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ACS-100 SORA and its technological innovations: into the future general aviation scenario

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ABSTRACT

The recently created category of Light Sport Aircraft (LSA) in the United States of America (USA) opens up new perspectives and furthers the development of general aviation. Within this scenario, new enterprises are arising to meet the demand for more versatile airplanes. The ACS-100 SORA is a Brazilian response to the worldwide demand for a new generation of personal aerial transportation. This paper presents the most relevant parts of the engineering development and construction cycle of an all composite sport aircraft with high standard performance, comfort, safety and low cost.

INTRODUCTION

Conceived to meet the Light Sport Aircraft (LSA) standards, the aircraft was originally based on a doctoral thesis of Professor Claudio Barros from Universidade Federal de Minas Gerais (UFMG). The original project was conceived as a wood and fiber glass fabric homebuilt airplane. The project was redesigned to be airworthy within the LSA requirements and to attend the demand for a modern and safe aircraft. Following this premise, allied with the tendencies in the new general aviation market the airplane integrates the latest technological innovations available, such as diesel engine, ballistic rescue system, inflatable restraint system, modern avionics and a completely composite material structure.

Aircraft are weight sensitive structures and composite materials for structural applications can have high strength-to-weight and stiffness-to-weight ratios, and in many cases reduction of costs. The preliminary design of the airframe was built to achieve weight, strength, crashworthiness, resistance to wear and corrosion goals, meeting and in some cases exceeding the LSA requirements. To allow for superior structural properties and design concepts that could lower part counts, guarantee replication of production, ease of fabrication and eliminate costly fasteners, an all composite airframe concept was chosen.

Safety is a main concern for modern aircrafts. Following this tendency a ballistic recovery system was adopted to the airplane. The system is commanded by the pilot and greatly increases security to the passengers and the aircraft. In case of a critical engine stall or a serious structural failure, the parachute can be activated. The parachute canopy is expelled from the aircraft by a rocket and guarantees the safe descent of the aircraft to the ground.

Diesel engines are opening new perspectives for general aviation and will certainly dominate the next generation of piston aviation. Functioning equally well with regular diesel or aeronautic kerosene, the advantages of these motors compared to similar gasoline motors are enormous. Fewer movable parts guarantee a lesser probability of failure and a lower maintenance cost. The absence of electrical system eliminates electro-magnetic interference and significantly reduces the probability of failure. Aside from this, the fuel consumption is less and in most places it is less expensive to run using either kerosene or diesel. Because of these numerous advantages SORA is powered by a diesel engine.

Two digital panels with Liquid Crystal Display (LCD) equip the aircraft. One panel consists of a Primary Flight Display (PFD) which concentrates all of the basic flight information with a visual interface that greatly increases the pilot’s ability to interpret the information, therefore ensuring greater situational control and the resulting security of the flight. The other panel consists of a Multi-Functional Display (MFD) that gives information about the engine, navigation with Global Positioning System (GPS), meteorological conditions and a moving map on multiple screens.

Powered by a 100 hp diesel engine and with a maximum take off weight of only 600kg, the two-seat light aircraft sustains load factors of up to +6/-4g, cruises at a speed of 260km/h, with autonomy of 5 hours or a range of approximately 1200km. The aircraft can be used for aerobatic, recreational or instructional flights. The aircraft's initial design and specifications follow in Figure 1 and Table 1 respectively.

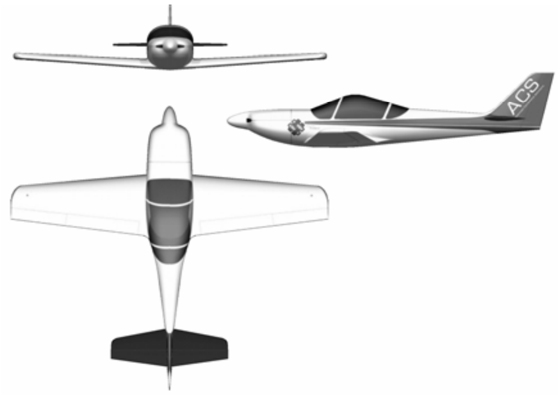
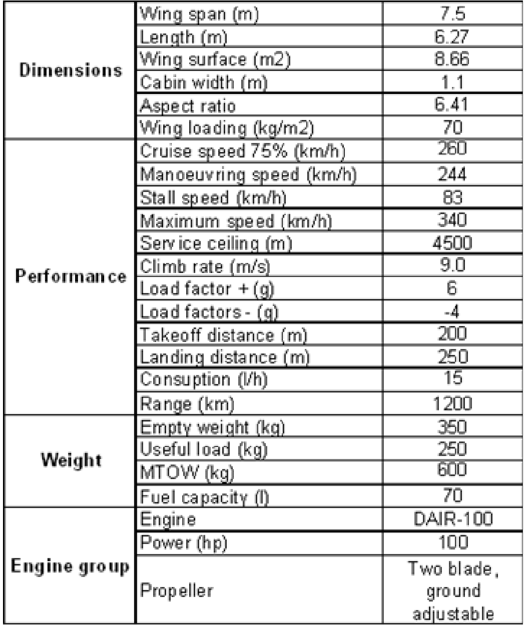


Figure 1: Three View

Table 1. Airplane Specification



Dimensions	Wing span (m)	7.5
	Length (m)	6.27
	Wing surface (m2)	8.66
	Cabin width (m)	1.1
	Aspect ratio	6.41
	Wing loading (kg/m2)	70
Performance	Cruise speed 75% (km/h)	260
	Manoeuvring speed (km/h)	244
	Stall speed (km/h)	83
	Maximum speed (km/h)	340
	Service ceiling (m)	4500
	Climb rate (m/s)	9.0
	Load factor + (g)	6
	Load factors - (g)	-4
	Takeoff distance (m)	200
	Landing distance (m)	250
	Consuption (l/h)	15
	Range (km)	1200
Weight	Empty weight (kg)	350
	Useful load (kg)	250
	MTOW (kg)	600
	Fuel capacity (l)	70
Engine group	Engine	DAIR-100
	Power (hp)	100
	Propeller	Two blade, ground adjustable

PROJECT DEVELOPMENT

STRUCTURAL DESIGN – consists of composite sandwich shells in which the main construction element is fiber glass. This ensures low weight together with high strength and durability. The structure was developed providing both safety for the occupants and structural integrity of the cell itself. The material used to build the airframe is a sandwich of fiberglass with Polyvinyl Chloride (PVC) foam on an epoxy resin base. The orientation of the fiber glass layers were chosen depending on the kind of efforts applied on each structure. Some areas are reinforced with unidirectional fiber glass. Figure 2 shows the basic structure design.

Primary structures such as fuselage, wings, spars and control surfaces, as well as some minor parts such as spinner, doors and interior parts, are built in female molds to ensure accurate shape and structural integrity, adding both simplicity and low cost to a relatively complex high performance aircraft. In addition, replicable quality is assured and airframe longevity is achieved.

The construction process of the composite parts is hand lay up, one of the simplest and most low cost methods. The process is incremented by the application of vacuum after the resin impregnation, which contributes to a more efficient compression of the layers and the elimination of resin excess.. The parts can be cured at room temperature, or depending on the resin chosen, the cure cycle can be accomplished by the addition of heat during a specific time.

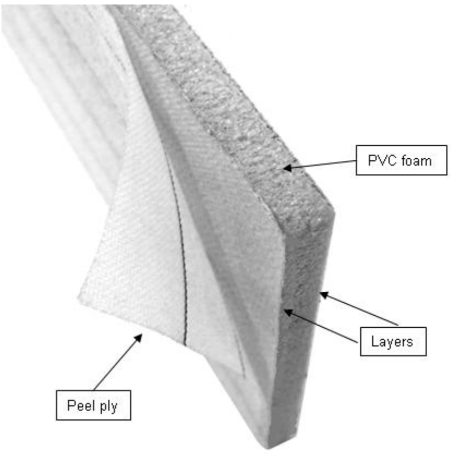


Figure 2. Basic sandwich structure design

<u>Fuselage concept</u> – comprised of two main parts, a left and right side laid up in two female half molds. The two parts are mated at their wide ends, which guarantee effective distribution of loads and fewer internal structures. A flange surrounding the fuselage,

trimmed off later, helps the join process while a fiber glass fabric is applied.

The parachute is attached to the fuselage on three different hard points: two located at the front firewall bulkhead and the other at the tail root. The attachment points are designed to withstand up to 5g at the time of parachute canopy opening.

Figure 3 shows the fuselage structure and internal arrangement with approximately only 25 parts.

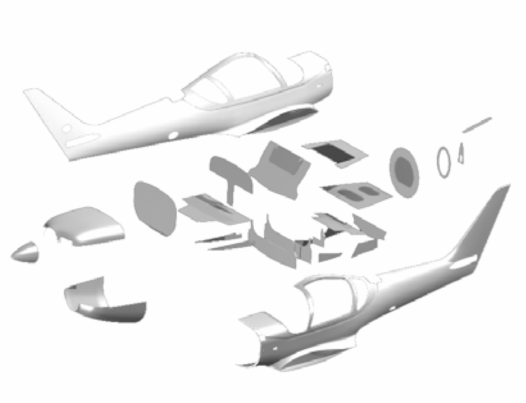


Figure 3. Fuselage structure

Wing Concept – consists of composite sandwich shells joined along the leading edge and connected by two spars, main and secondary. The main spar has an 'I' section and is built in its entirety during a single fabrication process to ensure structural integrity. The main spars are made with unidirectional fiber glass spar caps and sandwich fiber glass fabric shear webs. The spar caps are bonded to sandwich wing panels. To achieve a uniform spanwise displacement due to aerodynamic loads, the spar caps thickness is reduced from root to tip which also contributes to a smooth stress distribution. The ribs are made of a sandwich construction with PVC foam and fiber glass fabric also bonded to wing panels. The secondary spar is a sandwich shear web, located at the wing trailing edge. Figure 4 presents the wing's interior structure.

The wing tanks are located totally separately from the fuselage which eliminates the risk of fuel leakage to the airplane interior and hence the contamination of passengers in case of an accident. The outer and inner wing tank boundaries are designed to withstand the lateral and forward pressures due to fuel slosh.

For more details of wing and spars structure, see Figure 4.

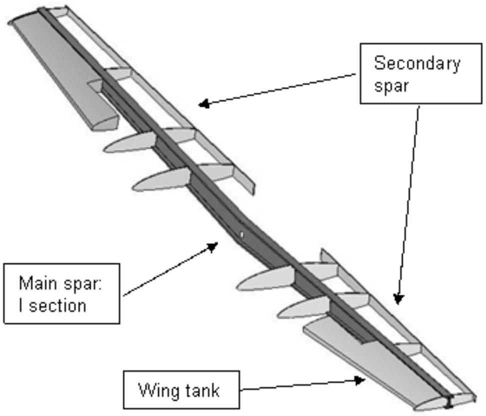


Figure 4. Wing structure

Roll Cage – In addition to the phenomenal strength of the composite airframe structure, the roll cage is designed to protect each occupant during emergency landing conditions according to LSA requirements. These are three independent conditions of load factor of 3.0 up, 9.0 forward and 1.5 laterals. The roll cage structure uses unidirectional fiber glass tapes on all hoops which are wet laminated after the fuselage have been mated. Figure 5 shows the roll cage design.

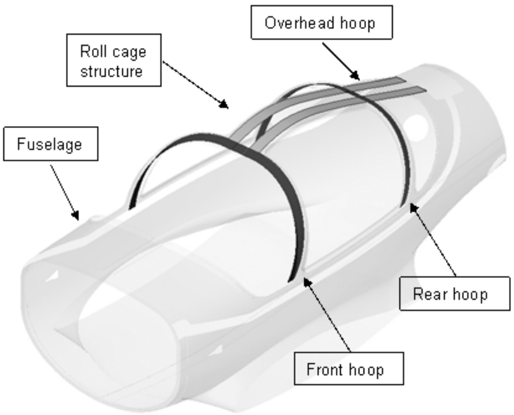


Figure 5. Roll cage detailed design

Wing Fuselage Junction – was conceived with the premises that the shear loads and bending moments due to spanwise lift distribution are acting on the main spar which is not attached directly to the fuselage. The main spar is only bonded to the wing panels through the lower and upper spar caps. The wing is attached to the fuselage by wet fiber glass layers applied on the wing root and fuselage, as seen in Figure 6. This allows the torsion moment to be transmitted mainly through the wing panel to the fuselage. The configuration proposed simplified the assembly process while eliminating bolt joints and the need of hard attachments points which can be critical for stress concentration.

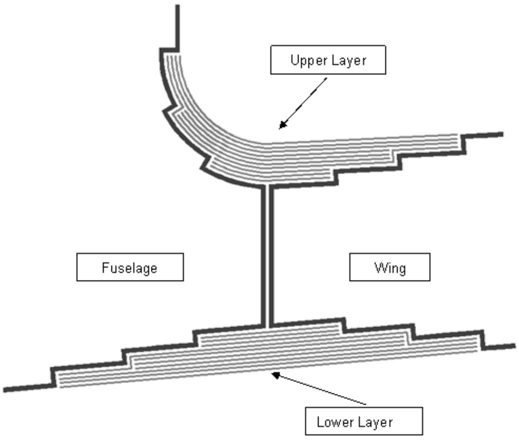


Figure 6. Wing-Fuselage junction

Surface Junction – was conceived with a flange, as shown in Figure 7, which is use to facilitate the final assembly of the upper and lower aerodynamic surfaces. Once bonded, the flange is trimmed off and a pre-molded piece is attached and bonded in the outer side of the leading edge in what is called a‘step joint’. The inner bonded joint is added before the final assembly to improve the strength of the leading edge where the highest shear load occurs. The use of a pre-molded outer joint guarantees the aerodynamic leading edge shape.

See Figure 8 that presents the two pre-molded pieces that are bonded in the inner and outer side of the leading edge.

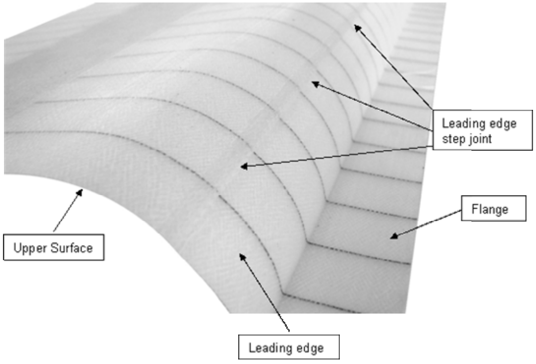


Figure 7. Flange detail and step joint

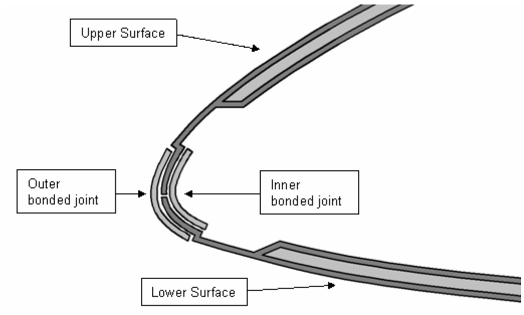


Figure 8. Leading edge surface junction

Beveled Firewall – makes the aircraft more crashworthy by allowing it to slide over obstacles that would otherwise bring it to a sudden stop in the event of an emergency landing or accident on ground, see Figure 9**.**

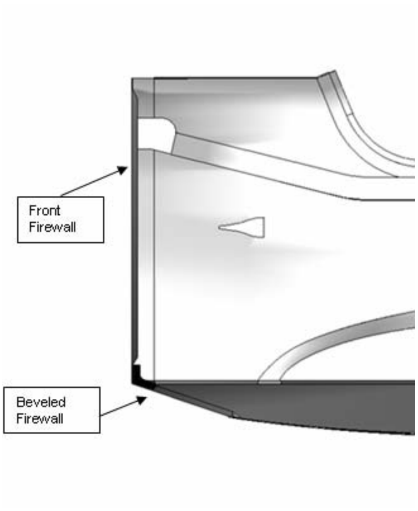


Figure 9. Beveled firewall

CONCLUSION

Significant advances in the aeronautical scenario are within our reach. The composite materials achieve a compromise between weight, strength and cost as the development of carbon fibers, resins, and nanotechnologies cause a continued drop in price. New design details for cockpit layout and safety devices can also be improved upon in the areas of comfort, noise reduction and crashworthiness. In addition, the enormous variety of electronic applications for pilot interface, fly by wire, flight data recorders and flight calculations can be widely used in general aviation. There is room for improvements in structural design and fabrication process in minimizing costs and time. Not to mention the development needed in engine groups, from electric motors to fuel cells with regard to attainable range, costs and environment benefits. Finally, there are challenges in aerodynamic research considering interference drag in wing-fuselage and empennage areas, and airfoil studies for prevention of laminar bubbles especially at low Reynolds numbers.

Considering all of these possibilities its certain that the future of general aviation holds a wide variety of challenges for aircraft designers to face.

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Alexandre Zaramella, 33 years old, mechanical engineer, graduate of UFMG, 9 years experience in the development of aeronautic products. Started his career at Embraer where he worked as a product development engineer in the structures and loads departments. Recently he worked for Airbus in England on the development of aircraft A350 and A400M. Since July 2006, he has been exclusively dedicated to coordination of all engineering activities in product development at ACS.

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