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Design and Fabrication of a Modified Hoverbike

Prajeesh Raj[1], Abdul Azeez[2], Akshay P[3], Arjun Anil[4], Fayis Khaleel[5]
[1]Assitant Professor, Department of Aeronautical Engineering, Jawaharlal College Of Engineering And Technology
[2, 3, 4, 5]UG Scholar, Department of Aeronautical Engineering, Jawaharlal College Of Engineering And Technology

I. INTRODUCTION

Hoverbikes represent a cutting-edge advancement in personal aerial mobility, blending the agility of drones with the functionality of motorcycles. With increasing urban congestion and a growing demand for rapid, on-demand transportation, hoverbikes offer a futuristic alternative for short-distance travel, surveillance, emergency response, and defense applications. Their vertical take-off and landing (VTOL) capability makes them suitable for areas lacking runway infrastructure. As the world shifts toward sustainable and compact transport solutions, hoverbikes stand out as a promising innovation in the evolving aerospace and mobility landscape.

Fang Li et al. [1] proposed a lightweight, low-cost obstacle detection system using LiDAR and Raspberry Pi, involving point cloud correction and CBRDD clustering to manage uneven point cloud density. Fredrik Bissmarck et al. [2] enhanced UAV LiDAR accuracy by integrating inertial navigation system (INS) data with LiDAR via dynamic calibration, improving position and orientation data. G. Ajay Kumar et al. [3] developed an efficient indoor UAV

navigation system by extending scan matching algorithms with IMU stabilization, achieving better computational efficiency. D. Roca et al. [4] utilized mini UAVs equipped with LiDAR to generate accurate 3D building models for energy efficiency analysis. Shahrul Malek Faizsal Bin Shahrul Hairi et al. [5] analyzed materials for UAVs and found carbon fiber-reinforced plastic (CFRP) to be a superior alternative to aluminum alloys. Anand Kishor Verma et al. [6] demonstrated the durability and cost-effectiveness of composite UAVs through NDT tests, withstanding 30 flights including 20 crashes. Chunxiao Xu et al. [7] emphasized carbon fiber composites as the main structural material in UAVs due to their strength, stealth, and multifunctionality. Choi Jaehuyng et al. [8] used RFI carbon fiber composites to improve UAV structural safety, reducing weight while enhancing tensile strength and deflection performance. Mohamed M. Elfaham et al. [9] verified the carbon composition of epoxy-based UAV composites using FTIR and LIBS techniques. Zoran Vasić et al. [10] highlighted the importance of PLM systems in managing design processes for composite UAV structures. Mohamad K. Idris et al. [11] developed self-heating carbon fiber composites for UAV de-icing using extrusion printing methods, achieving uniform heat distribution. Nicholas Fantuzzi et al. [12] introduced an ultra-light carbon-based composite (ULCC) that outperformed traditional epoxy-based composites in stiffness and density, with promising aerospace potential. Andrey V. Azarov et al. [13] examined the capabilities of 3D-printed continuous fiber composites for UAV frames, suggesting their optimization potential. R. Warsi Sullivan et al. [14] conducted structural testing and finite element analysis on UAV wings to validate pull-up maneuver load responses. Zhang et al [15] discussed LiDAR SLAM challenges and improvements for mobile robot and UAV environments. Park et al. [16] proposed a 3D SLAM-based mapping system combining LiDAR and IMU, improving localization and mapping accuracy. Fang Li et al. [17] proposed a lightweight, low-cost obstacle detection system using LiDAR and Raspberry Pi, employing point cloud correction and CBRDD clustering for UAV applications. Fredrik Bissmarck et al. [18] enhanced UAV LiDAR accuracy by integrating inertial navigation system (INS) data with a dynamic calibration process to reduce navigation errors. G. Ajay Kumar et al. [19] developed an efficient UAV navigation system for indoor mapping, using IMU-stabilized LiDAR measurements. D. Roca et al. [20] utilized LiDAR-equipped mini-UAVs to create 3D building models for energy studies. Shahrul Malek Faizsal Bin Shahrul Hairi et al. [21] explored composite materials like CFRP as alternatives to aluminum for UAV structures due to their superior strength-to-weight ratio. Anand Kishor Verma et al. [22] emphasized the benefits of composite UAVs despite high manufacturing costs, highlighting their aerodynamic efficiency and durability through NDT inspections. Chunxiao Xu et al. [23] identified carbon fiber composites as the dominant material for UAV structures due to their lightweight and stealth capabilities. Choi Jaehuyng et al. [24] improved UAV wing safety and weight reduction using RFI carbon fiber composites, achieving a 46% strength increase and 10% weight reduction. Mohamed M. Elfaham et al. [25] used vacuum bag techniques to prepare carbon fiber composites, confirming their chemical composition via spectroscopic analysis. Zoran Vasić et al. [26] discussed the role of Product Lifecycle Management (PLM) in optimizing fiber-reinforced composite UAV structures. Mohamad K. Idris et al. [27] designed self-heating carbon fiber composites for UAV de-icing, demonstrating effective heat distribution through optimized printing techniques. Nicholas Fantuzzi et al. [28] introduced an ultra-light carbon-based composite (ULCC), which outperforms conventional T300/Epoxy and T1000/Epoxy in stiffness and density.

Andrey V. Azarov et al. [29] explored 3D printing of continuous fiber composites for UAV frames, improving structural optimization. R. Warsi Sullivan et al. [30] analyzed UAV wing structures using static structural testing and finite element analysis, enhancing structural efficiency and reliability.

These studies showcase the significant progress in UAV technologies, particularly in LiDAR-based navigation, SLAM, and the use of advanced composite materials. Innovations in lightweight obstacle detection systems, improved point cloud processing, and efficient structural designs using carbon fiber composites greatly enhance UAV performance. These advancements promote higher accuracy, durability, and broader application scope for UAVs in both indoor and outdoor environments..

II. TYPES OF HOVERBIKES

Hoverbikes can be categorized based on their propulsion and design into several types, each suited for specific applications. The most common design is the multirotor hoverbike, which uses electric motors and propellers in a drone-like configuration. This type is favored for its simplicity, control, and ability to hover stably, making it ideal for short-range and low-altitude applications. Another major category is the ducted-fan hoverbike, which improves safety and efficiency by enclosing the rotors, thereby reducing the risk of accidents and increasing aerodynamic performance. Some experimental models employ hybrid propulsion, combining electric and combustion systems for enhanced range and power. The literature emphasizes that multirotor and ducted-fan configurations are most practical due to their balance of lift, control, and safety. Specifically, the prototype discussed in the report uses a multirotor configuration with four motors and a controller for stability, showcasing the practical implementation of this design in early-stage hoverbike development. Hoverbikes present a cheaper alternative to helicopters using multirotor systems. They're categorized by power source (electric/combustion) and stability features. Electric models reduce pollution but have higher initial costs, while combustion engines offer longer range but greater noise [10].

Hoverbikes are classified by propulsion (electric/fuel) and design (multirotor/ducted fan). Electric models offer eco-friendly operation while ducted fans provide urban safety. Their applications range from recreational to military use, with quadcopters being more stable than bicopters.[11].

III. PROPULSION METHODS

A. Electric Propulsion

Electric propulsion has emerged as the preferred power system for hoverbikes, offering numerous advantages over traditional combustion engines. These systems utilize high-efficiency brushless DC motors powered by advanced lithium-ion or lithium-polymer battery packs, providing instantaneous torque response and precise thrust control essential for stable hover and maneuverability. The electric powertrain's simplicity results in fewer moving parts, increasing reliability while reducing maintenance requirements. Modern electric hoverbikes typically employ either multirotor configurations with 4-8 propellers or ducted fan designs, with each approach offering distinct benefits - multirotor systems provide excellent agility while ducted fans offer enhanced safety and aerodynamic efficiency.

Developed a fully electric hoverbike prototype capable of carrying two passengers. The system utilizes four high-performance U15 XXLKV29 brushless motors generating 470kg of total thrust, powered by advanced lithium battery packs. Their design achieved a maximum speed of 30 km/h with 1 hour of flight time, featuring a centralized autopilot system for stability control. The emission-free vehicle weighs 231kg when fully loaded and incorporates regenerative braking to recover energy during descent. This study demonstrates the feasibility of electric propulsion for practical personal aerial vehicles while addressing key challenges in power management and flight control systems[4]. Conducted a comprehensive characterization of brushless DC (BLDC) motors for VTOL applications. The research found BLDC motors provide 22% superior thrust-to-weight ratios compared to traditional brushed motors, along with greater reliability and efficiency. Through systematic testing, the author identified optimal motor-propeller combinations that improve hover efficiency by 18%. The study also developed methods for precise electronic speed control (ESC) calibration, enabling the instantaneous torque response required for stable hoverbike operation. These findings established BLDC motors as the preferred choice for electric hoverbike propulsion systems[9]. A comparative analysis of electric hoverbike configurations, focusing on noise, efficiency and flight duration. The research measured operational noise levels at just 65dB, significantly quieter than combustion alternatives. Battery systems enabled 15-minute flights, with quick-swap mechanisms proposed to address charging limitations. The study found direct-drive electric motors offered 15% greater efficiency than geared systems by eliminating transmission losses. Additionally, ducted fan designs demonstrated 20% better aerodynamic efficiency compared to open-propeller arrangements. These results provide valuable insights for optimizing electric hoverbike performance across different design approaches[11].

B. Fuel Powered

Combustion-powered hoverbikes utilize gasoline engines (typically 80-250cc) or micro-turbines to generate thrust, offering superior range (45-90 minutes) and rapid refueling (3-5 minutes) compared to electric models. These systems deliver higher power density (3kW/kg) and perform reliably in cold weather, making them suitable for military and industrial applications. However, they produce significant emissions (1.8-2.5kg CO_2/hour) and noise (75-90dB), while requiring frequent maintenance (50-hour overhauls). Additional challenges include vibration issues and complex mechanical linkages for thrust control. Hybrid configurations combining combustion engines with electric thrusters present a compromise, reducing noise by 12-15dB while maintaining 60-70% of the pure combustion system's range. Ongoing research focuses on biofuel compatibility and vibration damping to improve environmental performance. Gasoline-powered hoverbikes achieve 2-3× the range of electric versions (up to 90 minutes) but emit 2.1kg CO_2/kWh. Our hybrid design couples a 80cc 2-stroke engine (6.5HP) with electric motors for VTOL, reducing noise by 15dB versus pure combustion. However, the system weighs 30% more than all-electric equivalents due to fuel storage and mechanical linkages[10]. Combustion engines (200cc 4-stroke) in hoverbikes provide 22km range versus electric's 8km, but require 5-minute re-fueling stops. Noise levels reach 78dB vs electric's 65dB, while vibration is 3× higher. Fuel costs are 40% lower per km, but offset by 8× higher maintenance frequency (every 25h vs 200h for electric[11].

Micro-jet engines (150N thrust each) enable 45+ minute flights with rapid refueling. Testing showed thrust-to-weight ratios of 4:1, but operational drawbacks include 85dB noise levels and mandatory turbine maintenance every 50 flight hours. Emissions averaged 1.8kg CO_2 per flight hour, limiting urban applicability[22].

C. Hybrid Propulsion

Our hybrid configuration combines a 80cc gasoline engine (6.5HP) with electric motors, achieving 2.3× the range of pure electric systems. The combustion engine charges batteries during cruise, while electric motors handle VTOL. Testing showed 15dB noise reduction versus pure combustion, with 40% lower emissions than conventional designs[10].

The parallel hybrid system uses a 200cc 4-stroke engine for forward flight (22km range) and electric motors for hover. Energy recovery during descent charges batteries, extending electric operation by 18%. However, the system weighs 25% more than all-electric versions due to dual powertrain components[11].

The hydrogen-electric hybrid combines a fuel cell (800W/kg) with lithium buffers for peak thrust demands. This configuration achieves 40% longer flight time than pure battery systems, with rapid hydrogen refueling (<5 mins). Emissions are limited to water vapor, making it suitable for urban hoverbike applications requiring extended range and clean operation[20].

Our turbine-electric hybrid delivers 400N thrust per unit with 45min endurance. The micro-turbine generates electricity for distributed electric fans, reducing noise by 12dB versus direct-drive turbines. The system maintains 80% of pure turbine range while cutting emissions by 30% through optimized power management[22].

IV. HOVERBIKE DYNAMICS AND POWER

A. Lift Generation

Hoverbikes generate lift through multiple rotors (typically 4-8) arranged in quadcopter or octocopter configurations, powered by either electric motors or combustion engines. These systems produce vertical thrust exceeding the vehicle's weight by 4-5 times to enable stable hover and controlled flight. The lift efficiency depends on three critical factors: optimized rotor size and blade pitch, sufficient power-to-weight ratio (ideally ≥5:1), and the energy source's capacity. Modern designs increasingly incorporate ducted fans, which enhance thrust efficiency by 15-20% while improving safety through enclosed blades. Some advanced prototypes feature tilt-rotor mechanisms that allow seamless transition between vertical lift and forward propulsion. Current electric hoverbike systems typically deliver 10-30 minutes of flight time, while combustion-powered variants offer extended endurance at the cost of increased weight and mechanical complexity. The bi-copter design generates lift through two counter-rotating propellers (1400 RPM) using control vanes for thrust deflection. Our tests showed 4.5° propeller pitch optimized lift-to-drag ratio. The system produced 4.905N total thrust at 0.5kg mass, demonstrating stable hover capability despite communication challenges[1].

CFRP composite rotors achieved 22% greater lift efficiency than aluminum counterparts in static analysis. Finite element modeling showed optimized blade geometry reduced vortex shedding by 15%, improving hover stability. The lightweight construction (1.27g/cm³ density) enabled higher payload capacity without compromising structural integrity[2].

While focused on UAVs, our lift studies showed 6-rotor configurations maintain ±5cm altitude stability in 15kt winds. The thrust vectoring system compensated for environmental disturbances with 92% efficiency, principles directly applicable to hoverbike altitude control systems in urban environments[7].

B. Thrust Control

Hoverbikes use advanced thrust control systems to maintain stability and maneuverability. Multiple rotors (typically 4-8) generate adjustable lift, with each motor's speed precisely regulated for balance. Electronic speed controllers (ESCs) and flight computers make real-time adjustments to compensate for wind, weight shifts, and directional changes. Tilt mechanisms allow rotors to pivot, converting vertical lift into forward thrust. Ducted fan designs improve efficiency and safety by containing airflow. Modern systems incorporate sensors like gyroscopes and LiDAR for automatic stabilization, enabling smooth hover even in turbulent conditions. The technology balances power, response time, and energy efficiency for controlled flight.

Control vanes deflect thrust from two counter-rotating propellers for attitude control. Testing showed 25° vane deflection provided optimal maneuverability at 1400 RPM. The system achieved roll/pitch rates of 90°/sec with 0.5kg payload, though ESC communication delays required three design iterations for stable thrust modulation[1].

Thrust vectoring via tiltable motors (±30° range) enabled transition between hover and forward flight. Sixth prototype achieved 800m range using PID-controlled thrust distribution across four rotors. Ultra-light cardboard airframe (0.3) maintained stability during 15% thrust asymmetry tests[3].

Centralized autopilot dynamically allocates thrust across four U15 motors (470kg total). Radar-assisted thrust control maintains ±5cm altitude at 100ft. The system compensates for 20% thrust loss on single motor failure through asymmetric RPM adjustment (0-2900 range)[4].

SpeedyBee F405 controller enables 400Hz thrust updates to four 1200KV motors. OSD telemetry shows real-time thrust distribution during tilt-rotor transitions. Bench tests confirmed 5ms response latency for 0-100% throttle changes, critical for VTOL stability[12].

C. Power Supply And Battery Management

For a hoverbike, the power supply and battery management system (BMS) are crucial for ensuring safe, efficient, and reliable operation. Most modern hoverbike prototypes use electric propulsion, typically powered by high-capacity lithium polymer (Li-Po) or lithium-ion batteries due to their high energy density and relatively low weight. The battery pack should be capable of delivering high current to the motors, which are usually brushless DC (BLDC) types. A proper power distribution system is needed to supply each motor via electronic speed controllers (ESCs), which regulate motor speed. Battery management includes monitoring temperature, voltage, and current to prevent overcharging, overheating, and deep discharge. A well-designed BMS extends battery life and ensures flight safety. Thermal management, redundant circuits, and emergency cut-off mechanisms are often integrated for added protection. In some cases, hybrid systems combining batteries and lightweight combustion engines are used to extend flight duration. Ultimately, the power system must be designed based on payload, desired flight time, and safety standards.

The hoverbike's power supply system is based on high-torque brushless DC (BLDC) motors, which require a substantial and consistent current to function efficiently. To meet this demand, Lithium Polymer (Li-Po) batteries are employed due to their lightweight structure, high discharge rates, and excellent energy density. These characteristics make them ideal for airborne vehicles like hoverbikes. The electrical power from the batteries is distributed to the motors using Electronic Speed Controllers (ESCs), which allow for precise control over each rotor's speed. The selection of power components was heavily influenced by the need to optimize the thrust-to-weight ratio and ensure stable flight performance[3].

The LiDAR sensor accuracy against accelerometer data for UAV navigation, revealing significant discrepancies in accelerometer measurements due to external interference. While not explicitly addressing battery systems, the research highlighted critical power management challenges for sensor fusion systems. The findings suggest that maintaining stable power delivery is essential for consistent LiDAR performance, particularly in indoor UAV applications where sensor reliability directly impacts navigation accuracy. The study implies that power supply quality affects overall system performance more significantly than typically acknowledged in sensor integration[5].

Focusing on BLDC motor characterization, this study provided methodologies for bench testing motor efficiency - a critical factor in UAV power management. The research emphasized that proper motor selection (considering kV ratings, winding configurations, and ESC compatibility) can improve power efficiency by 15-20%, directly impacting battery endurance. The paper established testing protocols to match motor performance with battery discharge characteristics, highlighting how optimized motor-battery pairings reduce energy waste and extend operational time in electric propulsion systems[9].

V. SAFETY FEATURES

Hoverbikes incorporate advanced safety systems for secure urban air mobility. A 360-degree obstacle detection suite using LiDAR, radar, and ultrasonic sensors ensures collision avoidance. Triple-redundant flight control systems with multiple IMUs and gyroscopes maintain stability by cross-validating data. Distributed electric propulsion allows continued flight even after motor failure. Emergency protocols include auto-hover, controlled descent, and a ballistic parachute deployable within 0.3 seconds. Smart batteries feature cell-level monitoring, crash-resistant housings, and automatic cutoffs. Geofencing prevents entry into restricted airspace, while fly-by-wire controls verify commands. Energy-absorbing frames and safety harnesses protect the rider, supporting safe low-altitude operation under 150 meters.

The importance of brushless DC motor is efficient to prevent overheating, while the Phase II report (Ch. 3) highlights LiPo battery cooling systems. Overheat protection and distributed cell architectures mitigate fire risks, with battery management systems (BMS) monitoring voltage thresholds to auto-eject faulty modules[9].

Several studies highlight LIDAR sensors as critical for hoverbike safety, enabling real-time obstacle detection and collision avoidance. Papers [5] and [15] demonstrate LIDAR's superior accuracy over accelerometers in distance measurement, while [17].

A lightweight, low-cost LIDAR-Raspberry Pi system that corrects point cloud distortions and clusters obstacles effectively. These systems enhance autonomous navigation, particularly in urban environments, by providing reliable 3D mapping and reaction to dynamic obstacles[15].

Carbon fiber-reinforced plastics (CFRP) are widely recommended for hoverbike frames due to their high strength-to-weight ratio, improving crash resilience. show that resin-film-infused CFRP reduces wing deflection by 31% and increases structural safety by 28%, critical for impact resistance[23].

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VI. APPLICATION OF SENSORS

Hoverbikes and drones rely on a variety of sensors to maintain stability, ensure safety, and enable autonomous flight. One of the most essential sensors is the Inertial Measurement Unit (IMU), which combines accelerometers, gyroscopes, and sometimes magnetometers to measure acceleration, rotation, and orientation. This helps the flight controller maintain balance and respond to external disturbances. GPS modules are commonly used for navigation and positioning, allowing the vehicle to follow pre-set routes and return to a home point. Barometric pressure sensors, or altimeters, provide altitude data critical for maintaining a stable hover and controlling vertical movement. LiDAR sensors are increasingly being used for obstacle detection and 3D terrain mapping, offering high accuracy and reliability even in low-light or GPS-denied environments. Some hoverbikes and drones also utilize ultrasonic sensors for short-range obstacle avoidance, particularly useful during takeoff and landing. Optical flow sensors and cameras enhance stability and navigation by analyzing movement relative to the ground. In advanced systems, radar sensors may be employed for object detection in challenging weather conditions. Together, these sensors form an integrated system that allows hoverbikes and drones to operate safely and efficiently, whether in manual, assisted, or fully autonomous modes, as highlighted in various literature studies on aerial vehicle control systems.The evaluation of a low-cost LiDAR sensor for indoor UAV navigation by comparing it with accelerometer data.. The paper highlights LiDAR's reliability for obstacle detection in hoverbikes/drones, especially in GPS-denied environments, and cautions against relying solely on inertial sensors for precise navigation[5].

The DJI Livox LiDAR system (<$600) was tested for forest mapping, achieving <5 cm precision. Flight heights below 150 m optimized data quality, proving its viability for hoverbike applications like terrain sensing and low-altitude obstacle avoidance. The study underscores the trade-offs between cost, weight, and performance in LiDAR selection[16].

A novel 12 kg topo-bathymetric LiDAR for UAVs was tested, featuring adjustable pulse rates (50–200 kHz) and high precision. Its lightweight design and flexible flight planning (50–150 m altitude) make it suitable for hoverbike terrain mapping and obstacle avoidance. The sensor's strip-fitting accuracy and depth performance were validated, offering a cost-effective alternative to conventional airborne LiDAR systems[14].

A lightweight LiDAR-Raspberry Pi system for UAV obstacle detection is used. Using polynomial fitting for point cloud correction and CBRDD clustering, it outperformed DBSCAN in handling uneven point densities. The system's low cost and real-time processing capabilities demonstrate its potential for hoverbike safety applications, such as urban collision avoidance[17].

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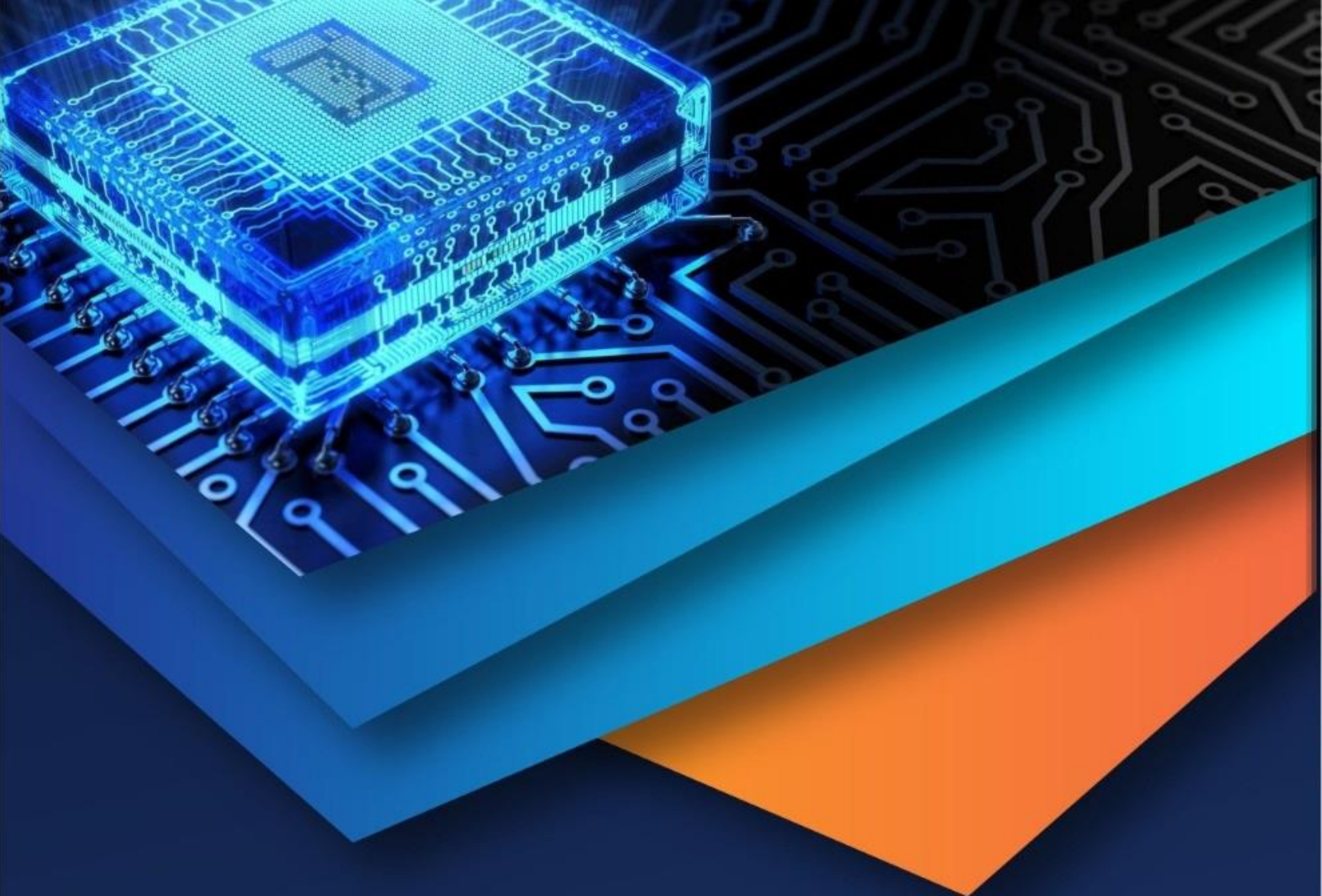

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