The design and manufacture of a remotely piloted aircraft

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Abstract: *The article is a compilation of data regarding the process of designing an UAV wing, generally speaking, and an iteration of the stress calculations made during the research. Therefore, we use the best materials and a design that fits the necessities and requirements of such an airplane. The purpose of the UAV is to have a precise goal, namely to be used by the authorities for the people. Example: flying at low height for the surveillance of a large forest fire or a highway, or even for collecting data regarding the air quality and the percentage of noxious particles in different urban and nonurban areas.*

Key Words: *UAV, wing, materials, composites, design, stress*

1. INTRODUCTION

Humanity has several unsolved issues so far. Many of these have occurred in the 19th century with the advent of the industrialization process.

Pollution is one of those disturbing issues. Due to the greenhouse effect and drought we witness more and more often the spontaneous fires that devastate large areas of forests, that precious “green gold” so vital to our planet. In this kind of situations the authorities dispatch teams of fire fighters, and often military support for the major forest fires, even helicopters/airplanes with specialists to monitor the wind direction and velocity to counter attack the expansion of fire.

Helicopters/airplanes are expensive, and pollutant. That takes us back to the premises that have been stated in the lines above.

A suggestion for this kind of critical situations is to use non-pollutant factors that have the same mission. And a better solution for the problem described is to use a remotely piloted aircraft. It can also be used for surveillance of highways and other high density populated areas.

Also it can be used to collect data on the percentage of noxious particles in the air at different heights. And these are only three non-pollutant ways to do the same thing, the difference being that earlier pollutant methods were used. The chosen constructive solution must satisfy the following criteria: geometrical simplicity, constructive simplicity, easy and fast assembly and dismantle, maximum load for the chosen dimensions. Also of great interest are the stability and good maneuverability in flight.

2. TECHNICAL DATA

A summary of the technical data is displayed in Table 1. Light and strong materials will be used for the project; the aircraft must be easy to assemble/dismantle and transport. The following values were chosen for the UAV: the empty weight of about 18 kg and the maximum weight of about 30kg. **Time in flight 40-45 minutes. Cruise speed**: 100miles/hour. Cruise height: 1500 meters, and a maximum height of 2000 meters.

Table 1 Technical data

Cargo	Digital Hi-Tech Device
Thrust (full thrust)	2x Hacker Brushless A-60 L
Dimensions:	
Span	3080 mm
Total length	2240 mm
Tail height	954 mm
Fuselage max height	370 mm
Wing area	1.109 m^2

The propulsion will be made by an electrical engine, a brushless motor.

A requirement of the project is the minimum total cost. The structure must be light and efficient.

This is a fundamental requirement for the mass production. The mass directly influences the structure, and also operability qualities and the performances required for the purposes first stated in this article.

The function of the missions established and the conditions in which the UAV must evolve are very important in determining the loads exerted on the elements, the requirements for stability and maneuverability, and also the safety level and endurance in time of the structure.

3. AIRPLANE CONFIGURATION

The wing has a classical structure with two spars positioned at 19% and 58% of chord made from polymer matrix composites reinforced with fiber glass of 1.2 mm.

Ribs and attach hinges of flaps are also made from the same material. The skin of the aircraft is from composite material (fiber glass of 1mm).

The fuselage for the prototype is made from fiber glass of 1 mm thickness having frames located at 100 mm distance one from another also made from fiber glass. In the sections of the wing attachment and the landing gear 2 metallic bulkheads made of sheet metal of 0.8mm will be inserted.

The rear fuselage is a truncated part made from fiber glass. In a second version some elements can be made of light and strong aluminum alloy (DurAl). A requirement of the project is that the weight of the structure doesn't overcome 11 kilograms. The power generated by an engine will be 2.75Hp~3HP.

One engine can carry a maximum of 25 kilograms. Each engine will be powered by 2 packs of 5 cells LiPo batteries (High C rating large capacity lithium polymer battery). Size: 200x51x35.5mm/ 7.87x2.01x1.40inches. Weight: 720g /25.4oz. Voltage: 18.5V 5S1P. Capacity: 5350mAh.

An interesting fact is that each engine will have a MasterSpin99Opto controller. The controllers are very important due to the fact that having 2 engines may create forces that could drive the aircraft into uncontrollable evolutions.

There will be 6 actuators: 2 for the flap, 2 for the ailerons, 1 for the rudder and 1 for the elevator. A DS 8922 BB/MG DIGITAL SERVO GRAUPNER controller will be installed for the actuators.

4. THE BALANCE OF THE AIRPLANE. MASS ESTIMATION

After approximating the weight of every component a balance approximation must be done. The calculus is made generally for two cases, these being the extreme cases correspondent to the minimum and maximum masses of the airplane. The mass of each component is estimated, and the mean aerodynamical chord is calculated. Afterwards the center of gravity of the airplane must be determined and the balance of the UAV is calculated.

There are several methods to do this, one of them being Reymer formulas, and a second variant being to use a percentage method often utilized in aviation.

For this project there three cases were considered: the case of the structure (the structure mass of the unequipped airplane must not overcome 11 kilograms, as previous stated), the equipped case (structure + equipments ≈ 18 kilograms) and the equipped case with main load. After the calculus was done the conclusion was that the center of gravity is at 28% of MAC (mean aerodynamical chord).

5. MANEUVER & GUST DIAGRAM

The maneuver diagram (Fig. 1) is made using the cruise height, which is of 1500 meters. There are several cases that have an important role in this diagram. First, the load factor correspondent to value n=1 represents the situation where Lift=Weight and at this point the airplane is capable of sustentation. The maximum load factor 4.25 corresponds to the maneuvers made at cruise speed. On an inverted evolution taking in account the dive case, the load factor doesn’t overcome max -2 for the negative value. The gust diagram (Fig. 2) uses the standard gust values. It can be easily observed that the maximum load factors are 3.5, and -1.6. The intersection of these two charts gives us the flight envelope (Fig. 3).

6. THE DISTRIBUTION OF LIFT FORCE ALONG THE WING SPAN (DIEDERICH METHOD)

Using the formula of the lift force distribution we can generate a diagram that displays the distribution along the wing span (Fig. 4).

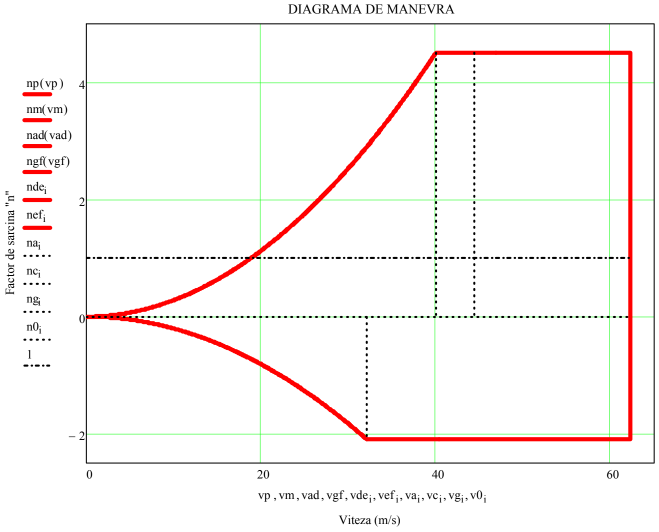

Fig. 1 Maneuver Diagram

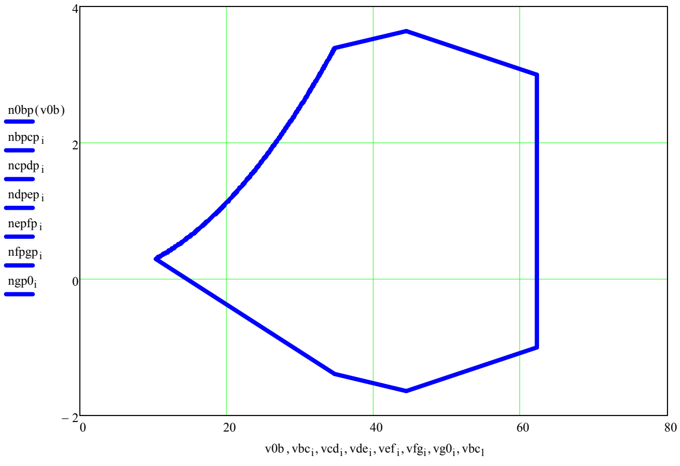

Fig. 2 Gust Diagram

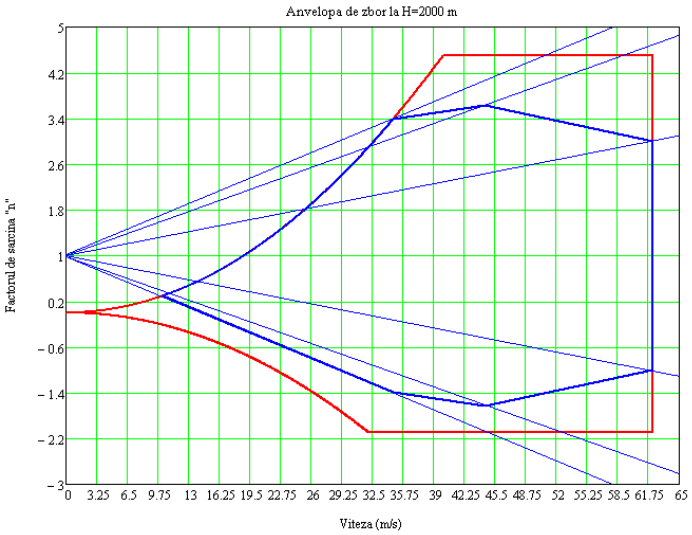

Fig. 3 Flight envelope at 1500 meters

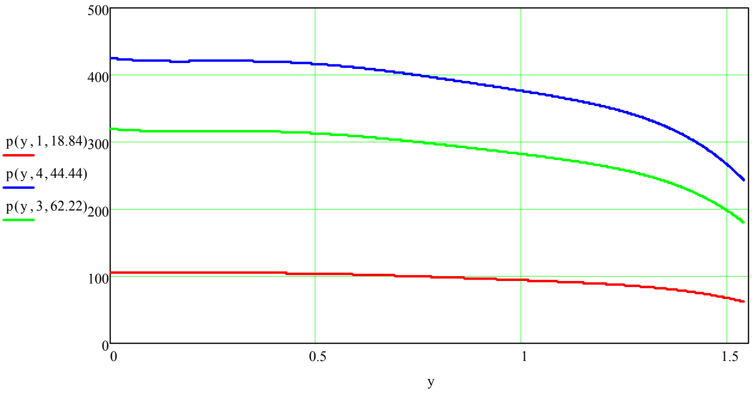

Fig. 4 The lift distribution along the wing (Diederich method)

7. MATERIALS. CHARACTERISTICS. DESIGN

The materials used are composites with polymer matrix reinforced with fiber glass. The matrix has the role to link the fibers in one solid structure, to protect it from external aggressive factors and to assure a series of physical-chemical qualities.

The fibers have the role of taking the mechanical loads that reflect in the structure, acting similar to a barrier in front of the dislocations that may occur.

The most common fibers are metallic, carbon fibers, glass fibers, Bohr fibers, ceramic fibers, or even mixed.

The polymer matrix is made of thermoplastic materials or thermosetting materials. From the first category there can be used polyethylene, polypropylene, ABS (acrylonitrile-butadienstiren), polycarbonates, polyamides, PTFE (polytetrafluoroethylene), and from the second category, epoxy resin.

The aluminum alloy density is 2.854E+3 Kg/m^3 and the Poisson Poisson's ratio is 0.3. For the Scotchply 1002 the density is 1.8 E+3 Kg/m^3, and the Poisson's ratio is 0.26. For the maximum stress it was considered s_{allow}=15daN/mm^2.

The airfoil used for the wing is NACA 4412. The spars are located at 19% and 58% of the chord (see Fig. 5).

The structure of the wing has 2 „I" profile spars and 5 ribs, one of them being placed in correspondence with the fairing of the engine, to assume the aerodynamical loads that occur.

To see if composites are a good solution for the project, a modal analysis has been made using the finite element analysis (code) ANSYS v11 [3].

The results, after the process of meshing (Fig. 7 and 8), had even for the first mode of vibration higher values that the maximum stress calculated by hand calculus. The first 9 vibration modes are displayed in Fig. 9-17.

The modal analysis describes the structure using its natural characteristics: damping, frequency and mode shapes.

It represents the dynamic properties of the structure. Modal data are very useful and assist the design of the structure.

The understanding and visualization of mode shapes is invaluable to the design process. It undoubtedly helps to identify areas of weakness in the structure or areas where the design must improve the geometry.

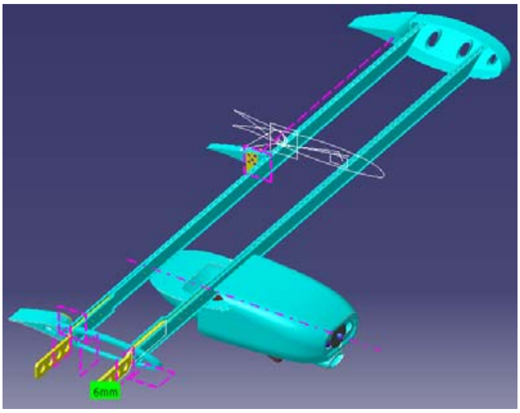

Fig. 5 Wing configuration with aileron functional sketch

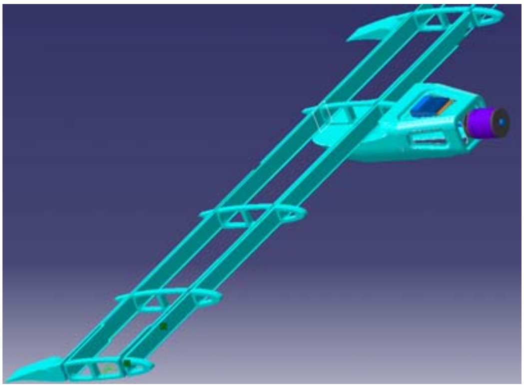

Fig. 6 Wing configuration with the ribs from the wing box

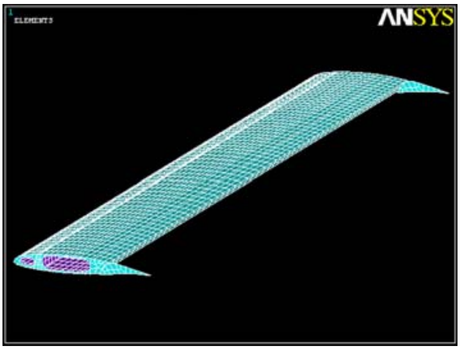

Fig. 7 Wing mesh

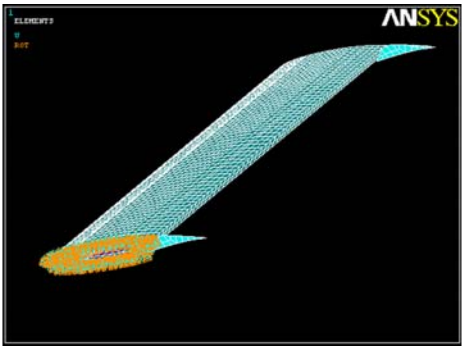

Fig. 8 Wing mesh with the assembly to the fuselaje points

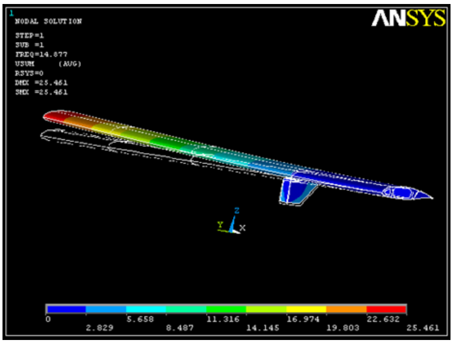

Fig. 9 1st vibration mode

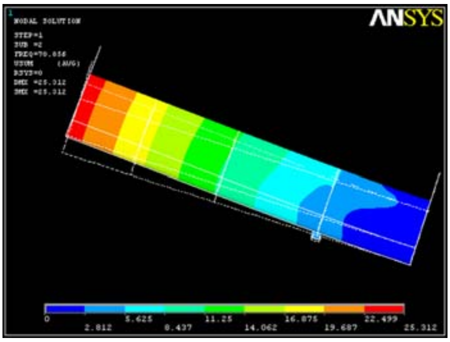

Fig. 10 2nd vibration mode

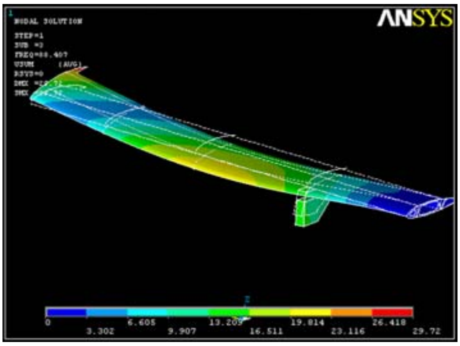

Fig. 11 3rd vibration mode

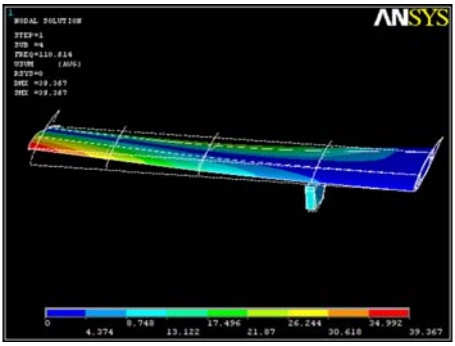

Fig. 12 4th vibration mode

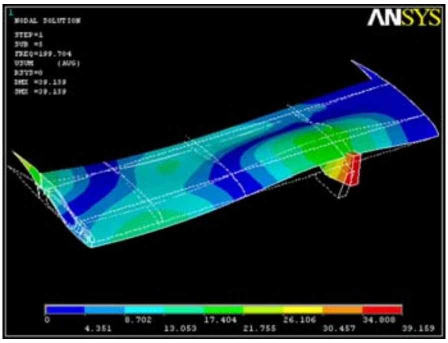

Fig. 13 5th vibration mode

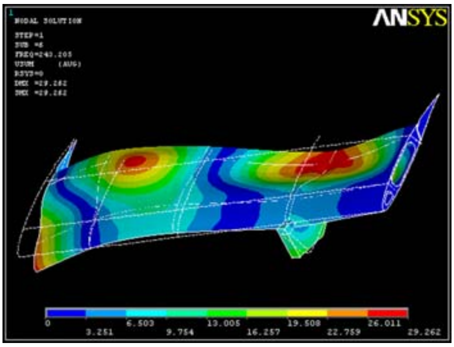

Fig. 14 6th vibration mode

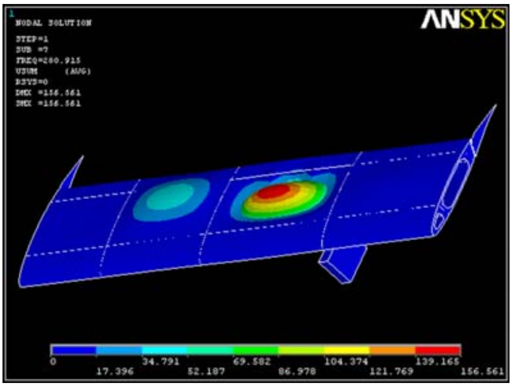

Fig. 15 7th vibration mode

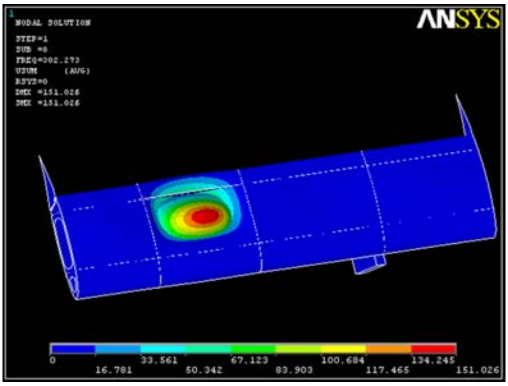

Fig. 16 8th vibration mode

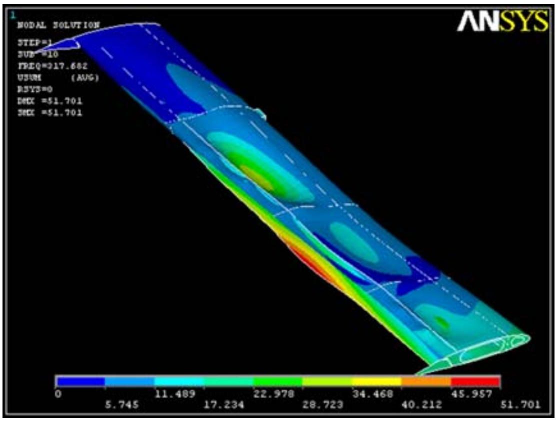

Fig. 17 9th vibration mode

8. CONCLUSIONS

We found materials more competitive then the classical materials (metallic), because their stress and stiffness properties could no longer be improved through other means. From this point of view it can be assimilated that the maximum efficiency of stiffening a certain material can be obtained by introducing in its structure reinforcement elements: fibers. QED: “that which was to be demonstrated”, composite materials have increased capacities and capabilities and are, undoubtedly, the most reliable materials of the moment for any type of projects.

9. REFERENCES

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