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DESIGN OF A LSA AIRCRAFT USING ADVANCED SOFTWARE

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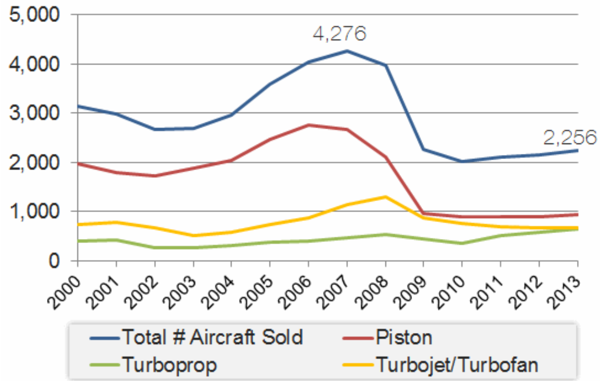
Abstract: *This paper is focused on the design of a light sport aircraft (LSA) in the university level. A market research and analysis study has been made and based on the General Aviation Manufacturers Association (GAMA) study, showing that 20-25% of light weight sport aircrafts are currently produced using reciprocating engines and within a few years this ratio could increase between 33% and 50%. A preliminary and conceptual design was done for a new lightweight, low-cost, low fuel consumption and long-range aircraft. The design process that covers by this paper is based on software tools like as Advanced Aircraft Analysis (AAA) and CATIA. Using the data from this paper, the design will follow a series of aerodynamic analysis in wind tunnel, and flight experiments to determine the real performance of the airplane.*

Keywords: *preliminary and conceptual design, aircraft, lightweight structure, Computer Aided Design*

1. INTRODUCTION

The reason for choosing this theme was the result of an economic analysis of data from General Aviation Manufacturers Association (GAMA) [7] resulting that the global sales of various planes, best-selling aircraft are equipped with piston engine. "In 2013 the aircraft sold worldwide in 2256, 933 (41.4%)", which can be seen in fig. 1. At the same time range aircraft piston engine, the lightweight are in development, "the update of economic, figures seem to show that LSA is somewhere between 20% and 25% of sales piston GA and this share will increase with LSA becoming close to 33% to 50% of total sales piston engine airplanes" [7], fig. 2. "FAA issued a 20-year forecast for aviation in 2030, according to LSA aircraft sales will increase by 825 per year until 2013 and then increase to 335 per year" [7].



Fig,1. Aircrafts sold by category between 2000 -2013 [7]

According to the last year's market analysis, CS - LSA (Light Sport Aircraft) regulation allows an facile certification of aircraft and the total investment for production is less compared to other category of airplanes. Because LSA aircrafts have a lower selling price than other aircrafts, 60.000$ – 190.000$ and lower fuel consumption, this type of airplanes becomes more and more attractive for people passionate about flight. Most modern airplanes from this category are capable for long flights, up to 1400 km without refueling. This type of airplanes are ideal for business and leisure flight, because their low fuel consumption, and the maintenance cost and taxes are lower than other categories of airplanes. According to the simplicity and flying cost of light sport aircrafts, it could be a market opportunity for Romania.

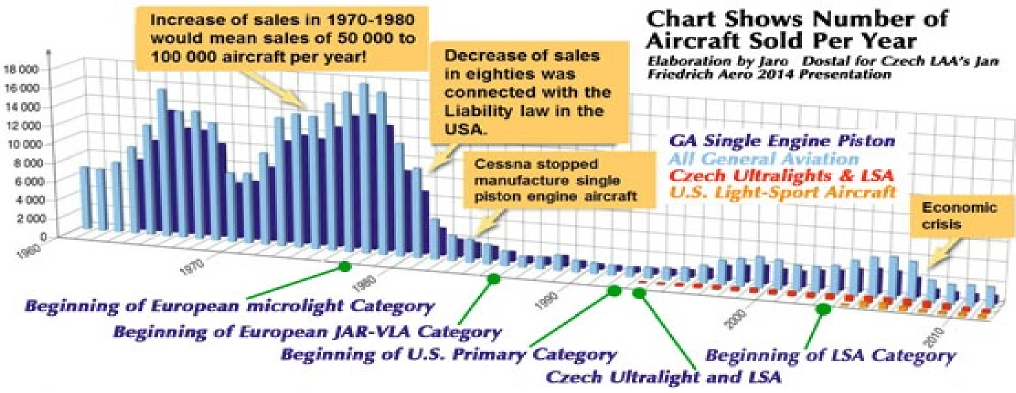


Fig. 2. Number of LSA sold per year, from 1960 to 2014 [1]

2. PRELIMINARY DESIGN OF THE AIRPLANE

Generally the aircraft development process consists in the following steps: market analysis and customer requirements, mission specifications, conceptual design, preliminary design, detailed design, prototype manufacturing, flight test, and finally the aircraft production.

In the conceptual design phase, the aircraft will be designed in concept without the precise calculations. The preliminary design phase tends to employ the outcomes of a calculation procedure. As the name implies, the parameters that are determined in the preliminary design phase, are not final and will be altered later. Also, in this phase, parameters are essential and will directly influence the detail design phase. One of the results of the preliminary design is used to define the geometry of the aircraft. These parameters will be used as input data to 3D modelling of the aircraft. In a modern design process, the 3D model of the aircraft plays a crucial role.

Designing an aircraft can be an overwhelming task for a new designer. The designer must strive for a better, lighter and optimal solution as the concept to be competitive with the best aircraft in the current market. An optimal design could mean lighter structure, lower fuel consumption or lower price.

The conceptual design of the aircraft was started by studying the current competitors in the same regulation class. After the studies between several possible configurations it was chosen the best configuration for the concept.

After collecting this data from other aircrafts, it starts the preliminary design of the airplane. The preliminary design of the aircraft was made by using a commercial aircraft design and analysis software, thus as Advanced Aircraft Analysis (AAA) from DAR corporation [6].

Table 1 General characteristics of the SkyDreamer airplane

Parameter	**Value**
Crew	Two
Empty weight Max. Takeoff weight	315 kg 600 kg
Fuel capacity	100 L
Powerplant	Rotax 912iS – 100 HP
Propelles	NEUFORM TXL3-65-47-101.6
Maximum speed Cruising speed	290 km/h 205 km/h
Range	1650 km
Service ceiling	5500 m

Generally, to design a new aircraft it is necessary a mission specification to be defined. Aircraft mission specifications come depending on the aircraft type and customer requirements [6].

The airplane presented in this paper is called SkyDreamer, having the general characteristics as shown in the table 1. The mission specification of the SkyDreamer aircraft consists in the following main segments: warm-up, taxi, take-off, climb, cruise, descend and land/taxi. The preliminary design of the aircraft was done using a design procedure, as seen from fig. 3.

The preliminary design phase is performed in the following steps, using AAA software:

- estimate aircraft maximum take-off weight,
- determine wing area and engine thrust (or power) simultaneously,
- aerodynamic consideration,
- estimation of the wing, flap, aileron, fuselage and tail dimensions,
- aircraft weight and balance and
- static stability.

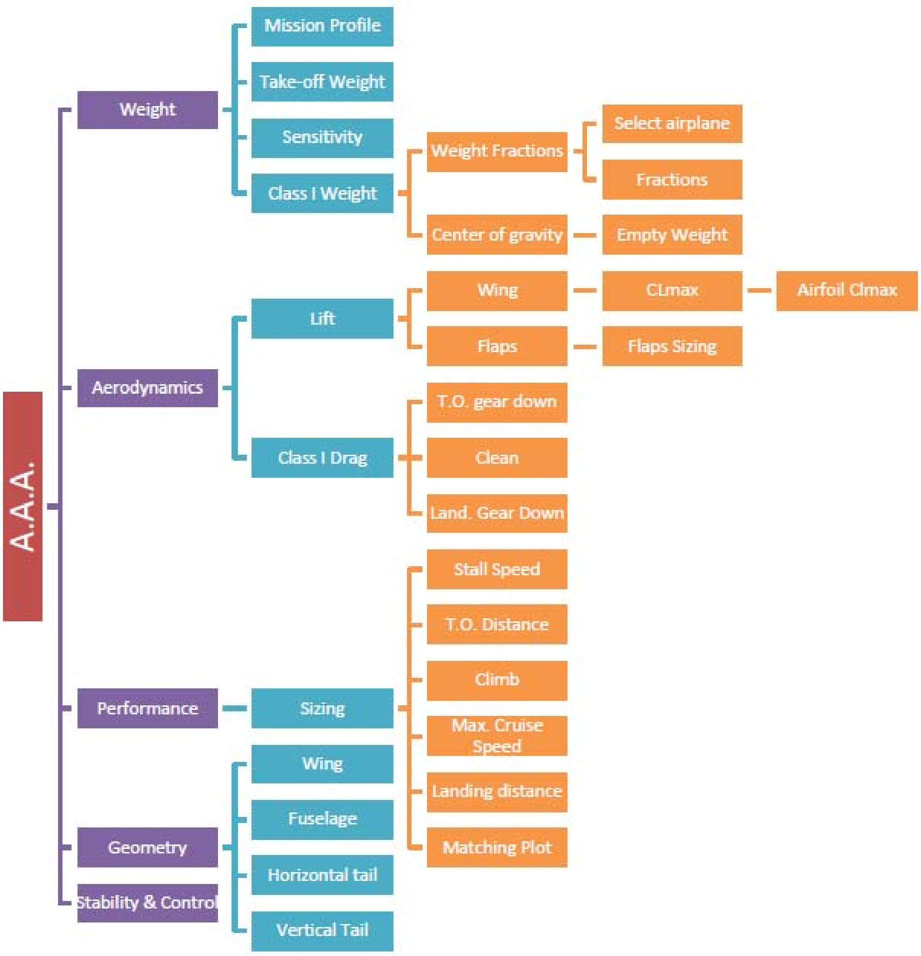


Fig. 3. The flowchart of preliminary design using AAA

According to achieve higher performance for the aircraft it was chosen a Rotax 912iS, 100 HP engine. Compared to other engines it has a lower fuel consumption, CO_2 emission and lower weight to horsepower ratio. For this type of engine it was choosen NEUFORM TXL3-65-47-101.6 proppeler having 1.65 m diameter.

The general technique to estimate the maximum take-off weight is as follows: the aircraft weight is broken into several parts. Some parts are determined based on statistics, but some are calculated from performance equations. Maximum take-off weight is broken into four elements: payload weight (W_{PL}), crew weight (W_C), fuel weight (W_f) and empty weight (W_E).

$$W_{TO} = \frac{W_{PL} + W_C}{1 - \left(\frac{W_f}{W_{TO}}\right) - \left(\frac{W_E}{W_{TO}}\right)} \quad (1)$$

In order to find W_{TO}, one needs to determine the three parameters (payload, crew, and fuel fraction) in a fairly accurately way, and the last parameter (i.e. empty weight fraction) from statistics.

The required amount of the total fuel weight necessary for a complete flight operation depends upon the mission to be followed, the aerodynamic characteristics of the aircraft, and the engine specific fuel consumption (table 2).

Table 2. Mission fuel weight calculation

	Mission profile	W_{begin} [N]	ΔW_{Fused} [N]	W_{Fbegin} [N]
1	Warmup	5967.3	29.8	720.6
2	Taxi	5937.4	17.8	690.8
3	Take-off	5919.6	11.8	672.9
4	Climb	5907.8	9.7	661.1
5	Cruise	5898.1	515.4	651.4
6	Descent	5382.6	37.7	136.0
7	Land,Taxi	5345.0	37.4	98.3

The general arrangement of the wing at the fuselage affects the parameters of the airplane. It was chosen a low wing configuration. The relative thickness of the wing is chosen according to a low cruise speed aircraft ($V < 0.7$ M), $\varepsilon 0$=14-20% at the root chord of the wing and εe=7-9% at the tip chord of the wing.

The optimal value for the dihedral angle is between ψ_V=5-7° for a low wing configuration in order to obtain a good lateral stability for the airplane.

Some of the preliminary design results are presented below.

a) The main configuration of the fuselage

- The length of the fuselage, L_f = 6.45m;
- Maximum height of the cabin, h_{fmax} = 1.05 m;
- The maximum width of the fuselage, l_f = 1.18 m.

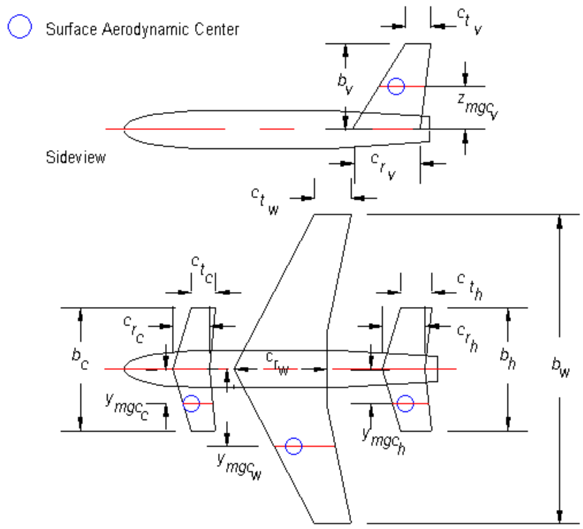


Fig. 4. Wing geometric parameters

b) The main configuration of the wing. The main parameters of the wing (fig. 4) are:

- airfoil type, Eppler 562 [2] having a relative thickness, (t/c)w =15% at 27.6% c;
- span, bw= 10.09 m;
- area, S_W=11.5m^2;
- aspect ratio, AR_W= 8.85;
- taper ratio, λ= 0.65;
- leading sweep angle, Λ_{LE} = 3.86^0;
- trailing edge sweep angle, Λ_{TE}=-1.61^0;
- quarter chord sweep angle, $\Lambda_{c/4w}$ = 2.5^0;
- dihedral angle, ψ= 5$^{0;}$
- angle of attack, i_W= 1.5^0;
- root chord length, c_{rw} =1.38 m;
- tip chord, c_{tw}= 0.9 m;
- mean geometric chord, c_w=1.16 m.

c) The configuration of the tail. The main parameters of the horizontal tail are:

- horizontal tail span, b_h= 2.79m;
- root chord, c_{rh}=0.92 m;
- tip chord, c_{th}=0.69 m;
- mean chord length, c_h=0.81 m

- sweep angle, $\Lambda = 2.5^0$;
- horizontal tail area, $S_h = 2.25\ m^2$;
- aspect ratio, $AR_h = 3.45$;
- taper ratio, $\lambda = 0.75$;

  The main parameters of vertical tail are:
- tail span, $b_v = 1.22$ m;
- root chord, $c_{rv} = 1.29$m;
- tip chord, $c_{tv} = 0.84$ m;
- sweept angle, $\Lambda = 15^0$;
- vertical tail area, $S_v = 1.3m^2$;
- aspect ratio, $A_{rv} = 1.15$;
- taper ratio, $\lambda = 0.65$;
- mean tail chord cv=1.08.

d) Pre-dimensioning of the landing gear. The main parameters of the landing gear (fig. 5) layout [3, 4, 6] are:

- X-coordinate of forward critical gear ground containing point, Xgear.for=0.745m;
- X-coordinate of after critical gear ground containing point, Xgear.aft =2.12m ;
- Y- coordinate of the after critical gear ground containing point, Ygear,aft=0.955m;
- lateral tip-over angle, $\psi = 44.220$.

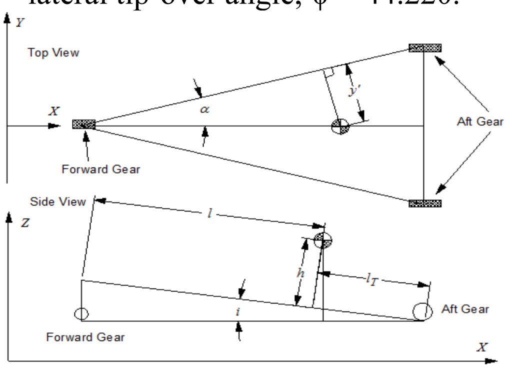


Fig. 5. Landing gear configuration

e) Calculation of aerodynamic characteristics of the aircraft. The aerodynamic characteristics for the airplane it was calculated for the following conditions: take off with gear down, climb with gear up, cruise, descent with gear up and landing with gear down. The drag polar plots are shown in the fig. 6.

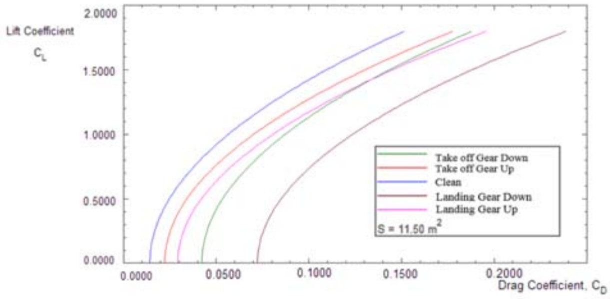


Fig. 6. Drag polar

3. DETAIL DESIGN OF THE AIRPLANE

Based on the dimensions obtained from AAA, the SkyDreamer aircraft was 3D designed using the advanced Computer Aided Design (CAD) software, CATIA [5]. The detail design of the airplane was started from the configuration of the cockpit. The layout of the cockpit is design to ensure maximum comfort for the pilot at long duration flight. The seats and the rudder pedals are adjustable to ensure access to the instrumental panel and flight commands, in function of the height of the pilots (1.63 m – 1.91m). The CAD models of the cockpit, fuselage, tail of the SkyDreamer aircraft are presented in the figures 7, 8, 9 and 10.

Fig.7 General layout of the cockpit

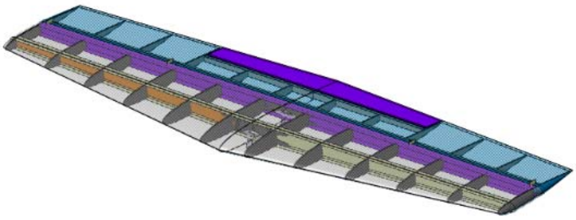


Fig.8. CAD model of horizontal tail

Fig. 9 CAD model of the fuselage

Fig. 10. Concept aircraft – SkyDreamer

4. CONCLUSIONS

This paper presents some steps of the SkyDreamer project. According to the estimated performance, the new concept could be competitive with the top sales light sport aircrafts in the current market. The estimated flight range of this new aircraft is 1650 km with 100 l fuel, which means 14.89 l/h fuel consumption, according to AAA results. Using advanced software tools (Advanced Aircraft Analysis, Catia), the design process of a new aircraft is made in a relative short time and it is simplified. The results of the present study reflect only the preliminary design of the airplane, which will be followed by further tests and design optimization, to obtain the final layout of the airplane. After wind tunnel analysis, flight tests and further optimizations, the aircraft could be passing towards to the production.

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