British Model Flying Association

University of Strathclyde Team C - Q12

Payload Challenge 2 – Quantity

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Technical Report

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INTRODUCTION

This report outlines the process of designing and manufacturing a model aircraft to compete in the British Model Flying Association 2016 University and Schools Payload Quantity challenge. Over a 24 week period, the aircraft was optimised for maximum efficiency and constructed precisely from technical drawings created during the design stage. The original design was modified several times during construction due to superior alternatives, cost/material restrictions and practical inexperience. The majority of these alterations ultimately benefited the final build.

DESIGN PHILOSOPHY

The aircraft was designed and constructed according to the following principles: large payload capacity minimal structural mass, minimum load/unload time, to meet the take-off requirements and also be straightforward to construct.

It was decided to take an approach where the aircraft would complete fewer circuits, carrying a larger payload on each flight. Maximising the number of balls carried on each circuit was therefore a priority. Unlike the weight challenge, the payload-to-mass ratio was not critical but still had to be maximised in order to carry the largest payload possible. This was achieved by minimising the aircraft's structural mass.

Reducing the time that the aircraft was grounded would allow more flights to be conducted, therefore the loading/unloading process was to be extremely time efficient. It had to be ensured take-off was achievable within 61m as set out in the competition rules, even with a large payload. Finally, the aircraft had to be designed such that it did not require any over-complex manufacturing techniques. This was important, as it was to be constructed by students with no experience of building model aircraft.

PLANNING AND MANAGEMENT

It was clear from the outset that managing a project with a large team would be very difficult; therefore communication and teamwork would be crucial to the completion of the task. A project leader was elected and sub-teams were created in order to complete tasks in the early stages of design. Several methods were used to communicate and share data amongst the team:

- Facebook was used to organise team meetings and tasks
- Dropbox was used to share files and minutes of meetings between members
- Google Sheets were used for the technical data log of the aircraft. This was invaluable as live updates avoided members over-writing each other's work.

The entire aircraft was constructed on a budget of £75, which was used for all parts of the aircraft, with the exception of provided components such as electronics and solar film. Forward planning was critical in the early stages of manufacture. A frugal approach to material use was imperative, as any wastage would impact the budget at a later date. By the end of the project, the budget had been used in its entirety.

DESIGN AND MANUFACTURE

The aircraft was manufactured from the technical drawings created in the design phase of the project, which were updated, amended and improved throughout the construction. Many parts of the aircraft were designed to be laser-cut, which saved time and weight, improved accuracy and eased construction.

Selecting a suitable wing profile was crucial, as the wing had to provide sufficient lift to facilitate take-off and sustain flight. Following careful consideration of various aerofoils, the Selig 1223 profile was chosen. It was decided that a reasonably low aspect ratio, ideal for manoeuvrability, would be beneficial for this challenge. A span of 2m and chord 0.3m were chosen, resulting in an aspect ratio of 6.67. It was not tapered in order to avoid further complications in the manufacturing stage.

The wing was largely constructed from balsa wood, with plywood reinforcements where structurally required. Cyparis was chosen as the main spar material, as it provided ample strength to support the wing, without over-engineering. The C-beam was appropriately stressed for 3G forces, and with an incorporated safety factor of 1.5. This meant the wing was fully stress tested up to 4.5G.

A flat plate aerofoil profile was selected for the tailplane, complying with the design philosophy of simplistic construction. The final dimensions of the tailplane were 0.5 x 0.2m. For structural purposes, the grain of the wood had to be in the correct direction. Strips of balsa wood were cut and glued together to create this structure. The final tailplane setting angle was reduced to -2.9 degrees by lengthening the hollow carbon fibre tail boom to obtain a setting angle within the efficient range.

In a similar manner to the wing, the fuselage consisted of ribs known as formers, and stringers. These stringers would act as a cage to carry applied loads and provide the main structure of the fuselage. This addition to the original design proved crucial to the aesthetics and aerodynamics of the fuselage - keeping the wrap taught, preventing increased drag and adding torsional rigidity. The stringers were constructed from alternating balsa and cyparis struts, which reduced weight whilst adding the required structural strength.

The former was a trapezoidal shape, allowing for three rows of tennis balls to be situated on the upper level and two underneath, with each row carrying 10 balls. The payload loading method was along balsa wood ‘runners’ which connected the formers. The final structural mass of the aircraft was 2.18kg, therefore accommodating 50 tennis balls would equate to a payload-to-mass ratio of 1.36.

Between several of the formers, laminated plywood plates were added to the top and bottom of the fuselage to provide mounting surfaces. To attach the wing, one former was designed with an extension protruding from its top edge. The height of this extension allowed for a wing rigging angle of 3 degrees. A hollow foam nose was attached to the fuselage which allowed the electrical components to be housed.

The undercarriage configuration for this aircraft consisted of a tricycle arrangement. The front undercarriage was shaped steel wire with an in-built suspension loop. The rear undercarriage was created from fibre glass, giving the best available combination of strength and lightness.

In choosing a propeller, it was apparent that a high diameter, low-pitched propeller was more suitable for the aircraft. They typically promote low speed flight whilst providing good acceleration and climb, along with finer speed control. The 12x6 propeller was recognised to be the most effective and efficient for the aircraft.

Upon completion of the sub-sections, the wing, fuselage and tailplane were wrapped in aerodynamic ‘solar film.’ This iron-on material served no structural purpose, however it was imperative for smoother air flow. Required electronic components were added along with the control surfaces which were attached using hinges.

PERFORMANCE CHARACTERISTICS

The critical measure of aircraft stability is known as the static margin, expressed as the distance between the centre of gravity (H_g) and the neutral point (H_n). For the aircraft with zero payload, the centre of gravity was found to be 0.487m from the datum point, and the neutral point was calculated at 0.512m, resulting in a static margin of 16.2%. For maximum payload, these values were found to be 0.480m, 0.534m and 18.6% respectively.

The BMFA drag estimation guidelines were used to calculate the drag for each component of the aircraft, resulting in C_{Do} and k values of 0.037 and 0.064 respectively.

Based on attained values for the aircraft, the stall speed was determined to be 8.59ms^{-1}, the maximum speed 21.35 ms^{-1} and the maximum rate of climb 1.57ms^{-1}. Using a take-off speed of 1.2 V_{stall} and assuming a runway surface of long wet grass, the take-off distance was estimated to be 29.3m with the maximum payload.

MODIFICATIONS AND INNOVATIONS

As previously mentioned, the design went through numerous stages of optimisation. For instance, the fuselage was originally designed with a foam structure, but it was quickly realised that this would exceed the budget restriction. The final fuselage structure proved to be a much lighter and more cost efficient alternative.

When the tailplane was constructed following the initial design drawings, it was visibly obvious that the fin and rudder were not large enough. Consequently, the tailplane was increased in height from 0.15m to 0.22m, which resulted in the volume coefficients increasing to the upper limits of the allowable range.

There were several innovations during the build phase. For the motor mounting, a removable marine-ply assembly was created. This novel idea proved to be useful, as upon testing, the original motor failed. Had the motor assembly not been removable, the entire nose assembly would have had to been removed and rebuilt.

Another creative concept was the spacers that were used for the wing construction. These wood pieces had precise, laser-cut notches along their length in order to maintain the correct distance between wing ribs. They also validated the span was the correct length and ensured that the ribs remained parallel along the wing. The edges of the outer ribs were reinforced and rounded for a more aerodynamic finish. An additional innovation was a custom-made sanding block, which allowed for more accurate sanding of the wing profile. These simple yet effective ideas proved to be extremely useful in the construction phase of the project.

CONCLUSION

There were many conclusions that could be drawn from this process. These relate to both the theoretical work and calculations in the design phase, as well as the practical and logistical challenges during the construction of the aircraft. For example, in design, once several iterations of optimisation were completed, judgement had to be made to decide whether a value required further refinement, as this process could continue indefinitely.

Prior to the construction phase, there were sections of the aircraft where the complexity of the build was underestimated, such as the wing, where it was unknown the several stages of assembly. Finally, the relatively small budget required forward planning and utilising funds efficiently, which gave an appreciation of maximising the use of each piece of material. Through managing a complex engineering project and in designing a complete aircraft from beginning to end, a newfound understanding and appreciation of the complexity of aircraft design and manufacturing was gained.