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Fabrication of UiTM's Energy Glider

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ABSTRACT

Glider is a fixed-wing aircraft which does not depend on engine. A glider can fly for an extended period depending on the design and area of the lifting surface. Just like any other aircrafts, the design of wings is crucial to produce lift to keep aircraft fly in the air. Gliders have long wings and are designed to be lightweight which allows it to have a high lift-to-drag ratio to glide at a long distance. The maximum lift-to-drag ratio, L/D_{max} can indicate how far the glider will glide as it is one of the most important performance parameters. This study aims to design, build, and fly an energy glider. Before starting on the design of the energy glider, statistical analysis has been done by comparing data from different literatures to aid in determining the initial values of the glider. Then, the general design of the energy glider has been decided during the preliminary design. To support the design decision made, ANSYS Fluent software has been used to study flow of air over KFm-5A airfoil which has been chosen during the early stages of design. The model of the energy glider was designed in CATIA V5 software before fabrication with a wingspan of 1.52 m and fuselage length of 0.69 m. Lastly, flight test was conducted to achieve the study's objectives. During the flight test, the glider reached a ceiling height of approximately 300 m and obtained a velocity of 144 km/h. The analysis of the glider performance will be used as an aircraft data for future research.

Keywords: Glider, lifting surface; kfm-5A, fabrication, CFD

Abbreviations

CAD	computer aided design
FAA	federal aviation authority
KFm	Kline Fogleman modified
PDS	product design specification

1.0 INTRODUCTION

According to the Federal Aviation Authority (FAA), a glider is a heavier-than-air aircraft whose free flight is supported by the dynamic response of air against its lifting surfaces rather than an engine [1] and [2]. Gliders have high aspect ratio as it has fuselage and long narrow wings which minimize drag. High aspect ratio wings are typical in long-endurance and high-altitude aircrafts like glider [3]. Majority of modern gliders have a glide ratio greater than 60:1. In comparison to a Boeing 747 which has a 15:1 glide ratio, a glider can glide for 96.6 km with an altitude of 1.6 km [4]. The high lift-to-drag ratio of gliders makes it possible for it to produce enough lift when gliding for long distance. An altitude gliding engine is equipped in some gliders and can be turned off once crucial lift has been obtained; thus, allowing it to have minimal impact on the environment. There are several unique characteristics of a glider; each having unique wing design, aerodynamic efficiency, pilot position, controls, and intended usage.

Aerodynamics is the study of characteristics of air movement around aircraft. Aerodynamic techniques to determine wing lift, wing drag, and wing pitching moment are essential in wing design process [5]. It is crucial to determine the performance of aircraft in real world and its endurance. When flying straight and level, the aircraft is subjected to four forces which are lift, weight, thrust, and drag. A force that is equal to or greater than the force of gravity must be produced for the aircraft to take off in the air. This force is referred as lift. Lift is produced in

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heavier-than-air aircraft created by passage of air over an airfoil. Any physical body moved through the air will encounter airflow resistance. This resistance is referred to as drag. Drag is proportional to dynamic pressure and area as it operates on like lift. Drag opposes propulsion while lift opposes gravity [1]. The lift to drag ratio of an airfoil must be sufficiently high to allow it to produce high lift at minimal drag for it to be functional [6]. The drag is influenced by the type of airfoil and the wing area that faces the wing. The value of lift and drag depends on the angle of attack between the wing's chord line and the direction in which it moves through the air. Wings are generally designed with a rounded front. This is because leading edge splits air easily, while the trailing edge prevents upward spill of air as pressure under wing is higher than top of wing. An aircraft's weight is a determining factor in its design. A large aircraft needs more lift than small aircraft. To accelerate on ground, greater thrust must be needed. The force that propels an aircraft through the air is called thrust. To overcome drag of an aircraft, thrust is used through some sort of propulsion system such as engines. Figure 1 below shows the aerodynamic forces such as the lift, weight, thrust, and drag acting on the aircraft.

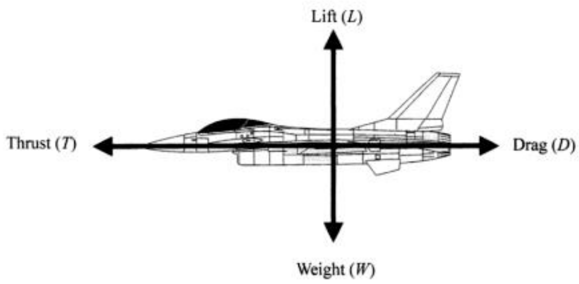

Figure 1. Relationship of forces acting on an aircraft [7]

Selecting the right airfoil is crucial. For the aircraft to function at its peak and have safe flying characteristic, the airfoil must have appropriate aerodynamic properties. The airfoil selected for this project is the Kline-Fogleman modified (KFm) airfoil. KFm airfoils are a series of stepped airfoils designed by Kline and Fogleman [8]. Kline and Fogleman claimed that this series of airfoil creates a resistance to stalling as there is a bound vortex formed behind the step [9]. Theoretically, the vortex generates a zone of negative pressure that permits the airfoil to take advantage of a greater angle of attack before the airflow splits [8]. Stability and low stalling effect provided by this series [10] allow it to be the best selection for the energy glider. However, this series of airfoil is not suitable for full-size aircraft [11].

The Wright Brothers made advancement to the glider in the early 1900s by adding control surfaces which allow the control of vertical and horizontal components [12]. The energy glider for this project contains control surfaces which are aileron, elevator, and rudder. The primary control system, which consists of ailerons, elevator, and rudder, is necessary for an aircraft to be controlled safely during flight [13]. Typically, an aircraft has three aerodynamic controls, each of which can produce moments around one of the three fundamental axis – roll, pitch, and yaw [14]. Control surfaces are used to regulate motions in these axes. Ailerons are used to control the roll, elevator is used to control the pitch, and rudder is used to control the yaw [15]. In commercial aircrafts, the control surfaces are controlled by hydraulic systems. In this project, one end of a metal rod will be attached to the control surface and the other end to a micro servo. Figure 2 shows the parts of glider.

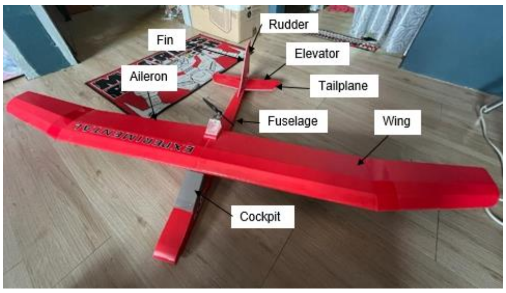

Figure 2. Parts of Glider

The present study focuses on the design, build and fly an energy glider.To complete this study, there are some limitations faced such as time constraint as it is time consuming to obtain all aerodynamics data of the energy glider. Next, wind tunnel testing, which is conducted to learn more about how the glider will fly, is unable to be done due to lack of testing equipment. Also, the maximum flying distance of energy glider is 1.5 km as the receiver used can only operate up to this distance.

2.0 METHODOLOGY

2.1 Design requirement

Determining the methodology allows the selection of the most suitable path to approach this study by creating a guideline to ensure the study runs smoothly. Methodology approach is used to achieve the objectives to design, build, and fly the energy glider [16]. The first step is to determine the PDS where the requirements, constraints, and specifications for the energy glider are identified. The next step is to do literature review where parameters such as wingspan, weight, and speed are obtained and compared in graphs. Following to that, the selection of electronics is determined based on the PDS and an analysis of airflow over the airfoil is studied on ANSYS Fluent software. The analysis of airfoil is done at 0° angle of attack. As the analysis of airflow is acceptable, the next step which is to create CAD of the energy glider is done. The final step before flight test is to manufacture the energy glider. During flight test, the flight data performance is obtained, and discussions are made for future improvements. Shown below is the flow chart for design methodology of energy glider.

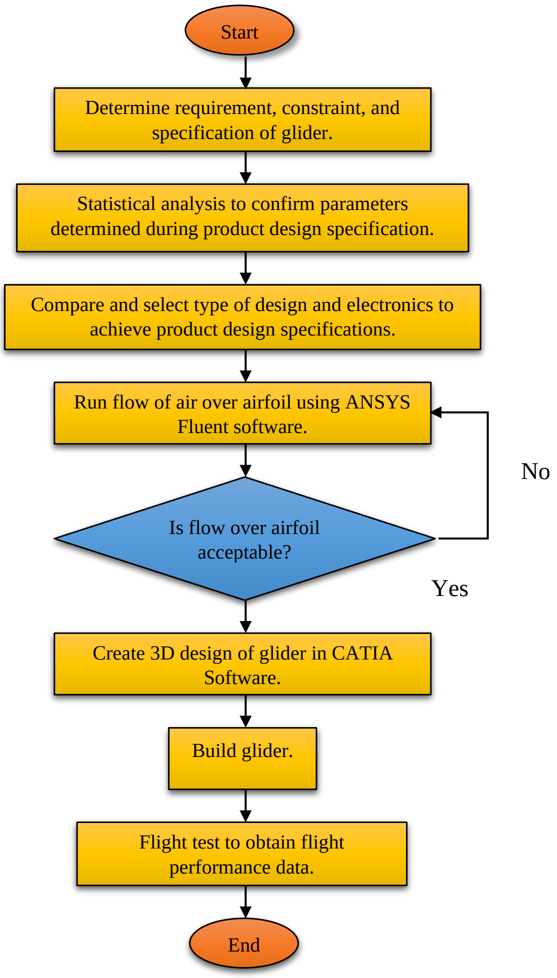

Figure 3. Process flowchart

2.2 Design and electronic Component Specification

Product Design Specification (PDS) is a fundamental description [17] of the energy glider. Table 1 shows the table for product design specifications that contain requirements, constraints, and specifications for the energy glider.

Table 1. Product design specifications

Parameters	Specifications
Material	Lightweight
Aesthetic	Bright colour
Ceiling Height	>200 m
Endurance	>30 mins
Range	>1 km
Weight	<7 kg
Propulsion System	Electric motor with propeller
Speed	>80 km/h

Table 2 shows the electronic components used in this project as well as the specifications for each component.

Table 2. Electric component specifications

Components	Specifications	
Electronic Brushless Motor	kV	1400
	Weight (g)	50
Electronic Speed Controller	Constant Current (A)	30
	Weight (g)	35
Battery	Capacity (mAh)	2200
	Weight (g)	170
Propeller	Pitch (in)	4
	Diameter (in)	8
Micro Servo Motor	Torque (kg.cm)	1.8
	Weight (g)	9

2.3 Airfoil and aircraft modelling

The KFm-5A airfoil is chosen for the energy glider. Kline-Fogleman (KF) airfoils have better lifting capabilities even at low speed. However, this is only applicable for small size aircraft [11]. Range and endurance of energy glider can be improved by selecting this airfoil. An analysis of the airfoil is done on ANSYS Fluent to study the flow of air over the airfoil at 0° angle of attack. Figure 4 shows the KFm-5A airfoil.

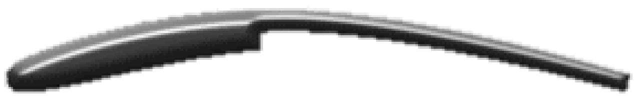

Figure 4. KFm-5A Airfoil

The design of the energy glider is chosen by studying the design of other gliders which are drawn in CATIA software. Gliders generally have a larger wingspan to fuselage ratio. These longs wings aid in lift once the glider is in the air. Creating the CAD drawing on CATIA helps in making the glider design more accurate as well as for better visualisation. The wingspan for the energy glider is 1524 mm. Figure 5 to Figure 8 shows the drawings of energy glider created on CATIA software.

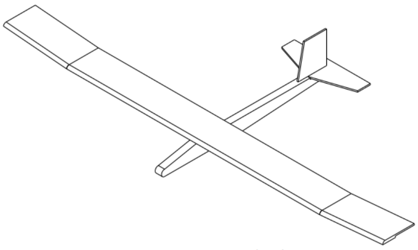

Figure 5. Isometric View

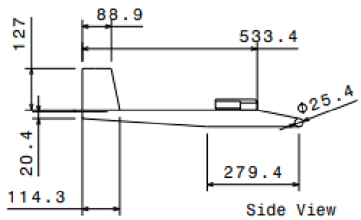

Figure 7. Side View

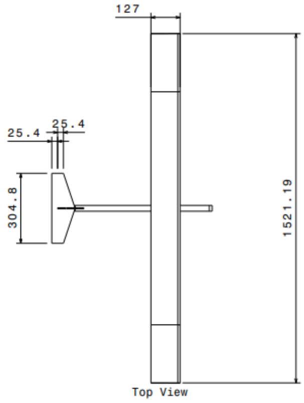

Figure 6. Top View

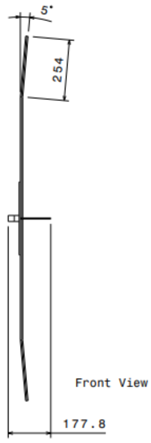

Figure 8. Front View

2.4 Fabrication of glider

The energy glider takes a total of three days to be manufactured, from cutting foamboard until the installation of electric and electronic components. A pen knife is used to cut the foam board to the required shape and size. The parts are assembled with tape and hot glue gun. Then, the wings are strengthened with carbon fibre rods. The electronic components in the fuselage are connected to the control surfaces – rudder and elevator with steel wires. Finally, the energy glider is cleaned and decorated. Table 3 below shows the manufacturing process and its descriptions.

Table 3. Fabrication Process

Manufacturing Process	Description
Cutting  **Figure 9**. Cutting Foamboard	Template of the drawing is printed and placed onto foamboard. The template is kept in placed with tape and cut according to shape and size with pen knife.

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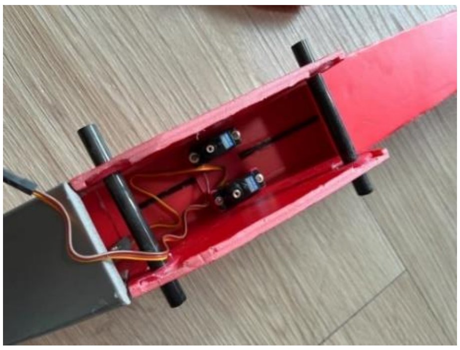
Assembling Wing  **Figure 10.** Wing Assembly	Wing is supported with carbon fibre rod. Under wings is taped with bright colours for easy identification of glider orientation when flying.
Assembling Fuselage  **Figure 11.** Fuselage Assembly	Each part of fuselage is assembled with each other by using hot glue gun and tape. The fuselage will house the electric and electronic components.
Installing Electric and Electronic Components  **Figure 12.** Electric Brushless Motor Attached to Wing  **Figure 13.** Micro Servo Installed	Electric brushless motor is attached to the top of wing and connected to receiver. Propeller is attached to the electric brushless motor. Micro servo motors are installed into fuselage and connected to control surfaces by using steel wires. Also, it is connected to receiver.

Final Assembly  **Figure 14.** Final Assembly	Wing is attached to fuselage after installation of electric and electronic components.

3.0 RESULTS AND DISCUSSION

The initial values of energy glider can be determined by doing statistical analysis during initial stage of design. Data are collected and compared from different literatures. When all data from existing gliders and studies are gathered, it is compared in line graphs. Two graphs are plotted which included graph of span vs. mass, and speed vs. span. Fitted curve method using Microsoft Excel is chosen to obtain the initial values. Both graphs show an increasing linearly trend. Speed of 22.22 m/s (80 km/h) decided in the PDS acts as the basis to know the value of span and mass. By substituting the value of speed into speed vs. span graph with the speed of 22.22 m/s, wingspan will be approximately 11.8 m, and when wingspan is 11.8 m, the mass will be approximately 248 kg. However, these values are only for estimation guideline to build the energy glider. Figure 15 and Figure 16 show the graphs plotted for statistical analysis.

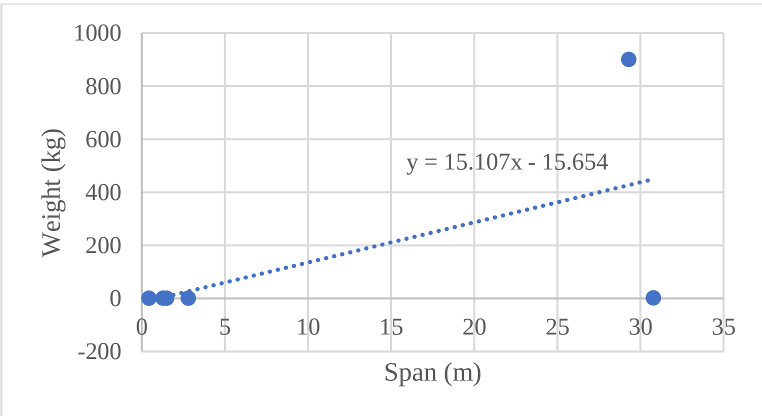


Figure 15. Span vs. Weight from Statistical Data

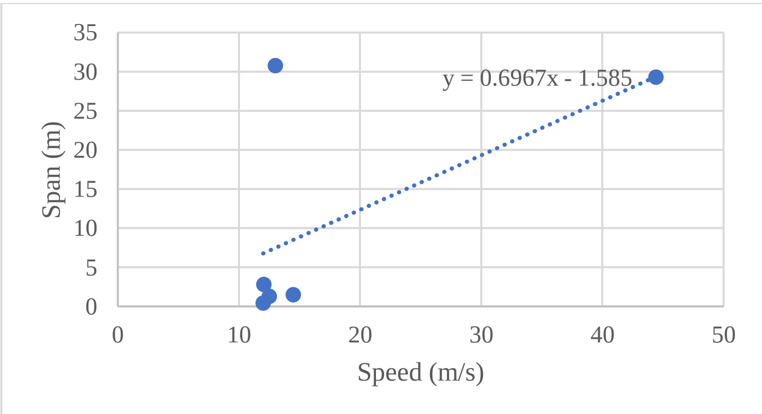


Figure 16. Speed vs. Span from Statistical Data

One energy glider is produced and underwent flight test. The flight test is important to ensure the success of energy glider design. During the flight test, aircraft performance data are obtained. Figure 16 and Figure 17 show the finished prototype of energy glider and energy glider during flight test. Table 4 shows the data obtained during flight test.

Figure 17. Finished Prototype of Energy Glider

Figure 18. Energy Glider Flight Test

Table 4. Aircraft Performance Data

Parameters	Value
Ceiling Height	Approx. 300 m
Endurance	40 mins
Range	1.2 km
Speed	144 km/h

During the flight test, the energy glider starts its flight smoothly and it is hand launched. After take-off, glider struggles to gain stability due to external disturbances such as wind. However, this problem did not persist for long as the glider gains stability soon after. Once it is stable, the glider can glide smoothly at approximately 300 m height. Due to the lack of advanced electronic components, safety precautions are taken from flying the glider at a greater height to prevent losing sight of glider. The velocity is measured by calculating the time taken for the glider to glide across a 200 m runway which is an average of 5 s. Speed obtained during the flight test is 144 *km/h* which is more than the targeted speed in PDS, >80 *km/*h. The formula used to calculate speed is as follows:

$$V = \frac{d}{t}$$

Where *d* stands for distance travelled and *t* stands for time elapsed.

Based on statistical analysis done, by using the gradient from graph of speed vs. span, y = 0.6967x – 1.585, a value of 208.96 m can be obtained for the wingspan. From this study, an energy glider with a shorter wingspan, 1.52 m is fabricated successfully which has a higher speed compared to other gliders studied for statistical analysis. However, landing of glider is bumpy due to lack of experience manoeuvring but it did not cause any damage to the glider.

A study of the airflow over airfoil at 0° angle of attack is done in ANSYS Fluent. ANSYS Fluent can produce reliable fluid simulation which is appropriate for the study of airflow over the airfoil. Some parameters are determined to help the study of the airflow. The parameters are determined from the data obtained during flight test. Table 4 shows the parameters for analysis.

Table 5. Parameters for Analysis.

Parameters	Value
Mach Number	0.11655
Normal Atmospheric Pressure	97754.26 Pa (at 300 m ceiling height)
Temperature	13.5 °C (assume 15 °C at sea level)
Wingspan	1524 mm (60 in)
Airfoil Chord Length	127 mm (5 in)

Two diagrams are generated during this analysis which are pressure contour and velocity contour diagram. Pressure contour is a line joining points with the same heights at a given barometric pressure; the point at which a plan parallel to mean sea level intersects a surface with a constant pressure. Velocity contour is done by measuring the elemental areas between subsequent isovels and adding the product of each area by the mean of its boundary velocities to determine the discharge of a stream. The analysis of the airflow over airfoil is acceptable as it complies to the logical compliance of airflow over airfoil as discussed in literature review. Figure 19 and Figure 20 show the pressure contour and velocity contour diagram.

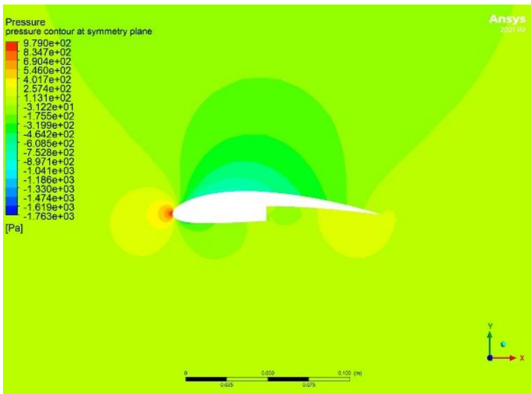


Figure 19. Pressure Contour

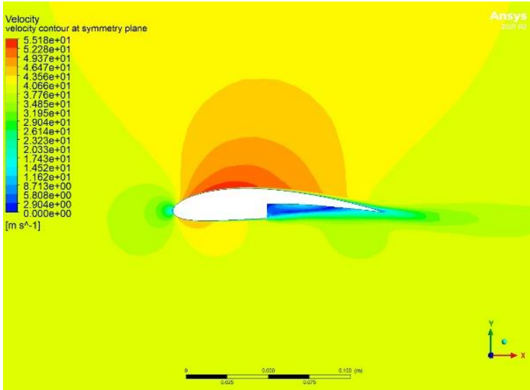


Figure 20. Velocity Contour

4.0 CONCLUSION

We can conclude that the study has met all its objectives to design, build, and fly an energy glider. Aerodynamics data such as speed of the energy glider are obtained during the flight test at 144 km/h. Although there are problems in landing the glider, overall, the flight test is successful. The design methodology is introduced to aid in running the project smoothly and ANSYS Fluent software has proven to be useful in studying the flow of air over airfoil.

Based on the results obtained, there are some suggestions that can be done for future improvement. Since the glider is hand launched, it is difficult to obtain the take-off velocity. Therefore, it is suggested to install a variometer as it can obtain various flight performance data accurately. Variometer is frequently used on gliders to measure the rate of ascend and descend by using a diaphragm-capillary device which can detect minor changes [18]. Apart from that, the estimation of ceiling height is obtained based on experience of expertise. To obtain an accurate value, altimeter can be installed to get the altitude of energy glider. To increase the duration of flight, a battery with larger capacity can be used. Apart from that, landing gear can be installed to ease glider landing. Glider performance can be analysed for future research and improvement.

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