Design and Fabrication of Glow Engine RC Plane

Abhimanue surendran[#1], Mento thomas[#2], Midhun venugopal[#]3, Deepak sabu[*4], Deepak kumar[*5]
[#]*Student & Aeronautical Engineering*
[*]*Student & Mechanical and Automation Engineering*
PSN College of Engineering and Technology, Melathidiyoor, Tamil Nadu, India

Abstract

Glow-engine powered UAVs are gaining much more acceptance worldwide. Small engines with less masses are attractive for use in low cost UAVs because they are mass produced and inexpensive. This project deals with the study of a glow engine UAV, its design and performance characteristics. The objective is to use the model ASP S46 Engine to collect data that provides insight into the processes/loss mechanisms governing small engine performance so that it may be improved and to develop the beginner's interest by meeting their requirements at a lower cost and leading them to the different pace of sport flying. This type comes under the category of engines in the 7.5 cc range that may be used by designers of low-cost UAVs. Until a few years before it was nearly the only method to fly a model with enough power. The material used for the fabrication of this model is Balsa Wood, due to its lightweight, high buoyancy and flexibility.

Keywords - *Glow engine, RC plane, UAV*

I. INTRODUCTION

The use of Unmanned Aerial Vehicle (UAV) for civil purposes is getting wider from day to day. The main advantages of UAV include the elimination of the need of air crews onboard, and its versatility in performing various operations such as to help researcher to reach inaccessible places that may contain research value, and use for reconnaissance purpose in military operation. However, for a specific UAV mission, the powerplant choices are not fully deployed and thus limiting the selection. In this study, testing of a type and size of nitro engine that are normally used for radio control (RC) aircraft will be conducted as a preparation for it to power an UAV. Model aircraft are often dismissed as `toys' and their potential for teaching many aspects of engineering is often ignored. This is rather unfortunate because the technology in modern radio-controlled model aircraft is leading edge and has considerable potential for productive and interesting projects in a number of areas less. The method that has been chosen for this project is by doing experiment to predict the engine performance parameters. This is because by using this method the measurement of engine performance parameters will be more accurate.

For a specific UAV mission, the powerplant choices are not fully deployed (in term of operational and performance sizing) and thus limiting the selection. In this study, testing of a type and size of nitro engines that are normally used for RC airplanes will be conducted as a preparation for it to power UAV.

A. Project Scope

Design test bed according to appropriate apparatus to find the unknown of parameters and detail analysis of UAV propulsion system by using mathematical equation. 2. Performance testing of UAV propulsion system can be executed by calibration for Force (N), Available Power ($\dot{W}$A), Shaft Brake Power ($\dot{W}$B), Propulsive Efficiency (%) and Specific Fuel Consumption (μg/ (W.s)). 3. The instruments such as tachometer to measure the engine speed were used to evaluate corresponding performance parameters at various RPM setting.

II. SMALL / UAV PROPULSION SYSTEMS

There are different views about the precise definition of UAVs (Newcome, 2004). For the purpose of this study, the definition provided by ASTM International was adopted. UAVs are here defined as an airplane, airship, powered lift, or rotorcraft that operates with the pilot in command off-board, for purposes other than sport or recreation (ASTM, 2005). The UAVs are designed to be recovered and reused (ASTM, 2005). *Electronic*

Fuel intake manifold to regulate how much gas is needed to produce a perfect mixture. Radio controlled flight, usually referred to as RC, was largely developed by people with interests in both flying and amateur radio, like two early pioneers named Clinton DeSoto and Ross Hull, who flew gliders in the first public exhibition of RC flight (Raine et. all, 2002). He also mentions about 1933 the first gasoline powered engines were developed for model airplanes. Although this made the model more realistic it also created the problem of preventing model with its expensive engine simply flying off over the horizon. It was Clinton DeSoto who first envisaged radio as the solution to this problem. Two other names must be mentioned in conjunction with the origins of RC whose is the twin brothers Bill and Walter Good.

The nitro engine was used in this project was the Max-46LA OS engine. As state by (Hobbico, 2000), the engine has been developed to meet the requirements of beginners and sport flyers which is modern design and having a separate needle valve unit mounted at rear, where manual adjustment is safely remote from the rotating propeller, they offer the advantages of reliability and easy handling, at lower cost. Nevertheless, the four-stroke engines also enjoy some popularity, mainly because they produce a lower, more scale-like sound and consume less fuel. They have lower power/ weight ratio and lower RPM, but provide more torque (use larger propellers) than theirs two-stroke counter-parts.

III. EFFECT OF PERFORMANCE PARAMETERS ON TEST BED DESIGN

The parameters of this study are to measure the engine performance such as available power, shaft brake power, brake specific fuel consumption, propulsive efficiency, and thrust. There is only one type of engine that will be used in this study which is 2-stroke engine. The throttle control of the engine will be used to simulate the engine operating range from idle speed condition until achievable the maximum speed.

A. Performance Parameters

There are four performance parameters that will be study as follows:

1. Thrust.
2. Available and Shaft Brake Power.
3. Propulsive Efficiency.
4. Brake Specific Fuel Consumption.

Table 1 shows the summarized of the equations that are used in this study and the unknown parameters to be finding from the test bed.

Table.1 Performance Parameters

Performance Parameters	**Equation**	**Parameter to be measured**
Thrust	$F = kx$	X
Available power Shaft brake power	$\dot{W}A = FN\ Vo = \dot{m}Vo\ (Ve-Vo)$ $\dot{W}B = \dot{m}\ ((Ve^2/2) - (Vo^2/2))$	Ve , Vo Ve , Vo
Propulsive efficiency	**Error! Reference source not found.**p = FN prop Vo/ $\dot{W}B = \dot{W}A/\dot{W}B$	Vo
Brake specific fuel consumption	$BSFC = \dot{m}fuel/\dot{W}B$	$\dot{m}fuel$

B. Thrust of the engine

The forces acting on the airfoil-shaped cross section of a propeller blade are complicated to determine analytically. At first glance, a seemingly simple method of calculating the thrust produced by a propeller blade would be to sum the forces for a small differential radial element (dr) along the length of the blade. It is possible to determine the differential lift (dL) and drag (dD) from the lift and drag coefficients (CL and CD) derived from the local airfoil shape and then integrate this equation (Ward, 1966).

However, an ideal approximation of thrust can be derived from the momentum equation by considering a control volume enclosing the airflow accelerated by the propeller (Figure 2.9). This analysis assumes that the air flow steadily from a region in front of the propeller (Po, Vo, ρo) to the exit region behind it (Pe, Ve, ρe). This method is generally known as the momentum theory (Ward, 1966).

Table.2 The suggested propeller sizes

LA Series	**Running-in**	**Trainer & Sport**
40 LA	11×5	10×6-7, 10.5×6, 11×5-6
46LA	11×6	11×6-7
65LA	12×6	12×7-8, 13×6-8

There are several types of propellers in use on model airplanes. They include two, three, and four blade types. By far, the most popular propeller for a trainer plane is a two-blade type made of wood or plastic (Tressler, 2008). Most used are plastic propellers. Propellers are sized using two numbers; diameter and blade pitch. A very common prop size for a 40 to 46 trainer engine is a 10-7. The first number is the diameter of the propeller in inches. The second is the blade pitch expressed as a number representing the theoretical distance the airplane travels forward for each revolution of the propeller.

IV. DESIGN DESCRIPTION

A. Components and Systems

The aircraft is a total of 65.25 inches length, 129 inches in width, and 15.5 inches in height. It is powered by a two-stroke gas powered engine. The entire thing is constructed out of balsa wood and piloted wirelessly through a 6-channel transmitter and receiver that control the throttle and control surfaces of the aircraft. It is a total of 13.75 in weight without any payload. See Figure 1 for the finished product.

B. Engine

The engine used to power the aircraft is a Magnum XLS.61A. It is a two-stroke engine that runs on model aircraft glow fuel, 15% nitromethane. A manual for the engine can be found in the Appendices that contains all other necessary information about the engine. See Figure 1 below for a picture of the engine

Fig 1: Glow engine

C. Wing

The airfoil used in the design of the wing is the Selig 1223. The total wingspan of the aircraft is 10.2ft. The wing configuration is designed with 4 different aspects in mind: taper, twist, angle of incidence, and dihedral. For the final design, each half wing (pinion) has a starting chord length of 16 inches, tapers down to 12 inches and remains a constant 12 inches chord length from 2.55 feet (middle of the half wing) out to the tip. The wing is attached at an angle of incidence of 3°, has a dihedral of 2°, and the whole wing has 2° of twist. The wings were constructed with balsa wood using a standard spar and rib technique. Each wing has one flap and one aileron. The method in which each wing is affixed to the fuselage is by a 1-inch x 1inch aluminum tube that runs from inside of the wing and protrudes from the first rib by 2.25 inches. This aluminum tube slides into an aluminum tubing sheath that is located in the fuselage and is fixed in place by two bolts and nuts on each half wing.

D. Fuselage

The final fuselage is a very basic design with a removable cover on the top of it that allows access to the components contained inside of it. The floor of the fuselage is made of balsa hardwood where two bolts extend upward to secure the payload plates during flight. The engine mount on the nose of the fuselage is also constructed out of hardwood balsa and is designed in a way the engine is completely exposed.

Like the rest of the aircraft, the fuselage was constructed with a rib and spar technique with a single boom extending back to the empennage. A PVC pipe runs from the fuselage back to the empennage that contains all of the wiring controlling the surfaces on the horizontal and vertical stabilizer.

Two plates mounted on the sides of the fuselage are made of balsa hardwood with a square hole cut into the side where the two wings mount into 1x1 aluminum tubing sheathes contained in the fuselage.

E. Wireless Systems

The wireless system consists of a Spectrum DX6i 6 channel 2.4GHz transmitter and an AR6210 2.4 GHz receiver. See Figure 2 below.

Fig 2: Transmitter and Receiver

F. Landing Gear / Externals

The landing gear of the aircraft consists of a fixed set of two wheels that are attached to the underside of the fuselage, close to the centre of gravity. A single wheel is also located under the empennage. As the aircraft sits on the ground, the landing gear is oriented so as to give the aircraft a positive angle of attack to assist in producing lift during take-off.

V. DESIGN CONCEPT PROCESS

A. Engine Selection

There was virtually no design choice to be made for the power plant of the aircraft. The SAE Aero Rules and Restrictions required anyone competing in the regular class to choose between two similar engines. The choices are the Magnum XLS .61A and the O.S. 61 FX. Both engines are the same size bore and there are negligible differences in the performances of each engine. The group chose the Magnum XLS .61A for the engine based on cost and availability as the O.S. 61FX is discontinued in production and the group wanted a brand-new engine to work with.

B. Airfoil Selection

After the initial organization of the project, as well as familiarization with the rules, the tentative design process leads to the characterization of the wing. each component of the aircraft is of great importance and intended to accomplish a specific task. however, one must always keep in mind one essential rule of aircraft design – a process of trade-offs and optimization is inevitable. there are as many aircraft configurations as there are tasks for an aircraft to complete, and the goal of the engineer should be to arrange for a design that is tailored to the specific goals at hand. Along with the thrust available from the engine and propeller system, it is one of the primary limiting factors for the overall aircraft performance. So, naturally, it was decided to focus the early part of the project on the wing design. It was thought that obtaining desirable and workable performance from the wing was deserving of time and attention and that due to the logic above, many other decisions would follow from the final choices made with regard to the wing.

C. Operating Conditions

It was then time to study airfoil geometry from the perspective of our project. That is, with respect to design of a relatively slow flight small scale craft intended to lift a maximum amount of weight. To do this, certain information which defines the operational flow must be known. Given the size of the engine selected, and well-known typical speeds of large models, airspeed was expected to range from just a few feet per second, up to perhaps 100 feet per second, although the latter would be rather extraordinary.

Another issue to contend with was the fact that atmospheric conditions are less than stable and uniform at sea level. It is not difficult to imagine an aircraft of small size being forced off-kilter by a burst of wind, or encountering slight variations in density and temperature over a single flight. This meant that our choice had to provide desirable characteristics over a decent range of angles of attack. Clearly the goal was to find and use an airfoil section that provided the high coefficients needed in a lifting competition over a range of angles of attack, and was efficient at lift production in the low Reynolds number regime.

D. Resources Utilized

Several books published on home-built aircraft design were found and perused for information. Often times, such references come with comprehensive lists of airfoils which designers commonly use. Perhaps the most well-known resource examined was "Theory of Wing Sections" by Von Doenhoff and Abbott, although this book is not intended for model building. Several suitable sections were found in "Model Aircraft Aerodynamics" by Martin Simons. Another valuable resource for finding airfoil data was the University of Illinois maintained database, run by Professor Michael Selig (the designer of many of his own sections). This resource is of particular note, given that one of its main focuses is the low Reynolds number regime.

E. CAD Model

In the design process, some modelling was needed to get an idea of how things fit together and how things looked, space-wise. Preliminary SolidWorks was done for one-half of the wing to help determine how large and how complicated the wing would be to fabricate. The preliminary model incorporated the twist, the taper, and the rib/spar technique that was used in the construction process. This model was then used to build a mock-up of the half wing and to guide the construction of the mock-up. The model helped the group determine how long the construction would take for at least the wing of the aircraft. Preliminary modelling was also done on SolidWorks of the fuselage. The group needed to know that the design of the fuselage was large enough to fit all of the components. Below, Figure 3 shows the original spacing SolidWorks model of the fuselage.

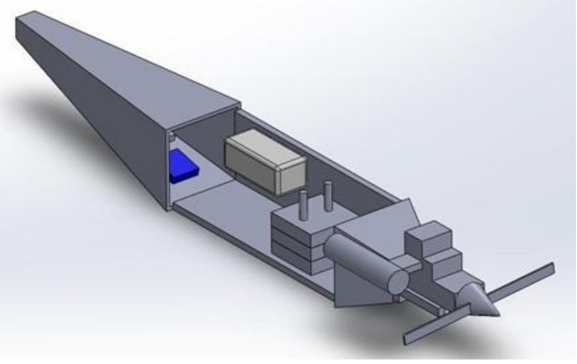

Fig 3: CAD Model Fuselage

The main component in a Hydrogen-on-Demand system is the HHO or Hydroxy gas generator. This device can be a simple one-cell unit or have as many cells as needed to produce the quantity of HHO gas desired. Electric current is the driving force that creates electrolysis in such generator. It separates chemically bonded compounds in water by passing an electric current through them. By adding an electrolyte to the water, the electrolysis process can be enhanced. An electrolyte is any substance containing free ions that behaves as an electrically conductive medium. Catalyst, would be the correct term because of the function it performs to speed up the production of HHO gas.

Another important component for regulation is the Amp Meter, this is a tool used to measure the amperage flowing through a wire or other conductive material. It is a very important tool for this project, because the number of amps sent to the cell determines the amount of HHO gas generated. Moreover, we need to add an EFIE to the car's ECU to make sure the mixture of air, gas, and HHO are well balanced as well as the use of a PWM (pulse width modulator) to adjust the frequency of the current in order to decrease the number of amperes needed for the water breakdown.

The final major component of our design is a vessel that's big and sturdy enough in which to conduct electrolysis in. It has to be able to maintain high enough pressure of HHO gas to the able to send it through hoses and into the engine's combustion chamber. Furthermore, some machining is need for the vessel. Holes are drilled on the bottom of the vessel to allow for screw.

VI. TAIL CONFIGURATION SELECTION

The twin-tail configuration was selected as the tail configuration for the advantages it offered for our particular aircraft. This configuration eliminates the effect of the prop wash (a helical wind around the fuselage caused by the propeller) on the yaw of the plane. Furthermore, it allows for a horizontal stabilizer that is wide and, consequently, has a lot of surface area. The more surface area the horizontal stabilizer has, the less distance there needs to be between the tail and the wings. Shortening that distance is advantageous since it reduces the length, width, and height constraint.

A. Horizontal Stabilizer Airfoil Selection

Based on advice given by experienced remote-control aircraft hobbyists, the choices of airfoils were narrowed down to symmetrical airfoils. These airfoils are called "symmetrical" because of their symmetry along the chord line. There are several airfoils in the NACA 4-digit series that are symmetrical and have aerodynamic data readily available. The NACA0012 was chosen because it had just enough thickness to house the elevator and rudder servos with a 10-inch chord.

B. Horizontal and Vertical Stabilizer Sizing

The horizontal stabilizer was chosen to have a 10-inch chord length, which make its thickness enough to hold our servos, as mentioned above. The width of the horizontal stabilizer was chosen to be 36 inches simply for convenience of construction. The balsa leading edges come in 36-inch lengths, so no modifications would need to be made to its width with a 36-inch horizontal stabilizer.

With the chord length and width of the horizontal stabilizer known, the distance known as the tail moment arm was to be selected. This is the distance between the quarter-chord points of the wing and horizontal stabilizer. The choice of tail moment arm was made so that another parameter, called the horizontal tail volume coefficient, falls within a range typical of successful existing aircraft. The horizontal tail volume coefficient is defined in equation 1 below:

$$V_H = \frac{S_H * l_H}{S_w * MAC}$$

C. Empennage Position Relative to Wings

The position of the tail assembly is partially described by the tail moment arm, which is described above. The height of the tail assembly above or below the plane of the wings is chosen so that the tail is not shadowed by the flow behind the wings. Since the velocity of the flow in the wake of the wings is slower, the surfaces in the tail will have less of an effect if placed there. So, the height of the empennage is bumped up so that it is well out of the wake of the wings. A height of 3 inches was found to be sufficient based on the method outlined for estimating the position of the wake.

D. Incidence Angle

The incidence angle of the horizontal stabilizer is the angle between the chord line of the horizontal stabilizer and the roll axis of the body. The tail boom is parallel to this axis and may be considered the roll axis for all intents and purposes. Incidence angle affects the pitch-up or pitch down force on the empennage the same way the angle of attack of the wing affects the lift on the wing. The best angle of incidence to have is very sensitive to the weight of the aircraft and the position of the aircraft's centre of gravity (CG). That is to say, choosing a good incidence angle for the aircraft without any payload might make the plane very difficult to fly with payload added. It is complicated further by the fact that the location of the CG is difficult, at best, to know with certainty before the entire plane is designed assembled**.**

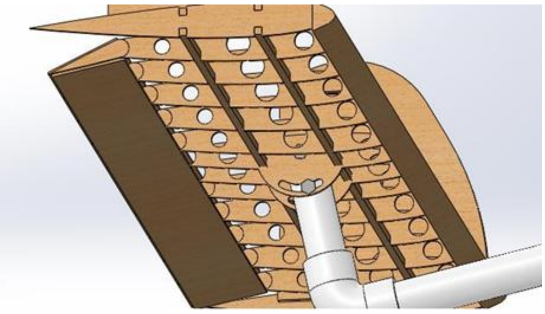

Fig 4: Tail Angle Adjustability

VII. TESTING AND EVALUATION

Brian Barainca, President and Founder of the Black Bearons Flying Club on campus was the test pilot of the team's aircraft. He has been flying for a number of years and is more than qualified. No member of the group had even remotely enough experience with flying RC aircraft to be comfortable trying to fly. Our testing plan included the following:

- Test the aircraft with no payload added. Take off, complete a 360° circuit, and land successfully.
- Adjust the aircraft as needed and repeat the circuit.
- Load the aircraft with payload in increments of 1lb until take off is unachievable.

Let it be noted that the final aircraft as built is not a perfectly balanced aircraft in regards to the pitch axis. The centre of gravity of the aircraft is slightly aft of the quarter chord line of the wings which causes the aircraft to be tail heavy. A perfectly balanced aircraft could be held up at the quarter chord point and be perfectly balanced. But the final design as built tends to have more weight toward the tail. This caused the aircraft's pitch to be difficult to control.

Fig 5: Emergency Repairs

Fig 6: Off-kilter empennage

VIII. RESULTS AND EVALUATION

With the wind blowing into the face of the aircraft, the aircraft had no problem taking off. The competition requires take off within 200ft and our aircraft with no payload in it took off in less than 40ft. With the crooked empennage and a heavy tail, the aircraft was difficult to control in the air. Of course, the high winds did not help this situation any. But as competition required, a full 360º turn was made and the landing approach began. While trying to land the aircraft, the wind picked up and blew the aircraft of course and spun the tail end around, causing a very rough landing which upon impact, broke off the landing gear from under the fuselage.

However, the landing gear was still attached to the plane by some Monokote, so by competition standards, that would have been a successful landing. As long as nothing on the plane becomes completely disconnected from the aircraft, it is considered a successful landing. Needless to say, flight testing ended abruptly due to no landing gear for the plane to take off or land on. There was no chance to load the aircraft with payload and attempt flight with extra weight.

A. Engine

The engine had plenty of power had more than enough power for the purposes of getting the aircraft off the ground.

B. Wings

The wings were by far the most thoroughly and best designed components of the aircraft. They held together well and connected to the fuselage with ease and sturdiness. Every aspect of the wings was designed well. According to the pilot, Brian Barainca, “Even with no wind assistance, the aircraft would have taken off no problem. The wings produced more than enough lift; the thing wanted to climb.” He also stated that the flaps were sized correctly, but the ailerons could have been sized a little bigger to help alleviate the control issues with the tail-heavy design. The wings of the aircraft were designed exactly how they needed to be designed.

C. Wireless Systems

The wireless systems acted just as they should have and provided quick, reliable response time between commands.

D. Controls

As evident in the analysis of the servos, the controls were sized properly and the servos could easily handle the loads that were experienced during flight.

E. Empennage

The final design of the aircraft was a little tail-heavy which lead to less than stable flight. That being said, the tail boom and tail assembly could have been designed to be a little lighter to solve this problem. “A tail-heavy aircraft is difficult to fly” according to Brian, and a result the aircraft was a little difficult to control during flight. However, the elevator on the horizontal stabilizer was definitely big enough if the aircraft had been properly balanced. The same could be said about the rudders on the vertical stabilizers. The control surfaces on the empennage were sized properly but the overall weight of it was too much.

F. Landing Gear/Externals

The landing gear was an under designed portion of the project as can be seen by their failure during landing. The connection between the landing gear and the bottom of the fuselage was not strong enough to withstand large loads so when the aircraft landed roughly, they failed and broke off. As for the decision to use Monokote for the outside of the aircraft, this was an excellent choice as the surfaces of the aircraft are very smooth and the final design is very aesthetically pleasing.

G. Evaluation Summary

Overall, the aircraft was designed to competition specifications. The aircraft would have no problem passing the inspections of the competition judges. This was a successful design process. During testing however, some components proved to be under-designed, as explained above, and this led to issues. This project met the standards of the competition and guidelines it was supposed and although the aircraft might not have scored well, the project can be looked at as a success.

Fig 7: Finished RC Plane

IX. CONCLUSION

Upon completion and evaluation of the project, it can be concluded that the design met all specifications required by the SAE Aero Design competition rules and speculations. However, there are a couple of reflection points to touch on. The design process, as stated was executed correctly and was well suited for the tasks at hand. That being said, the design process was carried out slower than it should have been. The entire first semester set the team back considerably in terms of design. As the first iteration of the SAE Aero team that UMaine has seen, the group had to get familiarized with all rules and restrictions of the competition. Then the group had to determine how this project would be carried out and the process of designing an aircraft from the ground up.

Once a process was determined, the largest chunk of the first semester went into the design of the wing. By the end of the first semester, a thorough, well thought-out design of the wing was complete. These extensive efforts were evident in the success of the wings in flight. So being the component that had the most time and effort put into, the wing indeed was the most successful piece of the project. By spending so much time on the wing design, other components of the aircraft lacked the time and effort that the wing got. Both the fuselage and the empennage, as stated in the evaluation, were under designed and as a result had some issues during final testing.

REFERENCES

[1] John D Anderson, "Introduction to flight" fourth edition.
[2] Mohammad Sadraey, "Wing design", Daniel Webster College.
[3] Mohammad Sadraey, "Preliminary design", Daniel Webster
[4] Mohammad Sadraey, "Tail design", Daniel Webster College.
[5] Anderson, "Aircraft performance and design", TMH publications.
[6] Anderson, "Fundamentals of aerodynamics", MH publications.
[7] Mohammad Sadraey, "Aircraft conceptual design", Daniel
[8] E.L. Houghton and P.W. Carpenter, "Aerodynamics for Engineering Students".
[9] Naresh.K, "Design, Development and Demonstration of Airplanes."
[10] Andy Lennon, "Aircraft design", TMH publications.
[11] Dr. Jan Roskam, "Airplane design", TMH publications.
[12] Robert C. Nelson, "Flight stability and automatic control.