Teaching Aircraft Design With Flyable Prototype

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Abstract: Aircraft design, a final year subject, integrates knowledge in aerodynamics, structure, stability and control, propulsion system and performance of an aircraft. In many universities, students will produce a conceptual design based on a Request for Proposal document. As a university that adopts Outcome-Based Education (OBE) concept, students in Universiti Teknologi Malaysia (UTM) are not only expected to apply knowledge to solve design problems but also skillful and able to work as a team. Using Problem-Based Learning technique, students taking the Aircraft Design subject are taught design technique and skills to build a flyable prototype. The challenges faced by instructor are ensuring the originality of the design and prototype is completed within budget and dateline.

Keywords: Aircraft design, Problem-Based Learning, flyable prototype

1. INTRODUCTION

Designing an aircraft involves a number of areas of aeronautical engineering such as aerodynamics, propulsion, lightweight structures and control. Each of these areas involves parameters that govern the size, shape, weight and performance of an aircraft. Since there are many parameters involved, the goal is to balance the different aspect of the total performance while trying to optimize a few based on a well defined mission requirement [1].

Due to the complexity of this course, syllabus for aircraft design in many universities is limited to conceptual design. The students form design groups and work on an aircraft concept design study according to the technical specification of a new proposed aircraft [2 – 6].

2. TEACHING AND ASSESSING AIRCRAFT DESIGN COURSE AT UTM

The Malaysian Qualification Agency requires that all programs conducted by higher education providers to follow the Outcome-Based Education (OBE). Under OBE, graduates must be equipped with knowledge of discipline areas; problem solving and scientific skills; practical skills; social skills and responsibilities; value, attitude and professionalism; communication, leadership and team skills; information management and lifelong learning skills; and managerial and entrepreneurial skills [7].

Aircraft design is a course taken by final year students of Diploma in Mechanical Engineering (Aeronautics) programme. Prior to the Year 2004, the aim of the course is to provide the students with the knowledge in aircraft design processes. Since 2004, generic skill such as problem solving, decision-making communication; and practical skills to produce a prototype are added to the course objectives [8].

Problem-Based Learning (PBL) is used as the teaching methodology for the course. This is because PBL can be designed to fulfill not only the content requirements, but also the generic skills required under OBE. In PBL, learning is initiated through a realistic problem that has engaged the learner to find a solution [9].

A total of 14 weeks with an equivalent of 120 hours student learning time are allocated to conduct the course. As shown in Figure 1, the design process is divided into three phases, which are the conceptual phase, the analysis phase and finally the prototyping phase. In each step, a brief lecture on the subject matters is given by instructor, which is followed by in class discussion and group discussion. Students are also expected to independently collect all information required for the design process.

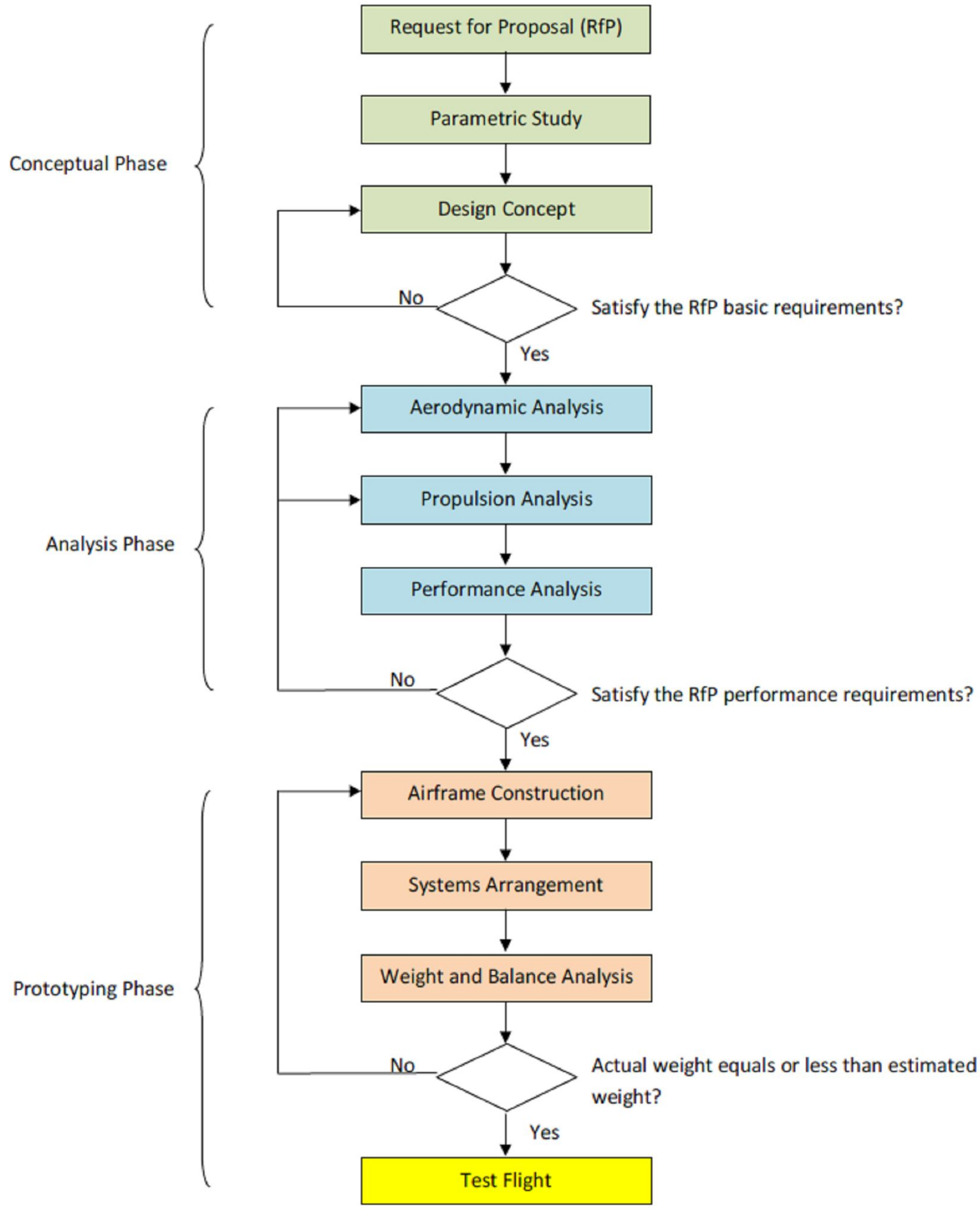

Figure 1: Aircraft Design Process

2.1 Conceptual Phase

At the beginning of the course, instructor proposes an aircraft design project. All required parameters and expected performance of the new proposed aircraft are given in Request for Proposal document. Based on the document, students conduct parametric study on similar aircraft. Data collected from the study are analyzed to determine relationships between the design parameters. Figure 2 is an example of parametric relationships gained from the study.

Based on these parameters, students proposed a few design concepts. During this phase, basic questions of configuration arrangement, size and weight are answered [10]. The concept that satisfy all the requirements set in Request for Proposal document with the best aesthetic value is selected.

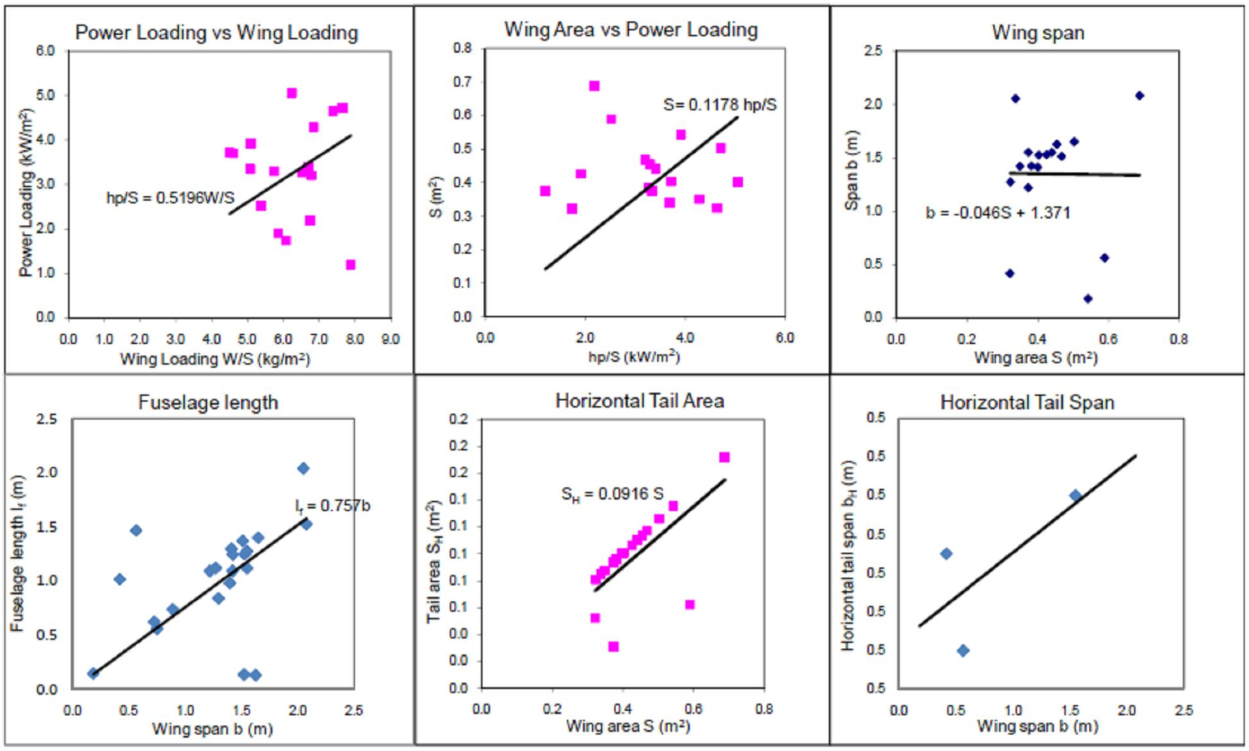

Figure 2: Graphs Generated During Parametric Study of a Small Unmanned Aerial Vehicle.

2.2 Analysis Phase

Once the final conceptual design is finalized, the analysis phase commences. In aerodynamics analysis, airfoil type, wing size and shape, and total drag of the aircraft are determined. In propulsion analysis, suitable propulsive system for the design is selected based on the aircraft thrust requirement. Finally, the performance of the aircraft is analyzed and results are compared with the requirements stated in the Request for Proposal document. These analyses are repeated until an optimum result is reached. Aircraft design software is used during this phase to ease the process.

2.3 Prototyping Phase

Based on the final parameters determined in the analysis phase, the aircraft airframe is constructed. Material for the airframe is selected based on wing load, its availability, strength-to-weight ratio and construction method. Propulsive system, flight control system and landing gear are installed to the airframe. During installation, careful arrangement of these systems is necessary to ensure that the aircraft is always balanced. Finally, the weight of the prototype is compared with the initial estimated weight of the aircraft. Lighter weight will increase the aircraft performance.

The university aeronautics laboratory and workshops provide spaces and facilities for the prototype construction. Lab technicians are always available to assist the students through out the prototyping phase.

2.4 Assessment Method

The students are evaluated by oral presentations, progress reports, final report and prototype flight test. Marks distribution for the assessment is shown in Table 1.

Table 1: Assessment Method and Marks Distribution

No.	Assessment	Number	% Each	% Total
1	Progress Report	3	10	30
2	Oral Presentation	2	5	10
3	Flight Test	1	40	40
4	Final Report	1	20	20
Overall Total				100

The progress reports are evaluated at the end of each design phases. Any group that fails to achieve minimum mark is not allowed to proceed to the next design phase.

In flight test assessment, the prototype is evaluated based on aesthetic value, ability to fly and its controllability. An eye-catching aircraft that easy to fly is the ultimate objective of the project. As most of the student did not have any experience flying an aircraft, the flight test is handled by a professional remote control flyer.

3 CHALLENGES

Due to the complexity of aircraft design process both the instructor and the students face these challenges.

3.1 Simplicity of the Design Project

To ensure that the course completes within 14 weeks, the design project has to be simplified without jeopardizing the design process. Thus, the design project is limited to:

a. Remotely controlled aircraft.
b. Single engine.
c. Electric motor or nitro-fuel engine.
d. Weights less than 1.5 kg.
e. Short range and endurance.

3.2 Knowledge in Producing Prototype

Prototyping is the process of developing such an approximation of the product [11]. Turning drawing into functional prototype requires practical skills. Both instructor and lab technicians must be trained to acquire necessary skills prior to teaching the course.

3.3 Time and Budget Constraint

Instructor must constantly monitor progress of the design process. Some group might be too ambitious in their design, which might not be relevant with the level of difficulty, cost and time frame. Instructor must to bring them back on the right track or their project will not finish with the given time and budget. Groups that progress slowly must be guided so that their projects complete on time.

3.4 Availability of Material and Components

Students must consider the availability and cost of material and components for their design. Some materials and components are expensive, restricted, or takes a long time to obtain. Students' creativity to improvise locally available materials and components are encouraged.

3.5 Authenticity of the Design

During the parametric study, students are exposed to many designs of similar aircraft. Thus the tendency to copy these design may occur. In additional, some design blueprints are available in the internet. To prevent imitation, instructor must be well informed with aircraft design.

4 DESIGN RESULTS

4.1 Design Project

Every year, a new type of aircraft specifications is given the Request for Proposal. The aircraft the students have to design varies from a remote control trainer airplane to lighter-than-air aircraft. Figure 3 shows some of the designed aircraft.

Figure 3: Some of the Designed Aircraft

Material selected for the airframe has changed from expensive balsawood to cheap and readily available polystyrene foam. Some group opted for corrugated plastic sheet which not only cheap, but also very strong. Unfortunately, this type of plastic is difficult to shape.

4.2 Student Marks

Median marks of the course under the authors' supervision are plotted in Figure 3. Prior to the introduction of prototyping; the students' median marks are around 55%. Although introducing the prototyping phase increases the students study load, it motivates the students to work harder. As the results the course's median increases to around 80%.

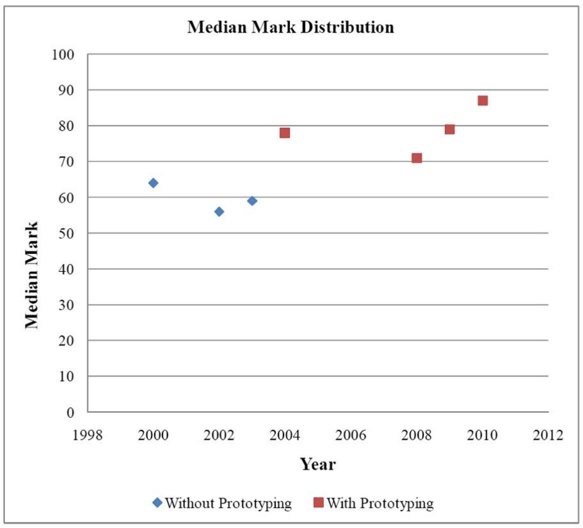

Figure 4: Distribution of Median Mark.

5 CONCLUSION

Teaching aircraft design with Problem-based Learning not only satisfy the Malaysian Qualification Agency requirement of Outcome-Based Education, but also impart generic skills such as critical thinking, problem solving and communication; the skills that students need to enter the competitive job market.

Introducing the prototyping phase poses many challenges and increases both the instructor and students' workload, but the students' results are better as the students are highly motivated and enjoy the course. Students are also able to consider materials selection and costing in their design project.

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ACKNOWLEDGEMENT

The authors thank the Ministry of Higher Education of Malaysia for sponsoring this research through UTM Research University Grant Vot 7140.02J19