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Analysis of Stable Flight of Poltekad Eagle Drone Using ANSYS Method

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Abstract: The purpose of this study was to analyze the movement of the wings of a self-made eagle drone using the ANSYS method. The drone analyzed for the wing type moves to fly by being thrown when the brushless motor throttle moves the flapping of the wings at maximum rotation. The aerodynamic model used for data analysis in this paper is optimized to determine and improve the operational performance of the wings of eagle drones, especially in terms of stability and flight time. These two aspects are very important to determine the efficiency of drone performance. The method used for simulation analysis uses ANSYS 13. In the next step, the numerical results will be compared with the results during the experimental flight process. The conclusion of this study presents the main results of the simulation, namely numerical magnitude, main flight coefficient and flight time that affect stable flight efficiency.

Keywords: ANSYS; Eagle drone; Flight coefficient; Wing flapping.

Introduction

Today, the emphasis on economic reasons for reducing costs gives rise to the idea of developing drones (Jagadeesh et al., 2019; Malik & Ahmad, 2010). Unmanned aerial vehicles (UAVs) are typically general-purpose devices. This is due to the fact that UAVs are very compact and primarily due to their ease of use. This has led to the granting of various missions as they have won a number of incredible abilities in the last few decades (Grlj et al., 2022; Mohsan et al., 2023). These aerial robots can be used in a variety of civilian missions such as disaster monitoring, traffic monitoring, law enforcement, and power line maintenance (Dronova et al., 2021; Noor et al., 2020).

UAVs are important mainly because of their ability to replace manned aircraft in routine tasks or especially in dangerous missions. The second argument comes from the fact that unmanned aerial vehicles can reduce the cost of air operations (Rovira-Sugranes et al., 2022). For example, the presented system has a level of cost of one hour of flight time compared to a liter of gasoline (Kim et al., 2018).

In principle, the UAV system consists of two parts: the active element (the vehicle itself) and the second - the ground station for video control and reception. UAV control can be achieved either by using a manual test unit or by using flight controls in autopilot mode, by integrating a GPS system for flight routes. Due to its low risk, low cost, and high turnover rate, it provides certain benefits and advantages that are unparalleled (Kanellakis & Nikolakopoulos, 2017; Nourmohammadi et al., 2018; Zhang et al., 2016).

The main advantages of UAVs are: a) they can be used in high-risk situations and inaccessible areas; can offer the possibility of data acquisition with high temporal and spatial resolution; c) low operating costs (a fraction of the cost of operating a traditional aircraft with a human pilot on board) (Nex & Remondino, 2013; Zhi et al., 2020).

Unfortunately, there are a series of limitations in the use of UAVs that can complicate the selection of suitable

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means: a) the main drawbacks due to the limitation of the payload; b) UAVs tend to use low-weight sensors (this is becoming less and less important as technology advances) (Keane, 2013; Mohsan et al., 2023). This application domain has led to the of further research to increase autonomy and reduce the development size of UAVs based on a working design. In this sequence, the dynamic performance of the machine can be dramatically improved in certain cases through a systematic and meticulous search of evolutionary algorithms through the space of all structural geometry allowed by manufacturing (Han & Sun, 2024; Mumali & Kałkowska, 2024), cost and functional constraints (Jagadeesh et al., 2019; Li et al., 2018; Lu et al., 2018). These flying robots, called UAVs, can be classified into four main categories: fixed-wing UAVs, rotary-wing UAVs, hybrid design UAVs, and 4) Ornithopters resembling birds, birds or insects (Sai et al., 2016).

An ornithopter drone is a type of drone that flaps its wings to generate lift and thrust with a flapping mechanism. Using a variety of Ornithopter Bio-mimics, designs have been suggested for civilian and military applications especially for surveillance purposes. In this writing, a highly aerodynamic design for a flapping wing UAV with advanced specifications has been created (Oubbati et al., 2020; Skorobogatov et al., 2020). Flapping wing UAVs are created that can be used for surveillance or reconnaissance of a particular target and also for a specific environment without its own consciousness. Ornithopter uses battery power, a gear mechanism, which makes it possible to increase the number of covers. We downgrade the specifications of various birds and try to turn them into perfect real-time mechanics. At the first initiative, the basic principles and operation of flight were studied to understand the mechanism of flapping wings (Mozaffari et al., 2019; Srigrarom & Chan, 2015). To keep the aircraft/bird at a constant altitude, Upward lift = Downward load force. To keep the aircraft/bird at a constant speed, Forward thrust force = opposite Pull force.

Method

Design Parameters

Tabel 1. Eagle Drone Parameter Table (Jagadeesh et al., 2019).

Design Parameter	Demotion	Units	Value
Length	L	M	0.32
Wing Span	B	M	0.64
Mass	M	Kg	0.587
Wing Area	S	M²	0.0940
Aspect Ratio	AR	----------	5.231
Torque	T	N	0.522
Wing Loading	W/S	Kg/m²	2.147

Drone Flight Parameters

Frequency

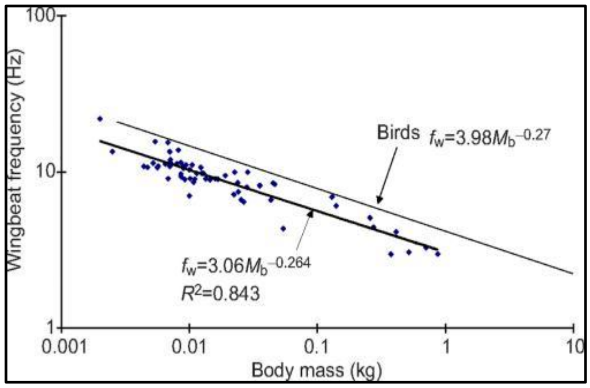

Figure 1. Flapping Frequency (Jagadeesh et al., 2019).

f =1.08 (m1/ 3 g1/ 2 b–1 S–1/ 4 ρ–1/ 3) (1)

f *(Small Birds)*= 116.3 $m^{-1/6}$ (2)

f *(Large Birds)*= 28.7 $m^{-1/3}$ (3)

The frequencies that are used as constants are as follows:

f = 2.5 Hz (4)

The frequencies that are used as constants are as follows:

f = 2.5 Hz (5)

Flying Speed (K)

The relationship between flight speed and mass of a bird drone is defined as follows:

$$K = 4.81\ m^{1/6} \quad (6)$$

Where m is the mass of the bird drone.

$$K = 5.4\ m/s \quad (7)$$

Flapping Wings

Angle (a)

Flapping Angle α is a sinusoidal function. The β and rate angles correspond to the following equations:

$$\alpha\ (t) = \alpha_{max} \cos 2\, f_t \quad (8)$$

$$\alpha\ (t) = 23.124°$$

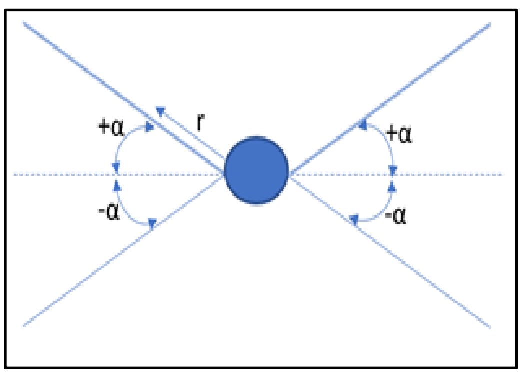

Figure 2. Flapping Angle (α) (Jagadeesh et al., 2019).

Grazing Rate (ar)

The equation for flapping wings is as follows:

$$\alpha_x(t) = -2\pi\, f_t \sin 2\pi\, f_t \quad (9)$$

$$\alpha_x(t) = -368.899 H_{z.s}$$

Angle of Nod (θ)

The angle of the gulp is the angle formed between the horizontal line and the line of the drone starting to fly or land.

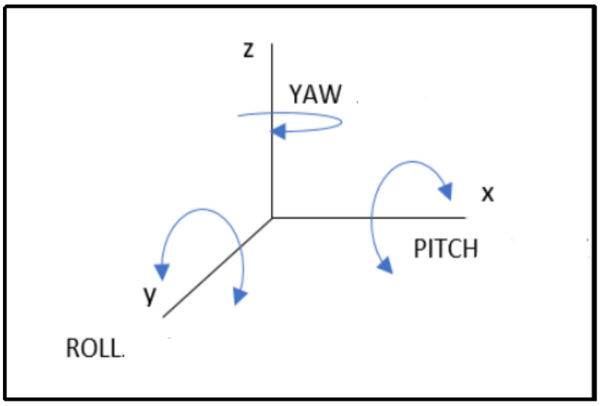

Figure 3. Nod Corner

According to the pitch equation, the angles formed are as follows:

$$\theta(t) = \frac{r_i}{\alpha}\theta_0 \cos 2\,\pi f_t + \varphi) \quad (10)$$

$$\theta(t) = 14.5°$$

Speed Parameters

Vertical Speed component of wind influence (Vy)

$$V_y = \sin(\delta) + (r_i.\alpha.\cos(\alpha)) + (0.75.c.\theta\cos(\alpha))) \quad (11)$$

$$V_y = 3.513\, {}^{m}/_{s}$$

Horizontal Componenet of Relative Wind Velocity (Vx)

The horizontal component of relative wind velocity is given by

$$V_x = K\cos(\delta) + (0.75.c.\theta\sin(\theta)) \quad (12)$$

$$V_x = 5.225\, {}^{m}/_{s}$$

Relative velocity (Vrel)

The relative velocity equation is shown below:

$$V_{rel} = (V_x{}^2 + V_y{}^2)^{1/2} \quad (13)$$

$$V_{rel} = 6.02\, {}^{m}/_{s}$$

Relative Angle (Ψ)

Relative Angle between 2 speed components ψ and effective angle of attack

$$\Psi = \tan^{-1}\left(\frac{V_x}{V_y}\right) \quad (14)$$

$$\Psi = 64.01°$$

Angle of Attack

Effective angle of attack (α_{eff})

Effective Attack Angle is the part of a specific attack angle located between the airfoil bow strap and the effective airflow.

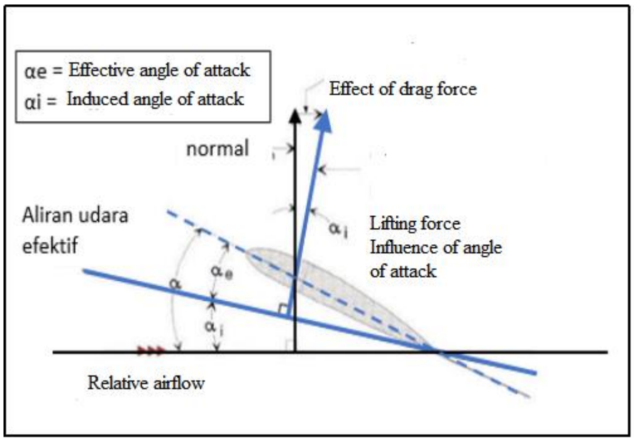

Figure 4. Effective angle of attack (Jagadeesh et al., 2019).

Effective airflow is a line that represents the resultant velocity of the disturbed airflow.

$$\alpha_{eff} = \Psi + \theta \quad (15)$$

$$\alpha_{eff} = 74.53°$$

Realistic Attack Angle (a)

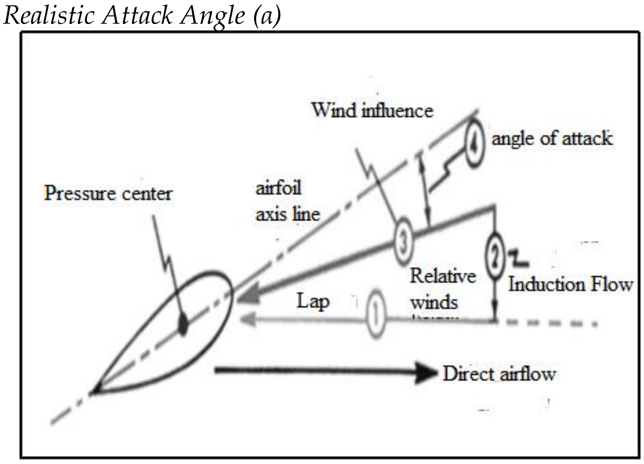

Figure 5. Relative angle of attack (Jagadeesh et al., 2019)

Flow Relative Angle of Attack (α')

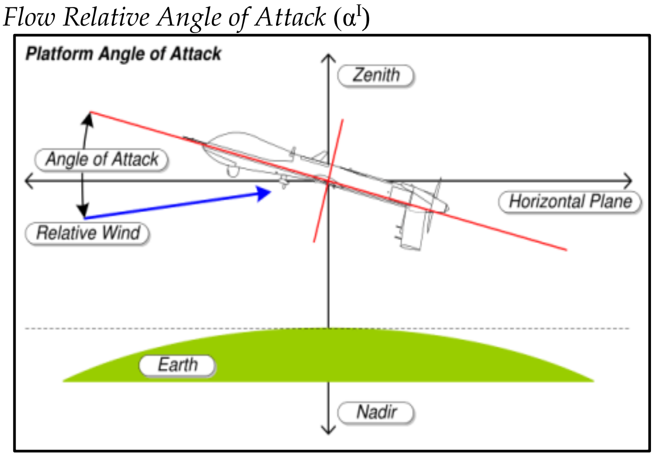

Figure 6. Angle of attack (Jagadeesh et al., 2019).

$\alpha^1 = 2.4°$

Cycle Angle (Φ)
The cycle angle is given by
$\varphi = 58°$

Section Mean Pitch Angle (θ^1)
The section mean pitch angle is given by
$\theta^1 = 60°$

Force Parameters
Horizontal Component of Force (Fhor)
The horizontal component of force is given by

$$F_{hor} = dL_c \sin\Psi \cos\delta + dN_{nc} \sin(-\theta) \cos\delta - dD_d \cos\Psi \cos\delta \quad (16)$$
$$F_{hor} = -1.332N \quad (17)$$

Vertical Component of Force (Fhor)
$$F_{hor} = dL_c \sin\Psi \cos\delta + dN_{nc} \sin(-\theta) \cos\beta \cos\delta \quad (18)$$
$$F_{hor} = 0.2812N \quad (19)$$

Normal Force (Nnc)
The vertical component of force is given by$N_{nc} = 0.413N$

Lift Parameters
Theodorson Lift Deficiency ($C(k)$)
Theodorsen Lift Deficiency factor which is a function of reduced frequency k
$$C(k) = \sqrt{F^2 + G^2} \quad (20)$$
$$F = 1 - \frac{c_1 k^2}{k^2 + c_2^2} \quad (21)$$
$$G = -\frac{C_1 C_2 k}{k^2 + C_2^2} \quad (22)$$
C_1 *and* C_2 *are given by*
$$C_1 = \frac{0.5\,AR}{(2.32 + AR)} \quad (23)$$

$$C_2 = 0.181 + \frac{0.772}{AR} \quad (24)$$
$$C(k) = 0.023 \quad (25)$$

Lift Coefficient Due to Circulation (C_{l-c})
The section lift coefficient due to circulation (Kutta Joukowski condition) for flat plate is given by
$$C_{l-c} = 2\pi\, C(k) \sin\alpha_{eff} \quad (26)$$
$$C_{l-c} = 0.19 \quad (27)$$

SECTIONAL LIFT (L_c)
The section lift can thus be calculated by
$$L_c = \frac{1}{2}\rho V_{rel}^2 C_{l-c}\, c\, dr \quad (28)$$
$$L_c = 0.159N \quad (29)$$

Gaya Lift (L)
Elevator force used as a constant: L=0.605 N (30)

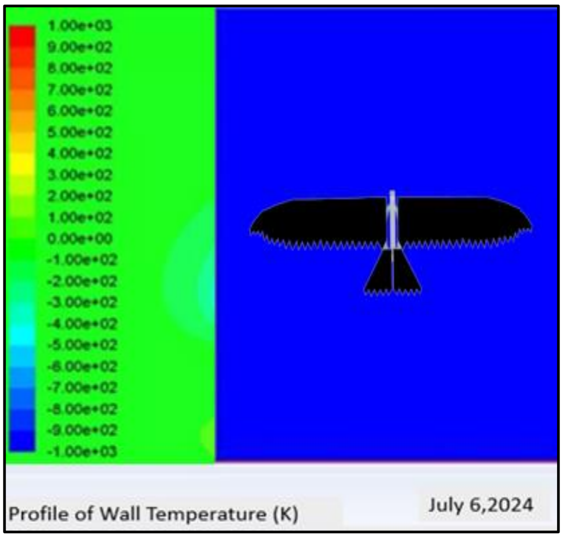

Figure 7. Lift force simulation (L = 0.605 N)

Thrust Parameters
Instantaneous Thrust (T)
The instantaneous thrust is given by

Lift Along Span (Lx)
The lift along the span is given by
$L_c = 1.098N$
$$T = dF_x \cos\theta - dN\sin\theta \quad (31)$$
$T = 0.237N$

Thrust Along Span (T_x)
The thrust along span is given by
$T_x = 1.53$

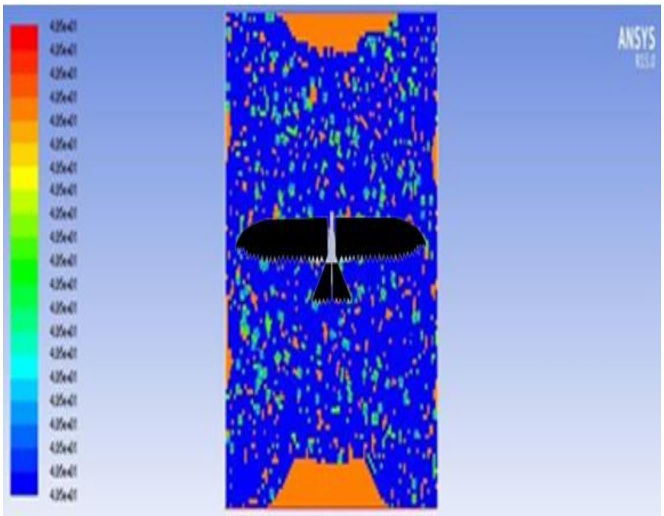

Figure 8. Simulation of Thrust along span

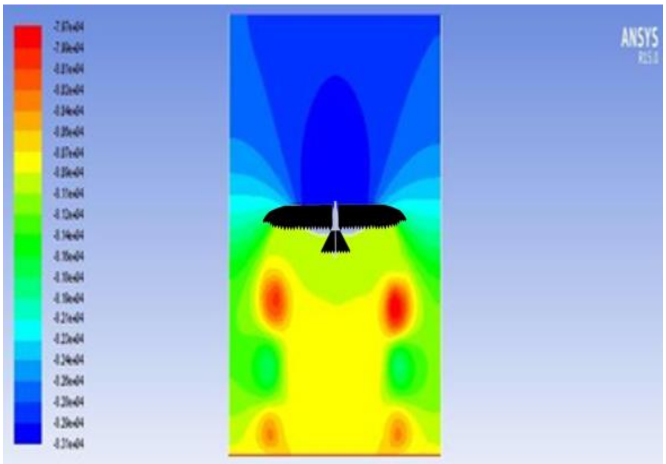

Figure 9. Total Thrust Simulation

Result and Discussion

As shown in Table 1 of the design parameters, the vertical speed Vy 3.513 m/s, Vx 5.225 m/s, Vrelative 6.02 produces the optimal speed for stable flight at a flapping wing angle of 23.1240 because to meet the optimum speed requirements for Vy between 3.5 m/s to 3.6 m/s, Vx between 5.1 m/s to 5.3 ms, Vy relative between 5.95 m/s to 6.05 m/s. If the value of the Vy parameter does not fall between 3.5 m/s to 3.6 m/s, then it is unstable, if the value of the Vx parameter does not fall between 5.1 m/s to 5.3 m/s, and if the relative Vy does not fall between 5.95 m/s to 6.05 m/s, it is unstable. Based on another study using Computational Fluid Dynamics (CFD) analysis researched by Oktay & Eraslan (2020), it shows that numerical prediction is found to be closer to the experimental results at lower air velocities (around 2.4 m/s). This shows that using the Drone Using ANSYS Method is more efficient than the speed.

The design parameters in Table 1 produce horizontal force Fhor = -1.332 N, vertical force Fver = 0.2812N and normal force Fnc = 0.413N. The parameters of horizontal force, vertical force and normal force result in elevator coefficient C(K) = 0.023, elevator Coefficient of Circular Motion Cl-c = 0.19, Sectional lift (LC) = 0.159N, and elevator force constant

From this study, the drone using the stability of the drone with an angle of 530 shows that the main results of the simulation are numerical magnitude, main flight coefficient and flight time that affect the efficiency of flying stably. The greater the value of the main flight coefficient, the faster the bird drone lifts but its stability decreases, but the lower the flight efficiency, the slower it is when flying and results in a low stability value. This refers to Nafisa et al. (2022) research which stated that the collision of the drone at the location between the ribs with an angle of 00 at a relative speed of 180 m/s horizontal stabilizer suffered serious damage. The collision of a drone with a smaller mass than on the horizontal stabilizer is more serious than the attack of a bird, because the drone damages the ribs, spars and skins on the horizontal stabilizer.

Conclusion

In this paper, the flapping wing UAV has been designed and analysed to evaluate its aerodynamic performance in the airflow. The main results of the simulation are numerical magnitude, main flight coefficients and flight time that affect the efficiency of flying stably. The greater the value of the main flight coefficient, the faster the bird drone lifts but the stability decreases, but the lower the flight efficiency, the slower it is when flying and resulting in a low stability value. The optimal value achieved in order to obtain a stable state and fast flight occurs at a coefficient value of 0.023 with a thrust of 0.237N and lifting force 0.605N.

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Author Contributions

N. R. S. M: conceptualizing research ideas, designing methodologies, management and coordination responsibilities, analyzing data, conducting research and investigative processes should be limited to those who have contributed substantially to the reported work. N. G., S. W., and F. K. conduct literature reviews and provide critical feedback on the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest

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