Vehicle Design

Team race number: 575

I. Introduction

The EFICEM relation with design runs in the team 's history. Being the pioneer in carbon laminate application created a need for design development, therefore the fairing cell - carenagem in portuguese - has the mission of combining the crucial points of the various requirements held by the team's main goal: Efficiency. Carenagem, from latin carina or carena, referring to flying birds' chest format, was the name given to the hull of vessels in order to increase their speed in the sea, lowering the environment resistance. In the modern era, fairing designates the carcass that covers the structure of vehicles that move in a fluid environment as on water, land or in the air, such as speedboats, automobiles and aircraft, attributing an aerodynamic or hydrodynamic aspect seeking to reduce the resulting friction from air/water resistance. In EFICEM, fairing plays an even more important role, in addition to the aerodynamic function, innate in its definition, through the use of carbon fibers, together with divinycell panels, epoxy resin and grade 1 titanium plates, acquires a structural function in our prototypes, providing resistance to fracture by fatigue and impact.

II. Concept Creation

Aiming the maximum performance in Shell Eco Marathon, the prototype was developed with one goal: Efficiency. In order to achieve the highest possible efficiency, the fairing cell fragmented the project in 3 areas, structural, ergonomics, and aerodynamic. In which the structural comprise safety, materials used, technical feasibility and the circular economy present in the project. While ergonomics studies are exclusively for the pilot comfort. Last and most important, the aerodynamics, the main responsible for the prototype's aesthetics. The prototype study was initiated with a restructuring of the cell, in order to improve the knowledge applied in the process. In the initial stages of the process, it was determined the use of CAE - Computer Aided Engineering - softwares, a complete monitoring, and the creation of reports towards generating and maintaining knowledge for the years to come, since the team has a high rotation of members, and, until then, had almost none material saved for the ones who were in the team. A brainstorm composed by the team captain, the fairing cell leader, a former captain, and two cell members, followed by an international benchmarking launched the aerodynamics studies. A line of creation was defined. The fairing cell started by analysing different formats of airfoils seeking the combination of low drag, high lift and large internal capacity. As restrictions the top view of the car should be composed by a symmetric airfoil, while the side view could be either symmetric or asymmetric airfoil. After the search and test of all of them, 3 for each view were selected and combined in a unique design. The design, since its beginning, always thought about technical feasibility and internal arrangement, based on theoretical knowledge of lamination followed by analysis from the university professors, and the better use of the car's internal space. Then, after the 3D model aerodynamics was analysed and approved, it was moved on to the structural analysis, simulating it with carbon fiber, epoxy resin, and grade 1 titanium plates. As the prototype was validated, the car construction was initiated. Since the machining of polystyrene to create the mold, through the lamination by infusion, and finalizing with the components assembly. With the car manufactured, physical tests of the prototype were started, experimenting and learning everything about the prototype and its behavior, also training our pilots to achieve the best performance for the competition.

III. Aerodynamics

If we observe in nature we can evidence an aerodynamic phenomenon that added a lot to the evolution of the profiles developed today. The simple dynamic movement of free fall, in a particle of water, results in the formation of a body whose surface behavior is favorable for the creation of a smooth flow. Based on the fact that the particle molds independently, due to being in a liquid state, the air resistance causes it to develop a profile that presents a frontal area that gradually decreases through its body, that is, the drop gets thinner and thinner, smoothing the air flow. For a long time this profile was taken as aerodynamic as possible, because in fact it was the one with the lowest aerodynamic friction coefficient. But as engineering is constantly improving, it was realized that nature once again provided us with a new object of aerodynamic study as good as the drop, the penguin. This sea bird, originally from Antarctica, is responsible for one of the biggest discoveries in the study of fluid mechanics. This is due their behavior, in the sea waters, is endowed with very agile and smooth movements. In addition to its fluff, in which the friction of its body with water decreases, the profile of the penguin has a friction coefficient lower than the water drop. When analyzing this profile, it can be seen that the set of the penguin's beak with its head provides a small transversal area when compared to the rest of its body. Assisting the penguin's subtlety to "cross" the water. Other than that, the rest of its body is constituted by a curvature, almost continuous, that creates in the back a smooth outlet for a non-turbulent flow.

All of this information led us to perform an aerodynamic study contemplating a series of airfoil, the cell analyzed 26 different types of airfoil as shown in the figures 1, 2, 3 and 4.

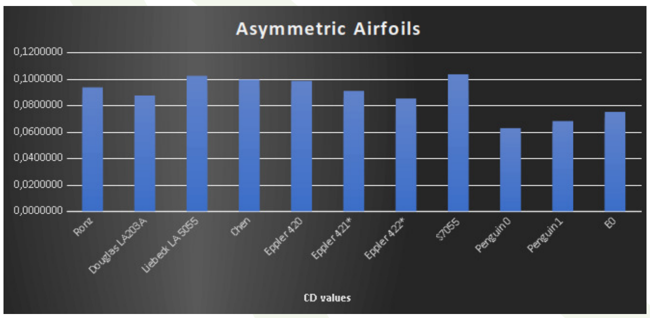

Fig. 1. Asymmetric Airfoils CD Values

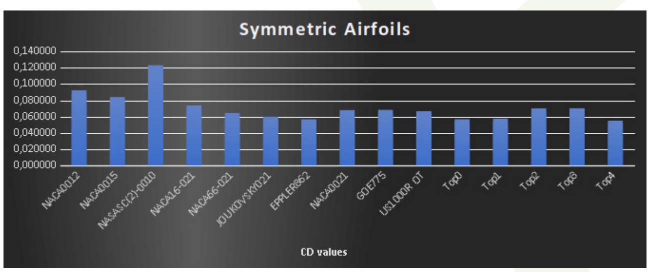

Fig. 2. Symmetric Airfoils CD Values

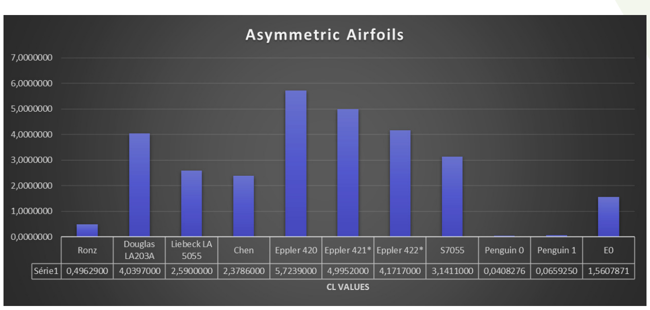

Fig. 3. Asymmetric Airfoils CL Values

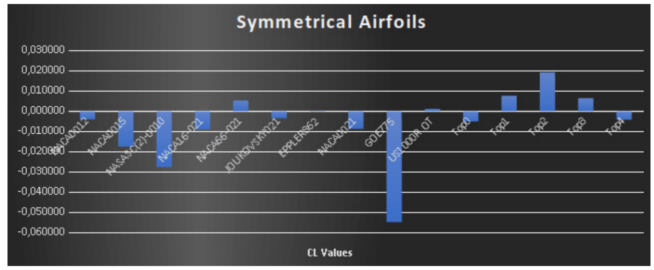

Fig. 4. Symmetric Airfoils CL Values

With the analysis, the fairing cell came to know that the airfoils named Penguin 0 and Top 4 were the most appropriate ones, once they presented the lowest drag coefficient and a satisfactory internal space. The lift coefficient, as the prototype won't perform in high velocities and, consequently, won't make the difference we first expected, were disconsidered.

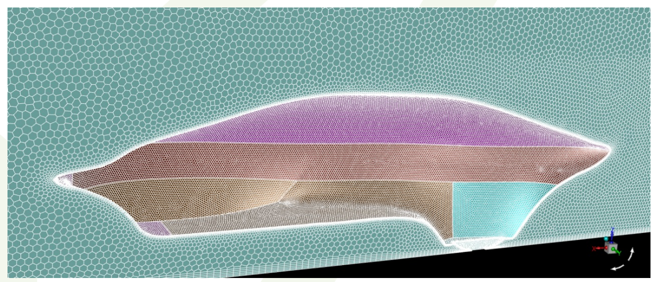

Fig. 5. Airfoil Side View

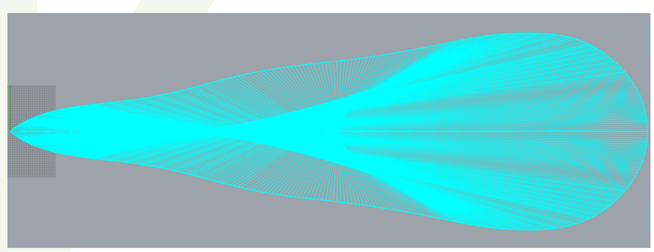

Fig. 6. Airfoil Top View

Once the 2D aerodynamic analysis was finished, the 3D studies started, adding volume and skirts to the prototype. Also requiring an overall aerodynamic study verifying the possible performance of the car, and proving all the effort to create it. Leading us to this unique penguin design that EFICEM presents in this brand new prototype.

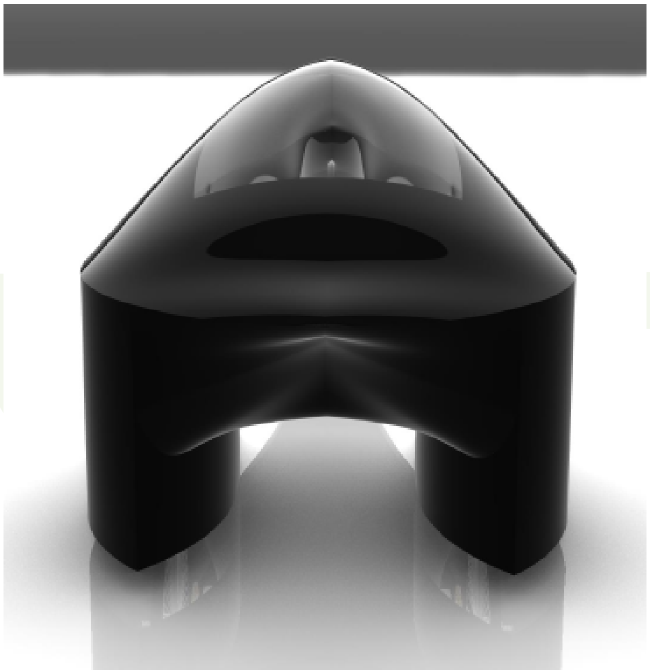

Fig. 7. Prototype Front View

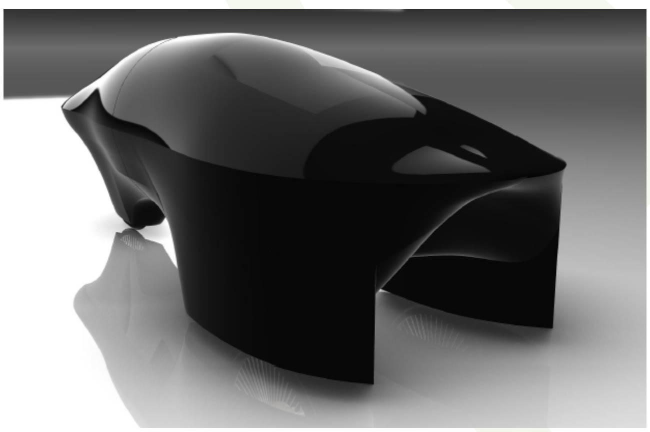

Fig. 8. Prototype Front Perspective View

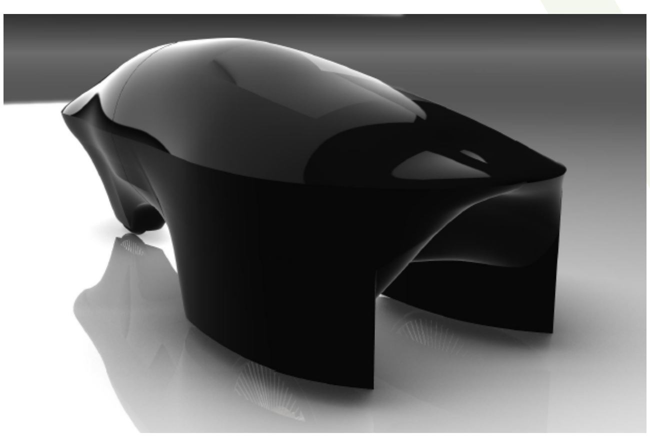

Fig. 9. Prototype Front Perspective View

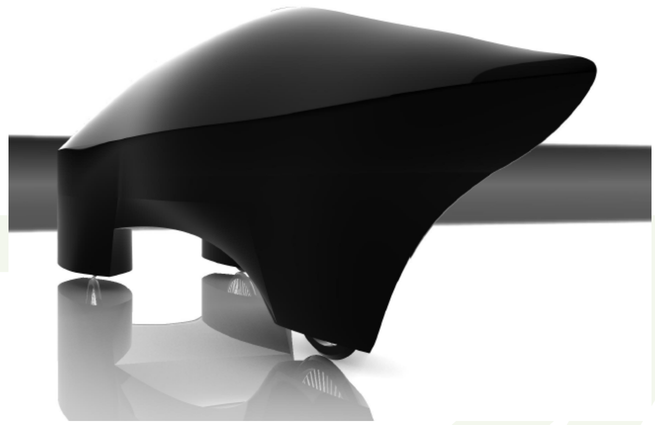

Fig. 10. Prototype Rear Perspective View

Fig. 11. Prototype Rear Perspective View

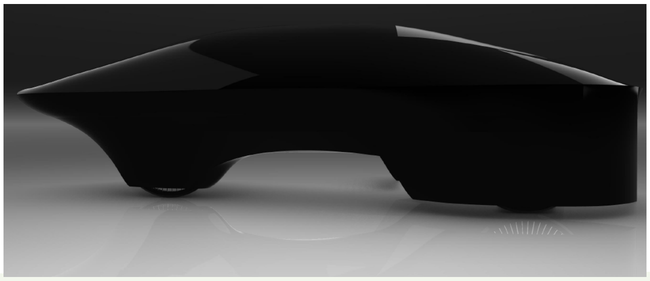

Fig. 12. Prototype Side View

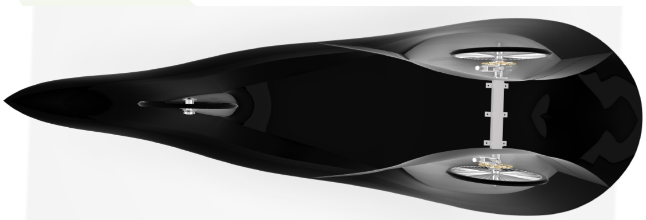

Fig. 13. Prototype Top View

IV. Ergonomics and Internal Arrangement

The ergonomics studies began in initial stages of the design process, always aiming for comfort and safety for those who may drive our prototype. The analysis contemplated the creation of real size models of our pilots in 3D softwares, combining possible driving positions and hand/feet movements, a great driving view, isolation from engine and mechanical parts in order to provide safety to the pilot, and a low center of gravity to maintain steadiness in our prototype performance. Due to the pursuit for less weight and precise movements, the team decided to use a stick in order to steer the wheel. Providing a thin aluminum stick directly connected to the right wheel, with the connection between them being covered by a layer of laminated carbon fiber. Occupying a precise amount of space inside the car, just right to the expected from the analysis.

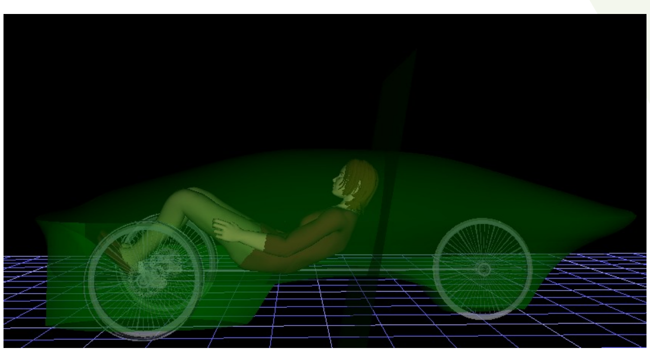

Fig. 14. Jack Side View

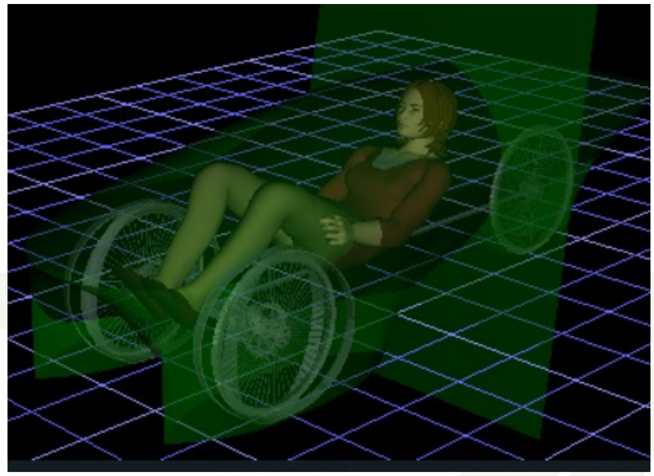

Fig. 15. Jack Perspective View

Also the "break fire", a piece of reinforced laminated carbon fiber covered by aluminum sheets, used to isolate the engine area from the pilots area, was placed at 1400mm from the start of the prototype, with an angle of 10°.

V. Structural

To finalize the analysis stages, the team conducted a series of trials to ease every possibility of fracture due to the car components and pilot weight. Also possible points of tension depending on how the pilot enters and exits from the prototype, or moves himself inside the prototype during the competition. All of these situations were previously thought off, and ruled out after the tests were conducted, certifying safety to the pilots. An excellent strategy, adapted from boat constructions, was to make the wheels protection, the break fire back and the "roll cage" all structural pieces, even though it added a little weight in these areas, it conferred great points of resistance and eased critical points of failure due to sharing the stress throughout the car.

VI. Materials and Circular Economy

Aiming an excellent performance in Shell Eco-Marathon, the structural analysis walked side by side with the weight reduction goal. Designed to meet these needs, the car's floor structure is composed of a laminate made of 2 layers of bidirectional carbon fiber, with divinycell foam between them, and specified areas with plates of grade 1 titanium. Providing an outstanding resistance while having reduced weight. As for the ceiling of the prototype, it was also made with lamination method, utilizing 1 and a half of carbon fiber layer, utilizing, for only specific points, the divinycell, towards lowering the cars final weight. As for the glass, the team used a polycarbonate. The final result is a 20 kilograms Prototype fairing capable to endure for the competitions to come. When it comes to circular economy, EFICEM, current winner of the Off Track Circular Economy Award, makes the best out of it. Always measuring everything at its finest to make sure that there is no waste of material. Also, as we work a lot with resin, we strive our best to maintain every tool clean to be able to reutilize it, instead of throwing out as most does. EFICEM cells developed a method of creating a thin powder of carbon fiber that is mixed with resin and becomes an excellent structural glue we call carbon microspheres. Still in the prototypes manufacturing stage, towards cost reduction and reuse of materials, the team makes cuts on the old prototypes that will no longer be utilized and transforms them in specific pieces in the new projects. Besides the car manufacturing, the team also tends to make the workshop furniture with reforested wood, old pallet wood, and pieces of metals and woods from other teams inside the university that will no longer utilize them and eventually will end up in the trash. EFICEM tries its best to be a low cost, highly adaptable, and smart thinking team, with an objective to spend money in specific materials that will highly increase the prototypes performance, while other parts may be less strategic ones, but always ensuring great results and safety.

VII. Conclusion

This project was inspired by nature's greatness, the search for efficiency, and sustainable design. This factors were crucial in the work performed by every member of the team. EFICEM based these prototype's development entirely in green thinking, looking to thrive a better future for the generations to come.