernoulli's principle, which states that air pressure decreases as speed increases. Thus, air streams that move faster over the wings create a low-pressure zone, while air streams that move slower below the wings create a high-pressure zone.

2. The geometry of the wing

Following a section through the wing we will be able to define the following elements:
- the leading edge is the front part of the wing that hits the airfoils during flight.
- the trailing edge is the rear part of the wing.
- the chord of the profile is the straight line that joins the leading edge with the trailing edge.

- the maximum thickness is the maximum distance between the upper surface and the lower surface
- the maximum curve is the maximum distance between the chord of the profile and the median line.

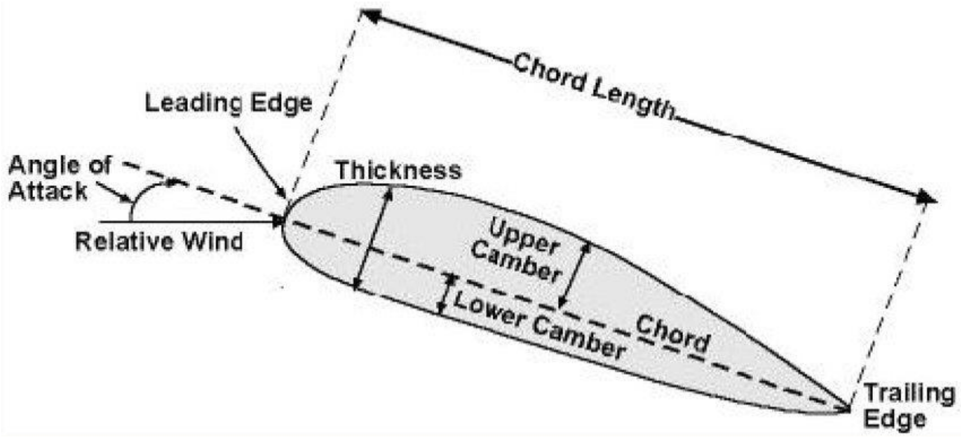

Fig. 1 – Elements of the wing

3. Choosing the airfoil for the wing design – NACA 23012

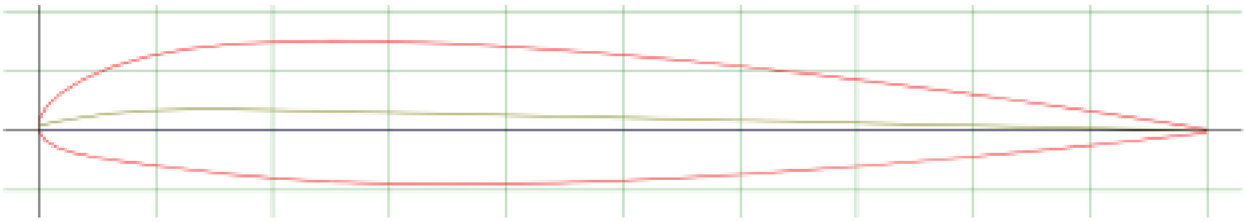

Fig. 2 – NACA 23012 airfoil

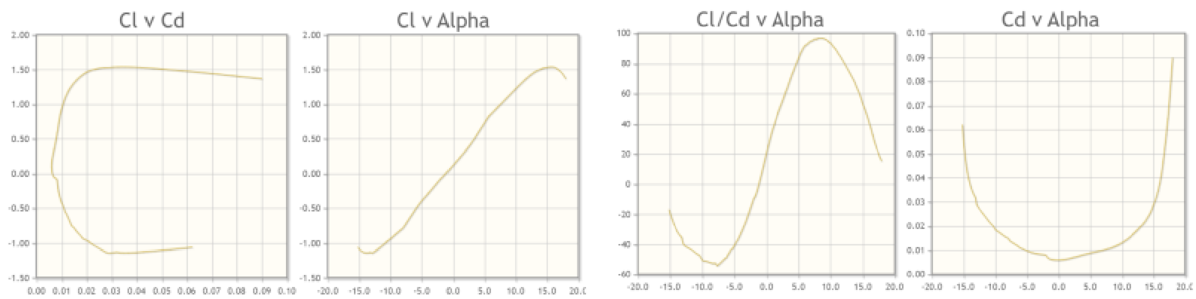

Fig. 3 – Graphs with the rapports between lift and drag coefficient and the angle of attack for NACA 23012 profile

Where:
Cl = lift coefficient
Cd = drag coefficient
Alpha = angle of attack
Cl/Cd = aerodynamic finesse

To calculate the Reynolds number for a glider wing with a wingspan of 18 meters, we can use the following formula:

$$R_e = \frac{\rho v l}{\mu} = \frac{v l}{\vartheta} \quad (1)$$

Where:
Re = Reynolds number
v = Characteristic velocity of the fluid (in meters per second)
l = Characteristic dimension of the wing (in meters)
ρ = Air density (in kilograms per cubic meter)
θ = Air viscosity (in kilograms per meter per second)

We consider a glider speed of 100 km/h. To convert it to meters per second, we will divide the value by 3.6. Therefore:
v = 100 km/h / 3.6 = 27.8 m/s

For standard air at sea level, the density is about 1.225 kg/m^3 and the dynamic viscosity is about 1.8 x 10^-5 kg/(m*s).
ρ = 1.225 kg/m^3
θ = 1.8 x 10^-5 kg/(m*s)

The trapezoidal wing has a span of 18 m and a chord of 1.5 m. For a trapezoidal wing, the characteristic dimension L is taken as half the span and the chord, so:
L = (18 m + 1.5 m) / 2 = 9.75 m

Thus, we can substitute the values in the Reynolds number formula:
Re = (27.8 m/s * 9.75 m * 1.2 kg/m^3) / (1.8 x 10^-5 kg/(m*s))

The result is about 1.85 x 10^7, which suggests that the airflow is flowing from laminar to turbulent on the glider wing, which can have a significant impact on the glider's performance. It is important to note that this is a rough estimate, and that the actual Reynolds number of the glider depends on several factors and can only be accurately calculated by knowing the exact geometric details of the wing and the air properties.

4. Materials used

Before presenting the materials used in the construction of gliders, we must see what they are for efforts are subjected to the parts that make up a glider. The requests to which they are subject the pieces are:
- traction or stretching (triggers, control cables, wing covers, etc.).
- bending (wing spars)
- shear occurs in flight during passage through a separation surface between a stream ascendant and one descendant. This phenomenon happens especially when flying in clouds of vertical formation.
- torsion - the wings during flight are subjected to tension efforts around the spar.

The plywood used in aviation must meet the following conditions:

- Tensile strength along the grain = 700 kgf/cm^2
- Tensile strength perpendicular to the grain = 450 kgf/cm^2
- Shear strength along the grain = 100 kgf/cm^2
- Shear strength perpendicular to the grain = 750 kgf/cm^2
- Shear strength at 45◦ = 150 kgf/cm^2

For the wing presented in this document, the following materials and dimensions were used. The inner part (the wing's core) was made of 10mm of resin to which three layers of 0.3mm fiberglass were added.

4.1. Fiber glass

The technological process of obtaining glass fibers includes two main phases: obtaining the glass and spinning the fiber. The raw material for the manufacture of glass fibers is fusible inorganic products, based on silicates, extracted from siliceous sands.

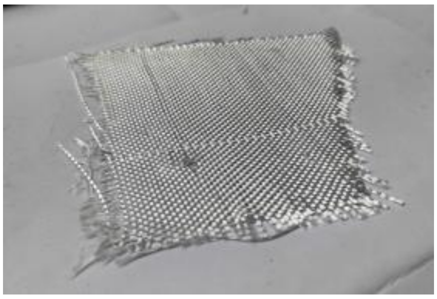

Fig. 4 – Sheet of fiberglass

The properties of the fiber glass are the following:
- good resistance to radiation;
- Silica fibers, unlike type E, have a better electrical and thermal insulation capacity.
- are resistant to chemical agents (except hydrofluoric acid)
- they are not toxic, and fungi and bacteria do not degrade them
- glass fiber is resistant to acids and alkalis. It is distinguished by an increased chemical inertness since it consists entirely of quartz sand.

4.2. Resin

Composites are a combination of reinforcing fibers in a resin matrix. The resin matrix holds all the bonded material and transfers the mechanical loads through the reinforcing fibers to the rest of the structure. In addition, the resin protects the composite from impact, abrasion, corrosion, environmental factors, and careless handling. Resin types come from a variety of chemical families, each type is designed to offer different advantages such as economic, structural, and strength performance.

UV resin is different from the others in that it consists of a single component. This type of resin requires exposure to UV light to trigger the chemical reaction that allows the resin to harden. You can use a UV lamp, specially designed for quick hardening of jewelry and miniatures. 3D resin is a type of material used in 3D printing that polymerizes under the action of UV (ultraviolet) light. This can be used in 3D printing with technologies such as stereolithography (SLA) or projection lithography (DLP).

5. Designing the wing and testing its characteristics

Work steps in SolidWorks:

1. The NACA 23012 airfoil was sketched using the sketch function and after using the smart dimensions function it was brought to the required dimensions.
2. A parallel plane was created at 8000 mm from the first plane on which sketch 1 was created. Here again a NACA 23012 airfoil was sketched again using the sketch function and the chord size was 1000 mm.
3. To create the contour of the wing, the Surface Loft function was used, thus joining the contours of the 2 sketches.
4. The Thicken function was used to create the thickness of the wing skins.
5. I created an Assembly in which I put the Part with the Wing created earlier.
6. I created a new part inside the Assembly to copy the wing through the offset surface function.
7. After making the offset surface on the outer surface, I used the thicken function and gave the desired size. This function helps us create the fiberglass layer we used.
8. I created another offset surface on the wing, only on the inner part. I used the thicken function again and created the resin layer that is in the wing construction.

Work steps in XFLR5:

1. Added NACA 23012 profile to XFLR5 application using the following options Module > Direct Foil Design > Foil > Naca Foils.

2. Airfoil performance was analyzed using the following options Module > Xfoil Direct Analysis > Analysis > Define an Analysis. A window appeared on the screen where the values obtained from the calculations were added and the OK button was pressed. In the upper right corner, the values of the angles at which the wing was tested to the flight horizontal were set and the Analyze button was pressed.

3. After checking the tables obtained from the polar analysis, the design of the wing was carried out, where the following steps were followed. Modules > Wing and Plane Design > Define a new plane.

4. After a new plane was defined and all components except the wing were removed the following were used under the Plane > Current Plane > Edit Wing menus.

5. After the wing was edited and the previously calculated values were added, a new analysis was performed on its performance.

6. The practical realization of the model

- Printing the glider wing on a reduced scale using the printer in the picture below
- Cleaning the piece of residues was carried out in a special device as in the image below
- The wing was sanded using 2 types of sandpaper with 1200 and 2000 grit
- Fiberglass was soaked in resin
- Fiberglass was applied to the wing surface, stretched, and smoothed
- Finally, a base was designed in Solidworks and printed with a 3d printer that uses PETG

Fig. 5 – the physical figure before and after glueing the fiberglass

7. Conclusions

After testing and calculations, it is observed that the NACA 23012 airfoil fiberglass covered resin wing model is extremely easy to design, print, manufacture and complete. Related to its strength, with the help of a professional printer and a high-performance resin, and with the help of a special chamber and furnace, where glass fiber can be applied, a high-performance wing can be made.

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