

Optimization of Different Materials for Drone Blades Using Computational Fluid Dynamics

Mustafa A. S. Mustafa

Department of Refrigeration and Air Conditioning Engineering, Al-Rafidain University College, Baghdad, Iraq
mustafa_atalib@ruc.edu.iq

Karar Saeed Mohammed

Department of Medical Physics, Al Manara College for Medical Sciences, Maysan, Iraq
karar.s.mohammed@uomanara.edu.iq

Hind Hussein Abbood

Training and Workshop Center, University of Technology-Iraq, Baghdad, Iraq
hind.h.abbood@uotechnology.edu.iq

Muhammad Asmail Eleiwi

Electromechanical Engineering Department, College of Engineering, University of Samarra, Samarra, Iraq
dr.muhammad@uosamarra.edu.iq (corresponding author)

Hasan Shakir Majdi

Department of Chemical Engineering and Petroleum Industries, Al-Mustaqbal University College, Hillah, Babylon, Iraq
dr.hasanshker@uomus.edu.iq

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ABSTRACT

This research utilizes Computational Fluid Dynamics (CFD) modeling to identify suitable materials for drone blades that present the best potential solutions. The primary objectives are the utilization of minimal resources and the implementation of lightweight construction methodologies to achieve optimal aerodynamic results. A distinct materials design strategy is employed in the blade's composition, with each component optimized for peak efficiency and performance. The modern aerial platform DJI Phantom 3 Pro was selected as the test platform due to its excellent capabilities and user-friendly interface. The original model of the DJI Mini 3 Pro drone was modified by printing its blades using an Anycubic printer that had 4K resolution and resin materials. An experimental procedure was designed to measure drone speed and maximum flight elevation after changing these newly designed blades. The choice of blade material significantly influenced flight performance. The speed of drone flight is 34.9 km/h when using XMODEL15 blades, 18.4 km/h with Industrial ABS, and 15.3 km/h with ABS-Like blades. CFD simulations predicted a maximum air velocity of 3.716 m/s around the blades. Additionally, the XMODEL15 blades demonstrated the highest durability, enduring up to 118,750 cycles, whereas Industrial ABS achieved 90,655 cycles and ABS-Like achieved 70,384 cycles. These results confirm XMODEL15 as a superior material in terms of both aerodynamic performance and structural durability.

Keywords-different materials; drone blade; CFD; DJI Phantom 3 Pro; 3D printing

I. INTRODUCTION

Drone technology advancements have led to a need to improve blade efficiency while addressing weight, material usage, and aerodynamic performance. This study uses

Computational Fluid Dynamics (CFD) to optimize multipolymer drone blades, focusing on the relationship between material characteristics and aerodynamic performance.

Authors in [1] examined the impact of factors like empennage position and material selection on the structural strength of a hybrid Vertical Takeoff and Landing Unmanned Aerial Vehicle (VTOL UAV). A 3D model of fiberglass and carbon fiber was created using SolidWorks software, and simulations were conducted. Their findings, which identified fiberglass as the optimal material for the top empennage, are crucial for understanding composite material strength and the optimal location for hybrid VTOL UAVs. Authors in [2] used artificial intelligence algorithms to apply generative design to an aerodrone structure system design case study. They examined the strengths and weaknesses of various Unmanned Aerial Vehicle (UAV) configurations, manufacturing methods, and materials. The refractory index was developed using square shape, 3D printing, and PEEK lens types. Their aim was to demonstrate that generative design is still applicable in optimizing drone frames. Authors in [3] described the design of a small UAV using the 3DEXPERIENCE program and materials like PLA, ASA, and ABS. The drone consisted of four main parts, and the study incorporated simulations and trade-off studies for stress, displacement, and weight. It was observed that the hook fastening design style eliminates the need for extra fasteners.

Authors in [4] analyzed the honeycomb rocket armor's impact on a UAV fuel tank during a blast using a tri-layer superposition model and bidirectional stress analysis. The results aid in optimizing the honeycomb barrier's structural design, leading to the creation of an explosively proof fuel tank structure for UAVs. Authors in [5] developed a multi-parameter optimization method for artificial wings using anisotropic honeycomb patterns. These pseudo-MEMS wings can sustain long-term resonance excitation, potentially enabling natural resonance flights. The study validated the use of metamaterial patterns in flapping flight engineering, as they can influence aerodynamic and acoustic properties of passenger planes. Authors in [6] aimed to improve the fly-ability, trim-ability, stability, and control of a mono-wing flying object as a wheeled under-actuated multi-body system. A non-linear system was developed using a software application and a conceptual prototype connected to hardware components. The model, based on a complex rotational dynamic, allowed for increased mobility and stability in hovering-climbing of the balloon.

Authors in [7] proposed a design method for lightweight, easy-to-maintain rotary-wing UAVs, focusing on configurable design, topology optimization through inertia release, fast manufacturing and maintenance, and dynamic testing for safety and crashworthiness evaluations. This expedient approach enabled the creation of thin-walled UAVs with a thin-walled structure. Authors in [8] exploited Template Optimization (TO) for creating challenging areas for the eVTOL Personal Air Vehicle (PAV) applications. Their target was to create wing strakes with the joining and wing fuselage structures that are able to use additive manufacturing without any negative effect. The mixtures should combine multiple material combinations and to be able to perform under aerodynamic pressure loading, vertical takeoff and landing, and cruise thrust loading. Authors in [9] examined the impact of ground delays, static water, and dynamic surges on the aerodynamic efficiency of ducted fans

in VTOL vehicles. The research used the sliding mesh technique to analyze the wall, water surface, and wave effects on the fan system. It was demonstrated that the rigid ground effect benefits the blade but limits the duct's lift, resulting in lower overall lift. The speed effect is evident in both ground and water effects, but the water effect has different rules governing lift and torque changes. The growing ripple has the greatest impact, causing aircraft to experience changeable changes in lift and torque.

Authors in [10] focused on the estimation of thrust coefficient and performance analysis of two- and four-blade propellers for quadcopters using CFD. By designing propellers in CATIA and analyzing them with Ansys Fluent, the research helps develop mathematical models to improve flight maneuverability and compares the performance in terms of thrust force and payload capacity. Authors in [11] employed CFD simulations to optimize the propulsion system of a ducted multi-propeller drone. A previously optimized single-propeller duct was initially used, attaining a 24.5% increase in lift and 38.1 percentage points increase in efficiency. Subsequently, a quadrotor was implemented and 22 cases of CFD were run to experiment with rotor spacings and heights. The duct improved performance by reducing vortex losses and enhancing airflow. The identification of the optimal configuration was facilitated by the implementation of a surrogate model. In the study by authors in [12], a comparative analysis was conducted between single and coaxial UAV propeller configurations using ANSYS Fluent. The models, prepared in SolidWorks, were evaluated at an inlet velocity of 15 m/s. The coaxial system delivered a higher airflow velocity (~416m/s vs. ~137m/s) at the expense of an increase in turbulence. CFD proved to be a valuable tool for the assessment and optimization of aerodynamic performance.

Authors in [13] aimed to conduct a cost-effective atmospheric CO₂ profiling using tethered sensors on quadcopters in urban India. It was shown that CO₂ and the comfort index levels change significantly depending on the diurnal and seasonal variation and altitude. By improving environmental monitoring with commercial drones that have high spatial resolution, this innovative methodology is an improvement.

This study aims to improve drone blade aerodynamic efficiency and reduce material usage, resulting in a lightweight design without compromising performance. The objective of this study is to replace blades from a DJI Phantom 3 Pro with different materials and to assess the impact of these materials on the speed and height of the drone. The material characterization will evaluate the impact of XMODEL15, Industrial ABS, and ABS-Like on the drone's speed, height, and fatigue life, aiming to find the most durable and high-performing material. The novelty of this study is related to the use of XMODEL15 material, which demonstrates the considerable advantages in aerodynamic characteristics (the highest speed, altitude, and fatigue life). These advantages are verified both with the help of simulation and experimental testing. Furthermore, the present study is among the first to combine CFD, material mechanical testing, and drone field performance tests utilizing high-resolution 3D-printed resin blades. These contributions suggest new approaches towards

material optimization of UAVs and create ground to further progress in the creation of lightweight, high-durability aerial components based on state-of-the-art printable resins.

II. MATERIALS AND METHODS

A. Geometry

The DJI Phantom 3 Pro is a contemporary aerial platform that combines advanced technology with user-friendly layout. This venture uses the SolidWorks software program to model the drone, ensuring precision and versatility in engineering layout. The drone's components, along with its aerodynamic frame and gimbal stabilization gadget, are meticulously modeled and refined to optimize overall performance, sturdiness, and consumer satisfaction. Advanced features like parametric modeling, meeting constraints, and finite detail evaluation ensure quality and reliability, as illustrated in Figure 1. This work aims to create a visually appealing rendition of the drone, surpassing expectations in capability and overall performance [14].

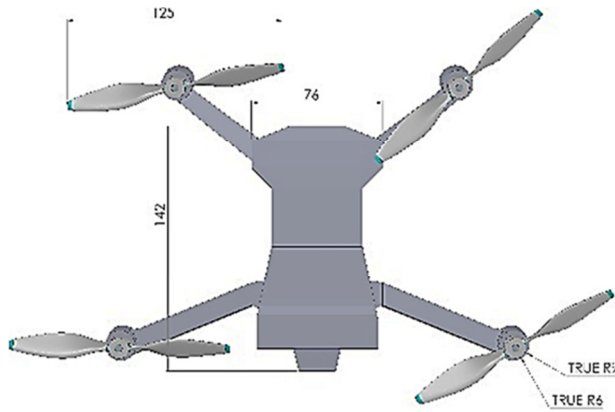


Fig. 1. Geometry of the drone with dimensions.

B. Mesh

The accuracy and stability of CFD results heavily depend on the quality and resolution of mesh treatment. Coarse meshes can lead to poor predictions of flow structures, velocity, pressure, and turbulence effects. Incorrect mesh refinement can result in undesirable numerical diffusion, rounding sharp gradients in aerodynamic performance measurements. The combination of elements with low ratios and poor boundary layer resolution can cause simulation errors, especially when analyzing turbulent and high-speed flows. To minimize mesh dependency, a grid independence study is conducted by testing numerical solutions with thinner meshes until predictions reach an acceptable tolerance level, as shown in Table I. This procedure ensures that mesh selection does not influence computational results.

TABLE I. MESH INDEPENDENCE

Case	Element	Node	Max. deformation (mm)
1	313,687	407,522	0.189
2	935,342	455,435	0.161
3	986,722	565,865	0.157
4	137,260	818,340	0.155

C. Boundary Conditions

CFD simulations using software such as ANSYS Fluent can provide insights into the drone's performance and structural fatigue. The study also focuses on the fatigue characteristics of key components, predicting their lifespan to prevent premature failure and ensure reliable operation over extended periods. This holistic technique for UAV layout and analysis combines CFD with structural sturdiness analysis and includes the following components:

- **Flow field analysis:** To simulate the aerodynamic behavior, CFD analyses were conducted using ANSYS Fluent with a tetrahedron mesh comprising 137,260 cells. The boundary conditions for the propeller and drone body were defined, including entrance velocity, output pressure, and wall conditions. The main variables examined were pressure distribution, streamline patterns, turbulence intensity, and velocity contours. These characteristics were used to assess the aerodynamic performance of different propeller materials.
- **Flow field estimations:** The study aimed to determine the drone's top speed on the selected propeller material, resulting in a maximum air velocity of 3.716 m/s around the blades. It also assessed the impact of material characteristics on propeller blade flow velocity and examined streamline patterns to understand the propeller's flow behavior, identifying flow separation points and high- and low-pressure zones. The pressure distribution on the propeller blades was estimated to determine lift and drag forces, with higher-pressure differences indicating better aerodynamic performance. The study also evaluated the flow field's turbulence intensity to determine how material qualities affect airflow stability, and compared performance parameters for several propeller materials. This comparison enabled informed decisions about the best material for drone propellers.

D. Governing Equations

1) Governing Equations for Fluid Dynamics

The behavior of airflow around the drone blades is governed by the Navier-Stokes equations, which describe the conservation of mass, momentum, and energy in a fluid. These equations are as follows:

- Continuity equation (mass conservation):

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho v) = 0 \quad (1)$$

where ρ is the air density (kg/m^3), and v is the velocity vector (m/s).

- Momentum conservation (Navier-Stokes equation):

$$\frac{\partial (\rho v)}{\partial t} + \nabla \cdot (\rho v v) = -\nabla P + \nabla \cdot \tau + \rho g \quad (2)$$

where P is the pressure (Pa), τ is the viscous stress tensor, and g is the gravitational acceleration (m/s^2).

- Energy conservation equation:

$$\frac{\partial (\rho E)}{\partial t} + \nabla \cdot (v(\rho E + P)) = \nabla \cdot (k \nabla T) + \Phi \quad (3)$$

where E is the total energy per unit volume, k is the thermal conductivity (W/m·K), T is the temperature (K), and Φ is the viscous dissipation term.

For the purpose of turbulence modeling, Reynolds-Averaged Navier-Stokes (RANS) or Large Eddy Simulation (LES) may be employed, with models like k- ϵ , k- ω , or Spalart-Allmaras.

2) Governing Equations for Structural Analysis

Since drone blades experience aerodynamic forces, structural analysis is required to evaluate stress, deformation, and fatigue behavior. The equations determining structural response are as follows.

- Equilibrium equations (force balance):

$$\nabla \cdot \sigma + F = 0 \quad (4)$$

where σ is the stress tensor and F is the external force per unit volume.

- Stress-strain relationship (Hooke's law for linear elastic materials):

$$\sigma = C : \epsilon \quad (5)$$

where C is the stiffness matrix, depended on material properties, and ϵ is the strain tensor.

- Strain-displacement relation:

$$\epsilon = \frac{1}{2} (\nabla u + (\nabla u)^T) \quad (6)$$

where u is the displacement vector.

- Modal analysis equation (natural frequency and vibration):

$$[M]\{\ddot{u}\} + [K]\{u\} = 0 \quad (7)$$

where $[M]$ is the mass matrix, $[K]$ is the stiffness matrix, and $\{u\}$ is the displacement vector.

For composite or advanced materials, anisotropic elasticity models may be required.

Fatigue testing was performed in order to assess the endurance and the structural lifetime of drone blades that are created using varied 3D-printed materials when subjected to multiple aerodynamic loads. In real-world flight conditions, drone propellers are subject to cyclic aerodynamic effects resulting from the rotor's high-speed rotation and its interaction with the air in and around it. These are cyclic stresses that may induce material fatigue, initiating cracks that propagate over time, causing blade failure. The purpose of the fatigue test was to estimate the service life (i.e., loading cycles) that each material should exhibit. The test was also used to determine which material exhibited the greatest resistance to fatigue failure when subjected to the same operational conditions. Furthermore, the results of the test provided support for material selection decisions for applications in which long-term structural integrity is vital, such as surveillance, delivery, and aerial mapping. A numerical evaluation of fatigue behavior was conducted using CFD and structural simulation in ANSYS. This was followed by the validation of critical responses of the

material in operational drone conditions. The numerical fatigue simulation parameters are as follows:

- Type of simulation: Coupled CFD–FEA (Fluid-Structure Interaction).
- Load type: Aerodynamic pressure variations simulating fluctuations in periodic lift and drag forces acting on rotating blades.
- Rotation speed: 7,000-8,500 rpm (typical for DJI Mini 3 Pro).
- Stress source: Variation in air pressure caused by rotor motion in the course of lift.
- Cycles applied: Up to 120,000 cycles (approximating \ long-term use of drones).
- Failure criteria: According to accumulated stress that is greater than the fatigue endurance limit.
- Mesh quality: Finer mesh is employed around the root and leading-edge regions to accurately capture stress concentrations.
- Solver: ANSYS fatigue tool without the Goodman mean stress correction.

The experimental validation parameters are as follows:

- Number of cycles: Estimated based on the usual duration of a mission (e.g., 20 m flight, ~100,000 propeller revolutions).
- Material degradation indicators: Cracking of the surface, delamination, and instability of hovering over extended periods are occurring.
- Visual monitoring: Endurance testing is conducted with the use of a high-speed camera and digital telemetry.
- Failure definition: Failure of blade or considerable degradation in the performance of a blade (vibration, noise, and deformation).

III. EXPERIMENTAL WORK

A. Experimental Setup

The experimental setup of this study was performed through a modified DJI Mini 3 Pro drone, whose initial plastic blades of propellers were replaced with custom-made blades made of three polymers. The new blades were 3D-printed with an Anycubic Photon Mono X 4K resin printer, a fabrication technique capable of producing high-resolution outputs suitable for aerodynamic testing.

Each blade type was subjected to the same flight conditions to ensure reliable performance comparison. The experimental setup included an outdoor environment with minimal wind interference, a fully charged battery to sustain consistent power output, and an identical payload and configuration. Flights were conducted in GPS-stabilized mode and the flight speed and maximum altitude were recorded using onboard telemetry and GPS data.

Every material was subjected to the same drone platform, and trials were made on three different occasions for each class of materials. Data averaging was employed to obtain mean results with a minimal variance.

B. Materials used for Blade Fabrication

The experiment focused on three materials, selected for their availability in resin 3D printing and contrasting mechanical characteristics, as shown in Table II.

TABLE II. MATERIALS USED FOR BLADE FABRICATION

Material	Source type	Description
XMODEL15	Resin-based (Nexa3D)	A high-strength, high-modulus photopolymer resin for precise and durable printing
Industrial ABS	ABS resin blend	An impact-resistant, industrial-grade ABS-like polymer
ABS-Like	Flexible resin	A more flexible, ABS-simulating photopolymer, easier to print but less rigid

C. Blade Material Properties

Table III summarizes the key mechanical properties of the materials as used in both simulation and experimental validation [15].

TABLE III. MATERIAL PROPERTIES

Properties	ABS-Like	Industrial ABS	xMODEL15
Izod impact resistance	2.32 kJ/m ²	9.5 kJ/m ²	1.44 kJ/m ²
Elongation at break	3%	7.2%	10%
Tensile strength	12 MPa	25.8 MPa	55 MPa
Tensile modulus	116 MPa	47.9 MPa	1800 MPa

XMODEL15 was the most rigid and strong, as evidenced by its high modulus of tensile strength, making it well-suited for use in bearing structures. Industrial ABS was a material that exhibited poor flight performance, yet it demonstrated superior impact resistance. ABS-Like demonstrated the greatest flexibility, yet it exhibited lowest mechanical strength, resulting in diminished speed and fatigue resistance.

The original DJI Mini 3 Pro drone model was printed with altered rotor blades using an Anycubic printer, which employed 4K resolution resin materials for printing. Subsequently, speed and altitude testing was conducted on the drone. The printed blades are illustrated in Figure 2.

D. Measurement Parameters

The parameters that were measured in flight tests included the maximum drone flight speed (km/h), the maximum altitude (m), the fatigue life (calculated from the number of loading cycles until failure), and the CFD damage contour. The results of the study were then compared and analyzed to determine the most suitable material for the fabrication of the drone blade, in terms of aerodynamic efficiency, strength, and fatigue resistance.

The primary objectives of the aerodynamic calculations in this research are the performance optimization and the

structural toughness of the blades constructed from different materials. First, the aerodynamic assessment aims to evaluate the influence of material properties, including tensile strength, stiffness, and density, on airflow patterns, pressure distribution, lift, drag, and overall thrust efficiency. These aerodynamic measures will directly influence the drone's top speed, altitude, as well as flight stability. For example, the XMODEL15 blades demonstrated enhanced aerodynamic performance due to their high strength and stiffness, which enabled the retention of their shape at high rotational speeds. This, in turn, resulted in increased lift, consequently elevating the flight speed and altitude.



Fig. 2. 3D-printed drone blades.

Secondly, the aerodynamic results serve as the basis for the subsequent analysis of structural fatigue. The pressure distributions resulting from CFD simulations are used as input loads during Finite Element Analysis (FEA) to assess the fatigue behavior of each constitution material under cyclic aerodynamic stress. This method facilitates the prediction of fatigue life and the identification of areas of critical stress that are likely to fail. Therefore, apart from enhancing the flight performance, aerodynamic calculations also convey the idea of long-term material durability understanding. This coordinated system ensures that material selection and blade design are optimized for both immediate aerodynamic efficiency and long-term structural stability through recurrent flights.

IV. COMPARISON WITH EXISTING STUDIES

Several prior studies have employed CFD to enhance the aerodynamic characteristics and material selection of drone propellers. For instance, authors in [10] and [11] investigated thrust coefficients and air flow behavior various blade geometries using CFD. Utilizing CFD, they were able to determine the optimal values, namely tip clearance set at 0.001 m, inlet height fixed at 0.045 m, the length of a diffuser fixed at 0.03 m, and an inlet radius set at 0.02 m. An increase of 24.5 %

in lift and a 38.1 percentage point increase in fan motor was observed in comparison with the non-ducted scenario. However, a direct comparison reveals that most of these studies were based on the common, traditional materials, such as PLA, ABS, or carbon fiber composites. The present study describes a new material for drone blades, namely the XMODEL15 high-

strength resin-based material that was not previously analyzed. In contrast to the aforementioned studies, this research not only simulates but also fabricates and experimentally tests drone blades with XMODEL15, Industrial ABS, and ABS-Like materials. This approach enables computational-experimental confirmation, as illustrated in Table IV.

TABLE IV. COMPARISON WITH PREVIOUS STUDIES

Study	Materials used	Max. speed	Max. altitude	Fatigue life	Experimental validation
[10]	PLA, ABS (simulated)	~25–30 km/h (estimated)	Not reported	Not reported	No
[11]	ABS, Carbon fiber (simulated)	Not reported	Not reported	Not reported	No
[12]	ABS variants (simulated)	~22–26 km/h (estimated)	Not reported	Not reported	No
This study	XMODEL15, Industrial ABS, ABS-Like	34.9 km/h (XMODEL15)	236 m (XMODEL15)	118,750 cycles (XMODEL15)	Yes

V. RESULTS AND DISCUSSION

This section presents a comprehensive discussion of the outcomes derived from the experimental tests, including the drone speed and height, as well as the fatigue behavior.

A. Effect of Blades on Air Velocity

Blade layout significantly influences airflow velocity and overall drone performance. The pitch and the angle of attack of the blades determine the path and speed of the airflow. Higher-

pitched blades generate more thrust, whereas well-designed blade profiles produce smoother airflow and higher thrust. The blade's form and profile impact airflow speed by influencing acceleration and redirected air. The material composition and weight of the blade have an impact on its inertia and reaction to motor strength. The diameter of the rotor and the Revolutions Per Minute (RPM) of the motor directly impact the volume and speed of the generated airflow. As illustrated in Figure 3, the maximum speed predicted by simulation for this blade design is 3.716 m/s.

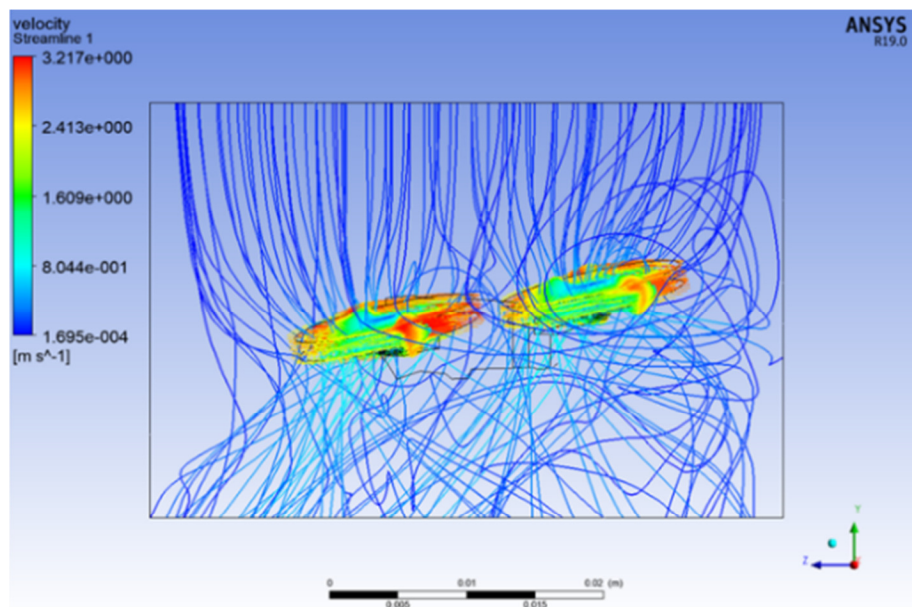


Fig. 3. Simulated airflow streamlines.

B. Effect of Blades Type on Fatigue Life

The type of drone blades significantly influences their fatigue life, with materials like carbon fiber or fiberglass-strengthened composites offering superior fatigue resistance. Well-designed blades, with clean surfaces, steady thickness, and uniform cloth distribution, are less susceptible to stress concentrations and premature failure. The structural integrity, stiffness, flexibility, and damping characteristics also influence fatigue life. Dynamic loading conditions, flight maneuvers, and

air density adjustments also have an effect on fatigue life. Regular maintenance and inspection are crucial for ensuring continued airworthiness and extending blade lifespan.

As illustrated in Figure 4, the number of cycles remaining to prevent overloading reached 118,750 cycles with the XMODEL15 material. Industrial ABS material reached 90,655 cycles and ABS-Like material reached 70,384 cycles. These results highlight the superior fatigue resistance of the XMODEL15 material.

C. Effect of Blade Material on Fatigue Damage

Blade material significantly influences drone fatigue damage resistance. Materials with high power and fatigue resistance, such as carbon fiber or fiberglass-bolstered composites, are less susceptible to damage and have better damping properties. Blades must be resistant to environmental factors like UV radiation, moisture, and temperature. Structural integrity, blade thickness, geometry, and reinforcement functions also affect fatigue damage. Dynamic loading

conditions like flight maneuvers and wind gusts can accelerate damage. Precision-made blades are less likely to cause fatigue cracks. Therefore, choosing top-quality blades, proper design, and rigorous quality control measures are crucial for drone blade durability and reliability. The magnitude of damage during air pressure in the simulation process was found to be 8,421.2 for the XMODEL15 material, 11,031 for the Industrial ABS material, and 14,208 for the ABS-Like material (Figure 5).

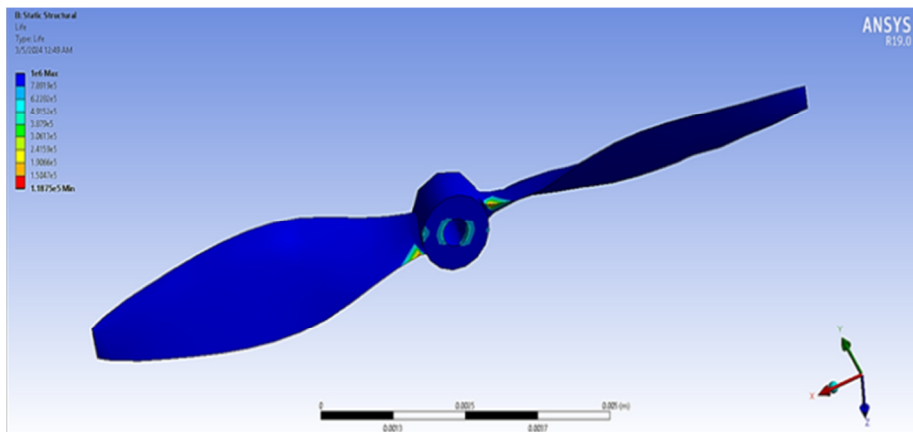


Fig. 4. Fatigue life contour of the XMODEL15 blade material.

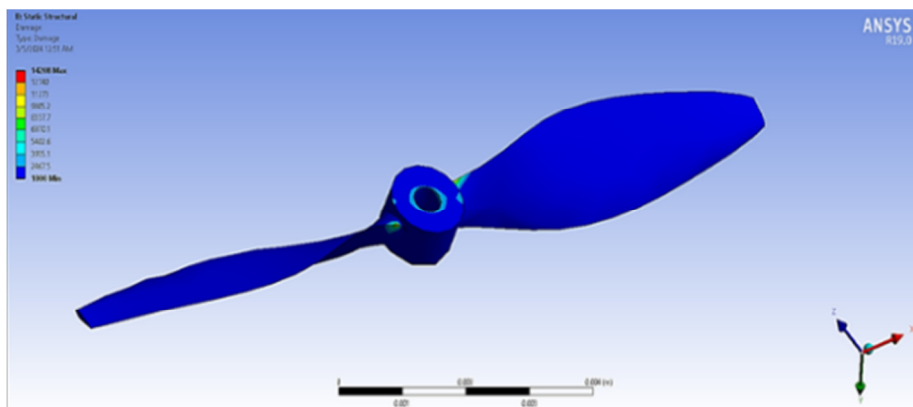


Fig. 5. Damage contour of the ABS-Like blade material.

Drone speed reached 34.9 km/h when using XMODEL15 blades, 18.4 km/h with Industrial ABS, and 15.3 km/h with ABS-Like blades. However, drone speed alone is insufficient for aerodynamic estimation due to its multifactorial nature. This multifactor nature includes factors such as air density, airflow patterns, pressure distribution, turbulence, blade shape, angle of attack, rotational speed of propellers, and environmental conditions. These factors cannot be fully captured by speed alone, and CFD analysis is used to estimate these flow fields and pressures. The aerodynamic performance also depends on the material and structure of drone blades, which affect stiffness, fatigue life, and deformation under load. Materials like XMODEL15, Industrial ABS, and ABS-Like influence aerodynamic efficiency by affecting blade behavior under aerodynamic forces, which cannot be inferred simply by speed. For rotary-wing drones, the rotational speed and pitch

angles are critical aerodynamic parameters, affecting thrust generation and overall aerodynamic efficiency. Drone forward speed is an effect of these forces but does not independently inform about the detailed aerodynamic interactions. Environmental conditions, such as air density, wind gusts, and turbulence intensity, also affect aerodynamic forces. Two drones flying at the same speed but in different atmospheric conditions will experience different aerodynamic performances. Fatigue and damage considerations are also influenced by aerodynamics, which cannot be captured by speed alone. To properly estimate aerodynamic performance, a comprehensive analysis including CFD simulations, material properties, blade geometry, rotational speeds, and environmental conditions must be considered.

VI. CONCLUSION

The objective of the present study is to optimize the aerodynamic performance and lightweight design of drone blades using Computational Fluid Dynamics (CFD) modeling. The DJI Phantom 3 Pro drone model was subjected to testing that entailed the printing of new blades using 4K resolution and resin materials, and a comparison was made of the speed and height attained by the drone. The results are summarized as follows:

1. Aerodynamic performance: The XMODEL15 material demonstrates the best performance at 34.9 km/h and a maximum altitude of 236 m, due to its superior aerodynamic properties and strength-to-weight ratio. Industrial ABS material achieves a maximum speed of 18.4 km/h and a maximum altitude of 179 m; however, its efficiency is compromised due to its less favorable aerodynamic and strength properties. ABS-Like material demonstrated the least effective performance, with a maximum speed of 15.3 km/h and a maximum altitude of 113 m, likely due to its lower strength and higher weight. CFD simulations revealed that the maximum air velocity around the blades is 3.716 m/s.
2. Fatigue life of blade materials: XMODEL15 exhibits the highest fatigue life, with 118,750 cycles, indicating its ability to endure the most prolonged usage under air pressure. Industrial ABS demonstrates a fatigue life of 90,655 cycles, whereas ABS-Like exhibits the lowest fatigue life at 70,384 cycles.
3. Damage from air pressure: Despite its high performance, XMODEL15 sustains the most damage, with a value of 8,421.2 units. Industrial ABS experienced moderate damage with 11,031 units, whereas ABS-Like suffered the most damage at 14,208 units, indicating it is less resistant to air pressure and fatigue.

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