“SAILPLANE!”

Aerospace 204/404H

Fall 2001 Design Project

The “MaNiBoJoJo”

Submitted to Götz Bramesfeld a.k.a Pipa

29 November 2001

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Abstract

The preliminary design of a lightweight, easy to build sailplane with reasonable climb and glide performance. Most important is a time estimate, after considering the scope of the student manufacturers and the difficulty of production. Then generate a first-approximation weight estimate using material properties and structural considerations. A conceptual drawing follows, with basic aircraft dimensions such as wing planform and fuselage shape. Then a performance analysis of the aircraft testing three selected airfoils is created. From this analysis a single airfoil is chosen based on given design criteria. Finally a cost estimate is determined.

Nomenclature

- Reynolds Number – Re – Ratio of inertial to viscous forces
- Weight – W
- Local Drag Coefficient – C_d
- Induced Drag Coefficient – C_{di}
- Local Lift Coefficient – C_l
- Aircraft Drag Coefficient – C_D
- Aircraft Lift Coefficient – C_L
- Airspeed – V
- Minimum airspeed – V_{min}

- Sink speed – V_s
- Minimum sink speed – V_{sink_min}
- Maximum airspeed – V_{max}
- Lift of the wing – L_w
- Dynamic Pressure – q
- Wingspan – b – length of wing from tip to tip
- Chord – c – width of wing from leading to trailing edges
- Wing Area – S_w – Area of wing
- Aspect Ratio – AR –Ratio of wing length to wing width
- Kinematic Viscosity – ν – value quantifying the viscous property of a fluid
- Span efficiency factor – e – correction factor measuring the deviation from an elliptical lift distribution (e = 1 for elliptical)
- Density – ρ
- Lift to Drag Ratio – L/D – Ratio of lift force to drag force, also gives the glide ratio

Introduction

The purpose of this project is to design a lightweight, easy-to-build sailplane that meets the following fabrication and performance criteria. First, the sailplane class must be able to implement the design over a period of two years. It requires the use of readily available materials and must meet the space limitations of our lab. Next, it has to be designed in a modular fashion. That is, each major component needs to be fabricated separately and be easily fitted and joined with the remaining pieces in order to complete the aircraft.

The design should meet the following performance criteria. It needs to accommodate all standard launching methods. This includes auto or winch-towing and an aerial launch from a tow-plane. The minimum airspeed must be between twenty and twenty-five knots while the maximum airspeed must be around sixty knots.

Other design concerns deal with safety and cost. The structure must adequately protect the pilot in case of impact with the ground or other obstacles. Structural design requirements must meet those set forth by the JAR22 guidelines. Finally, the cost of implementing the design must be reasonable so that it can be covered within the budget of the class.

Assumptions

In order to facilitate the design process a number of key assumptions were made. First the max pilot weight for this design is 175 lbs. Then the lift produced by the wings in steady level flight is equal to the empty weight of the aircraft plus the max pilot weight. The span efficiency factor for this particular planform will be around 0.97. Also, the lift coefficient of the horizontal stabilizer is said to be constant and equal to 0.15. On the other hand the vertical stabilizer produces nominal lift that can be neglected and therefore its drag can be approximated by flat-plate turbulent flow drag. Finally, because of the difficulty in finding the fuselage drag, along with the need for specified fuselage geometry, the fuselage drag is said to be equal to 25% of the wing profile drag, plus 5% of the wing total drag to account for interference.

Design and Discussion

Basic Aircraft Dimensions

Wing:

Span =	49.2	feet
chord =	3.5	feet
Wing Area =	172.2	ft^2
Aspect Ratio	14.06	
Estimated empty weight =	250	lbs
Estimated total weight =	425	lbs
e (efficiency factor) =	0.97	

Horizontal Tail:

Span =	8	feet
chord =	1.15	foot
Htail area =	9.2	
Apect Ratio	6.96	
e =	0.97	

Vertical Tail:

Span =	4	feet
chord =	2.5	feet
Vtail area =	10	ft^2

Fuselage:

Length (with tail boom) =	20	feet
Max height =	3	feet
Max width =	1.75	feet

The driving factor behind the design is ease of fabrication. The design is made as simple as possible so that all key components or their main elements can be purchased or easily fabricated. This simplicity also allows the components to be made in minimal time. A discussion of each main component in the design follows below.

Airfoil: The decision regarding a specific airfoil was done by first looking at some commonly used airfoils and picking a few that seemed to best fit the given design criteria. Afterwards, these airfoils are individually analyzed by doing a drag buildup on each using estimates specifically pertaining to the design (see appendix). These results dictated which design would be selected.

After looking at many common airfoils, the group decided to analyze three specific airfoils. The purpose of this is to see which would give better performance in the range of speeds best suited for the design. The three airfoils chosen are the FX61-163, Gö 532, and SM 701. A full drag build-up was done on each and the results are depicted in a drag polar. This sailplane is designed to operate at low speeds, so performance in this range is of most concern. It is clear that the FX61-163 and Gö 532 both perform slightly better than the SM 701 at extremely low speeds, however the performance of the latter is much greater at higher speeds. Since these higher speeds are well within the operational range of the design, the group determined that the performance gained by the SM 701 at higher speeds outweighs the slight increase of performance given by the FX61-163 and Gö 532 at the lower end of the range. Therefore, the SM 701 was selected for the design.

Tail boom: The tail boom consists of a simple carbon tube which can be purchased from a composites manufacturer. It has an outer diameter of six inches and a length of ten feet. The tube will be fitted to the back of the fuselage and the tail can be attached. The use of carbon allows for a lightweight and high-strength design while the purchase of a tube makes the design much easier to implement.

Fuselage: The fuselage gets its main structure from six or seven bulkheads defining the shape. The bulkheads will be similar to those created in lab, with a foam core sandwiched between 2 layers of alternating 45˚ fiberglass. At least two bulkheads will be closely spaced aft of the pilot. These aft bulkheads will serve as attachments for the landing gear, which will be stationary, and the tow hook. In order to maintain a more streamlined shape aluminum stringers will run from the nose to the back of the fuselage, connecting to the tail boom. Not only will these stringers help to define the fuselage shape, but also they will add structural support and an attachment to the tail boom. Dope and fabric will then cover the skeletal structure of bulkheads and stringers, allowing for a truly streamlined body.

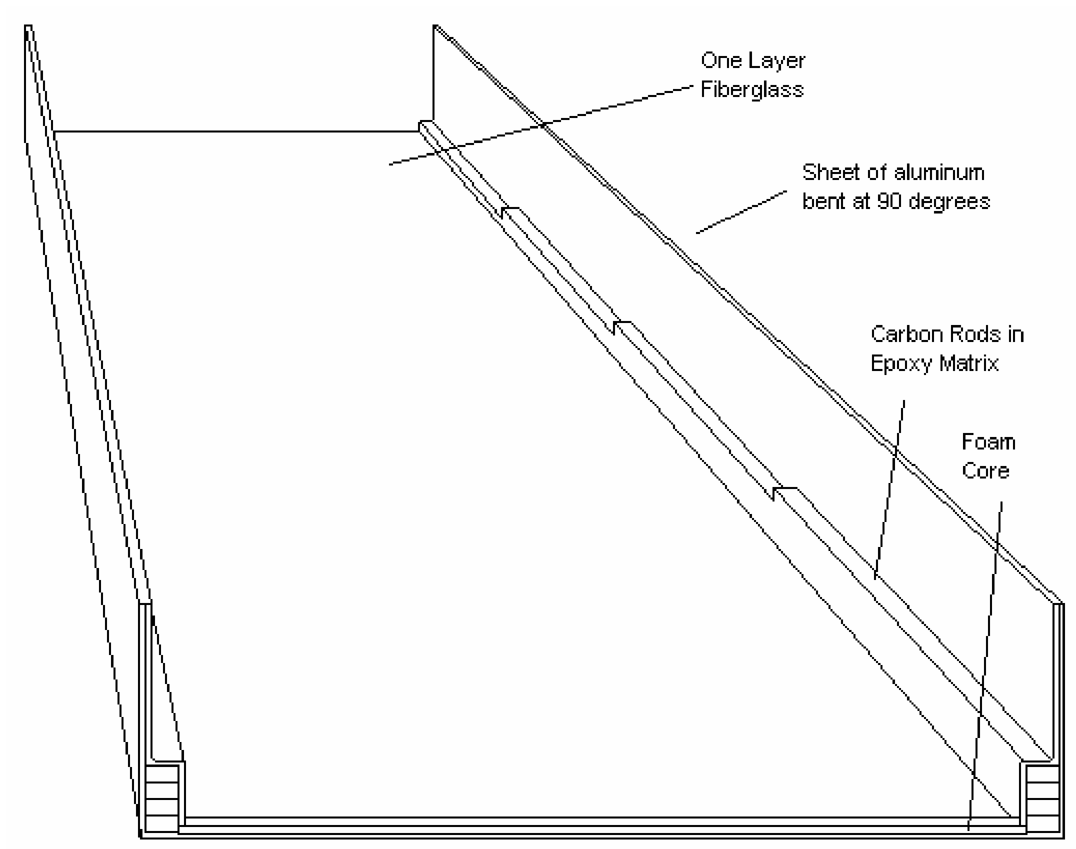

Figure 1: Spar construction

Spar: For the spar it was decided to use Graphlite Carbon Fiber Rods (http://www.aviasport.net) for the main structural strength. Construction of the spar is as follows; a piece of aluminum is laid down on a table and the top and bottom are bent up at 90 degrees. After waxing, a foam sheet will be placed in the bottom of the mold, the firsts rod will then be laid in the top and bottom corners, epoxy will be spread over the rod, then another shorter rod will be laid on top of the first rod. This process will continue until enough rods have been placed on top of each other for the appropriate strength. A layer of heavy glass will cover the rods and foam and complete half of the spar (see figure 1). Another half spar will be construed and then joined together. Spar construction is then complete (see figure 2).[1]

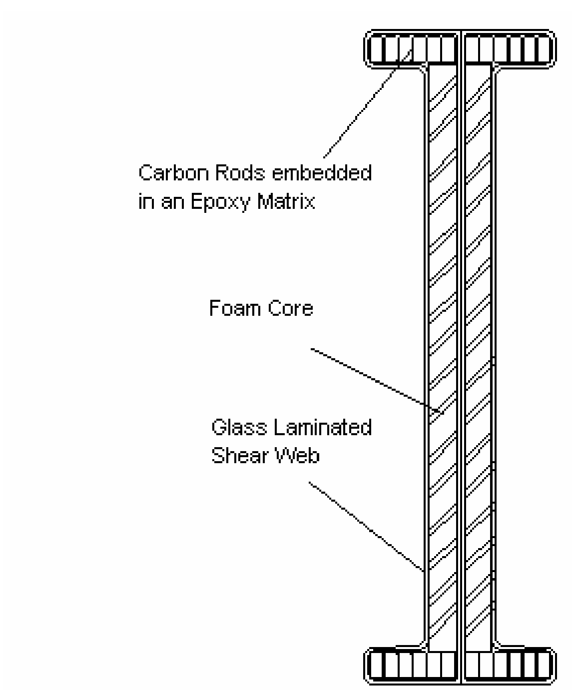

Figure 2: Completed Spar

Wing structure: For simplification in analysis the wing has a rectangular planform, with a constant thickness. The wing structure will contain the spar mentioned previously along with ribs spaced at regular intervals and a D-tube leading edge structure. The ribs will be made of the same material as the bulkheads, cut to the airfoil shape and hollowed out through the cross-section center. The D-tube will consist of 1/32 inch plywood reinforced with a small carbon tube at the leading edge. The D-tube will extend back to the spar on the upper and lower surfaces. The wing surface area will be a dope and fabric covering, similar to that used for the fuselage wetted area. Because of the slow operating speeds winglets would be very beneficial, and should be considered when a more detailed design is pursued.

Horizontal and Vertical stabilizers: The horizontal and vertical stabilizers will be constructed much like the wing, but will differ slightly. The structure will consist of ribs and stringers, covered by dope and fabric. A D-tube is not needed as long as the ribs are spaced more closely. For simplicity of manufacture, and with only minor performance penalties, a conventional tail design will be used as opposed to T-tail or V-tail alternatives.

Calculations

Air density and viscosity is said to remain constant so that

$\rho=2.377 \times 10^{-3}$ lbm/ft^3 and $\nu=1.57 \times 10^{-4}$ ft^2/s.

$$L_w = \text{Weight}$$

$$Re = (V*c)/\nu$$

$$q = ½*\rho*v^2$$

$$C_l = L_w/(q*S_w)$$

$$C_L = C_l$$

C_d is read off of airfoil data curve using Re and C_l

$$C_{di} = C_l^2/(\pi*e*AR)$$

$$Drag_{wing} = q*S*(C_d+C_{di})$$

$$Drag_{total} = Drag_{wing} + Drag_{Htail} + Drag_{Vtail} + Drag_{fuselage}$$

$$C_D = Drag_{total}/(q*S_w)$$

$$V_s = (2*W/(S*\rho))^{1/2} *C_D/C_L^{3/2}$$

Price Breakdown

Spar	\$200
Ribs/Bulkheads	\$300
Stringers	\$150
Fabric	\$200
Tail boom	\$500
Miscellaneous parts (instruments, controls, fasteners, etc.)	\$500
Total	\$1850

Weight Breakdown

Fuselage Structure	40 lbs
Wing	110 lbs
Tail boom	35 lbs
Vertical/Horizontal Tail	15 lbs
Miscellaneous	50 lbs
Total	250 lbs

Conclusion

The use of prefabricated components and simple construction techniques in this design allow for the creation of a lightweight and easy-to-build sailplane. The simplicity of the design will enable the class to easily construct the sailplane without using advanced fabrication methods and will be able to be completed by the incompetent, irresponsible, delinquent sailplane students within two years...or so...

Works Cited

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Reference

(1) Marske, J. (2000). *Graphlite Carbon Rod*. November 15, 2001, http://www.continuo.com/marske/carbon/carbon.htm