TEACHING UNDERGRADUATE STUDENTS AEROSPACE STRUCTURAL ANALYSIS BY ANALYZING, REDESIGNING AND BUILDING A KIT AIRCRAFT

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ABSTRACT
Traditionally, many Aerospace undergraduate students complete their degrees without really having the opportunity to get a close look at many of the structural components let alone the chance to design or build them. A new approach is explored whereby students are given design drawings of a real light aircraft which is usually available in the market as a kit aircraft. The students are then required to verify the design in terms of its structural ability to carry anticipated external loads while keeping structural integrity. Then they are required to re-design metal components using the currently popular composite materials. Finally, the students build some of their components out of metals and others out of composite materials to be physically tested and the results verified against their stress hand calculations and Finite Element Analysis (FEA). The students are eventually given the chance to take up the task of completing and flying the aircraft as a final year team project. The benefit of using kit aircraft is found to be in the ability to work with real aircraft design drawings, the availability of complimentary aids such as construction photos and videos as well the simplicity of building such an aircraft. An inspiration to the students is also drawn from the fact that they know they are working on an aircraft that could eventually make it to the skies. In this work, a light sport utility aircraft named CH750 which is designed by Zenith Aircraft Company is demonstrated as a typical example that gave students hands-on experience on aircraft structural design, analysis, manufacturing and testing.

Keywords: aircraft structural analysis, kit aircraft, aerospace education, finite element analysis, composite materials, aerospace design.

1. INTRODUCTION

Aerospace design is a rapidly progressing industry especially with the development of new computational tools for design and analysis of Aerospace Structures. Consequently, Aerospace Engineering students must possess new abilities and skills to be ready for this challenging environment [1]. One important area of aircraft design and manufacturing is structural analysis. The latter can be the most practical part of an undergraduate course if it included hands-on experimental activities. However, most Aerospace courses concentrate on Conceptual Design, specifically, Aircraft Sizing [2]. Grasping the theoretical part of aircraft structural analysis can be a daunting task given the variety of available text books and analysis methods. It is therefore appealing to include more experimental activities in the course curriculum which helps the students improve their analytical skills while comparing to numerical analysis. Some universities have started to recognize experimental weaknesses in graduated students and have opted for building and flying aircraft as part of students' courses [3]. However, the latter researchers and educators suffered the intensity of the work required due to time and cost factors. Other universities took different approaches whereby they sought collaboration with other universities (sometimes from different countries) and industries to design and build a marketable airplane [4]. However, their effort was a feasibility study to produce a low cost trainer aircraft at the expense of free students' labor.

For the execution of this work by King Abdulaziz University Aeronautical Engineering Department, students are exposed to the idea of working with a kit aircraft at earlier courses in their Bachelor degree program. In this way high motivation is guaranteed at an earlier stage in the overall Bachelor course. Then, gradually and lightly, tasks on the kit aircraft are introduced to students in the form of 3D modeling, stress calculation, building and testing of certain components. This exercise is also intended to encourage students to enterprise and enter the field of production while keeping a realistic relationship between cost, time and quality. This is partly achieved through treating the work as a real work project where a project manager is chosen, tasks are divided amongst sub-teams, and meetings with agendas are carried out as well as issues such as cost keeping and so on.

2. THE KIT AIRCRAFT

The studied kit aircraft shown in figures 1 and 2 is the CH750 which is a two-seat sport aircraft designed by Chris Heintz and produced by Zenith Aircraft Company [5].

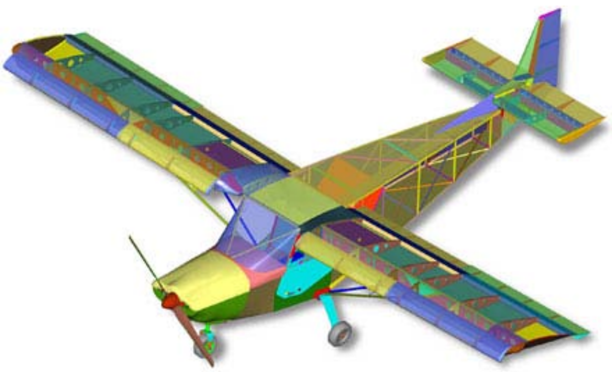

Figure 1 CAD drawing view of the CH750

Figure 2 Side view of CH750 airframe

The aircraft was developed for amateur builders and pilots. Two of its advantages are its ability to land in any reasonable terrain and it being a short take off and landing (STOL) aircraft.

In order to minimize required skills, Zenith Aircraft supplies parts pre-formed and ready for assembly as shown in figure 3.

Figure 3 wing components as supplied by Zenith Aircraft

However, for KAU Aeronautical Engineering students, the task is to build the components from the design drawings after having done the necessary 3D drawings from supplied blueprints. Then, stress checks and any necessary alterations to the original design are carried out. Furthermore, students can still purchase specialized components from the company if they opted for completing the project. Those components were the engine, propeller, controls and avionics.

3. TYPICAL STUDENTS TASKS

Having acquired the original drawings from the company, it was possible to delegate various tasks to the students which were mainly as follows:

3.1 3D Drawings

Students are given the chance to draw real aircraft components from 2D drawings as shown in figure 4. That way, they will refresh their drawings skills and acquire experience using various CAD software programs.

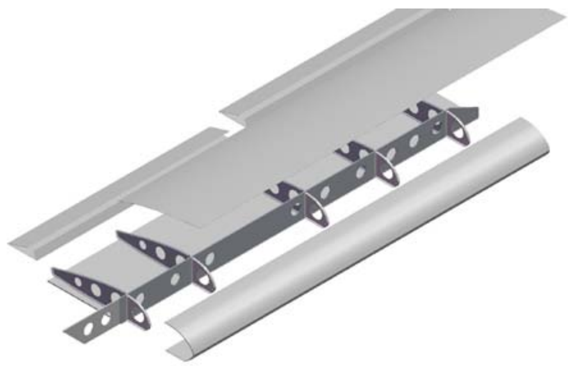

Figure 4 Wing components of CH750 drawn by KAU students

The CAD drawings are one the driving forces as far as the students are concerned. Being able to visualize the components give them great self-belief especially since this task does not require any mathematical calculations!

3.2 Finite Element Analysis

Having had the opportunity to master some CAD skills, students exported their drawings to FEA software to determine the stresses on the components. Given the known geometry, weights, CG and other details of the aircraft, it was possible to determine the anticipated loads. Also, the materials used was known (Al All T6160-T6) and hence its properties. Figure 5 below shows the CH750 fuselage truss-like structure being supported and loaded at specific points in preparation for FEA.

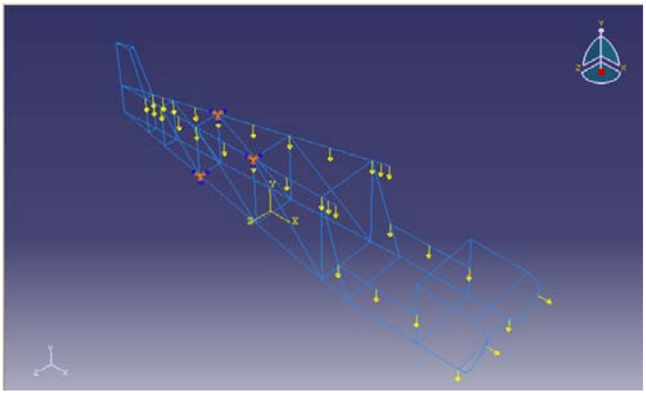

Figure 5 FEA model preparation of CH750 fuselage structure

The results of the numerical stress analysis are shown in figure 6 where determined values are compared to material strength and stiffness properties. It should be noted here that students were also investigating the structure under various flight regimes such as on the ground and in flight.

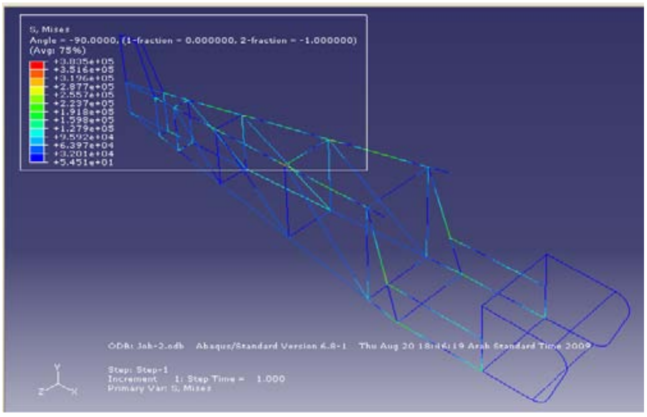

Figure 6 Stresses generated on CH750 fuselage structure under loading

3.2 Hand Calculations

An L-shape sub-component was chosen to be used for teaching students beam bending theory. In figure 7 the beam is being shown as a cantilever beam with a point load before its free end.

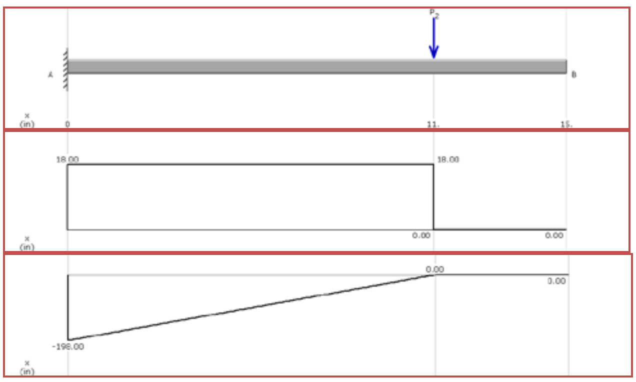

Figure 7 Beam analysis- shear force and bending moment diagram

As shown in figure 7, the students were asked to determine the shear force diagram and bending moment diagram. The latter was a task that required simple hand calculations using equations of static equilibrium to determine reactions at beam supports.

3.3 Manufacturing Metal and composite Parts

This task is one of the highlights of this work. Given that these Aerospace Engineers are at an earlier stage of their career, it was important for them to use their hands to build aircraft components. An example is shown in figure 8 where the students were able to manufacture a CH750 wing from flat sheets of aluminum using simple hand tools in the workshop. One important part of manufacturing aircraft is sheet metal working which was highlighted to students while carrying out this task.

Figure 8 Students-built wing rib (nose &tail sections)

Since composite materials are these days the material choice of Aircraft Engineers, it was important to give the students the opportunity to know about these materials. The students, having decided on the part of their choice from the CH750, were exposed to the method of vacuum bagging to manufacture carbon fiber reinforced composite components as shown in figure 9.

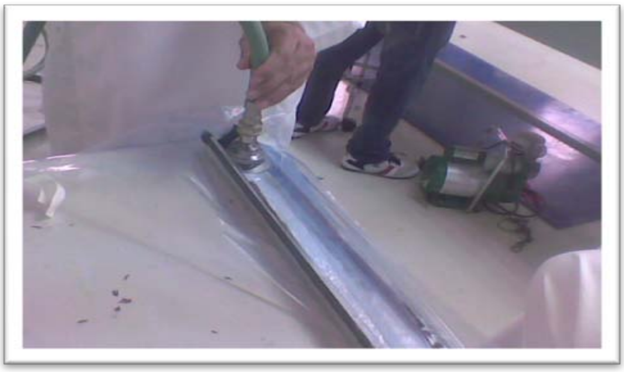

Figure 9 L-section composite beam manufactured by students using vacuum bagging

In the example shown in figures 9 and 10, students were able to manufacture the L-shaped beam studied earlier using woven carbon fiber plies stack at a specific sequence combined with epoxy resin and cured under resin-manufacturer recommended settings (in the form of cure temperature and time).

Figure 10 L-section composite beam after curing

3.4 Laboratory Testing

An experiment was setup where the composite L-shaped beam was fixed using bolts to a wall support as shown in figure 11. Then, a dial gage was fixed at a student-chosen location along the beam length while a point load was being added in increments near the free end of the beam.

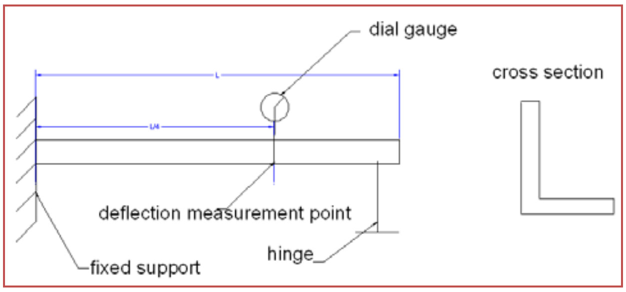

Figure 11 Cantilever Beam Deflection test setup of manufactured composite beam

Experimental results in the form of applied point load versus deflection readings at the dial gauge was summarized in figure 12. These results can then be compared to theoretical as well as numerical calculations that the students learn in class.

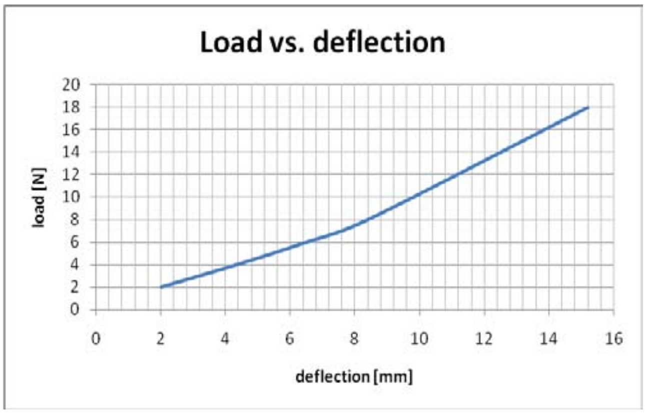

Figure 12 experimental results of beam deflection test

3.5 Redesigning Components

Going back to composite materials and as mentioned earlier about them being appealing to Aircraft Engineers, an advanced task was delegated to students where a chosen CH750 part (in this case the component is plate at the end of the fuselage/rudder region) was chosen to be redesigned using composite materials. Initially, students are taught in class about the various types of composite material, fibers, resin systems and manufacturing methods. Students are also shown how to choose a number of plies for a specific component and how to orient the direction of fibers according to the load intensity and the loads directions (a feature that makes composite materials very popular). With this background in their minds, students were able to model the part using Abaqus® FEA software package as shown in figure 13. For this plate the design was carried out using woven carbon fiber composite material that had know properties and was available in the department's composite lab.

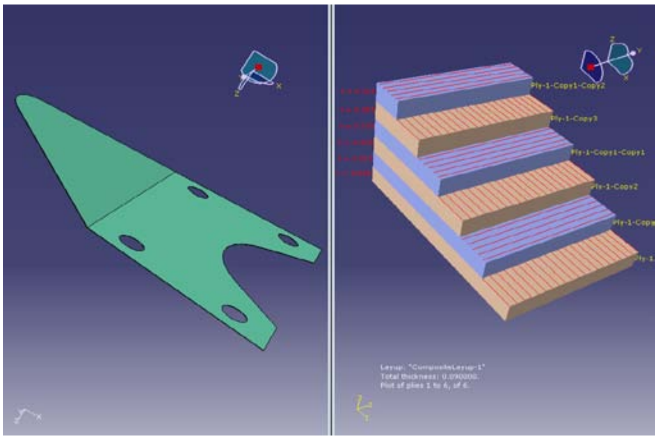

Figure 13 FEA of a CH750 component designed using composite materials

The FEA model results shown in figure 14 can then be studied to determine the justification of using composite materials in term of cost saving and strength properties.

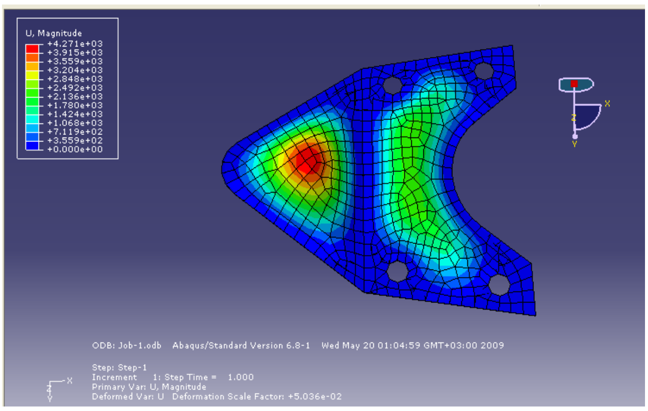

Figure 14 Results of FEA of the component after being subjected to bending loading

The students also will realize that FEA is obviously a time saving way of analyzing the part under anticipated load before embarking on costly manufacturing tasks in the case of an industrial company.

4. CONCLUSION

It has been demonstrated here that using an affordable kit aircraft to teach students aircraft engineering can be considered more of a novel idea. The students are exposed to so much aircraft engineering skills that it would have been impossible to do so by relying on lectures and tutorials only. Also, being able to acquire the aircraft engineering drawings enabled the tasks to be simplified while being challenging on the same time. It was obviously going to be hard if students had to do conceptual design from scratch, a task that would have been less exciting due to time the required. It is also worthy to note here that this idea of a kit aircraft study for Aerospace structural engineering was so much appealing that some students requested to take the task even further by redesigning the aircraft (to gain some engineering credit!) as well as build it, certify it and fly it as a capstone project. In addition, future students have the chance to work with other designs provided by the company and the department is in a great position to build a knowledge-base on manufacturing aircraft components. The latter gained expertise would eventually make conceptual design merge smoothly with building and testing exercises leading to complete design and build students projects which would give the students an extra advantage when going to industry for employment.

5. REFERENCES

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