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A Review on Stair Climbing Mini Manual Stacker

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Abstract: ***Material handling in small warehouses and retail spaces presents unique challenges, especially when navigating stairs and narrow aisles with conventional equipment. This review synthesizes existing research and design approaches relevant to the development of a Stair-Climbing Mini Manual Stacker, a compact, low-cost alternative to forklifts for light to medium-duty loads. Literature on forklift optimization, equipment selection frameworks, 360° fork rotation mechanisms, Tri-Star wheel stair-climbing systems, lightweight structural configurations, and finite element analysis is critically examined to identify design strategies that enhance safety, manoeuvrability, and load-handling efficiency. Comparative analysis highlights the trade-offs between mechanical simplicity, ergonomic operation, material selection, and cost-effectiveness. Special emphasis is placed on integrating manual belt-driven lifting systems with stair-compatible mobility mechanisms to meet the operational constraints of confined spaces. The review underscores that adapting proven mechanical concepts—while optimizing load distribution and structural stability can lead to practical solutions that reduce manual effort, improve operational efficiency, and ensure durability in small-scale logistics. This synthesis provides a foundation for future innovations in affordable, user-friendly, and versatile stair-climbing material handling equipment.***

Keywords: Stair-climbing stacker, manual lifting equipment, tri-star wheel, belt drive, lightweight design, material handling, literature review.

I. INTRODUCTION

Material handling process is the transportation of raw material, finished product through different stages of production and storage. In most industries, a forklift is employed for numerous operations like lifting, material delivery such as huge boxes, Raw materials, etc. The machine which we are going to produce named as "Stair climbing Mini Manual Stacker" is intended for the same operations but specially developed for small warehouses or retail spaces. At present the task of piling products in such premises involves manual labor and also wastes plenty of time. To accommodate the ever-growing demands of the customer, shopping stores need to make their personnel work overtime to ensure piling of products is made accessible. Thus, such a machine can be utilized in similar spaces for stacking and stacking easily. The equipment is economical, space saving, and can easily be handled by a person and maneuver through the narrow streets.

A manual stacker is a category of manual lifting equipment and is used usually in warehouses, factories, and other industry places to lift and transport loads. It has a frame, a lifting mechanism, and a pair of wheels or casters for transport. The lifting mechanism in a manual stacker would prominently feature a hydraulic pump or lever system that enables the load to be raised and lowered by the operator through the operation of a handle. The stacker's frame is intended to bear the load and offer stability, and it could be adjustable to fit varying load sizes. Manual stackers are available in different sizes and capacities to accommodate various applications. Some are intended for light-duty use, while others handle heavy loads. They can also be equipped with extra features like adjustable forks, straddle legs, or varying wheels or casters to meet certain applications. Generally, a manual stacker is a cost-effective and handy lifting tool that can improve efficiency and safety in many industrial settings.

II. LITERATURE REVIEW

Ugale Sachin et al. (“Forklift Design, Development, and Modeling") Design of low-capacity manual forklifts basic forklift development, modeling, and layout provide grounding for basic forklifts. To reduce deflection under static or dynamic load, model the fork geometry according to Ugale et al. and then modify it using FE stress analysis techniques. The study by Ugale Sachin S. et al. (2014) offers a good place to start when creating a forklift system with a modest capacity. You can customize a structurally solid belt-drive stair-climbing stacker by adding more thorough stress analysis lift mechanics and stability concerns. While maintaining safety, parameter selection can be accelerated by utilizing design reuse frameworks. [1]

Prasad Karande and Shankar Chakraborty (“Material handling equipment selection using weighted utility additive theory”) addressed a practical issue commonly faced in industries: how to choose the best material handling equipment when multiple options are available, and each has its own set of advantages and disadvantages.

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Instead of relying on trial and error or personal opinion, the authors used a smart decision-making method called the Weighted Utility Additive Theory. Karande and Chakraborty's work provides a practical and structured decision-making approach that can be directly used in evaluating and optimizing your stair climbing mini manual stacker. Their WUTA-based model helps balance multiple design factors like cost, weight, ease of use, and safety ensuring that the final design meets user needs effectively and efficiently. [2]

Patel Rahul "360-degree rotation of forks in manual stacker" his team introduced a manual stacker design where the forks can rotate 360 degrees, giving it a unique ability to place or lift loads from multiple directions without moving the entire machine. This is especially helpful in tight or narrow spaces, like small storerooms or factory aisles, where turning the whole stacker may not be practical. The design uses a roller guide mechanism to allow the forks to slide sideways, and then a twin circular plate setup to allow full rotation. The lifting mechanism works through a hydraulic jack, which offers double mechanical advantage meaning it lifts more load with less input movement. work shows how smart mechanical design like fork rotation and sliding guides can solve real-world handling problems without the need for full automation. For your manual stair-climbing stacker, adopting similar ideas can add flexibility, reduce operator strain, and make it more adaptable to different spaces. While their design is focused on floor movement, your adaptation focuses on vertical and stair mobility, making the two complementary. [3]

P. Jey Praveen Raj "Design and fabrication of stair climbing trolley" designed a motorized stair climbing trolley to reduce the human effort required when lifting and moving loads over staircases—something we often face in schools, colleges, apartments, and industries. Their main innovation was using a Tri-Star wheel mechanism, which allows the trolley to "walk" smoothly over steps.The system included a DC gear motor, chain drive, and battery to power the wheels. The trolley's frame was made from mild steel, and they carefully calculated shaft dimensions and structural strength to ensure safety while carrying heavy loads. P. Jey Praveen Raj and his team shows how a smart wheel setup and strong frame can make stair climbing easier for transporting loads. While their version used motors and batteries, the core design concepts like the Tri-Star wheels, safe frame design, and mechanical transmission fit perfectly into your manual belt-driven stacker by adapting their ideas, your design stays affordable, user-friendly, and eco-friendly, while still handling the same real-world challenge: moving loads safely over stairs. [4]

Adhyanth G Ajay "Design and development of lightweight mechanical staircase climbing trolley with better stress distribution" Lightweight Mechanical Staircase Climbing Trolley with Better Stress Distribution. This design uses Tri-Star wheels and a frame made from PMMA (acrylic) to reduce weight while keeping strength. To improve stress distribution, a curved junction in the frame allows loads to spread more evenly through the wheel frame instead of focusing at the center joint. The design features three-wheel star assemblies for climbing stairs, which lowers user effort on steps by engaging wheels in sequence. The design considers stair steepness, trolley stability, and cost-effective production, and the team used FEA to evaluate stress distribution under load. Adhyanth G Ajay and others provide valuable insights into lightweight structural design and stress distribution, particularly through curved webs and tri-star configurations. By applying these ideas to your belt-drive mini stacker, you can create a lighter, more effective frame that distributes tension evenly and remains easy to use. [5]

Snehita Kilari et al. (2019) In their 2019 study, Snehita Kilari and her team designed a tri-wheel staircase climbing trolley to help users carry loads up stairs more easily. They used a smart setup, tri-wheel clusters positioned at 120° angles, which made climbing standard stairs (about 140 mm rise, 300 mm tread) require less effort.They modeled their design with CATIA software and built it using mild steel and bearings, making it both strong and affordable. Even though our project uses a belt drive instead of wheels, Kilari's design offers us several valuable insights: - Stair Compatibility: Just as they matched wheel size to stair steps, we need to design our belt and pulley system to fit stair dimensions. Structure: - Their use of a steel frame is practical and budget-friendly, which we can apply directly to our stacker design. Load Handling: Their trolley managed 20 kg smoothly, so we can aim for a similar or slightly higher load (20–30 kg) with our belt system. Shock Absorption: While they used wheels to absorb shocks, we will ensure our belt has good grip and tension to avoid slipping or jerks. Snehita Kilari's stair trolley shows that smart, simple mechanical design can effectively address stair transport challenges. [6]

Manish Gosavi "International research journal of modernization in engineering technology and science in their 2019 study, Snehita Kilari and her team created a tri-wheel trolley designed to help users carry loads smoothly up stairs. They chose a smart setup with tri-wheel clusters placed at 120° angles, which made it easier to climb standard stairs about 140 mm rise and 300 mm tread with less effort.They used CATIA software to model their design and built it with mild steel and bearings, ensuring it was strong and affordable. Their main goals were:- Reducing manual effort while climbing stairs- Safely handling loads up to 20 kg- Creating a simple, low-cost product- Minimizing shocks and jerks during stair movement. What We Can Learn for Our Belt-Driven Stacker Even though our project uses a belt drive instead of wheels, we can apply concepts from Kilari's design in several ways:- Stair Compatibility: Just like they matched wheel size to stair steps, we need to design our belt and pulley system to fit stair dimensions.-

Structure: Their approach with a steel frame is practical and budget-friendly, which we can use in our stacker design. Load Handling: Their trolley could manage 20 kg easily, so we can aim for a similar or slightly higher load of 20 to 30 kg with our belt system. Shock Absorption: While they used wheels to absorb shocks, we need to ensure our belt has good grip and tension to prevent slipping or jerks. Snehita Kilari's stair trolley demonstrates that a simple mechanical design can effectively address stair transport issues. For our belt-driven mini stacker, her approach motivates us to focus on proper alignment, low-cost construction, and user-friendly operation, which are key features that will enhance our device's practicality and efficiency for everyday stair use. [7]

Rohit Rai "Design and static analysis of manual pallet truck using FEM method by Ansys software"

The study explores the structural design and static stress analysis of a manual pallet truck, a simple floor-level load-handling device using CATIA for CAD modeling and ANSYS for Finite Element Analysis (FEA). Simulation-Driven Design: Components like the carriage and forks were modeled in CATIA and analyzed in ANSYS under static loading. This shows clearly how design choices affect stress and deformation. Material Comparison: The authors compared multiple materials structural steel, aluminum alloy, magnesium alloy, and epoxy carbon composite under a 1000 kg load: Structural Steel: 50.58 MPa stress, 4.19 mm deformation Aluminum Alloy: 50.34 MPa stress, 11.74 mm deformation Magnesium Alloy: 50.18 MPa stress, 18.45 mm deformation Epoxy Carbon Composite: 49.38 MPa stress, 11.83 mm deformation Among these, carbon composite offered substantial weight reduction (30%) while maintaining strength .This paper offers important design insights that align with your goal of building a strong, lightweight, manually operated stair-climbing stacker The study highlights the trade-offs between weight and structural stiffness .Carbon composites and aluminum alloys offer major weight savings crucial for a portable, stair-climbing device while steel gives lower deflection. You can replicate their CAD-to-FEA workflow for your tri-star wheel arms, belt pulley fixtures, or frame members. Analyzing those components under expected load and stair climbing forces ensures your design stays safe and durable. Just like their conclusions, you can use composite or lighter materials where possible to reduce manual effort, without compromising on strength. By adopting the modeling techniques and material insights from this study, you can meaningfully improve your design safety, portability, and weight efficiency. Conducting your own FEM simulations ensures that belt mounts, wheel supports, or frame sections will perform reliably under load. A composite or aluminum frame could make your manual stacker much easier to maneuver on stairs, without sacrificing structural strength. [8]

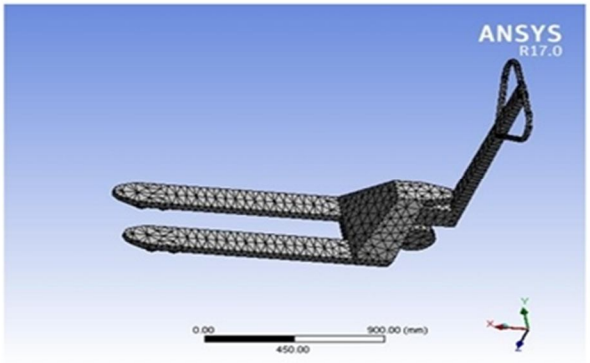


Fig.1.0 Geometry Meshing

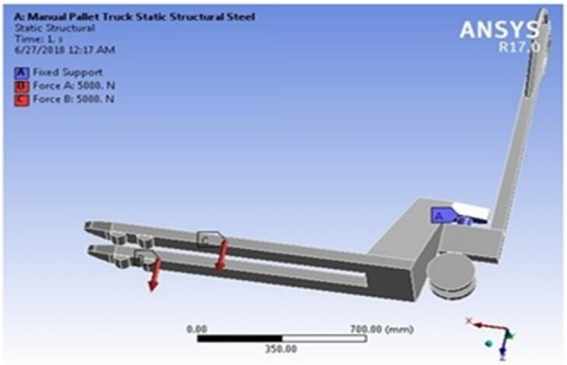


Fig.1.1Boundry conditions (Structural steel)

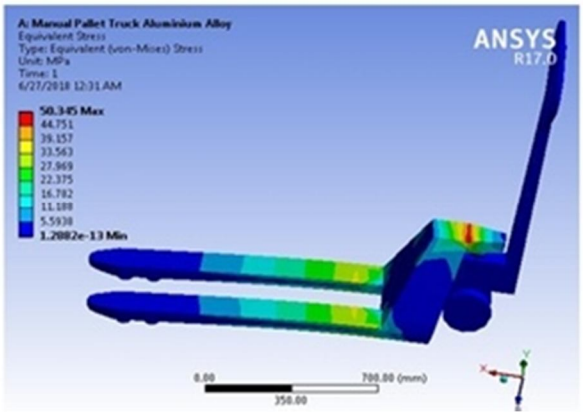


Fig.1.2 Equivalent stress (Aluminum alloy)

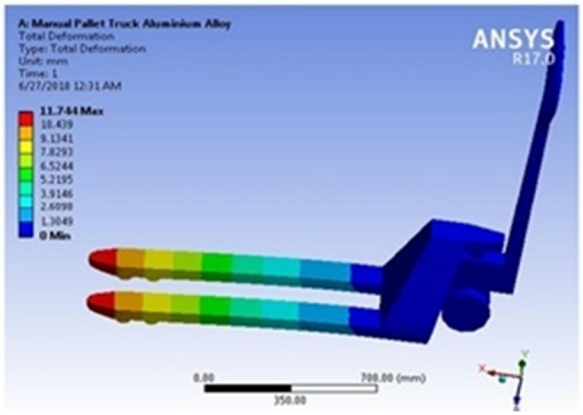


Fig.1.3 Deformations (aluminum alloy)

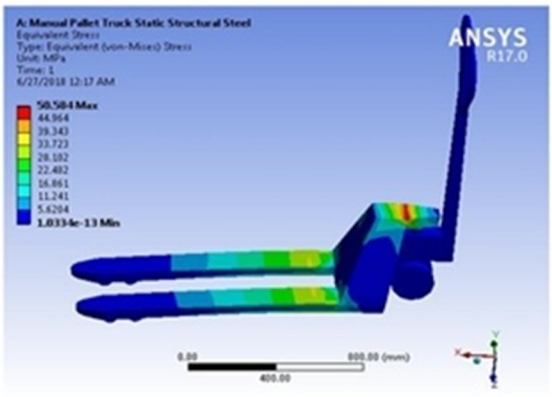


Fig.1.4 Equivalent stress (Structural steel)

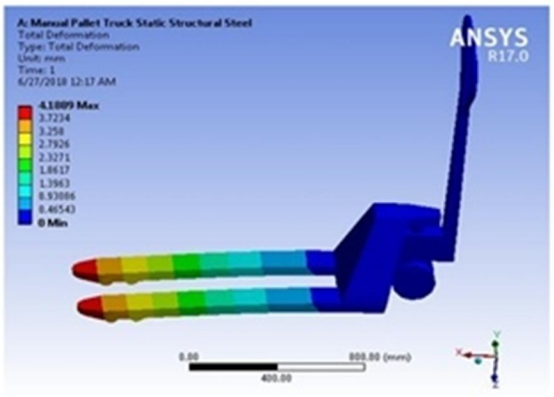


Fig.1.5 Total Deformation (Structural steel)

IV. RESULTS & DISCUSSION

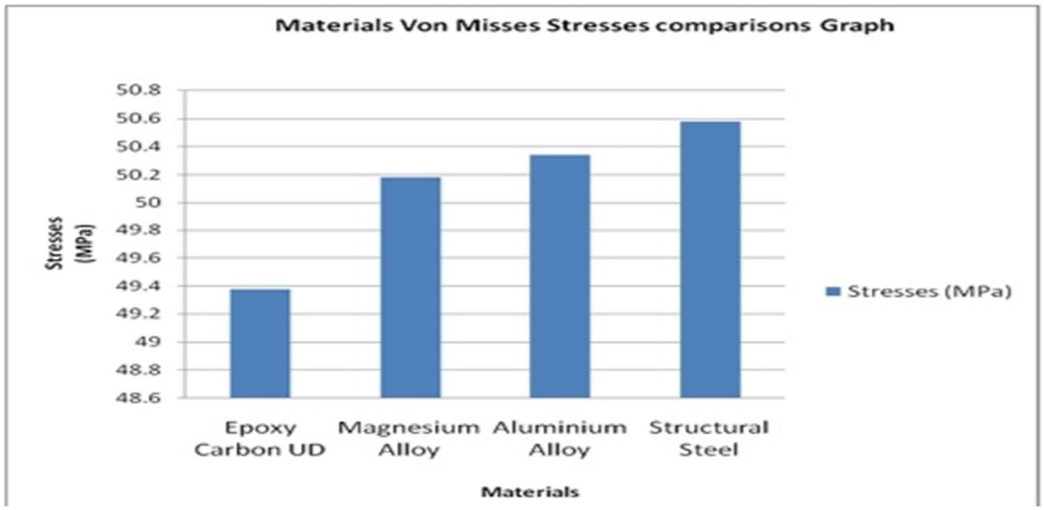


Fig.1.6 Stress comparison with different materials

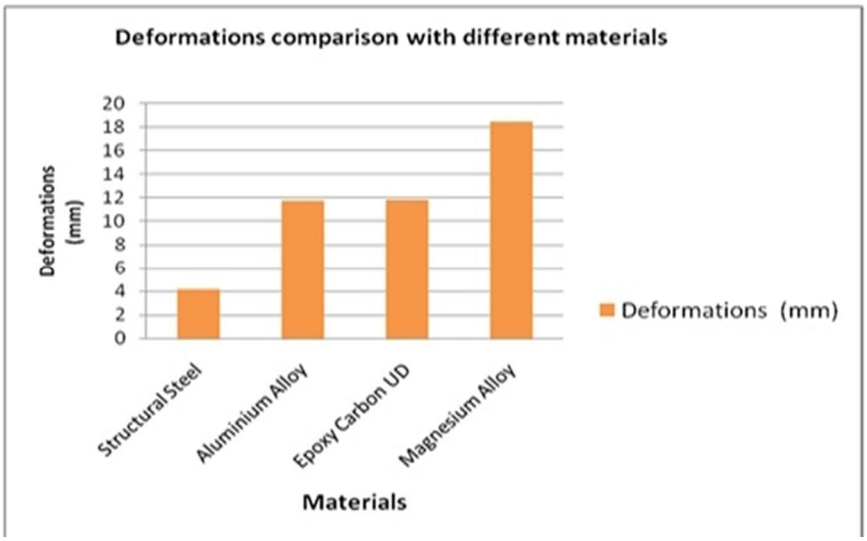


Fig.1.7 Deformation comparison with different materials

III. CONCLUSION

The review of existing literature and industrial practices highlights a clear gap in material handling solutions for small warehouses and retail environments where stairs, narrow aisles, and space constraints hinder the use of conventional forklifts. Studies on forklift optimization, decision-making frameworks, fork rotation systems, tri-star wheel stair-climbing mechanisms, lightweight structural configurations, and finite element analysis provide a solid foundation for developing a compact, affordable, and ergonomically efficient Stair-Climbing Mini Manual Stacker.

Key insights include the importance of optimized load distribution, robust yet lightweight materials, and stair-compatible mobility systems to reduce manual effort and improve stability. Adaptations from motorized stair trolleys, tri-wheel configurations, and hydraulic/manual lifting mechanisms can be combined with belt-driven systems to maintain simplicity and cost-effectiveness. Material studies further suggest that composites and aluminium alloys can enhance portability without compromising safety or strength, while steel remains advantageous for low-deflection applications.

By synthesizing proven mechanical concepts with targeted design improvements, the proposed stair-climbing stacker can address the operational challenges of small-scale logistics. This approach not only improves efficiency and worker safety but also offers a practical, low-maintenance solution adaptable to various confined-space material handling needs.

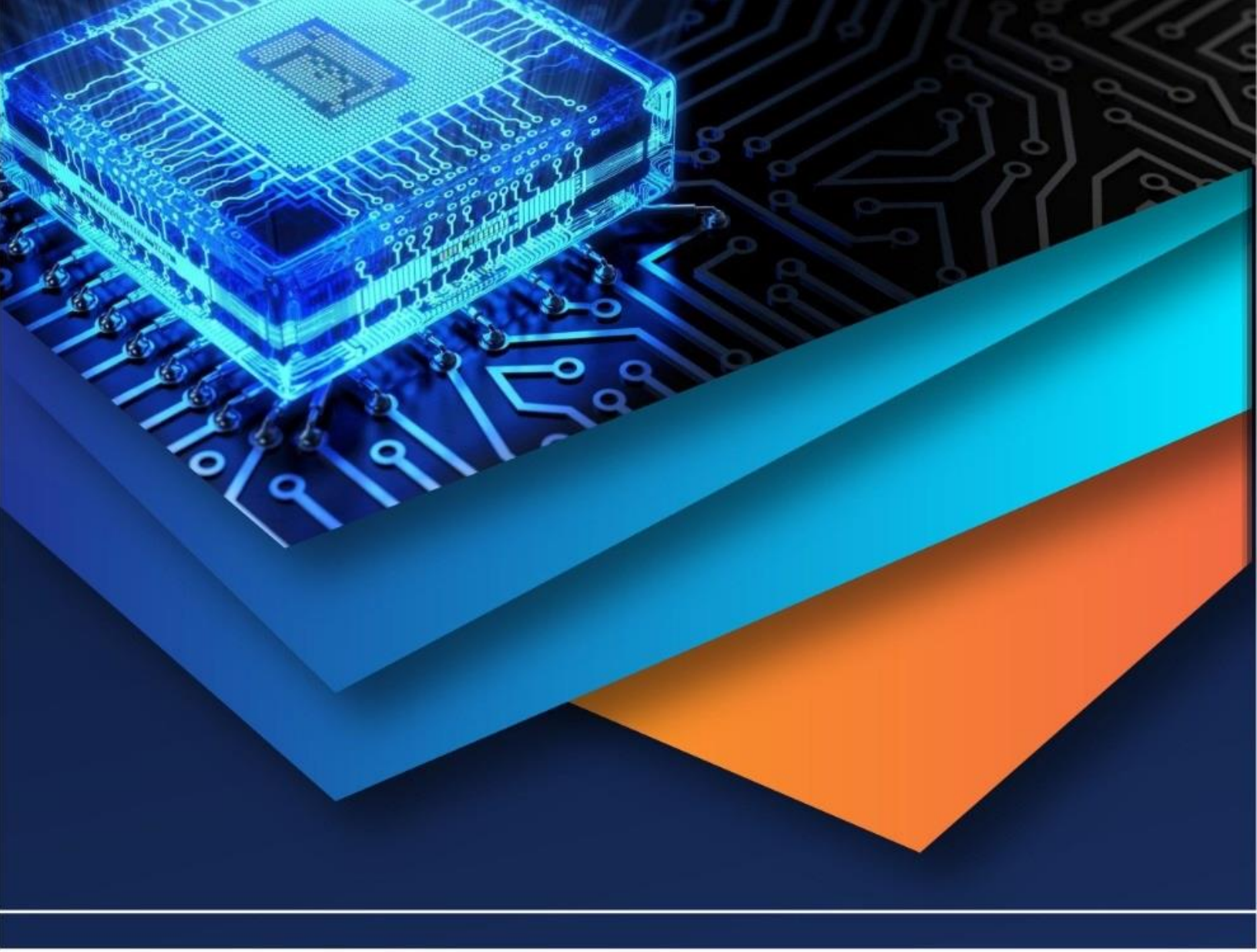
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