ASSIGNING NEW RESPONSIBILITIES FOR UNDERGRADUATE STUDENTS IN THE DESIGN PROCESS OF UAV PLATFORMS

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Abstract

Design and building of UAVs (for civil and military missions) is a field of actuation where the most important Universities, research Centers and Aeronautical designers have dedicated a lot of human effort. This paper describes a long research work carried out by a group of UPM professors who are currently coordinating the design and building of an Unmanned Aerial Vehicle (UAV) at the EUIT. Aeronáutica to synthesize the work done in the twelve years. We first focus with the validity of this experience as a means to develop some skills and to achieve some teaching competencies which will be essential for engineers in the 21st Century, according to the Bologna Process project Tuning. The second part presents the highlights of the project: all the features and stages of this engineering project, and the current moment of evolution in the process will be presented, together with a description of the main difficulties the project has undergone, as a global experience in engineering design and development.

Keywords: Preliminary design, unmanned air vehicles, student cooperative work, multidisciplinary skills, general competences.

1 INTRODUCTION

The experience of the authors is the area of design and construction of UAVs for civil applications and rapid prototyping and manufacturing for UAVs is presented. In the UAV design and manufacturing area, they have directed the activities of a group of students to in practice design and build an UAV; in that sense, the following articles can be looked up [1] y [2].

The concept “rapid prototyping” (quick prototype generation) has become usual in conceptual design processes and prototype design applied to engineering and other parts of the applied sciences. Our experience was presented in [3]. Other universities present similar experiences in activities of undergraduate students [4]. In the aerospace industry, also this concept of rapid prototyping has been used with relative importance. For instance [5] show the use of rapid prototyping in the manufacturing to generate airfoils to be tested in aerodynamic tunnel.

In the other hand, the results in the design of robust optimal controllers for UAVs is show in [6] and their utilization in the set up of mission design in the flight envelope of unmanned aerial vehicles [7].

In the development of this vehicles play an important role the real time acquisition and management of on board data. In this sense interesting reference to that applied to rotorcraft can be found in [8]. Other applications as those presented in [9] refer to micro-UAVs. In the paper presented by [10] is shown the solutions taken to integrate several sensors in small rotorcrafts.

Some computational toolboxes have been developed to simulate real time signals related with optimal flight path control. The results related with this concept are presented in [11]. A computational approach to generate real-time, optimal trajectories for a flight control experiment is presented. Trajectories are computed for hover-to-hover and forward flight maneuvers for both maneuvers and in the presence of obstacles. QoS (Quality of Service) techniques have also been applied to aircraft FMS (Flight Management System) with good results as is exposed in [12].

In other hand, is important to take into account some classical references for preliminary aircraft design: [13], [14].

2 A REVIEW OF UAV DESIGN STAGES

2.1 Preliminary sizing and initial layout

The aim of the project is to design an UAV for civil aerial observation. Once its mission has been defined, a wide research analysis of similar airplanes is carried out since, in the initial stage of the project, it is quite common to resort to similar airplanes for estimating some important data of our design. Next, the preliminary sizing is undertaken, taking as a basis weight and wing loading estimations.

First, a group of graphic representations of several airplanes sharing common characteristics (thrust – weight, payload-weight) will be developed. In the pre-design stage we will point out two main parameters: weight estimation and wing loading estimation.

We concluded that the preliminary values for weights will be: W_{PL} = 8 Kg, W_{MTOW} = 30 Kg , W_E = 13Kg , W_F = 9 Kg.

Before calculating the wing area, and, therefore, being able to establish our prototype's wingspan, we needed to calculate the wing loading. This value is conditioned to the corresponding phase of flight we are going through; as a consequence, we had to determine the wing loading for each of the possible situations.

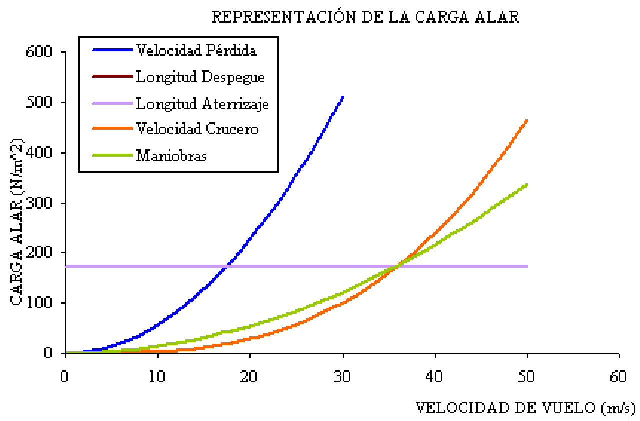

Fig. 1. Wing loading vs speed. Different phases of flight

This figure shows the wing loading variation, for each of the conditions which have been studied. These were considered as final numerical values with respect to estimation of the wing area. In the same way we can see the region of the wing area which verifies all different conditions and the final estimated wing loading numerical value in that region.

Once all the preliminary sizing data had been determined, the following stage of the project was deciding the aircraft's layout.

Making a decision on the type of fuselage to be used was one of the first objectives of this stage. Figure 2 shows the draft of the initial plan view and the profile of the initial configuration of our design.

Fig. 2. Plan view and plotting draft

2.2 Aerodynamic analysis and static load tests

The following stage in the project, after determining the preliminary configuration, was calculating all aerodynamic features and the aircraft's performance so that they could later be checked and recalculated.

To complete all these steps, a sound analysis of the most important elements of the aircraft had to be done, from the geometric and the aerodynamic points of view.

As an example of the results we obtained, in fig 4, we offer the graphic illustration of the wind tunnel results, and the computational ones.

We concentrated on testing aerodynamic forces using our wind tunnel. The next figure presents the model used in wind tunnel testing of the whole aircraft.

Fig. 3. Wind tunnel tests model

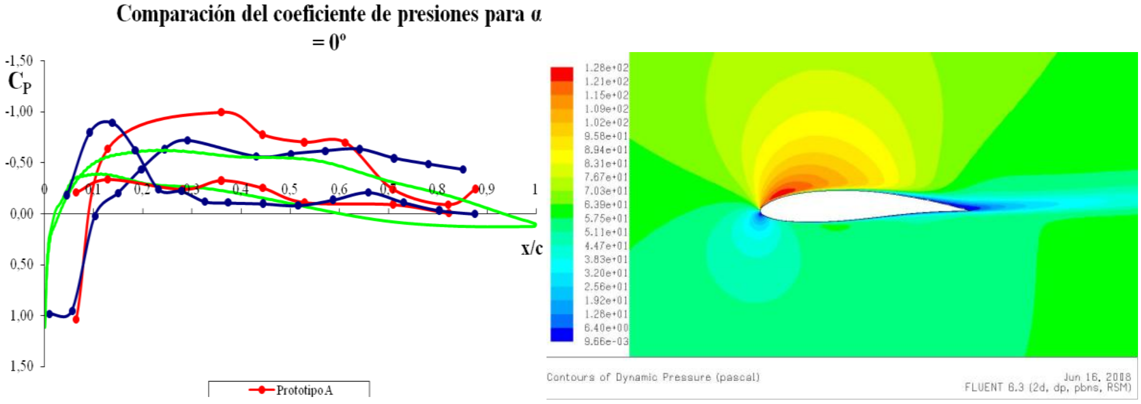

Fig. 4. Comparison between wind tunnel results and computational ones. Pressure distribution

Once the study of the airplane from the aerodynamic point of view was completed, we had to carry out a basic structural study. Before constructing the final prototype and as an essential part of the whole project, we carried out a series of test at our workshop. We also checked the most critical structural elements by means of static load tests.

The following photo shows one stage of the static loading test. In this stage, we load the primary longeron of the wing until its collapses.

Fig. 5. Loading tests until crash

2.3 Rapid Prototyping Equipment

Within the framework of the UAV design project, described in the previous chapter, it was addressed the design of a rapid prototype generation process for design and building some important elements of the UAV.

Some covers and aircraft fairings are designed like surfaces whose geometry is quite difficult to build by other methods, besides the obvious advantage of speed and versatility of assembly.

Rapid prototyping is a technology that enables to produce models and prototypes directly from 3D solid model generated in the CAD system.

Unlike manufacturing processes that remove material from the original part to obtain the desired model, rapid prototyping systems produce the piece from the additive union of liquid, layer by layer, starting from cross sections of the piece obtained from the 3D model. Rapid prototyping machines (printers) produce pieces in plastic, wood, ceramics or metals.

Data for Rapid Prototyping machines are generated by the STL format CAD systems, which approximates the solid model by small triangles or facets. Once the STL file is generated, other operations are executed by the program that accompanies the rapid prototyping machines. CATIA© is the tool CAD / CAM / CAE chosen by the majority of multinational engineering-related.

Advantages:

- It is a communication tool that prevents different interpretations and/or erroneous reading of the conceptual design or assembly.
- Allows certain functional, assembly and interference testing.
- Facilitates the provision of improvements, either in the design and functionality, or in the building process.
- The techniques of rapid prototyping can be applied to many areas such as automotive, aviation, architecture, education, …

2.3.1 Preliminary design

As an example of this, one of the elements manufactured using this technique is shown below: the UAV's tail-boom fairing.

Once both the forward and aft part of the tail-boom fairing have been designed, it is the moment to join them. Tangential conditions between the forward and aft zones have to be kept so that transition is as smooth as possible, hence avoiding wind boundary layer separation while flow moves over the fairing. Fig. 6, shows the area resulting of joining the forward and aft parts of the fairing.

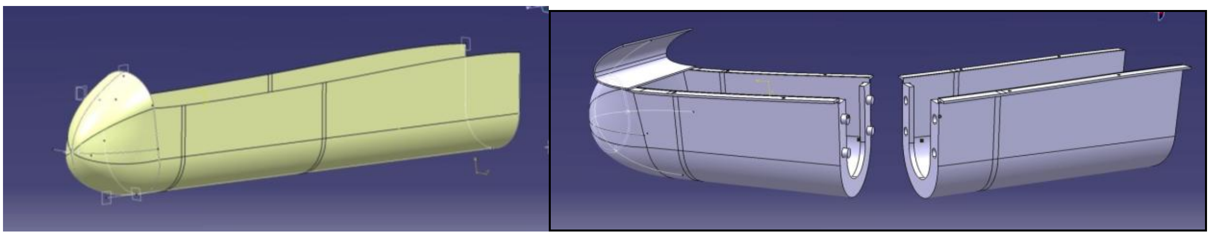

Fig. 6. Preliminary design and two parts final assembly

2.4 Building the airplane

After we concluded the stage corresponding to the preliminary essential calculations we moved forward to the detailed designed and manufacturing stages. A global designed was developed and we had to define materials, joining elements and fasteners, the most important of which are shown here.

We also include some comparisons between initial design of the most important elements of the aircraft and the final manufactured ones.

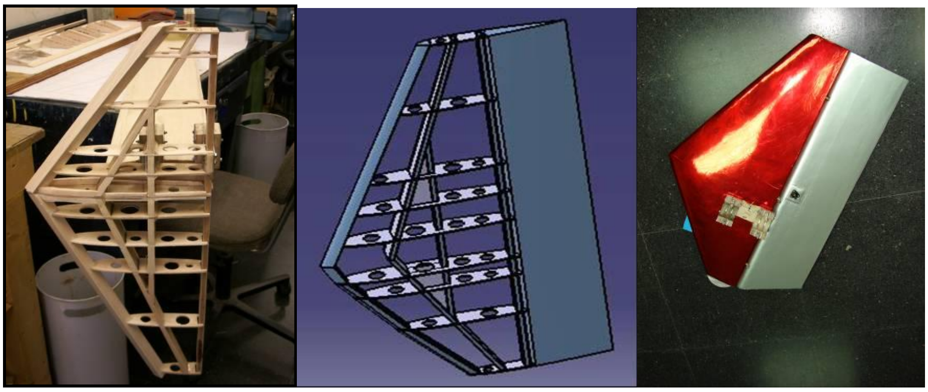

Fig. 7. Comparison between design and final mounting. Fin

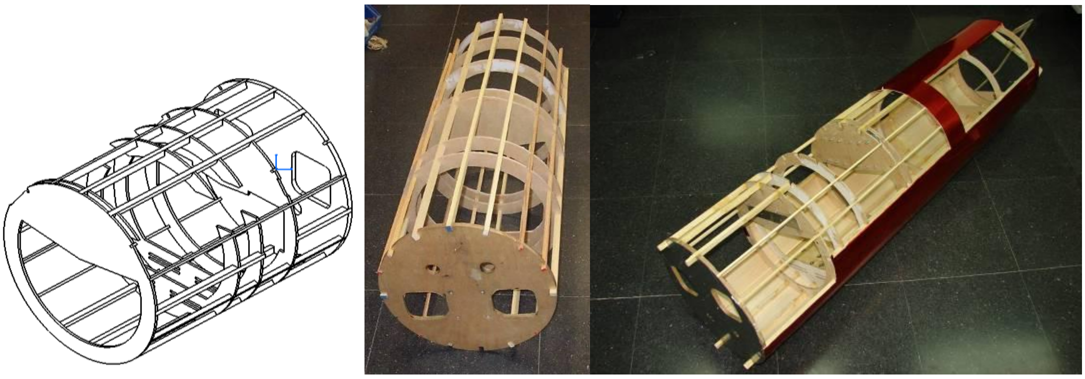

Fig. 8. Structural design of the fuselage

Fig. 9. Final result

2.5 Real Time Data Acquisition

One of the challenges of this Project was based on the data acquisition of the UAV on board sensors. On board data are given by on board sensors, mainly related with the following parameters:

- Power plant temperatures.
- Engine speed.
- External temperature.
- Static and total pressure.
- Level of fuel.
- Stall sensor.
- Data acquisition system temperature.

In the developing phase, LabVIEW© software together with a data acquisition system were used to simulate the whole sensor reading and to perform the mathematical process related with each one. The aim is to perform a real time data acquisition on board as a preliminary phase for the developing of a flight automatic system.

The hardware used is based on the CompactRIO© (National Instruments) platform. This hardware and the LabVIEW© software, form the rig to perform ground tests. This test platform is set up in the Aerodynamics Laboratory of the EUIT Aeronáutica of the Universidad Politécnica de Madrid (UPM). In this laboratory were developed the test instrumentation and were perform the UAV on board sensor simulations.

3 THE ROLE OF THE UNDERGRADUATE STUDENTS

When we first thought of designing and building an UAV at the EUITA, in the last years of the previous century, our aim was basically the achievement of some engineering objectives. Acquiring the technological knowledge in this field, proposing some modest innovations for processes and procedures, applying our knowledge into a wholly aeronautical project, developing our own design of the cell and creating the software for managing its flight were some of them.

We conceived the Project to be developed totally by final year students, so that each of their End of Degree Projectworks would constitute a part of the general Project. From this, it logically followed that, once the initial stages were started, it was clear that the project offered another research perspective besides the one originally proposed. This was related to the development of the skills and competences that the students needed to acquire if they were to carry out the Project successfully. The following were considered the most relevant ones:

- Ability for teamwork
- Manual skills for building and assembling
- Ability for coordinating and leadership
- Capacity for communicating ideas and proposals
- Capacity for the interpretation of drafts and schematics
- Quite an important knowledge of other disciplines such as electrical plants and electronics
- Competence in the process for selecting the materials in accordance to their…
- Establishing the technical requirements for a system

The objectives for this new research perspective had to be decided on, as well as the most suitable way to assess the acquisition of the generic competences.

Some of them are precisely related to those a student of engineering has to develop in the process of carrying out his/her End of Degree Projectwork.

It has already been stated that initial aim of our Project was the design and building of an UAV, as a pure engineering task. However the evolution of the students' involvement into the project along these years has led us to a point where, while being still important, the initial aim is not more important than the development of the learning environment, quite suitable for the acquisition of generic competences, which has arisen.

4 EVALUATING THESE NEW RESPONSABILITIES

The development of the project has required continuous monitoring on the part of the faculty, analysing the results obtained and presenting the students with several alternative solutions to each problem.

We must also admit that not all projects have been successful and occasionally, after great efforts were made on the development of several solutions which did not achieve the results expected and were never used.

The End of Degre Projectwork has traditionally been considered as a very valuable teaching instrument. It allows the development of an integrative process where students have to apply all the knowledge they have acquired along their course. The development of our project has shown that it can also be used for the acquisition and assessment of generic competences which otherwise would be difficult to acquire and evaluate in an engineering course.

The students, who will be starting their professional career three or four months after completing their End of Degree Projectwork, will bring to their first job not only a high level of engineering knowledge but some experience in the application of general competences.

The students are quite conscious of how important these competences are for the development of their careers, they value very positively the opportunity they have been given to develop them. They are particularly concerned about the following: planning and time management, problem solving, teamwork, ability to work in an interdisciplinary team, concern for quality, oral and written communication in his/her mother tongue, decision-making, critical and self-critical abilities, interpersonal skills and environmental concern.

Of all these the last is the only one not mentioned in the Tuning Project's [15] list of generic competences.

Nothing would have been done without the enthusiasm and the dedication of all the students who have taken part in the project.

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