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Fundamental Study of the Magnetic Fields Applied for Efficient Rotor Drone Thrust Selection

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Abstract:
Energy-efficient design has become a priority research area in drone technology, with motor and aero foil selection playing a critical role in optimizing performance. This study develops a simulation-based framework that integrates magnetic field analysis and aerodynamic modelling to improve rotor drone efficiency. The primary research problem addressed is the need for aero foil pilot testing under real environmental conditions to identify the most suitable aero foil type for drones. Secondary and dependent problems, such as pilot test selection, test machine design, power supply, and payload capacity, are also considered. The methodology involves three key stages: (i) applying magnetism fundamentals to develop a complex magnetic field simulator for motor efficiency analysis, (ii) conducting aerodynamic simulations and benchmarking thrust performance across different aero foil designs, and (iii) integrating simulation results with pilot tests to validate drone performance. The outcomes enabled the selection of a high-efficiency motor–aero foil configuration. A prototype drone was subsequently developed and tested for coconut plucking applications, demonstrating the practical viability of combining magnetic and aerodynamic simulations for energy-efficient drone design.

Keywords—drone motor, magnetic field simulator, aerodynamics, energy-efficient UAV, coconut harvesting

1 Introduction

Motor Selection for Drone Applications with Coconut Plucking Device

As a practical application, this study also considers the development of a coconut-plucking device. Traditionally, coconut harvesting is carried out using labour-intensive methods that consume significant time, energy, and manpower. The proposed device leverages optimized drone motor technology to assist in plucking coconuts efficiently. Such a system can reduce health risks, save money and time, conserve energy, and improve overall productivity. From an industrial perspective, this approach offers a scalable and systematic solution that can enhance economic outcomes and promote sustainable agricultural practices.

2 Literature Review

a. Problem Analysis

The primary problem is the design of an efficient rotor drone for harvesting coconuts, aiming to select the most suitable type of drone under real environmental conditions. Secondary problems include evaluating design types, identifying current drawbacks, and selecting appropriate methods. Dependent problems involve deeper ethical considerations related to implementation.

Magnetism

Magnetism was first observed in ancient times with lodestones—naturally magnetized pieces of magnetite—that could attract iron. The first scientific discussion is attributed to Thales of Miletus (c. 625–545 BCE), and by 1187, Alexander Neckam described the compass in Europe. Significant advances followed: Niccolò Cabeo (1629) expanded earlier studies, Ørsted, Biot, and Savart (1819–1820) explored the link between electricity and magnetism, and André-Marie Ampère analyzed forces between current loops. Faraday (1831) discovered that a changing magnetic flux induces voltage, and Gauss, Weber, and Maxwell (1861) formalized electromagnetism, later applied by Einstein in 1905.

Magnetism is central in engineering, with applications in motors, relays, transistors, and more. In drones, Brushless DC (BLDC) motors are widely used for their efficiency and reliability. Selecting the optimal motor is complex due to interactions between magnetic fields and aerodynamic forces, making the study of both essential for energy-efficient drone design.

Aerodynamics

Aerodynamics is the study of air motion, particularly when interacting with solid objects such as airplane wings. Fundamental concepts of continuum, drag, and pressure gradients date back to Aristotle and Archimedes. In 1726, Sir Isaac Newton developed the first theory of air resistance, followed by Daniel Bernoulli's *Hydrodynamica* (1738). Leonhard Euler (1757) published the general Euler equations for compressible and incompressible flows, later extended to include viscosity, resulting in the Navier–Stokes equations. In 1799, Sir George Cayley identified the four aerodynamic forces of flight. Francis Herbert Wenham constructed the first wind tunnel in 1871, allowing precise measurement of aerodynamic forces. Drag theories were developed by Jean le Rond d'Alembert, Gustav

Kirchhoff, and Lord Rayleigh. Charles Renard (1889) predicted the power required for sustained flight. Otto Lilienthal achieved successful glider flights, and the Wright brothers conducted the first powered flight in 1903. Frederick W. Lanchester, Martin Kutta, and Nikolai Zhukovsky independently developed theories connecting fluid circulation to lift.

3 Study Objectives

3.1. The main objectives of this project are, introduce a SMART agricultural mechanism for safe and efficient coconut plucking. Develop and implement an automated control system for the plucking process. Reduce labor dependency and improve operational visibility, addressing challenges of traditional harvesting. Conduct laboratory testing to identify potential failures, implement improvements, and finalize an optimized system.

3.2. Sub-objectives for this sub-study include:

- Develop a high-efficiency motor.
- Develop an empirical estimation tool to measure magnetic fields (currently using iron dust tests), aerodynamics, and buoyancy.
- Explore philosophical and parametric analyses of magnetism, aerodynamics, and thrust, justifying the validity of complex particle interactions in relation to ontology and near-shape functions.

4 Methodology:

In this project, the literature review focuses on fixtures suitable for agricultural harvesting and available. The research involves designing and developing a machine, selecting and applying appropriate motors, and creating a high-efficiency motor. The study also includes deep metaphysical modeling of magnetism and the development of empirical and conceptual frameworks for magnetic systems. A simulator will be created and tested under actual operating conditions to analyze forces in complex magnets and evaluate drone motor efficiency. Aerodynamic simulations will also be conducted to benchmark thrust and optimize the propulsion mechanism. The device is intended for industrial coconut harvesting, where it can reduce energy consumption, costs, time, and health risks compared to manual plucking.

Magnetism Fundamentals:

- Magnetism is the force exerted by magnets when they attract or repel each other.
- The motion of electric charges generates magnetism.

- Every atom contains electrons, whose movement generates electric currents and causes each electron to act like a microscopic magnet.
- In most substances, equal numbers of electrons spin in opposite directions, canceling out magnetism.
- In substances such as iron, cobalt, and nickel, most electrons spin in the same direction, making the atoms strongly magnetic, though not yet permanent magnets.

a. Conceptual frame analysis for simulators

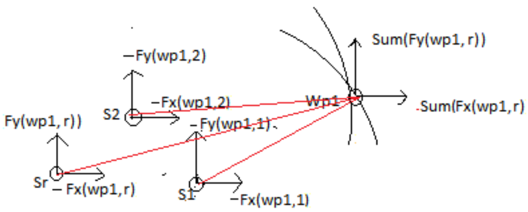

Fig. 1. Gauss and Reaction forces graphical analysis

Let,

Particle Sr force on the particle Wp1 $= F1, r$; $Fr, 1$ is a force vector on WP1 by Sr

Then Net force on the particle WP1 by whole particles Sr $= Sum(F1, r)$

$F1, r = Fx(wp1, r)\ i + Fy(wp1, r)\ j + Fz(wp1, r)\ k$

$Fr = Sum(Fx(wp1, r)\ i + Fy(wp1, r)\ j + Fz(wp1, r)\ k)$

$F1,r=f(L ,m1, m2, uo)$;

L = distance between particle ; m1,m2 strength of particles ; uo space coefficient of relativity

m1 strength can be electrical or inertia or magnetic or other particle that have reactions force on m2 same or different particle.

5 Results

a. Preliminary and Pilot research of the appropriate motor for the drone. For a Coconut plucking drone effective motor selection pilot test.

Magnetism Fundamentals:

- Magnetism is the force exerted by magnets when they attract or repel each other.

- The motion of electric charges generates magnetism.
- Every substance is made up of atoms, each containing electrons that carry electric charges.
- The movement of electrons generates electric currents, causing each electron to act like a microscopic magnet.
- In most substances, equal numbers of electrons spin in opposite directions, canceling out their magnetism.
- In substances such as iron, cobalt, and nickel, most electrons spin in the same direction, making the atoms strongly magnetic, though they are not yet permanent magnets.

Considering these fundamentals, a simulator was developed to analyze forces in complex magnetic systems, allowing for detailed evaluation of drone motor efficiency. An aerodynamic simulator was also created to benchmark thrust and optimize the propulsion mechanism. Using these analyses, a high-energy-efficient drone was selected and implemented for coconut plucking.

b. **Pilot Magnetic motor test**

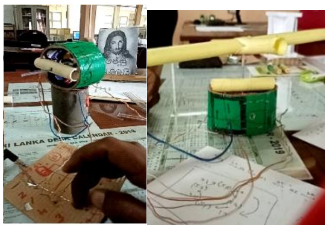

Fig. 2. Actual pilot test of the second BLDC Motor for rotor drone to high efficient (Preliminary study)

Fig. 2 shows the pilot-made motor at the NERD Centre, constructed using a copper coil, two permanent magnets, and cardboards (Picture 1). A 12V DC PWM power supply was applied to each coil, and the resulting movements were observed. After identifying the pattern for full rotation, a helicopter blade made of PVC was attached to the motor and tested for functionality.

c. Simulator development for magnetisms

To observe the magnetic field, a recently used tool involves spreading iron dust on a surface perpendicular to the field. However, no proper empirical methods exist for analyzing groups of magnetically induced solids. Magnetic fields are not linear across a surface, unlike light. This may be due to the need for sensory transformation to perceive magnetic fields. Additionally, magnetic fields depend on ontological and spontaneous axiological dimensions, so near-shape dimensions must be estimated. This arises from the justified law of electron rate of change extended to magnetism measurements, with highly complex mathematical algorithms required to explain the observed coherencies. After a detailed study, the magnets and fields were analyzed using advanced calculations, and a simulator was developed to model the magnetic fields. In this simulator, magnets were considered as individual particles, with flux assigned to each particle. Complex curves were generated using the coordinates and flux at each point. To calculate forces and moments for other complex curves, the effects of each particle were taken into account. Figure 3 shows the coordinates, flux strength, and results represented in graphs. In these graphs, the components (Fx, Fy) were calculated and plotted at each point to scale.

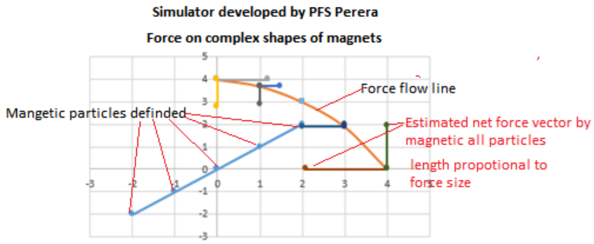

Fig. 3. One image of complex magnets curves simulator for force estimates

d. Actual benchmark of the simulator of excel by magnets and iron dust.

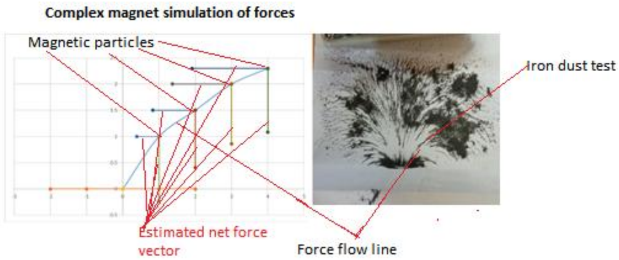

Fig. 4. One magnet field in flat surface simulation benchmark with the actual for force estimates

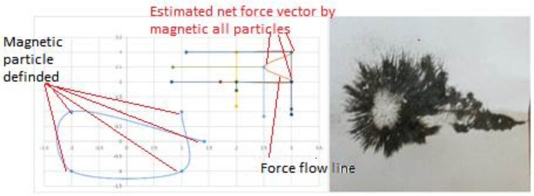

Fig. 5. Two magnet fields in flat surface simulation benchmark with the actual for estimates

Fig. 4 shows the actual test of a magnet using iron rust to visualize the field. A cylindrical magnet was placed tangent to a paper surface, and its magnetic field was observed. In the simulator, forces along two paths were calculated by placing a single magnetic particle, and the results were compared with near values on the graph.

Fig. 5 shows similar simulations performed with two cylindrical magnets. One magnet's flat surface was placed on the paper, while the other's rounded surface was placed on the paper surface. Using the concept of magnetic particles, the forces between the magnets were analyzed and benchmarked against the actual experimental results.

6 Further developed Simulations of the drone motor made at NERD Centre

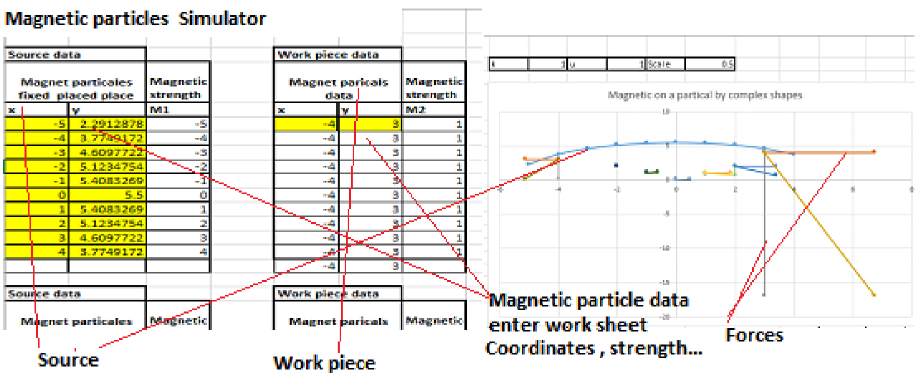

Fig. 6. Magnets simulator further developed.(Top left magnetic particles data and coordinates to enter and the right estimated force required points with magnetic strength). Bottom graph visual show of the values to scale

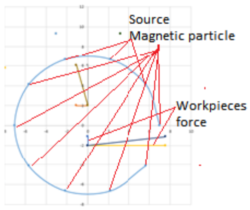

Fig. 7. Simulation of the magnetism made for forces estimates.

Fig. 6 indicates the calculated forces along with the resultant force. The calculations were performed using Excel, utilizing its mathematical, graphical, and modular capabilities. The results show that when magnetic particles are close to each other, the force is very high, regardless of the magnetic moment.

After developing the simulator, the motor shapes and magnet rotor were simulated and their values verified. The appropriate positions for placing the coils were then identified. Fig. 7 shows the motor simulations corresponding to the motor shown in Fig. 2**.**

7 Aero dynamics forces

a. Simulator tested by Excel worksheet.

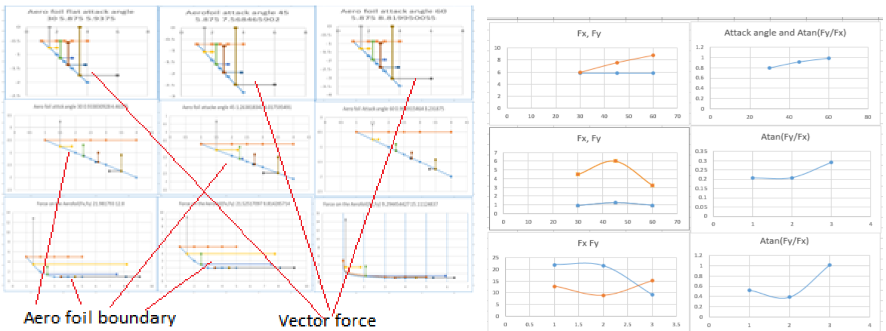

Fig. 8. Estimate of the aero foil for the drone by excel simulator made

The Excel sheet was used to obtain near values for different shapes, similar to the magnetic simulations. Fig. 8 shows the aerodynamic forces acting under constant airflow. In the first series, a flat surface was angled at 30°, 45°, and 60°. A similar procedure was followed for the second series. The third series involved a complex aero foil, showing the forces acting on the complex surfaces. It is clear that the third row, third column configuration produces the highest lift. From Fig. 8, it can be observed that as the attack angle increases, both Fx and Fy increase with the aerofoil length. Using the arctangent of (Fy/Fx) versus the attack angle, it can be concluded that the ratio of forces along Fy increases with increasing attack angle. These calculations were simulated for a wind speed of 10 m/s.For the simulations, the wing length was set to 2.5 cm and the width to 2 cm. The graph corresponding to the maximum force shape was used to determine the optimal aerodynamic configuration. Per length the lift force on the wing = 1511 N,Per length the drag force on the wing = 929 N,Therefore, by the force analysis it is clear that,

$$Power\ need\ at\ the\ 10ms^{-1}\ speed\ per\ length\ =\ 929*10W\ =\ 9.29kW$$

$$Per\ 2.5cmx2cm\ blade\ power\ need\ at\ 10ms^{-1}\ speed = 929*10*\frac{2}{100}\ W$$

$$= 185.8\ W$$

By the graph, it is clear that under the uniform conditions force on the wings were constant. Ratio between the Fy/Fx = 1.626.

So the power need to lift the 2.5cm x 2 cm wings are without load at 10ms-1 = Fx*10 = 929*0.025*10 = 235.2W

Also, at this speed the total load can take 151.1 kg

So the motor types, Let the Motor coil properties as below,

Coil turns=N1, Wire dimeter=d1, Coil length= l1, Coil width=b1

Then;

$$V1 = I1*R1 = I1*pi*2*N*\frac{l1+b1}{\frac{d1^4}{4}} \text{ ---(1)}$$

$$I1 = V1/(\,pi*2*N*\frac{l1+b1}{\frac{d1^4}{4}})\text{---(2)}$$

$$B1 = U*\frac{I1}{2*pi*r1}\text{- ----(3)}$$

$$C1 = B1*I1*N1*A1*sin(a1)\ \text{-----(4)}$$

b. For a rubber balloon

The flying time of a rubber balloon was checked using a YouTube video as a reference. It was observed that under normal conditions, a rubber balloon could fly for approximately nine seconds when an additional paper cup weight was attached.

Fig. 9. H_2 balloon trust increase and energy efficiency increase methods [2]

This implies that without any battery power but only compressed air some materials can float in the air.

Inside pressure = Outside pressure + Rubber surface pressure

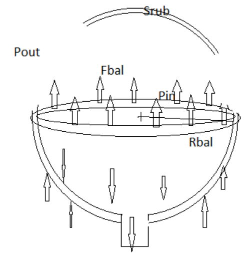

Fig. 10. Force analysis of the floating balloon strength

$$Fbal = Pout * Abalout - Pin * Ain \;----(5)$$

$$\frac{Fbal}{Abalout-Abalin} = \frac{Pout*Abalout-Pin-Abalin}{Abalout-Abalin} \;---(6)$$

$$Sbal = \frac{Pout * Abalout - Pin - Abalin}{Abalout - Abalin}$$

$$Fbal = k * Dx; ---(7)$$

$$k * Dx = Pout * Abalout - Pin * Abalin \;---(8)$$

$$Pin = \frac{Pout*Abalout-k*Dx}{Abalin} ---(9)$$

By the B'nule theory,

$$Pout + 0.5 * Dair * U^2 = Pin + Dh * Dair * g \;--(10)$$

$$U = sqrt\left(\frac{Pout - Pin}{.5 * Dair}\right) \;----(11)$$

$$Moment\ change\ of\ the\ air\ inside = \frac{d(mv)}{dt} \;--(12)$$

$$\frac{d(mv)}{dt} = Dair * Aoutmouth * (V^2 + x * a) --- (13)$$

So;

$$Balloon\ lift\ force\ by\ mouth = Dair * Aoutmouth * U^2 \;--- (14)$$

$$Balloon\ lift\ force\ by\ mouth$$
$$= Aoutmouth * \left(Pout * \left(1 - \frac{Abalout}{Abalin}\right) + k * \frac{Dx}{Abalin}\right) - - - (15)$$

$$Balloon\ power\ out = \frac{d(PV)}{dt} = \frac{(\frac{2}{3} * d(Pout * pi * \frac{Dbalout^2}{4} - k * Dx) * Dbalin)}{dt} \quad ----(16)$$

8 Excel Simulator for H_2 balloon lift estimates.

D mouth	0.002	m					
Amouth	0.001570796	m^2					
Pout	1000000	Pa					
Young modulas of the rub	10000000	Pa					
E=S/e=F/A/(dx/L)=FL/A/dx							
F=kdx							
E=kdxL/A/dx=kL/A							
A=2*pi()*r*t	1.5708E-05	m^2	r0 bal	0.025	m		
L0	0.1	m	to bal	0.0001	m		
k=EA/L	1570.796327						
Abal out	0.020106193	m2	Dbal out	0.16	m		
Abal in	0.020106168	m2	Dbal in	0.1599999	m	k1	0.001
Dx bal	0.1	m					
F lift	12.26989815	N	1.226989815	kg			

Balloon power out= (2/3)*d(Pout*pi()*Dbalout^2/4-k*Dx)*Dbalin)/dt			
per second energy need	2135.194418	J	

By the balloon forces analysis, excel calculations were done to find the energy consumption of the balloon to lift with the assumed values of the balloon shown.

Benchmark of the Positive displacement pumps and axial pump for drone lift.

Table 1. benchmark of the Pump efficiencies [3].

Pump Type	Overall Efficiency %
External gear	85
Internal gear	90
Vane	85
Radial piston	90
Bent axis piston	92
Axial piston	91

a. Positive displacement pump formulae

$$\text{Energy in} = (\text{Work done on the piston})$$
$$= (\&\text{Piston Friction loss}) + (\text{Internal energy rise in the air})$$

$$\text{Energy on air} = \text{Air kinetic energy increase}$$
$$\text{Energy efficiency} = \frac{\text{Air Kinetic energy increase}}{\text{Piston mechanical loss} + \text{Internal energy rise in the air}}$$
$$= 1 - \frac{\text{Mechancial losses}}{\text{Work done on the piston}}$$
$$\text{Mechanical losses}$$
$$= (\text{Friction by piston}) + (\text{Friction by shafts})$$
$$+ (\text{Friction by the air heat})$$

b. Axial pump

$$\text{Energy in} = \text{Work done on the blade}$$
$$= \text{Kinetic increase of the air} + \text{Internal energy increase in the air}$$
$$+ \text{mechanical losses}$$
$$\text{Energy on air} = (\text{Kinetic increase of the air} + \text{Internal energy increase in the air}$$
$$+ \text{Mechanical losses})$$
$$= 1 - \text{Mechcnial losses/Work done on the blades.}$$
$$\text{Mechanical losses} = \text{Blade drag Losses} + \text{shaft losses}$$

9 Discussion

From the magnetic study, it is clear that this simulator effectively models complex magnetic curves in practical cases, assisting in the selection of low-energy, efficient devices for rotor drones. It also aids in determining optimal magnet placement in motors and the design of other complex magnetic devices. Regarding energy efficiency, piston pumps are observed to be more efficient for drones due to the absence of mechanical losses in the flow. From the aerofoil design analysis, it is evident that lifting a payload of at least 5 kg requires the motor blade speed to satisfy Fy/Fx > 1. For example, if Fy/Fx = 1, Fx would need to be 5 kg. However, drag losses are present in aerofoil blades. Using compressor-type blades can eliminate these drag losses, implying that compressed air systems provide higher efficiency and longer flight times.

Overall, rotor blade-type drones consume more energy due to two main factors: energy losses in the motor and energy losses due to aerodynamic drag forces. The simulations show that drag and lift cannot be entirely eliminated for any blade shape due to air-material interactions. However, for continuous operation, axial pumps in superheated airflow regions may improve efficiency by optimizing the drag coefficient.

10 Conclusions

From the magnetic study, it is evident that the simulator effectively models complex magnetic curves in practical scenarios, assisting in the selection of low-energy, efficient devices for rotor drones. It also helps determine optimal magnet placement in motors and guides the design of other complex magnetic devices. Regarding energy efficiency, piston pumps are observed to be more effective for drones due to the absence of mechanical losses in the flow. From the aero foil design analysis, it is clear that lifting a payload of at least 5 kg requires the motor blade speed to satisfy $Fy/Fx > 1$. For instance, if $Fy/Fx = 1$, Fx would need to be 5 kg. However, drag losses are present in aerofoil blades. Using compressor-type blades can mitigate these drag losses, suggesting that compressed air systems provide higher efficiency and longer flight times. Overall, rotor blade-type drones consume more energy due to two main factors: energy losses in the motor and energy losses caused by aerodynamic drag forces. The simulations indicate that drag and lift cannot be entirely eliminated for any blade shape due to air-material interactions. However, for continuous operation, axial pumps operating in superheated airflow regions may improve efficiency by optimizing the drag coefficient.

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