University of Minho
School of Engineering

Hangar 9 Solo Trainer Aircraft Structure Restoration

Master's in Aerospace Engineering

Projeto Aeroespacial

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1. Main Mission Definition

The group's main mission is to physically restore the UAV (Unmanned Aerial Vehicle) structure, ensuring optimal flight conditions in all phases.

2. UAV Repair

The UAV repair process started with the identification of all the damaged components and structures, which resulted in the damage report. This document can be consulted in Annex A. The tasks performed in the scope of UAV repair are described in the following subsections.

2.1. Cover removal

At its initial condition, the UAV was fully covered, exhibiting a graphical identity identical to all the commercial model airplanes, as presented in Figure 1. The cover removal was the first task performed for two main reasons: (i) the identification of all the areas that required repair was possible only after this step as the cover could hide damaged areas and components, and (ii) the process could itself damage the structure as the peel off could remove wood layers.

(a) (b)

Figure 1 - UAV model before cover removal (a) fuselage and horizontal and vertical stabilizers and (b) wing.

Due to their curved geometry, which makes handling them more difficult, and the low thickness of the balsa wood applied, wings are the most sensitive structures and, thus, the most challenging ones. Such characteristics led to the group's decision to start by removing the cover from the wings. Some regions showed a lack of glue, and, thereby, the cover was detached from the wood balsa beneath it. These were the points that the group used to start to carefully peel off the cover. The process went smoothly, and no additional damage occurred. The cover from the fuselage and the horizontal and vertical stabilizers was then removed, and, as it was with the wings, the process was carried out without major issues.

After removing the cover (see Figure 2), the whole structure was sanded to remove the glue residues to create a clean and smooth surface suitable for the application of the new cover chosen - Oracover®.

Figure 2 - UAV after cover removal.

2.2. Ribs replacement

During the analysis process, problems and damage were identified in 9 out of 16 ribs. In order to ensure the structural integrity and functionality of these elements, the group chose to replace all the damaged ribs using wood balsa of the same thickness and following the same geometry profile, including the cutout to reduce the element’s weight.

In a balsa wood board with a thickness of 2,5 mm and using as model one of the original ribs (Figure 2 (a)), the rib contour was drawn, after which it was cut using a bistoury. Although the dimensions were kept as close as possible to the original ones, some adjustments were needed to place the ribs at their positions inside the wing’s structure. In this sense, small cuts were made, and sanding of the ribs was performed to allow the ribs to fit the dimensions required. The ribs were then glued to the wing's structure using wood glue, as presented in Figure 2 (b).

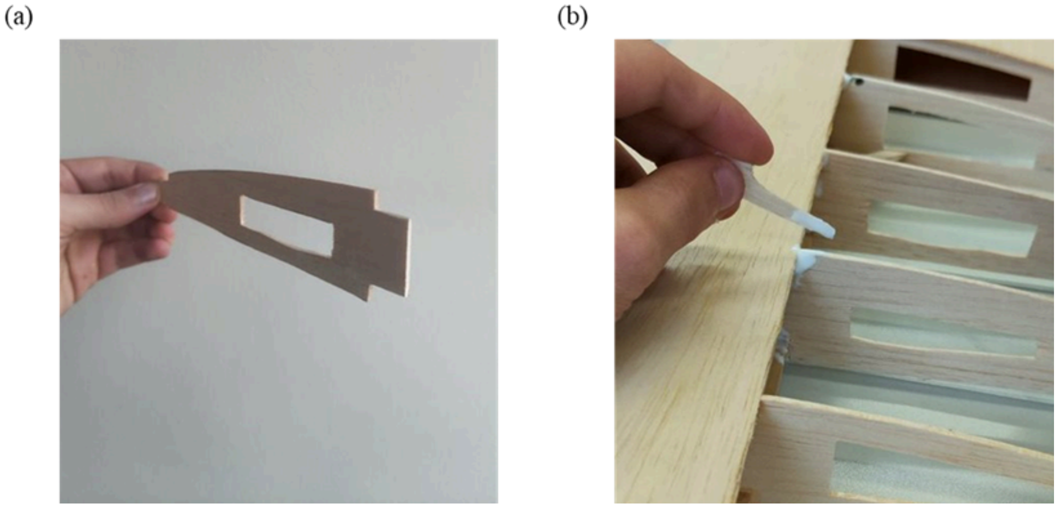

Figure 3 - (a) rib model and (b) ribs attachment to the structure using wood glue.

Finally, after a rest time to ensure that the glue had already dried, the attachment regions were carefully sanded to remove any glue excess.

Figure 4 - Wing after ribs replacement.

2.3. Repair of the fuselage opening for motor-ruddle connection

A metal rod connects the servomotor placed inside the fuselage with the ruddle through an opening existing at the back region of the first. However, such a fully open design allowed the rod to deflect, as there was no lateral constraint to its movement, which, in turn, could compromise its integrity and functionality.

Using a wood balsa board with a thickness of 5 mm, a new piece (see Figure 5) with the same outer geometry as the back opening of the fuselage was placed there, after which a cut whose width was close to the rod diameter was made. The opening length was determined by positioning the ruddle at two extreme positions: fully up and fully down. Such a modification of the original structure allows the connecting rod to move free in the vertical, as the opening length is compatible with the stroke required to allow the ruddle full control.

(a) (b)

Figure 5 - New piece placed at the back of the fuselage with an opening to allow the ruddle control (a) top view and (b) back view.

2.4. Repair of the fuselage back cover

The fuselage's back region was severely damaged, as can be observed in Figure 6, where a top cover was missing.

Figure 6 - Fuselage's back region severely damaged.

To repair the damage, the first step was to remove the remaining parts of the previously existing cover and properly sand the region to remove residues and smooth the surface. Afterward, measurements were made to define the design of the top cover to be made, which was drawn on a wood balsa board whose thickness was 5 mm. The cover was cut from the board using a bistoury and sanded to fit the opening.

Additionally, three holes to allow screwing will be made manually using a drill, and a keyway to allow the vertical stabilizer assembly was cut using the bistoury.

The cover was then placed at the fuselage's back region and glued using wood glue, as presented in Figure 7.

Figure 7 - Placement of the top cover at the fuselage's back region.

After completely drying, the whole region was carefully sanded to remove the glue residues, granting a smooth surface.

2.5. Horizontal Stabilizer repair

Along with the placement of the top cover at the fuselage's back region, the horizontal stabilizer was also repaired. As can be seen in figure 8, the screw holes that attached it to the fuselage were wide and did not guarantee good cohesion between parts.

Figure 8 - Screw holes before intervention.

The holes were previously covered with a paste made from balsa chips and glue (figure 9 (a)), leaving it to dry for some time. Once the surface was completely dry, it was carefully sanded to make it uniform, as can be seen on figure 9(b). These holes will be reopened when the fuselage is assembled, and correspond to the blue dots visible in the back region represented in figure 7.

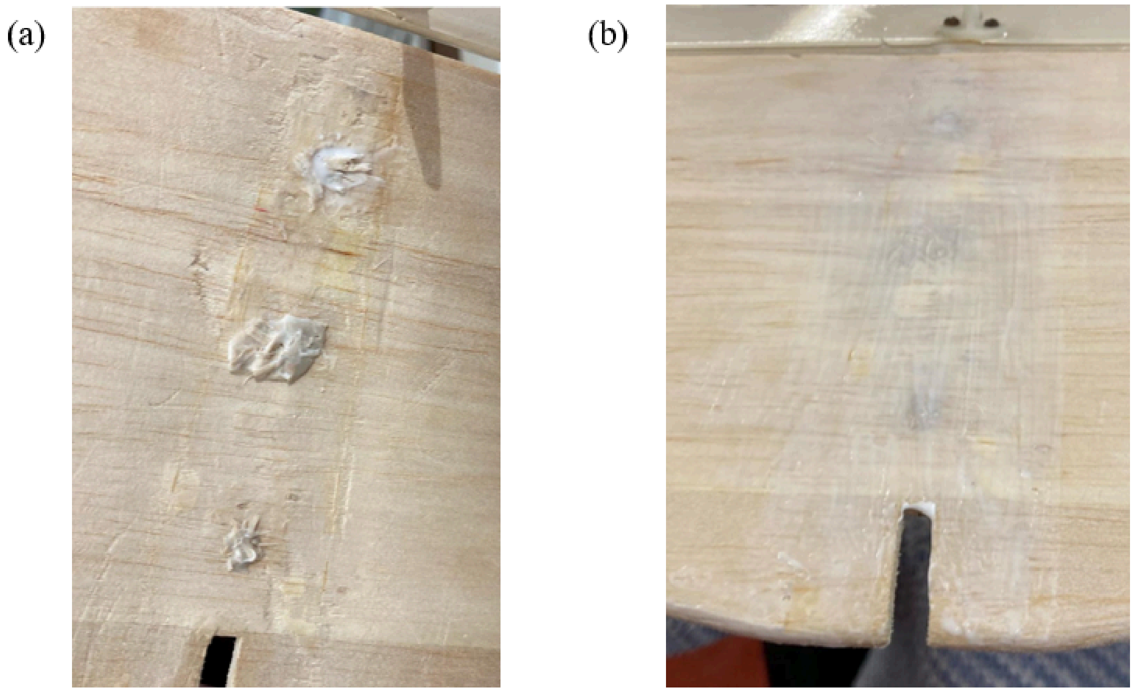

Figure 9- Screw holes during intervention (a) and after intervention (b).

5. Hole repair in left wing

Among the repairs identified, an accident occurred with the left wing: localized excess pressure caused a hole measuring around 3x4 cm area, visible in figure 10.

Figure 10 - Left wing hole.

The approach to the problem initially involved transforming a hole of imprecise dimensions into a square-shaped hole, measuring around 4 centimeters per side, and building a grid with 5mm thick balsa sticks (figure 11a), placed on the inside of the wing. Starting by building the grid warp, and after drying, placing the weft, it was possible to fill the square with a 5 mm piece of balsa of the same dimensions, the edges of which were completed with wood glue. The final result exceeded expectations, as the area appears to be reinforced, as can be seen in figure 11b.

(a) (b)

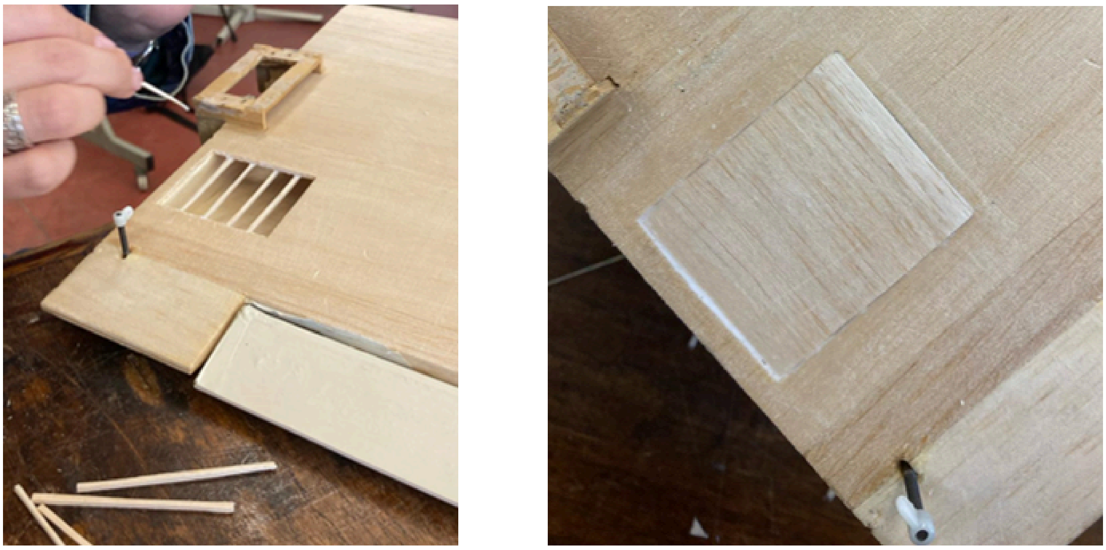

Figure 11 - During and after reconstruction of the hole in the left wing.

3. UAV structure Coating

To understand which will be the best coating to use on our UAV we will have to:

1. Understand which coatings exist and are commonly used in UAVs;
2. Compare the various coatings;
3. Choose the coating to be used on the UAV according to the comparison between them.

After an analysis of the various coatings used to cover the UAVs, we realized that Oracover and Vinyl are the most suitable for what is intended.

That said, let's make a comparison between the two selected coatings, going through 5 points that we consider essential: resistance, weight, flexibility, ultraviolet resistance and the price of each coating.

The comparison between these two coatings results in the following conclusion:

- Strength and Durability:

Oracover is known for its durability and wear resistance, and is widely used in model airplane applications. It offers optimal protection against scratches.

Vinyl can also be considered a material with some durability, but it can be more susceptible to tears and scratches compared to Oracover

- Weight:

Weight is a crucial consideration in UAVs, as it directly affects flight performance.

Vinyl tends to be heavier than Oracover, which can result in a heavier UAV with a shorter flight range.

- Flexibility:

Oracover is known for its ability to adapt well to uneven surfaces and complex curves, which is important in the UAV surface coating process.

Vinyl can also be flexible, but it may not adapt as easily to the more complex and curved surfaces of the UAV.

- Ultraviolet Resistance:

Oracover tends to maintain its colors and structural integrity even when exposed to sunlight for long periods.

Vinyl has a lower resistance to degradation when exposed to direct sunlight for long periods.

- Price:

The cost can vary depending on the brand, quality, and quantity required. In general, vinyl tends to be more cost-effective than Oracover.

After analyzing the 5 essential points in choosing the covering, we will choose to use OraCover, even though it is a little more expensive.

4. UAV Block Diagram

The UAVs structure interacts directly with servo motors stored inside the fuselage and wings. In order to have a better understanding of how this interaction works, we can look at the block diagram represented on figure 12.

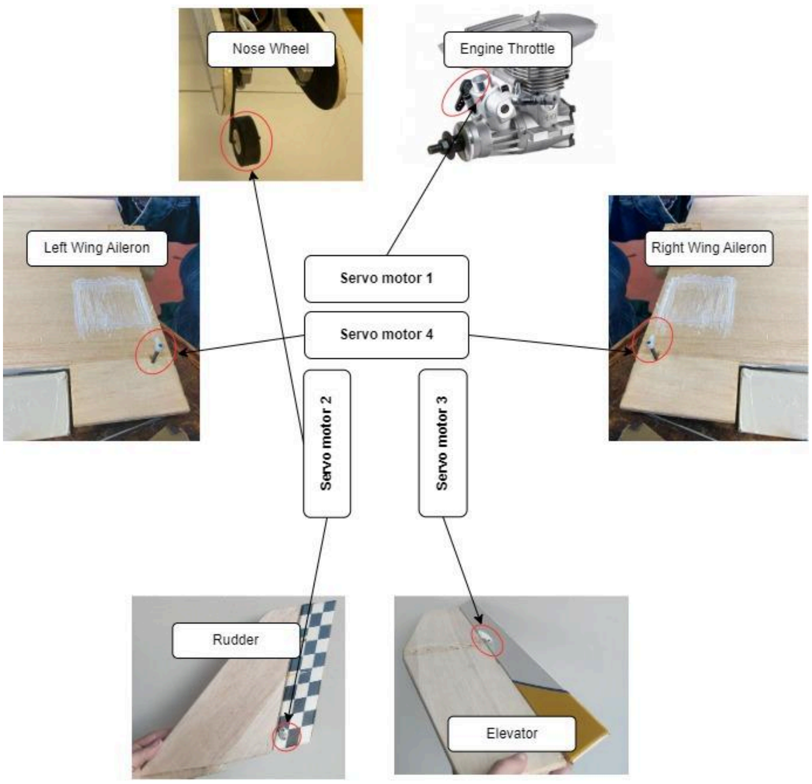

Figure 12 - UAV Servo Motors Block Diagram

The servo motors layout is composed of the first three servo motors which will be installed in the fuselage. On the other hand, the Servo Motor 4 will be placed in a small compartment between the UAVs wings.

The diagram represented on figure 1, shows where each servo motor will act over on the plane:

- Servo Motor 1: Controls the Nose Wheel direction & the Engine Throttle position;
- Servo Motor 2: Controls the Rudder direction;
- Servo Motor 3: Controls the Elevator position;
- Servo Motor 4: Controls the Ailerons position from both wings.

5. Schedule Update

As the project has been being developed, our group has come across challenges that weren't possible to have been predicted when we first made our Schedule for the project. Therefore, we had to rethink our approach to the project and adjust some deadlines on our schedule.

We've also used the opportunity of updating the schedule, to sync it with the also updated schedule of the avionics groups. In this way, we can assure that the work from both groups is aligned with the expectations of its members.

TASK	START	END
Structure Optimization		
Study of the structural optimization possibilities	27/02/2024	04/03/2024
Topological optimization, regarding the wing's structural components: spars & ribs.	05/03/2024	16/03/2024
Substitution components manufacture	19/03/2024	31/03/2024
Implementation of the new components, on the UAV structure	01/04/2024	19/04/2024
Evaluation		
UAV validation	22/04/2024	26/04/2024
Connect the avionic and motors systems with the UAV	29/04/2024	03/05/2024
Carry out final tests of the entire UAV system	06/05/2024	10/05/2024
Solve any remaining issues	13/05/2024	17/05/2024

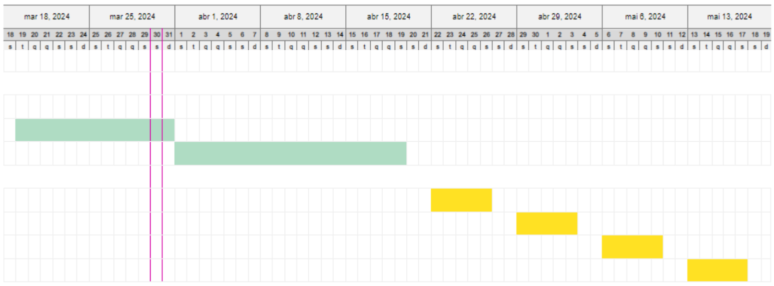

Figure 13 - Updated Schedule