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Advance Concepts of Launching Girder in Metro Railway

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Abstract: The rapid expansion of metro rail networks in urban areas demands innovative construction techniques to ensure speed, safety, and minimal disruption to existing infrastructure.
This paper explores advanced concepts in the implementation of launching girders, focusing on their evolving role in accelerating elevated metro construction. It highlights the engineering innovations, automation strategies, and real-time monitoring technologies that are redefining girder launching methods. The study also presents a comparative analysis of traditional versus advanced launching techniques, emphasizing improvements in structural integrity, operational efficiency, and worker safety. Case studies from recent metro projects provide practical insights into deployment challenges and the effectiveness of modern solutions. This paper aims to serve as a reference for engineers and project managers seeking to optimize metro rail construction through cutting-edge girder launching technologies.
Case studies from recent metro rail projects in India and abroad are analysed to demonstrate the successful implementation of these advanced concepts, with metrics including reduced construction time, enhanced safety, and cost efficiency. The challenges associated with deploying advanced launching girders such as site constraints, logistical complexity, and workforce training are also discussed along with potential mitigation strategies.
Keywords: Launching Girder, Metro Rail, Cutting-edge Grider Launching Technologies, Automation, Safety, Structural Integrity.

I. INTRODUCTION

As cities throughout the world become more urbanised, there is a growing need for mass transit systems that are eco- friendly, high-capacity, and efficient. Metro railroads, which provide quick mobility and less traffic, have become a dependable answer to the problems associated with urban transit. Elevated metro routes have become more popular as metropolitan landscapes get denser and land becomes more limited since they cause less disturbance at ground level and can be completed more quickly than underground systems.

One of the most critical components in the construction of elevated metro corridor sis the launching girder system, which facilitates the erection of precast segments or girders that form the viaduct structure. Traditionally, launching girders have relied on manual or semi-mechanical operations, often facing limitations in speed, accuracy, flexibility, and safety. However, the advent of advanced technologies and engineering methodologies has revolutionized the way Launching girders are designed, deployed, and operated.

Modern launching girders are complex systems that incorporate automation, hydraulics, adaptability, and real-time monitoring; the y are no more only mechanical constructions.

These developments allow segments to be erected more quickly and safely over difficult alignments, including tight urban environments, complex intersections, varied spans, and abrupt curves. Additionally, the use of digital techniques like Finite Element Analysis and Building Information Modelling during the planning and execution phases has enhanced project coordination, load management, and design accuracy.

One possible technological advancement that might be incorporated into the apparatus or temporary construction is a monitoring system that gauges structural responses. However, there hasn't been any research done on construction monitoring using the answers from structural monitoring of construction equipment. As seen in Figure 1, this study investigates the viability of evaluating construction productivity and progress utilising structural responses from construction equipment. This study assesses the viability of this concept by testing it on a metro rail viaduct construction.

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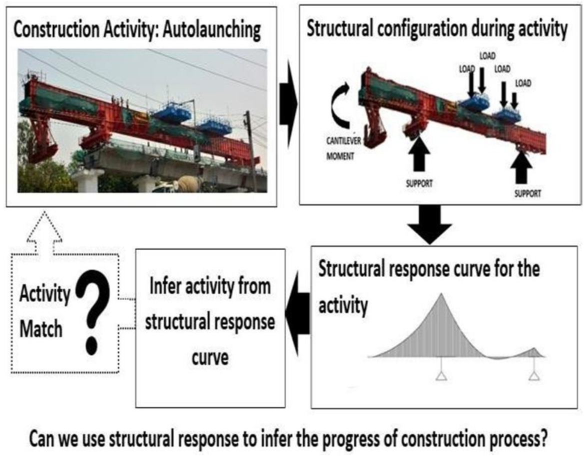

Fig-1: Viability of Evaluating Construction Productivity

This paper focuses on the implementation of these advanced concepts in launching girder operations for metro railway projects. It aims to provide a comprehensive understanding of the innovations, their practical applications, and their impact on overall project performance. By analysing recent case studies and real-world applications, this study highlights the role of advanced launching girders in overcoming site constraints, reducing construction time, improving worker safety, and optimizing costs.

II. LAUNCHINGGIRDERANDITSOPERATIONS

The different stages (or state of launching girder) for the construction of a span and its associated bending moment diagram (BMD is for illustration purpose and may not be accurate on schematic)areasshowninFigure2andFigure3 respectively.

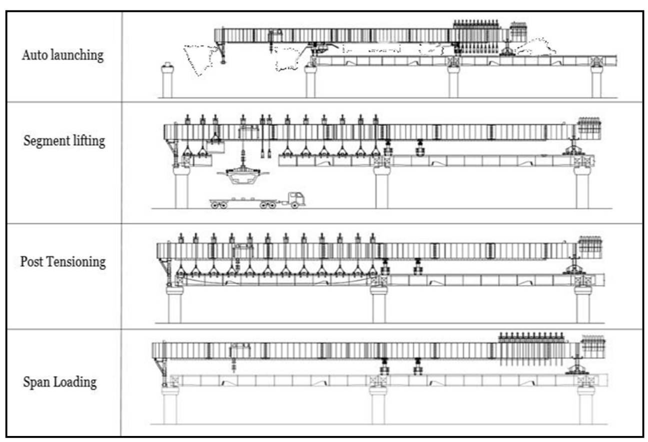

Fig-2: Launching Girder operations

A. Auto Launching

Auto-launching is the process when the launching girder is moved from the ‘constructed span’ to the ‘next to be constructed’spanoftheviaductasshowninFigure1.4.Inthis process, the front support of the launching girder is released and launching girder is supported by remaining supports. Launching Girder is launched to the subsequent span by pushing the plate girder forward to the next pier. Counterweight placed at the rear side of the LG balances cantilever moment created by the front portion until the front support reaches the next pier. The support is then rested on the pier which marks the end of Auto launching operation.

B. Segment Lifting

This operation takes place after the auto-launching. It involves lifting each prefabricated segment from the ground sequentially and assembling it along the span to form the viaduct as shown in Figure2. Once all the segments are lifted, they are then aligned and moved into position to be joined and placed on the piers. All the segments lifted remain suspended on the front portion of LG. Typical BMD of the operation is shown in Figure 3.

C. Post-tensioning

This process, which takes place after the segment lifting involves joining all the segments through a post-tensioning process as shown in Figure 2. Cables are run through the segments and then tensioned to the designed stress with a hydraulic jack while the segments are suspended on the front portion of LG. Once the stressing is done, the assembled segments act as a single structure. Load of the segments is still borne by the front portion of the LG. The bending moment is similar to segment lifting, however, the moment on the front side is partly negative in this case since the launching girder is fully loaded.

D. Span lowering

The post-tensioned span is lowered onto the piers in this process. Once the span rests on the pier, Segments are released from the launching girder. The span transfers its self-weight to the piers. LG is free from the load of the segments. Once this process is done, LG is ready for auto launch to the next to be
constructed span. Schematic of this stage is shown in Figure2. The bending moment during this stage is similar to the beginning of segment lifting but with a higher magnitude of the negative moment on the rear side.

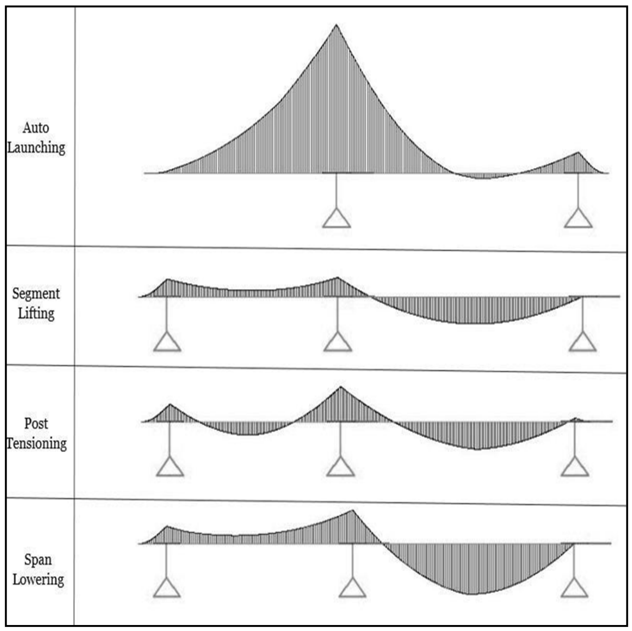

Fig-3: Bending moment associated with launching girder activities

The bending moment changes continuously with respect ot he operation. It starts with a BMD similar to span lowering as shown in Figure 3. When the support is released during launching. BMD on the front will have a negative moment which increases with the increase in the distance launched. Finally, when front support rests on the girder, BMD corresponds to the one at the start of launching. Then, during the start of launching front side of the launching girder will have a positive moment which progresses to negative moment as the no. of segment lifted progress, Post-Tensioning and the end of segment lifting would have the maximum negative moment on the front side of the LG. However these can be differentiated since the end of segment lifting will have a sudden change in slopes of BMD while that of Post-tensioning would have gradual changes. Once the span is lowered on to piers, the BMD changes to the initial state before the launch.

By measuring the structural parameters with sensors likes train gauges, load cells, etc., these changes in stress patterns can be detected in real time. After obtaining the strain pattern, the strain pattern throughout the LG's length can be used to identify the LG's condition. However, there are risks associated with LG's operations, including support settling, counterweight variations, segment weight variations, etc.

The outcomes of the basic analytical model and the field observations will differ as a result of these field uncertainties. Furthermore, the nature of field conditions may lead to measurement uncertainties and sensing inaccuracies. These uncertainties should be taken into account by the system identification algorithm while determining the launching girder's condition.

III. LITERATUREREVIEW

The evolution of launching girder technology in metro railway construction has been widely studied. Early literature highlights the use of conventional steel truss girders, which were manually operated and limited by slow speed and safety risks. With advancements in hydraulics and automation, researchers like Kumaretal.(2011)emphasized the benefits of mechanized systems In improving alignment accuracy and reducing labor dependency.

Recent studies have focused on modular and adaptable launching girders capable of handling complex alignments and varying span lengths. The integration of Building Information Modeling (BIM)and Finite Element Analysis (FEA), as noted by Singh et al. (2018), has enabled better planning, design optimization, and collision detection.

In addition, real-time monitoring systems using sensors have enhanced the safety and reliability of launching operations, as discussed by Cheng et al. (2020). Case studies from Delhi Metro and Mumbai Metro projects showcase successful implementations of these advanced techniques in urban settings.

IV. METHODOLOGY

A. Problem Statement

The preceding chapters covered the necessity of keeping an eye on the launching girder as well as the difficulties in putting up a monitoring system. The launching girder's operations might not be sufficiently monitored by the standard automated data collection techniques utilized in construction. In order to solve the problems brought on by the typical ADCs, a new ADC technique must be created. Installing a structural health monitoring system on a piece of equipment and connecting the structural reactions to the construction activity could solve this issue. Sensor placement must be methodical for this approach to be successful. Sensors ought to be positioned in areas that provide unique structural reactions that can differentiate between different construction activities. The focus of this study is to develop a monitoring system that classifies the operations of the launching girder in order to evaluate the progress of the construction of the metro rail viaduct. This is tested byutilizing the strain responses from theplate girder of the launching girder and evaluating the strain pattern. Additionally, inferring the construction operation from the structural responses requires well-designed algorithms and methodology tailored for the purpose.

B. Objectives

This study's main goal is to create a framework for automatic progress tracking of girder operations in real time. This goalis further broken down into three smaller goals, which are as follows.

1) To create a wireless sensor network for real-time monitoring by collecting and transmitting data from launching girders.
2) To identify the best sens or positions for launching girder operations inference.
3) To assess and enhance current techniques for determining the launching girders' condition from sensor data.

C. Scope

The integration of real-time monitoring systems on launching girders provides a proactive approach to safety. These systems can detect anomalies, structural stress, or deviations from planned construction parameters in real-time. Automate dalerts and shutdown mechanisms can be implemented to halt operations if any safety concerns are identified, preventing potential accidents.

The methodology followed in this study is as shown in Figure 4.Itisdividedinto3phases.

1) Phase1

Visiting the launching girder construction site and closely examining the structural design and functionality of the launching girder is the first phase of the research technique. The assumption behind these site visits is that they will provide input for the design of the wireless sensor network and sensor placement. Apart from the site inspections, the first step of the examining the literature for comparable issues and their fixes in the construction sector is another aspect of approach.

2) Phase2

The research's second phase is divided into three parts. Wireless sensor network design is the first category. The wireless network sensor design is completed in phases using the inputs from site inspections, spatial circumstances, and environmental factors. The initial step involves choosing a wireless sensor network technology from among those that are available, taking into account aspects like cost and environmental and geographical performance. Choosing the topology is the second step in a wireless sensor network. The next step is to build the WSN's architecture to accommodate the environmental and spatial circumstances.

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Choosing hardware components that complement the WSN architecture is the next step in the design process. Assessing performance first in the lab and the non the site is the last phase in designing a wireless sensor network.

In this step, system identification techniques from similar research are first critically examined. After selecting a compatible System Identification Methodology, its effectiveness is assessed. The System Identification Methodology is adjusted to meet the needs if the efficiency is less than what is needed.

3) Phase3

Validation is the third phase of the study. The WSN must be installed on a functional launching girder for this phase. After that, the sensor data is gathered for a while. After then, this data is identified by the system, and the conclusions are noted. The conclusions must be compared to the logbook information that documented the site's events. Each methodology's percentage of matches is noted, and the accuracy is compared using that information.

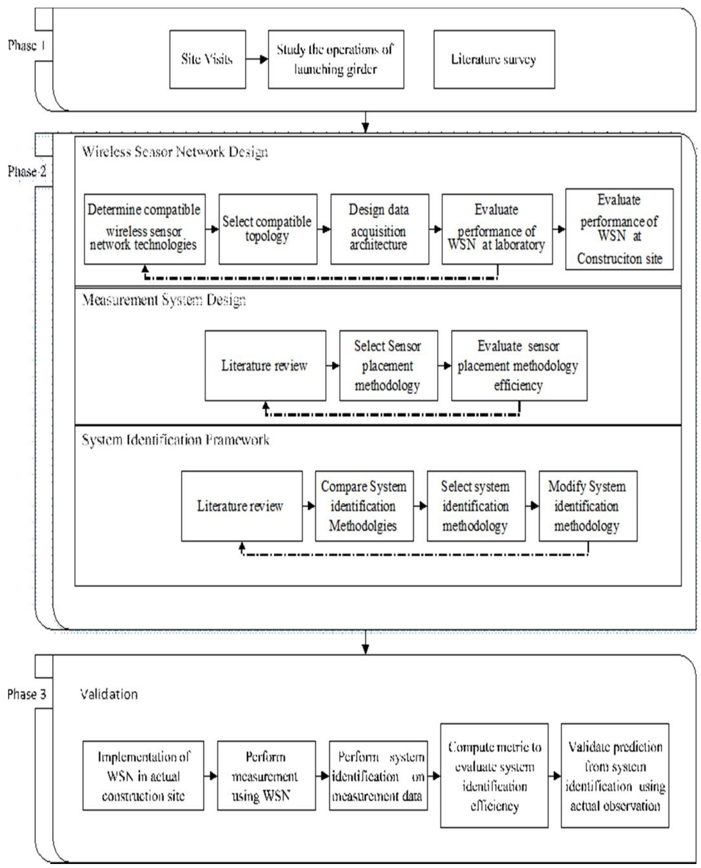

Fig-4: Methodology

V. RESULT

The implementation of advanced launching girder technologies in metro railway construction has yielded measurable improvements in key performance areas. Based on the data collected through site visits, project reports, technical specifications, and expert interviews, the following results were observed.

A. Time Efficiency and Span Launching Speed

The integration of hydraulic systems, modular components, and digital tools significantly reduced the average span launching time.

1) Traditionallaunchingtimeperspan:8to10hours
2) Advanced system launching timeperspan:6 to 7.5 hours
3) Timesavings:Approximately20–25%perspan

This reduction in cycle time contributed to faster project milestones, enabling early completion of viaduct sections and minimizing disruptions to urban traffic and communities.

B. Performance Evaluation on Launching Girder Construction Site

Theanalysis'sfindingsaredisplayedinFigure5.Nonetheless, RSSI variation is in line with findings published in the literature(Piyareetal.2013). Not with standing the variations in RSSI values, every result is over the -102dBm XBee requirements threshold. Furthermore, the PDR values are constantly higher than 90%.Thus, it can be said that the current wireless sensor network satisfies the dependability standards and has sufficient signal strength to permit data transfer within the designated range.

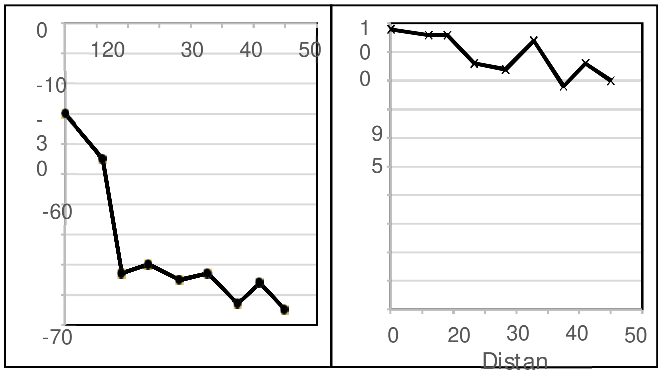

Fig-5:Performance of Wireless sensor network.

The routers and end devices at each location were taken out and replaced in a methodical manner to test the network's redundancy and ensure that it would remain stable in the event of a device failure. As expected, a network was effective even without specific notes in between, automatically routing the packets through a separate device. The assessment verified that the technology, parts, and topology employed for the WSN were suitable for putting in place a wireless sensor network to keep an eye on launching girder operations.

C. Time Efficiency and Span Launching Speed

Figure 6 displays the RSSI (Received Signal Strength Indicator) variation with distance, which is in line with findings from the literature (Piyare et al. 2013).The farther one gets from the coordinator, the lower the RSSI. Plotting the strength decrease logarithmically, however, will not produce the anticipated linear connection with distance. This is consistent with (Parameswaran et al. 2009), which found that RSSI does not provide consistent behavior even under ideal conditions. Reflection and multipath phenomena caused by end walls and the presence of electromagnetic interference from devices like Wi-Fir outers can be linked to the variations in 10 bytes and 30 bytes at distances between 40 and 60 meters.

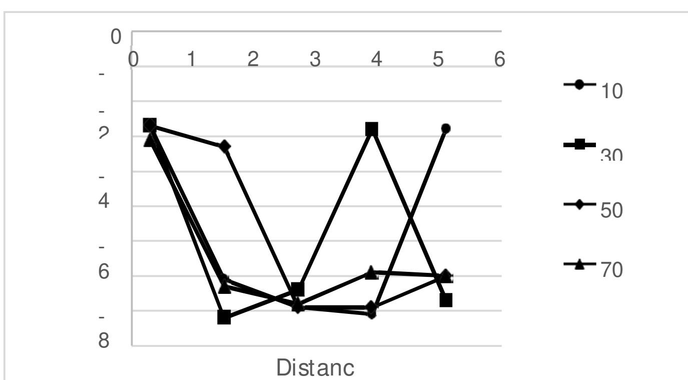

Fig-6: Variation of RSSI with distance

D. Safety Performance Improvement

Projects utilizing real-time monitoring systems (e.g., sensors for load, displacement, and alignment) reported improved safety outcomes.

- Safety incidents (traditional systems): Multiple near- miss and minor injury reports
- Safety incidents (advanced systems): Zero major incidents, significantly fewer minor events

Key factors: Sensor integration, controlled hydraulic operations, remote monitoring.
The data showed a notable improvement in operational safety, supporting better compliance with occupational health and safety regulations.

E. Structural and Alignment Precision
Precision in the placement of precast segments was significantly improved with the use of computer-controlled alignment systems and real-time deflection monitoring.
- Tolerance in alignment (traditional systems):±10mm to ±15 mm
- Tolerance in alignment (advanced systems):±5 mm to ±7 mm
- Reductioninreworkandadjustments:Upto60%

This increased accuracy led to better structural integrity and long-term durability of the viaducts.

F. Environmental and Traffic Impact
Use of faster and safer launching methods reduced the duration of road closures and minimized construction-related emissions.
- Traffic disruptions (traditional methods): Road blockages lasting 12–16 hours
- With advanced methods: Limited to6–8 hours

Lower public inconvenience and reduced carbon footprint from construction equipment

VI. CONCLUSION
The implementation of advanced launching girder technologies has marked a significant leap in the construction methodology of metro railway projects. Through the integration of hydraulic systems, modular structural designs, real-time monitoring, and digital tools such as Building Information Modeling (BIM), metro infrastructure development has become faster, safer, and more precise.
While initial investments in advanced systems are relatively high, the long-term gains in efficiency, reduced project duration, minimized rework, and enhanced safety justify the costs. Moreover, the reduced impact on urban traffic and lower environmental footprint make these technologies more sustainable and suitable for modern cityscapes.
In conclusion, the adoption of advanced launching girder concepts is not just an enhancement but a necessity for future metro rail projects, especially in densely populated and geometrically challenging environments. These systems provide a balanced solution that aligns with modern construction demands, safety standards, and sustainable development goals.

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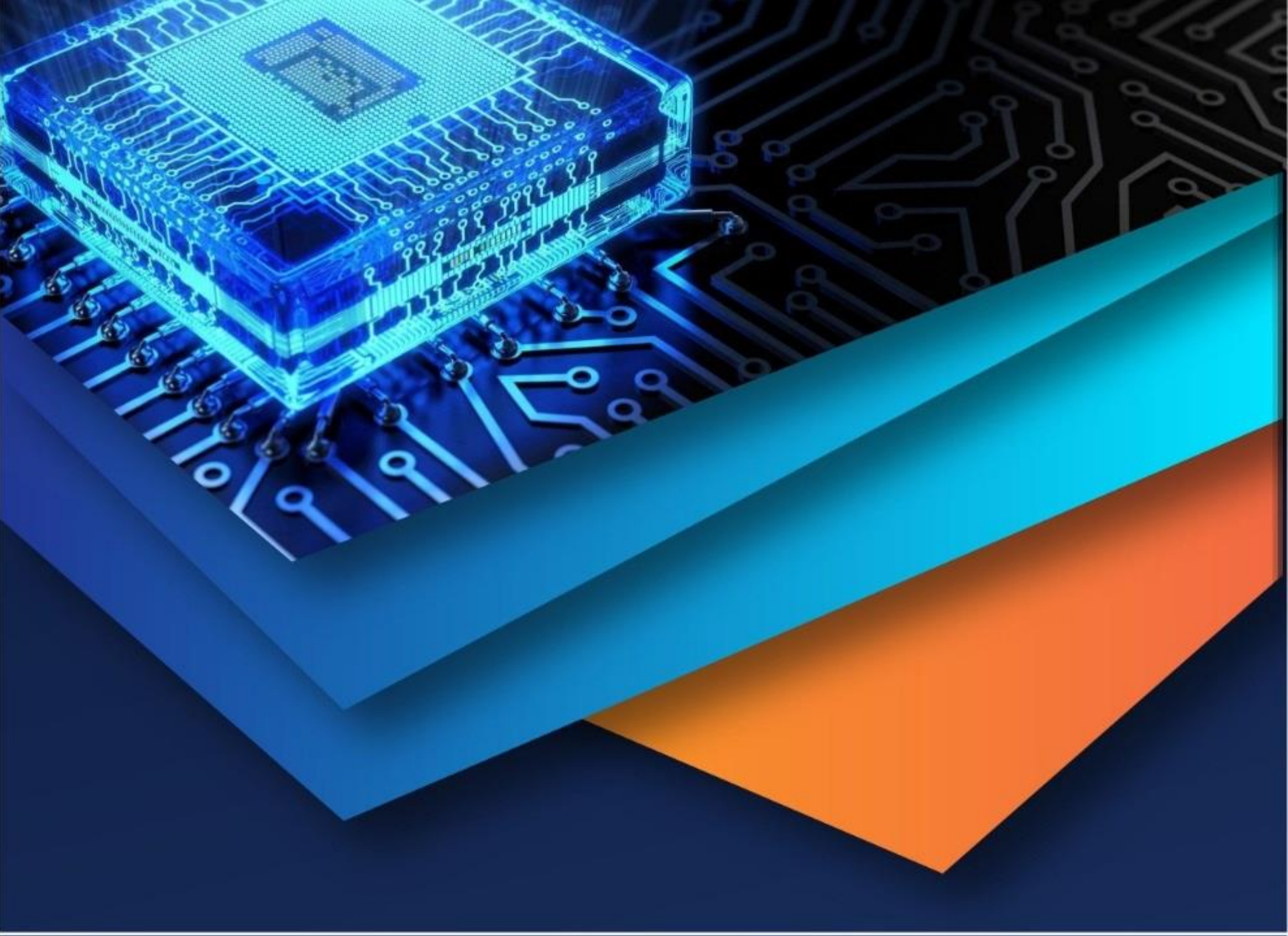

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