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Aerodynamic Project
ASK-13 R

The aerodynamic project of our ASK-13 is based on two main guidelines. The first is related to the gliding characteristics: being a scale glider, the model was expected to be very efficient at low to medium flight speed, in order to reproduce the realistic flight of the full-scale airplane. Second, we wanted to obtain a model that, despite the important dimensions and weight, was funny, fast in the maneuvers and able to perform good classical aerobatics.
From these few general concepts, we have defined the project specification:

- The model had to have a maximum Efficiency at lift coefficient sufficient to ensure a realistic flight and a low descent ratio
- the maximum lift coefficient had to be sufficiently high to be able to slow-down the model without risk of stall
- In the slow flight, the stall had to happen in a controlled way, progressively and in pre-defined specific zones of the wings
- The model shall be able to perform aerobatic maneuvers, without requesting extreme performances (typical of models of another category)
- The overall architecture of the model (positioning of the wings and tail surfaces with respect to the fuselage) has been maintained as in the original glider.

Choice of the airfoils and preliminary project
Due to the fact that the lifting surfaces are defined by the scale ratio, the first step of the aerodynamic project has been focused on the choice of the airfoils. In the case of a wing geometry like the one of the ASK-13 (tape ratio 0.39; forward sweep angle of 6°), it was important to consider that the wing bending deformation (i.e. the wing deformation along the longitudinal axis) caused by lift, causes also a change of the angle of attack of the wing airfoils (phenomenon linked to the transversal velocity of the airflow along the wingspan), that increases from the wing root proceeding towards the tip.
This has an impact on one side on the behavior of the wing in stall condition, on the other side on possible flutter phenomena.
Having as one the targets a high ratio between lift and drag (aerodynamic efficiency), we have selected 2 airfoils relatively thin and at the same time very efficient: the Wortmann FX 60-100 (max thickness 10%) and the S4062 (max thickness 9%). These two airfoils have been selected among a bunch of other airfoils “candidates” because they demonstrated the best global behavior during the different simulations, as described below.

All the simulations have been done at a flight speed of around 100 km/h, which has been considered as reference velocity for the characteristic flight of this model. With this assumption the reference Reynolds number for the airfoils at wing root and tip have been calculated.

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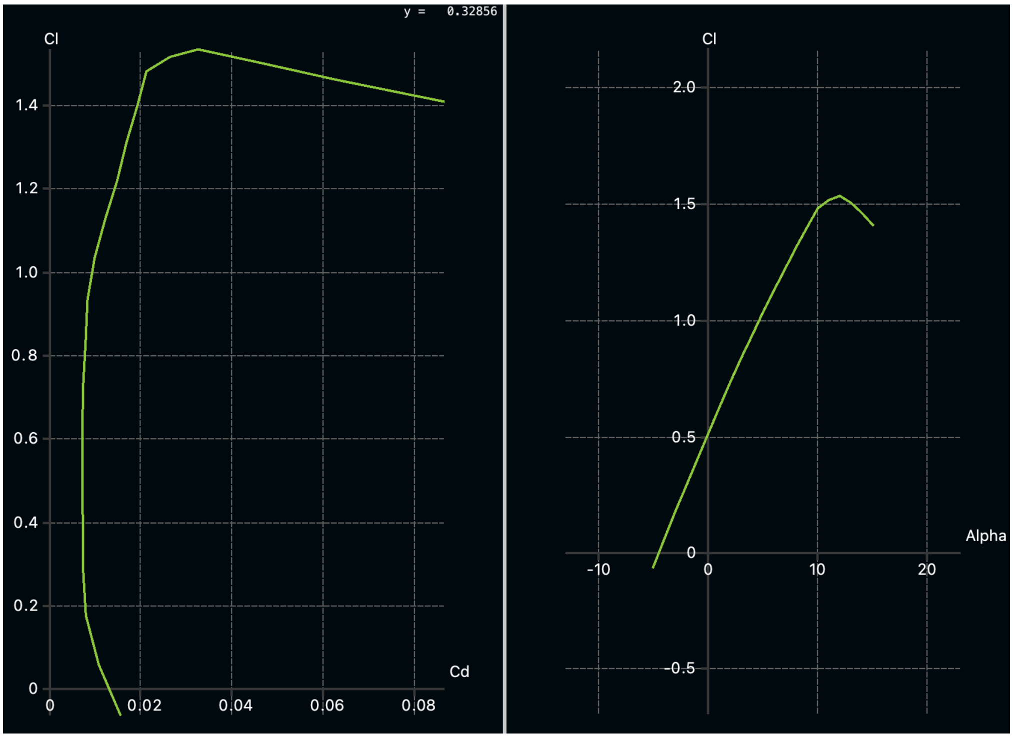

Figure 1: Polar Curve and e CL(α) of the airfoil FX 60-100 calculated at Re 661.000, corresponding to a velocity of around 100 km/h at wing root

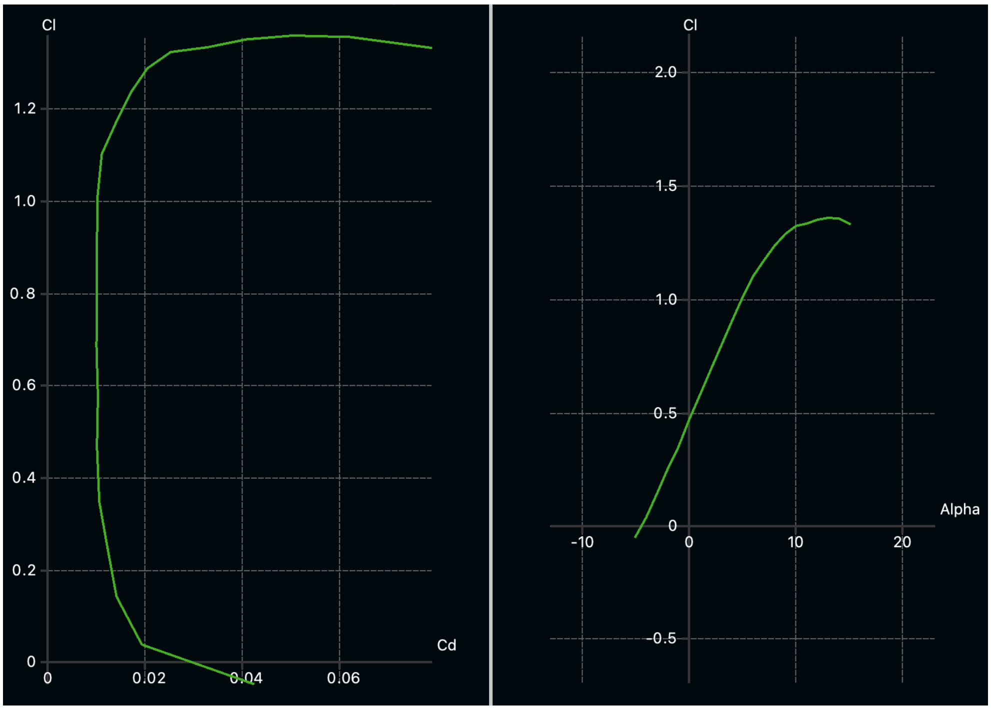

Figure 2: Polar Curve and e CL(α) of the airfoil S4062 calculated at Re 260.000, corresponding to a velocity of around 100 km/h at wing root

In the Figures 1 and 2 (left) we note as the airfoils have the capacity to maintain a drag coefficient low and constant for a sufficiently wide interval of lift coefficients. This suggests a good behavior of the wing in different flight conditions , at flight speed coherent with the nature of the model itself, that is a semi-scale.

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In the Figures 1 and 2 (right) we note as the lift coefficient has a linear behavior for a sufficiently wide interval of angles of attack and that the stall happens at a sufficiently high angle of attack (around 13°). This suggests good behavior at slow speed and during aerobatic flight.

With the aim to obtain an adequate lift distribution along the wingspan, after different simulations, we have chosen to use the airfoil FX 60-100 for the first 55 cm of the wingspan, and after the airfoil evolved in a continuous way until S4062 at the tip. In this way we have obtained the stall characteristics and the lift distribution that we wanted, without need of a geometrical twist angle.
These considerations have been verified also with 3D aerodynamic simulations, based on simplified calculation models (3D panel method), that have been used to evaluate some fundamental aspects:

- Evaluate the global aerodynamic performances (max Efficiency, polar curve, stall progression, …)
- Find the approximate CG position
- Evaluate the lift distribution along the wing and the stall progression
- Evaluate the performances of the model with and without flaps

The advantages of these simulations is that they allow us to verify many different configurations (airfoils, architectures, flight conditions) in relatively limited time. The results, even if approximate, can be considered anyways a good indication of the behavior of the model in flight. It has to be noted anyways, that the technical competence to properly interpret the amount of data produced remains fundamental to ensure a good final result.
The preliminary simulations have confirmed an optimal behavior of the “simplified model”, composed only by wing and tailplanes: a max Efficiency above 35 (in line with the full-scale glider, considering also the contribution of the fuselage) and a low overall drag. Figure 3 reports a representation of the simplified model used for these tests.

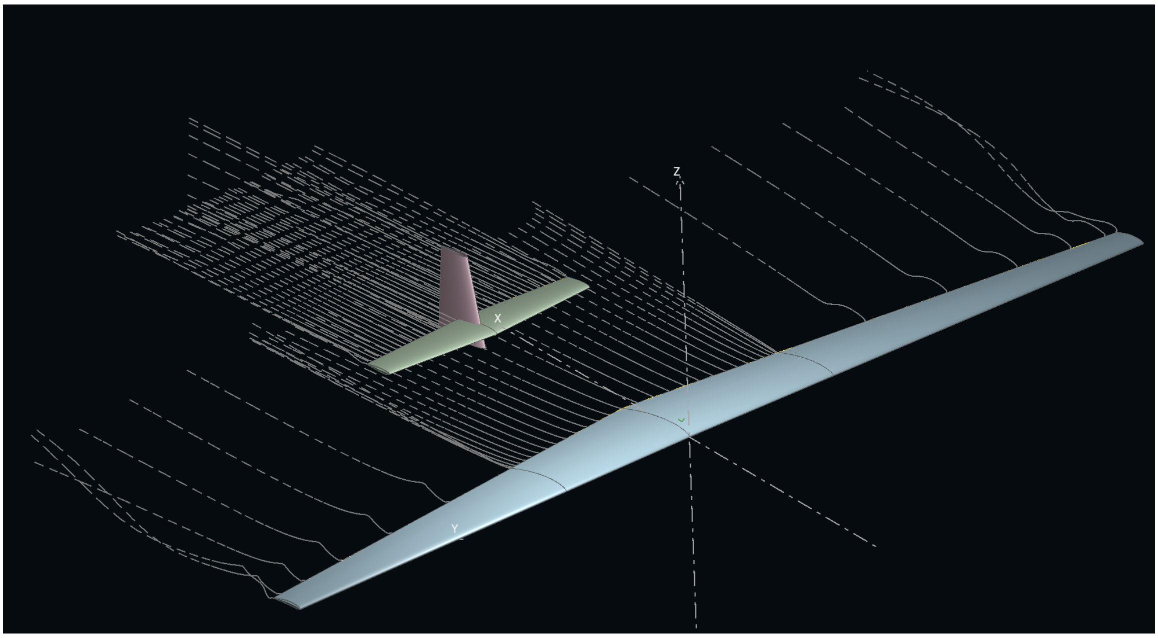

Figure 3: Representation of the simplified model. The figure includes also some of the streamlines, that show clearly the vortex trail that originates from the wing trailing edge

By means of simulations at different angles of attack, it is possible to estimate how the stall is generated and how it propagates along the wingspan. The turbulent wake generated by the stall stays outside the zone where the elevator is; this indicates a good maneuverability of the model also in stall conditions.

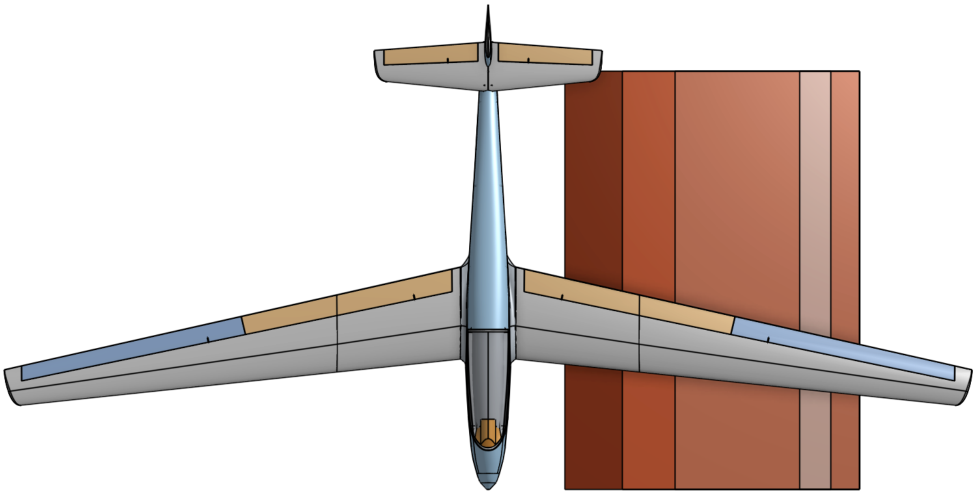

Figure 4: Stall propagation at angle of attack between 11.5 (zone light red) up to 13.5 (zone dark red). The elevator remains always outside the wake of the portion of the wing that is stalled.

To verify the airfoil behavior with and without flaps at different deflection angles, we have done specific simulations on the modified airoils, assuming different deflection angles for flaps and ailerons.
With these, we have seen as an example that the flaps have their maximum effectiveness (best compromise between max lift, drag and max angle of attack) when they are deflected by 7°. This has been the basic set-up for the flight mode “thermal”. The Figures below report a comparison between the behavior of the airfoils with and without flaps.
The curves of the flapped airfoils show obviously a certain increase of the max lift coefficient and a sharper lift coefficient vs angle of attack. These factors show how the flaps are useful to fly the model at low-speed . Clearly the price to pay is an increased drag, due to the fact that the deflected flap generates a disturbance at the aerodynamic flow around the airfoil itself.

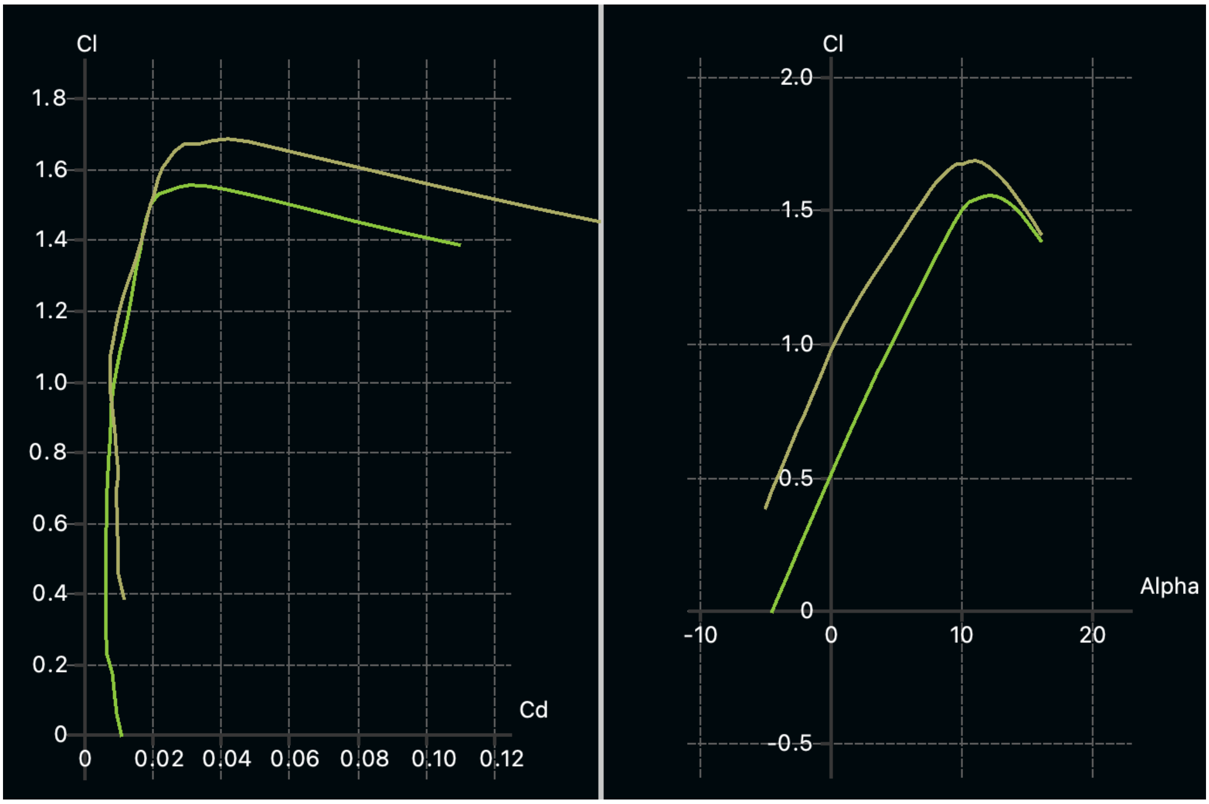

Figure 5: Polar Curve and CL(α) of the airfoil FX 60-100 with and without Flaps at 7°, calculated at Re 661.000 (green curve: standard airfoil; yellow curve: flapped airfoil)

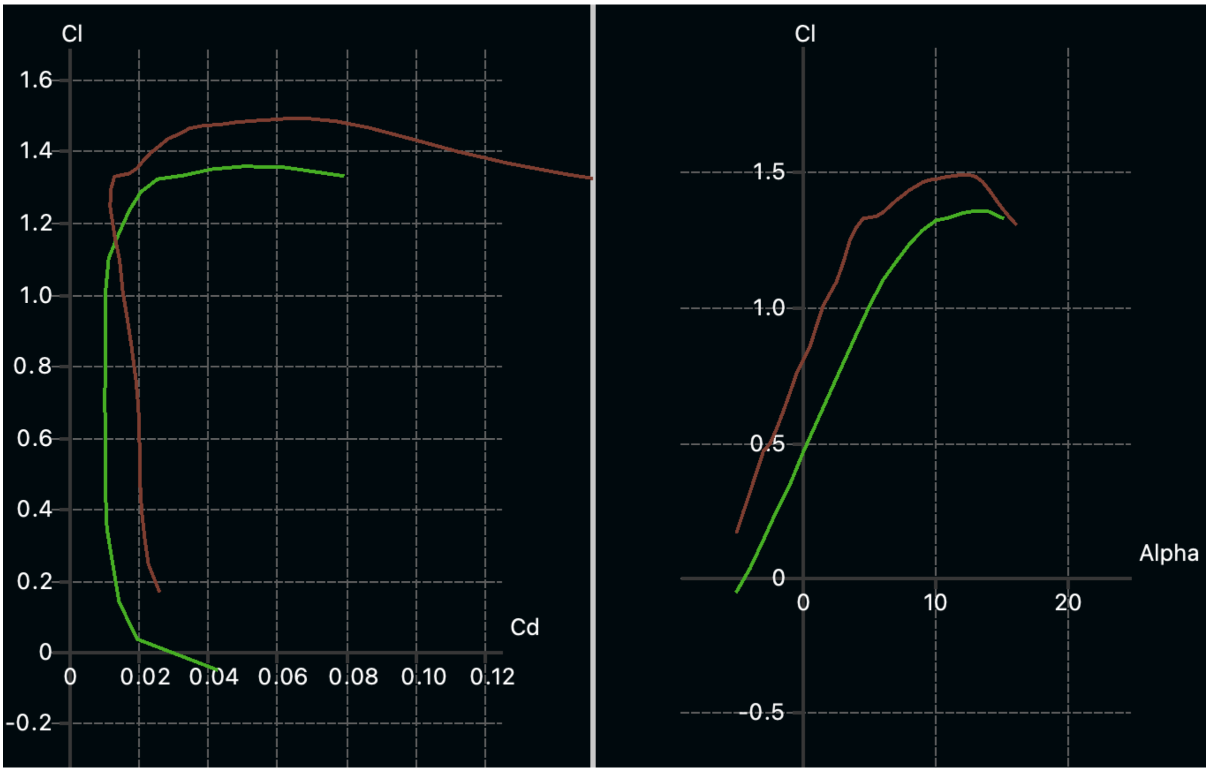

Figure 6: Polar Curve and CL(α)of the airfoil S4062 with and without Flap at 7°, calculated at Re 260.000 (green curve: standard airfoil; red curve: flapped airfoil)

In the same way, we have also done simulations with the control surfaces deflected upwards. These have allowed us to define the flight mode “speed”, thanks to that the ASK-13R expresses a dynamic and funny flight, up to the execution of the main aerobatic figures. The Figures below show the polars and the lift coefficient curves in “speed” configuration: as expected, the upwards deflection of flaps and ailerons has the effect of moving downwards the curves of the standard airfoil. In practice, this means that at the same angle of attack the model will fly faster.

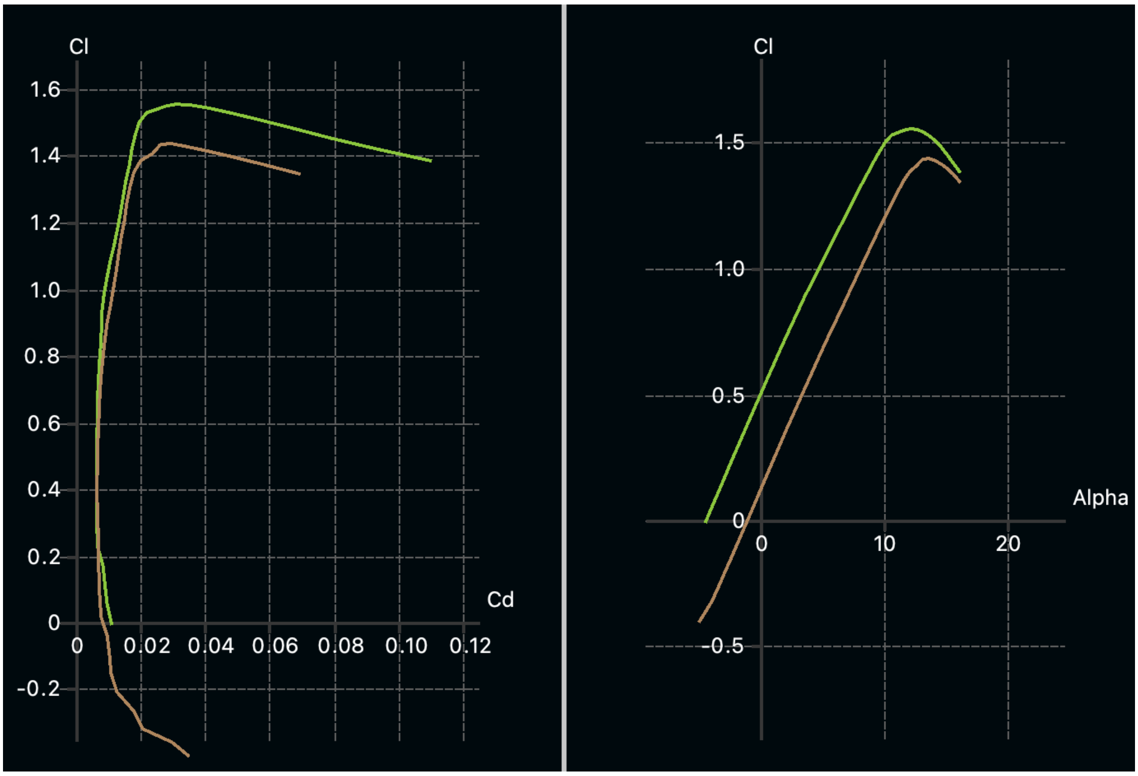

Figure 7: Polar curve and CL(α) of the airfoil FX 60-100 with and without flaps in Speed position (5° upwards), calculated at Re 661.000 (green curve: standard airfoil; brown curve: flapped airfoil)

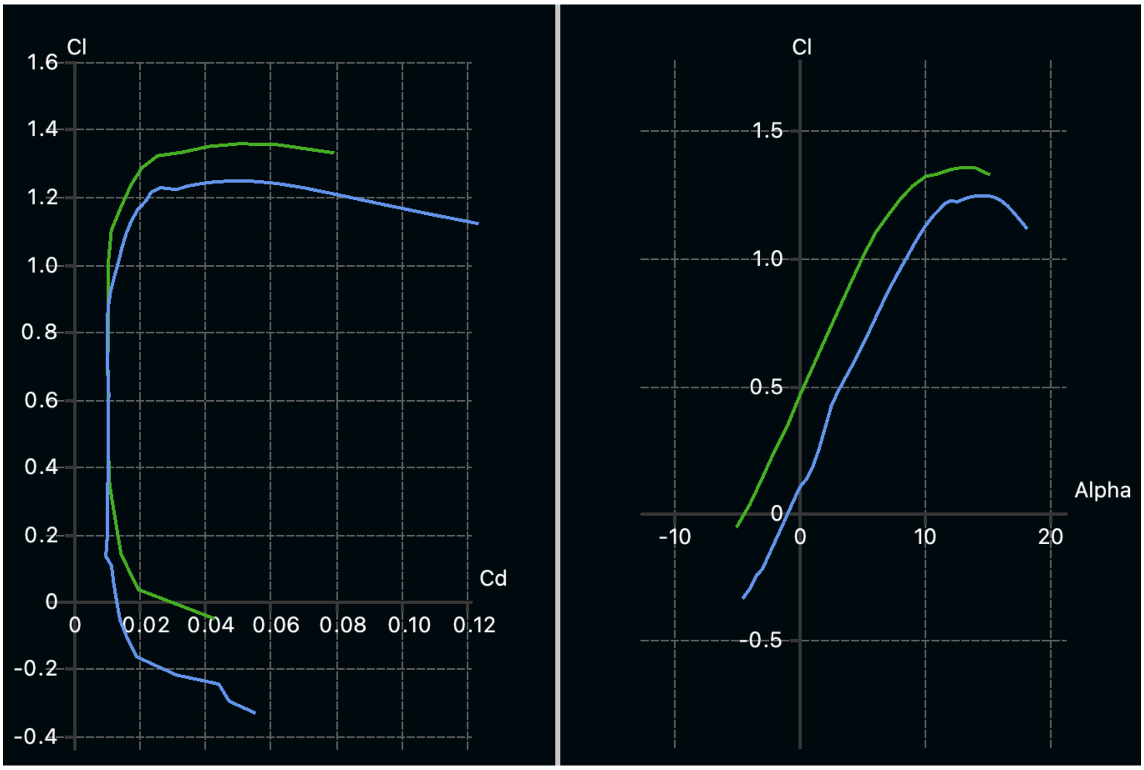

Figure 8: Polar curve and CL(α) of the airfoil S4062 with and without flaps in Speed position (5° upwards), calculated at Re 260.000 (green curve: standard airfoil; blue curve: flapped airfoil)

At last, we have dimensioned the control surfaces. (ailerons, flaps, rudder and elevator). These have not been defined using the scale factor from the full-size glider, but have been increased, maintaining proportions more typical of aerobatic gliders. This choice allows optimum roll, pitch and yaw rotation speed, very useful during aerobatic flight.

For the elevator, the airfoil chosen is a NACA0012. These airfoils showed to be the best in terms of drag, internal space (possibility to install servo inside the elevator itself) and stall characteristics.

finally, the vertical tailplane has a symmetrical airfoil designed specifically for this model, to be able to control the model also at high yaw angles (for example, during maneuvers or in case of lateral wind), to ensure the space to install a servo (if needed) and at the same time integrate in the best way the hinges of the rudder itself.

At this point the preliminary project was finished.

Detailed project

With the aim to verify the detailed local aerodynamic behavior in some specific zones of the model, we have done some advanced numerical simulations by means of CFD calculation models (Computational fluid Dynamics). Due to the fact that the models used for these kinds of simulations are quite heavy from the point of view of the calculation power requested to the computer, several processors have been utilized in parallel to calculate the solutions. These simulations have been used mainly for:

- Evaluate possible area of airflow separation in zones particularly complex (fuselage-wing interface, fuselage tail). These zones are particularly complex from the aerodynamic point of view due to the interference that generates from the interaction of airflow around the wing and the fuselage. As a consequence, if not optimized this area can be a big source of drag;
- Evaluate the stall of the wing at medium to high incidences, where the simplified models used in the frame of the preliminary project are less precise (it is therefore necessary to validate the results obtained with another calculation method, more accurate);
- visualize the streamflow, pressure and velocity fields around the model itself, to deeply understand the aerodynamic behavior of the model in every part;
- visualize elements of the model that contribute to create drag and understand if it is possible to further optimize their shape;
- estimate the lift curve of the complete model, to be able to cross-check it with the one obtained with the simplified models and validate in this way the solutions obtained.

The figures below show only some of the results obtained. For a more detailed explanation on specific topics, we invite our followers to contact us: we will be happy to discuss with you every detail of our ASK-13R!

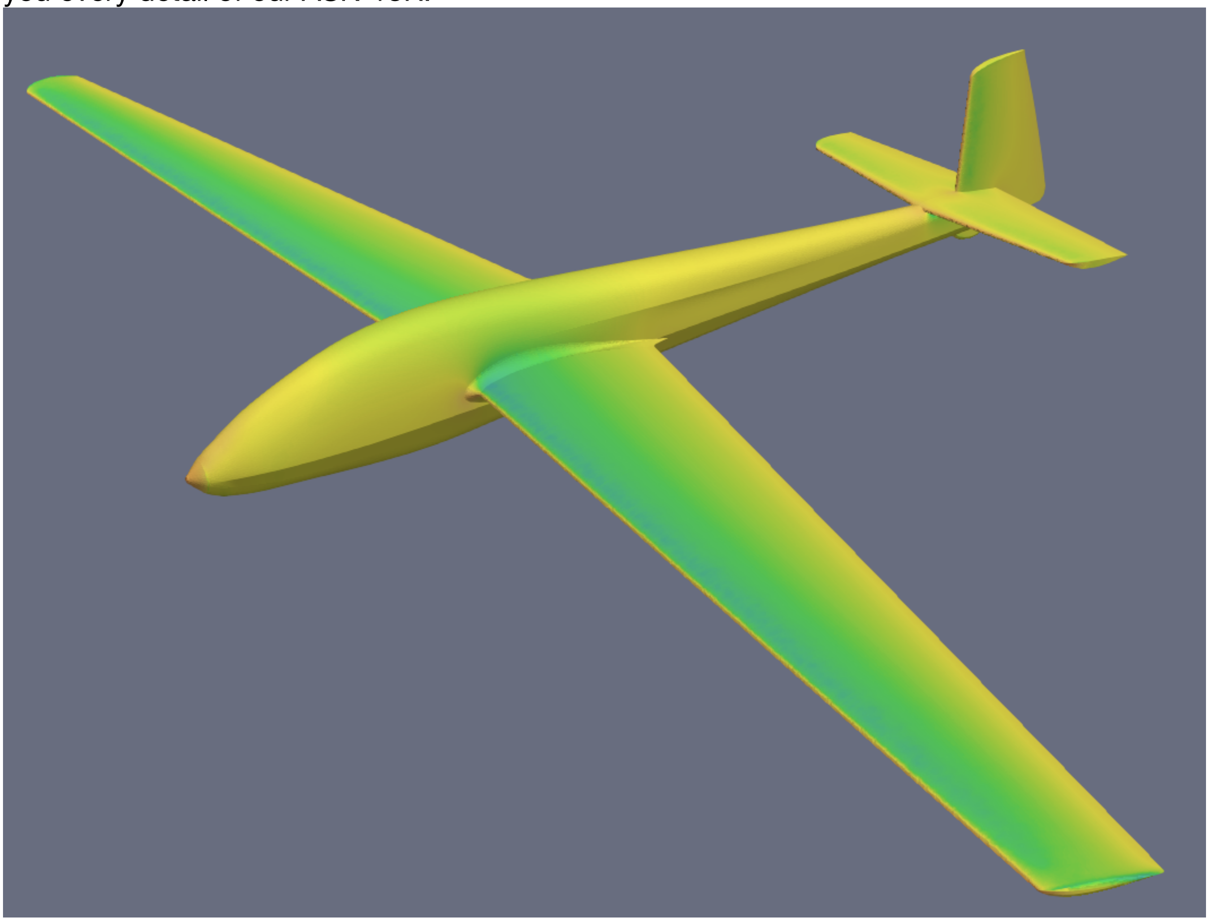

Figure 9: Pressure distribution on the model for a specific angle of attack and speed. (in red the zones at low speed / high pressure, in green and blue the zones at higher speed / low pressure). The pressure distribution around the model is coherent with what was expected, considering also the preliminary simulations: we can see the stagnation points on the fuselage nose, on the trailing edge of the wing and tailplanes. In addition on the upper

surface of the wing there is a low-pressure zone (in green), that is linked to the generation of lift.

Figure 10: Velocity distribution around the model. It is possible to note clearly the zone at slightly higher speed on top of the canopy (color orange/red) and the low-velocity wake behind the model (color green(light yellow). It is important to evaluate the velocity distribution around the fuselage, to ensure that the streamflow remains adherent to the model surface in every part of the fuselage itself. In addition, the shape and the velocity distribution inside the wake provide an indication of the overall drag of the fuselage and of the entire model.

Figure 11: Representation of the velocity distribution around one airfoil section, at 50 cm from the wing root. The zone in green/blue around the airfoil represents the boundary layer, very thin in this simulation. In general, the aim is to obtain this kind of streamflow for a wide range of flight conditions, in order to ensure that the wing airfoil works always at optimal conditions.

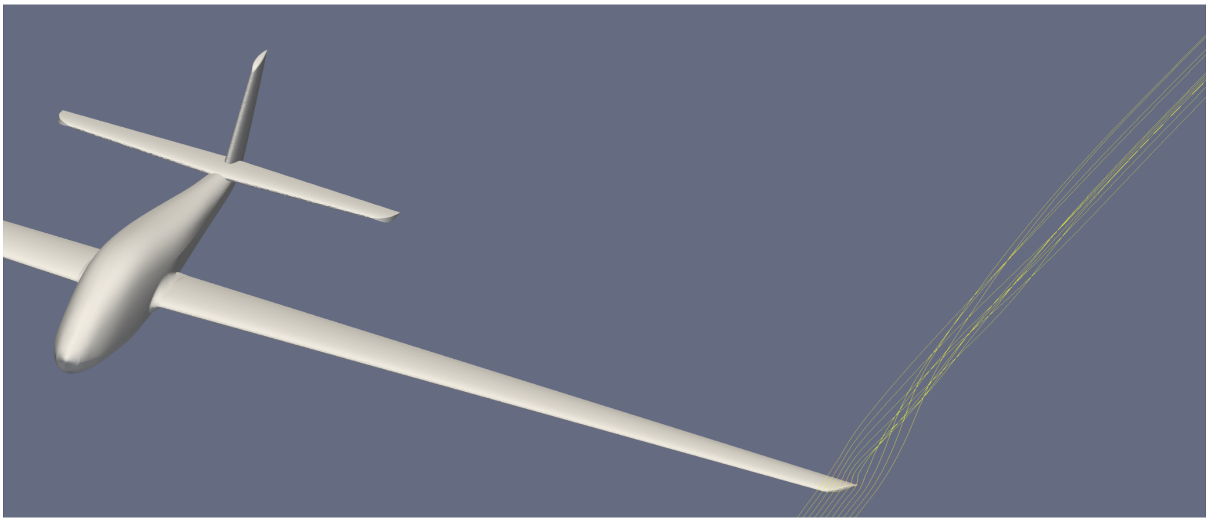

Figure 12: Representation of the vortex-wake at the wing tip. These vortices are due to the differential pressure between the upper and lower part of the wing, close to the wing tip. The results shown here are very coherent with the simplified simulations obtained during the preliminary project. Also this coherence contributes validating the simulations done.

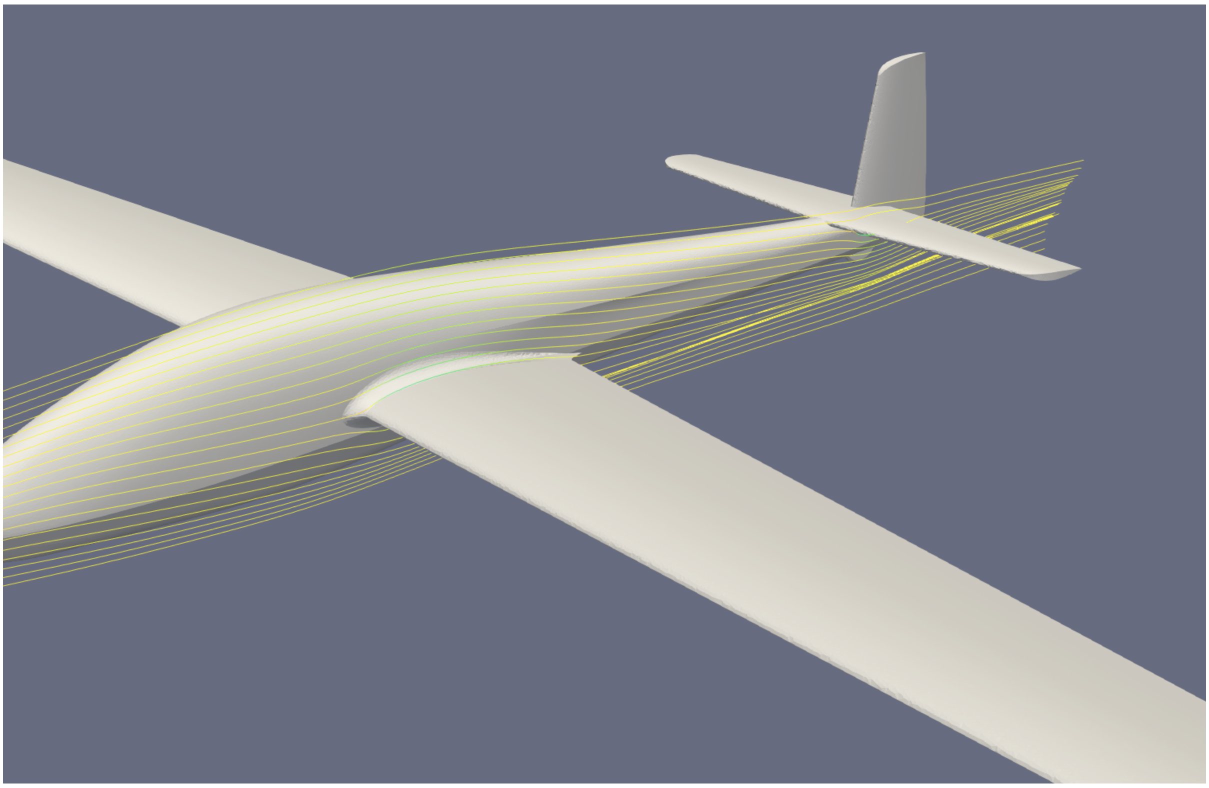

Figura 13: Representation of some streamlines in the region of the wing-fuselage interface. The airflow remains always adherent top the model surface, meaning that there are no separations, neither in some specific local area. In this Figure it is also possible to see how the elevator is working inside the airflow "disturbed" by the wing (in this case the model is simulated in a flight condition far from the stall).

The aerodynamic improvements applied to Design

The complete aerodynamic study and the analysis of all the data we collected, drove us to apply some specific design changes with respect to the original glider. These changes allowed us on one side to modernize the original design, on the other to optimize the aerodynamics of the airplane. Of course the peculiar design characteristics of the ASK-13 have been kept:

- horizontal stabilizer positioned in front of rudder
- Wing with 6° forward sweep angle

Other design solutions typical of the ASK-13R have been modified:

- Fuselage with vertical straight sides as the original design but optimizing the cross-section shape to reduce fuselage drag
- Rudder with a new modern shape, keeping the same scale surface proportion and ensuring a quick response to rudder control
- Tail skid below the fuselage with a new design, optimized to improve the local aerodynamic flow and minimize drag
- Increased control surfaces on wings and horizontal stabilizer to ensure best maneuverability.

Finally, some new modern design concepts have been integrated in the overall design. This has allowed to improve the overall aerodynamic performances by reducing overall drag, in favor of an higher model of Lift-to-Drag ratio (Aerodynamic Efficiency):

- canopy shape: the original canopy shape is a source of additional drag, due to the "bubble" shape. Therefore, on the new ASK-13R we have designed a new canopy with

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a continuous profile, that stabilizes the airflow along the upper part of the fuselage, from the nose up to the tail
- fuselage tail boom: the part of the fuselage behind the wing, until the rudder, has been re-designed to keep the flow boundary layer as thin as possible in a wide of flight speed
- wing tips: the specific angle of the wing tips has been optimized to reduce the wing-tip vortices even without the use of winglets
- horizontal stabilizer: the horizontal stabilizer has an increased aspect ratio with respect to the original glider, to reduce the Induced Drag and contribute to a smaller gliding angle
- wing airfoils, specifically chosen for this glider, as described extensively in the Aerodynamic Study