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CIRRUS SR-22 SIMULATION WITH SWORD COMPONENT PROPORITION FOR AIRSCREW

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Abstract: - Finding the locations of the propeller blade tips in relation to one another is known as "blade tracking" (blades rotating in the same plane of rotation). Tracking does not depict the blades' real path, merely their relative position. The blades ought to follow each other as closely as they can. A propeller, also known as an airscrew, is used in aviation to propel a craft forward or backward by converting the rotating motion of an engine or other power source into a spinning slipstream. It has a power-driven rotating hub to which many radial airfoil-section blades are attached, causing the entire assembly to revolve along a longitudinal axis. The blade pitch can be fixed, manually adjustable in a limited number of places, or automatically variable of the "constant-speed" variety.

Keywords: - Blade Theory, Propellers, Cirrus SR-22

1. INTRODUCTION

Aerodynamics is a discipline of physics that studies how air and other gaseous fluids move as well as the forces that are exerted on objects that are travelling through them. In particular, aerodynamics aims to clarify the fundamental concepts underlying the flight of aircraft, rockets, and missiles. In order to establish how well-built structures like bridges and towering buildings can withstand strong winds, it is also concerned with the design of cars, fast trains, and ships. The ancients speculated about the forces at play and how they interacted after observing the flight of birds and projectiles. But they didn't really understand the physical characteristics of air, nor did they make an effort to systematically research those characteristics. The majority of their concepts were based on the premise that air provides a driving or sustaining force. These ideas were largely founded on the then-understood principles of hydrostatics, which is the study of liquid pressures. As a result, it was once believed that the impelling force of a projectile was related to forces placed on the base by the obstruction of the airflow surrounding the body. Even though it was realised in the 16th century that a projectile's energy of motion was imparted to it by the catapulting apparatus, this view of air as a helping medium rather than a resistant factor lingered for centuries. [1]

Leonardo da Vinci made the observation that air provided resistance to the movement of a solid object near the end of the 15th century and attributed this resistance to compressibility effects. Galileo later conducted experiments to prove the existence of air resistance and came to the conclusion that the resistance was inversely related to the speed of the item going through it. Christiaan Huygens and Sir Isaac Newton discovered in the late 17th century that air resistance to a body's motion was related to the square of the velocity. [1]

An aeroplane must produce thrust in order to resist drag forces. Either a jet engine or a propeller driven by a motor is used to do this. The thrust force is just sufficient to offset the aerodynamic drag while the aircraft is flying level and at a constant speed.

Furthermore, forces that oppose the flow can be produced by air that is in motion. Lift is the term for the force that prevents an aeroplane from falling. The wing of an aircraft produces lift. The path over a wing's flat bottom is shorter than the trip over the wing's curving top. The air moves more quickly over the top than it does along the bottom as a result. According to Daniel Bernoulli, one of the most influential pioneers in the subject of fluid dynamics, faster moving air has lower pressure than slower moving air, all other things being equal. This distinction enables the slower flowing air to exert more pressure on the bottom of the wing than the quicker moving air is exerting on the top of the wing. This upward force is just sufficient to offset gravity's downward force during level flight. [2]

A pilot may also use flaps on the inboard section of the trailing edge of the wing during takeoff and landing. When in the downward position, flaps increase both lift and drag to allow the plane to fly slower without stalling. Some larger aircraft can also extend slats on the front or leading edges of the wings to increase lift at low speeds.

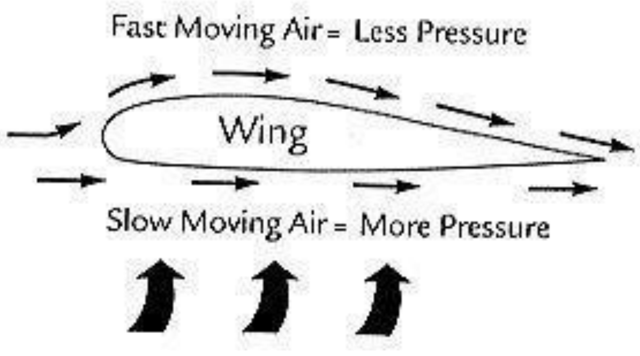


Fig 1 Aerodynamics in Planes

A stall can happen when the steady airflow across a plane's wing is interrupted, reducing the amount of lift. The Aircraft Flying Manual published by the Federal Aviation Administration states that "When the wing exceeds its critical angle of attack, this occurs. Any airspeed, any attitude, and any power setting can cause this to happen." Most stalls typically happen when an aircraft is travelling too slowly and the nose is angled upward at an excessively steep angle. Instead of moving along the top surface of the wing, the air disperses and creates turbulent swirls there. As a result, the plane begins to lose lift and fall, sometimes quite suddenly. [3]. Another A spin is a potential scenario for an aircraft. The Aircraft Flight Manual defines a spin as "an aggravated stall that happens in what is dubbed "autorotation," as the aircraft pursues a downward corkscrew trajectory." This often occurs in a progressive rotation when the faster outer wing stalls and the slower inner wing continues to provide lift. In "The Aerodynamics of a Spin" for the Canadian Owners and Pilots Association, Scot Campbell, a doctoral student in aerospace engineering at the University of Illinois at Urbana-Champaign, and Donald Talleur, an assistant chief flight instructor at the University of Illinois Institute of Aviation, write that "Successful spin recovery may be difficult if not impossible in many aircraft, especially at low altitude." One explanation for this is the possibility of going into a flat spin, wherein both wings and all control surfaces are stopped and the aircraft falls to the earth like a maple tree. [4]

Another potential outcome in an aeroplane is spin. The Aircraft Flight Manual defines a spin as "an aggravated stall that happens in what is dubbed "autorotation," as the aircraft pursues a downward corkscrew trajectory." This often occurs in a progressive rotation when the faster outer wing stalls and the slower inner wing continues to provide lift. In "The Aerodynamics of a Spin" for the Canadian Owners and Pilots Association, Scot Campbell, a doctoral student in aerospace engineering at the University of Illinois at Urbana-Champaign, and Donald Talleur, an assistant chief flight instructor at the University of Illinois Institute of Aviation, write that "Successful spin recovery may be difficult if not impossible in many aircraft, especially at low altitude." One explanation for this is the possibility of going into a flat spin, wherein both wings and all control surfaces are stopped and the aircraft falls to the earth like a maple tree. [4]

2. LITERATURE REVIEW

Lichuan Ma, Rong Ma, Peiqing Liu, and Zhongzhe Duan [1] The stratosphere airship propeller's aerodynamic design has challenges due to the stratospheric air's low density and the airship's slow flight speed. This paper first examines the characteristics of flow around an airship's propeller in an atmospheric environment and the relationship between sectional efficiency and the propeller outlet flow angle. It then discusses the theory and method of choice for the propeller's geometry parameter with the equal Re number and the equal stress principle. The authors describe a three-blade composite propeller with an airfoil with a low Reynolds Number and high lift in the design to specifically prevent the emergence of laminar separation bubble (which would reduce efficiency). Materials with variable speed and fixed pitch in accordance with the airship propeller's design parameters. The propeller's detailed specifications are: diameter D=6500 mm, real factor 62.3, maximum width 516 mm, and pith angle 32.80. The strip theory is used in the paper to examine the aerodynamic performance in great detail.

G. Chen, P. Liu, and H. Tang [2] Between dampening rings, airflow disruption has an impact on the aircraft's aerodynamics. In this research, the Reynolds stress model (LLR-QI) was used to evaluate the extra-fluent field of damping rings aircraft in order to mimic this disturbance. The findings of numerical simulations show that the gaps between the damping rings had an impact on drag coefficient. Based on these data, test results will be used to improve the aircraft's shooting accuracy.

Al-Mahadin, A., and Papageorgiou, E. [3] Due to the importance of unstable aerodynamics' influence on contemporary aircraft, particularly fighters, modelling techniques have been researched and developed. Conventional approaches, including the least-square and maximum likelihood approaches, are not fully able to anticipate all the necessary cases of unstable aerodynamics at very high angles of attack and with problems from additional factors like bad weather. Consequently, it is advisable to use artificial intelligence approaches to research alternative methods. It is well recognised that the artificial intelligence subfield of fuzzy logic can simulate unsteady and nonlinear systems in a variety of contexts, including control, stability, coupled-unstable systems, nonlinear stochastic systems, and nonlinear stochastic systems. This study looked into whether using fuzzy logic to simulate the aerodynamics of unstable aircraft was appropriate. It is determined that provided the proper aerodynamic inputs, such as angle of attack and pitch rate, are used, fuzzy modelling may reasonably describe unstable aerodynamics. It is crucial to use experimental data to train and test the FL model in order to build a trustworthy model of unstable aerodynamics. The model can be verified further by comparison with data that was collected analytically.

S. Periyasamy, K. Nikam, and V. G. Paul [4] For the design of flight control systems and in establishing the flight envelope of the aircraft, the behaviour of the aircraft during oscillations in pitch, roll, yaw, and plunge is critical. At the moment, flight tests are mostly used to anticipate the dynamic behaviour of the aircrafts. These analyses, which are costly and time-consuming, are done near the end of the aircraft development process, when there are few options to revise the design. Due to the high computational costs associated with conducting the necessary studies and the immaturity of the numerical tools available to predict the involved unsteady flow features, such as highly separated flows, computational fluid dynamics (CFD) has not yet been successfully applied in this field. The authors made an effort to perform comprehensive RANS simulations in carrying out the unstable forced dynamic motion of the aircraft and compared the results with the experimental data due to the availability of advanced computational capabilities and the maturity of CFD solvers. Moreover, efforts are made to assess the CFD-predicted flow physics. This study uses the CFD++ solver from Metacomp to validate low-speed, small amplitude pitch oscillation test data for a transonic cruiser (TCR) aircraft. The linear force fields' conservative or non-conservative estimates of the stiffness and damping of the normal force and pitching moment are used to examine how they affect the balances of energy and momentum.

M. Gerke, I. Masár, and F. Jeleniak [5] This article explains a novel method for modelling aircraft called the Projection Equivalent Method (PEM). PEM is a technique [20] that enables the creation of a mathematical representation of the aerodynamic forces and moments acting on the flying vehicle while it is in flight. PEM is unique in that it, in theory, offers an appropriate regression model for aerodynamic forces and moments with behaviour that is plausible and understandable from a dynamics standpoint. The primary benefit of the PEM is that identifying model parameters does not need conducting experiments in a wind tunnel. Certain correction parameters, which can be decided on the basis of experimental data received during an aircraft flight, can be used to generate a plausible dynamic behaviour for the model. The Projective Equivalent Technique is presented in this article and used to analyse an airship. The airship is a unique form of flying that has a very high sensitivity to the effects of aerodynamic forces. As a result, an airship makes a good comparison object between a PEM-calculated flight mechanics model and sensor data from an experimental flight. Liying Yuan, Yongqi Liu, Jiashan Cui, and Mingyu Pan[6] A type of adaptive fuzzy PID hybrid control technique, which is utilised to regulate the missile attitude motion, is intended for the characteristics of missiles during flights with nonlinear and coupling and dynamicity. The employment of fuzzy sets precise rules for the adaptive fuzzy PID controller for missile flight parameters for online self-tuning in order to more correctly reflect changes in the neighbourhood of the error rate of zero. The simulation results have demonstrated that this controller has a fast dynamic reaction time, excellent robustness, high stability, and adaptive anti-jamming capabilities. In order to improve the aerodynamic performance of the RC plane for SAE competition, this research focuses on learning the many procedures required in completing finite element analysis of computational fluid mechanics systems. The study is done for the entire aircraft as well as for wing optimization. The wing is subjected to a variety of alterations, which are subsequently evaluated. The best cases are then applied to the entire aircraft. The procedures involve developing a modelling strategy, choosing materials, modelling geometry, meshing models, implementing boundary conditions, and solving the models to arrive at the desired outcomes. Workbench is the programme used to carry out the finite element analysis. Once the results are acquired, the data are validated using model and result verification. Conclusion: The airplane-45 degree winglet provides the most lift force and the least amount of drag. K. Al-Aribe and M. Alkhedher [8] Aerodynamic loading that is nonlinear and unstable can be produced during flight manoeuvres. To model and predict aerodynamics coefficient under various values for angle of attack, Artificial Neural Networks (ANN) and Adaptive Neuro Fuzzy Logic Inference System (ANFIS) have been developed. The system is designed to simulate the pitch moment coefficients and the unstable aerodynamic normal force. The artificial intelligence models displayed low mean square errors in the results of the thorough investigation of the proposed identification methods.
F. Mohamad, R. E. M. Nasir, W. Kuntjoro, W. Wisnoe, Z. M. Ali, and N. F. Reduan [9] This document analyses the Blended Wing Body - Baseline II E2 unmanned aerial vehicle aircraft's aerodynamic properties. To determine the BWB's aerodynamic characteristics, computational fluid dynamics (CFD) Star CCM+ software has been used. By CFD analysis, utilising an unstructured mesh and the widely used Spalart-Allmaras one-equation turbulence model, the aerodynamic characteristics of the BWB-Baseline II E2 aircraft were predicted. In flight conditions of Mach 0.1 (around 34 m/s), lift coefficient (CL), drag coefficient (CD), and moment coefficient (CM) were investigated at various angles of attack,. The experimental result was contrasted with the CFD results. The findings demonstrate that lift curve trends are comparable in the linear zone (= -10° to 7°), but they diverge at higher angles of attack. The pitching moment curves between CFD simulation and experiment data diverge, with the experiment data showing a steeper curve than simulation, and the drag coefficient for CFD simulations is greater than the experimental result.

3. PROPOSED WORK

Actuator disc theory
Each pair is equal and faces the other way. They are not typically in opposition, though. The pilot must set the AA such that the lift is equal to the weight in order to fly straight and level; otherwise, the aircraft will ascend. When weight exceeds lift, the aircraft will drop. The throttles modify the engine thrust to balance the drag; if the engine thrust is more, the aircraft's airspeed will increase; if it is less, the aircraft's airspeed will decrease.
The simplest rotor theory is the actuator disc theory, which substitutes a permeable disc conveying an axisymmetric force field for the rotor. It dates back more than a century, with Froude obtaining the first analytical finding in 1889. In 1920 Betz and Joukowsky published the maximum efficiency of wind turbine rotors, while Joukowsky released the first rotor performance estimate for a helicopter rotor in hover in 1918. Even with several modifications and engineering add-ons, this momentum theory continues to serve as the foundation for contemporary rotor design rules. The classical idea with an actuator disc with thrust operating against the flow but without torque, and hence without wake swirl, is the most well-known. The Betz-Joukowsky limit can be found in this theory. Due to the influence of the pressure imparted by one annulus on the next, the findings vary when applied to a flow annulus rather than the complete stream tube. For rotors that operate with high torque at low rotational speed, the momentum theory for discs with thrust and torque is applicable. The performance rises from zero to the Betz-Joukowsky limit with increasing rotating speed. The meridional plane velocity vector at the disc seems to be constant in all flow scenarios, torque or no torque. The departure from the traditional momentum theory for the performance per annulus and the performance with torque is explained by categorizing force fields as conservative or non-conservative and investigating their impact on energy and momentum balances.

The term "actuator disc" refers to a method of evaluating rotor performance. In this model, the rotor is symbolised by a permeable disc that permits the flow to pass through it while still being impacted by the surface forces. The main component of the 1D momentum theory is the "traditional" actuator disc model, which is based on the conservation of mass, momentum, and energy. With it and a blade-element analysis combined, we arrive at the BEM model. Yet, the actuator disc might just as well be paired with a computational solution to the Euler or Navier-Stokes equations in its generic form.

The Navier-Stokes (or Euler) equations are commonly solved in a numerical actuator disc model using a second-order accurate finite difference/volume technique, as in a standard CFD calculation. However the viscous flow around the blades and their geometry remain unresolved. Surface forces that affect the incoming flow take the place of the swept surface of the rotor. This can either be done using local instantaneous values of tabulated airfoil data or at a rate equal to the period-averaged mechanical work that the rotor takes from the flow.
Propeller Blade Element Theory.

The use of Blade Element Theory is a reasonably easy way to forecast the performance of a propeller (as well as fans or windmills). The propeller is split into a number of independent portions throughout its length using this technique. A force balance that takes into account the 2D section lift, drag, thrust, and torque produced by the section is applied at each section. A balance of axial and angular momentum is applied simultaneously. This results in a set of nonlinear equations that may be resolved for each blade section iteratively. The section thrust and torque figures that result can be added to determine the propeller's total performance.
The hypothesis excludes secondary effects like the 3-D flow velocities caused by the shed tip vortex on the propeller or the radial components of flow caused by angular acceleration from the propeller's rotation. This theory will under-predict torque and over-predict thrust when compared to actual propeller performances, leading to a 5% to 10% gain in theoretical efficiency above observed performance. Some of the created flow assumptions fail under severe circumstances when the flow on the blade becomes halted or when a sizable portion of the propeller blade is configured as a windmill while the remaining portions are still providing thrust.
The hypothesis has been proven to be quite helpful for comparison research, such as figuring out the best propeller blade solidity or optimising blade pitch setting for a specific cruise speed. It remains the greatest tool available for obtaining accurate first order forecasts of thrust, torque, and efficiency for propellers under a wide variety of operating situations despite the aforementioned drawbacks

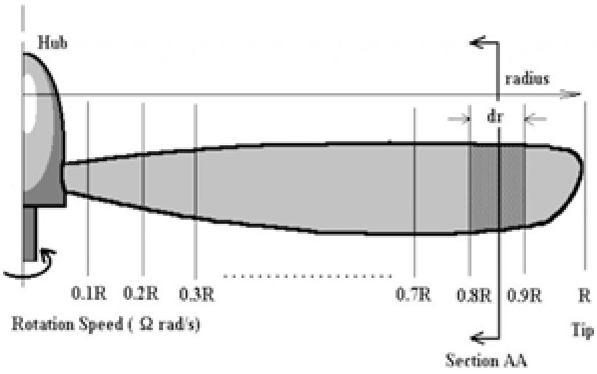


Fig 2 Blade Element Sub-Division

4. IMPLEMENTATION AND RESULTS

We used a Jabiru Light Aircraft Propeller for the simulation. The following attributes and dimensions were measured in labs using 12 pieces of 0.05 m. (5cm). The total number of blades 2 and diameter of blade is 1.52 m.

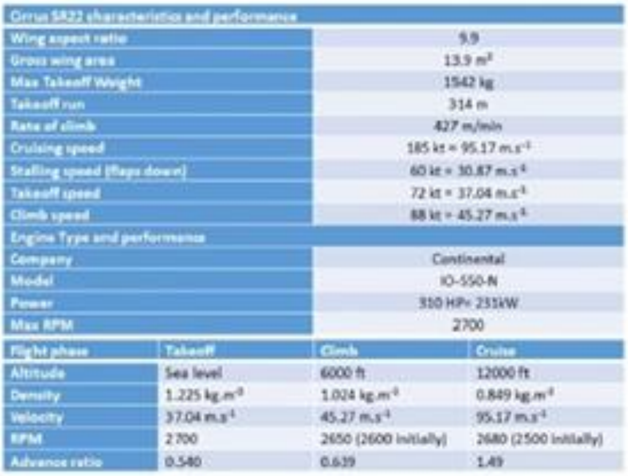
Table 1 Dimensions and Characteristics of Blade

SECTION (m)	Thickness to chord ratio	PITCH (rad)	CHORD LENGTH (m)	THICKNESS (m)
0.150	0.539	0.570	0.106	0.057
0.200	0.514	0.540	0.111	0.057
0.250	0.485	0.506	0.115	0.056
0.300	0.457	0.475	0.118	0.054
0.350	0.427	0.441	0.119	0.051
0.400	0.401	0.413	0.115	0.046
0.450	0.381	0.391	0.105	0.040
0.500	0.349	0.356	0.100	0.035
0.550	0.349	0.356	0.092	0.032
0.600	0.342	0.349	0.082	0.028
0.650	0.345	0.352	0.072	0.025
0.700	0.335	0.342	0.063	0.021

[Data Source : Sample Lab Study]

Fig 3 Cirrus SR-22

When simulating, we take into account that the Cirrus SR-22's Jabiru propeller has the characteristics listed in Fig. 4.



Cirrus SR22 characteristics and performance	
Wing aspect ratio	9.9
Gross wing area	13.9 m^2
Max Takeoff Weight	1542 kg
Takeoff run	314 m
Rate of climb	427 m/min
Cruising speed	185 kt = 95.17 $m.s^{-1}$
Stalling speed (flaps down)	60 kt = 30.87 $m.s^{-1}$
Takeoff speed	72 kt = 37.04 $m.s^{-1}$
Climb speed	88 kt = 45.27 $m.s^{-1}$
Engine Type and performance	
Company	Continental
Model	IO-550-N
Power	310 HP= 231kW
Max RPM	2700

Flight phase	Takeoff	Climb	Cruise
Altitude	Sea level	6000 ft	12000 ft
Density	1.225 $kg.m^{-3}$	1.024 $kg.m^{-3}$	0.849 $kg.m^{-3}$
Velocity	37.04 $m.s^{-1}$	45.27 $m.s^{-1}$	95.17 $m.s^{-1}$
RPM	2700	2650 (2600 initially)	2680 (2500 initially)
Advance ratio	0.540	0.639	1.49

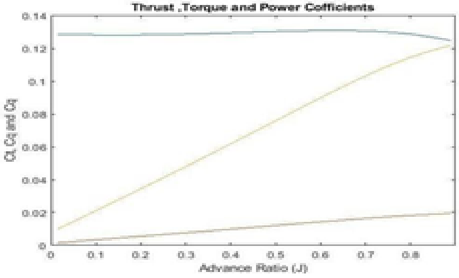
Fig 4 Cirrus Sr-22 Characteristics

We can utilise XFOIL (reference to MIT website) which provides these coefficients for the specific airfoils and Reynolds numbers to acquire the coefficients of lift and drag for our propeller in our MATLAB code for the calculation of the Cruse heights and velocities.

The engine is a Continental Io 550, and it has a maximum APM of 2700 and a power output of 301kw. Finally, the flight's altitude during cruise is 12000 feet.

The air density is zero point eight nine kilograms per cubic metres. The velocity of flight would just so is ninety five point seventeen metres per second. The OPM is two thousand sixty two thousand six hundred eighty.

Initially at the start of crews two thousand five hundred will take 2500 here and finally the advanced ratio of the propeller at cruising altitude and at this crew's velocity is one point forty nine we will run our Matlab program at cruise altitude and velocities of the Sirius or Cirrus.



So , cruise altitude and velocities of the Sirius assault 20 to equip the Jabiru proper so in order to obtain the coefficients of lift and drag for propeller because we need them of course in our blade element theory calculations to obtain the lift and drag we can use X foil which is a M.I.T. software open source software that is developed where a lot of different shapes of air falls are recorded and the software actually allows to work out a different lift coefficients and coefficients of drags and center of pressures and so on at different Reynolds Number.

Test Case for Takeoff

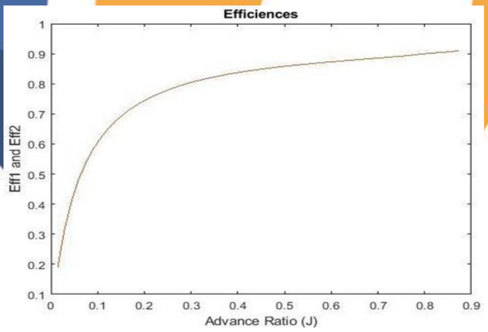
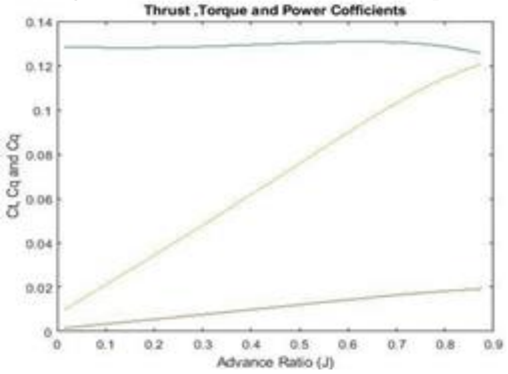
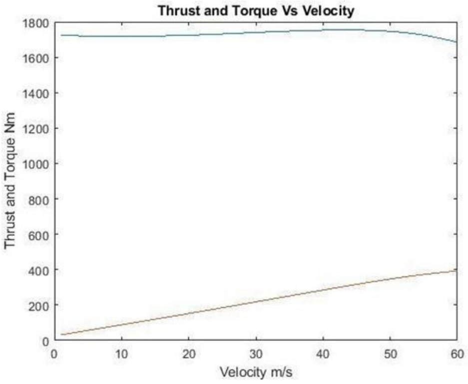


Fig 5 Takeoff Case Thrust, Torque and Power Coefficient Graph

Fig 6 Takeoff Case Efficiencies Graph





Test Case for Climb

Fig 8 Climb Case Thrust, Torque and Power Coefficient Graph

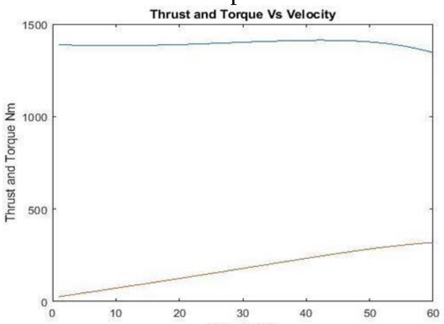


Fig 9 Climb Case Trust and Torque Graph

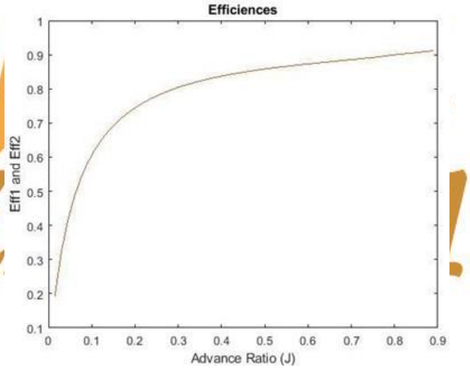


Fig 10 Climb Case Efficiencies Graph

5. CONCLUSION

We can utilise XFOIL (reference to MIT website) which provides these coefficients for the specific airfoils and Reynolds numbers to acquire the coefficients of lift and drag for our propeller in our MATLAB code for the calculation of the Cruse heights and velocities. The engine is a Continental Io 550, with a maximum APM of 2700 and a power output of 230 000 watts. Finally, the flight's altitude during cruise is 12000 feet. In order to obtain the coefficients of lift and drag for propellers because we obviously need them in our calculations using the blade element theory, we can use X foil, an M.I.T. software open source software that was developed where a lot of different shapes of air falls are recorded and the software actually allows to work out a variety of lift coefficients. Blade Element Theory in MATLAB has been used to build and model a propeller in actual flight conditions. The simulations are carried out utilising three flight modes: takeoff, climb, and cruising.

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