INTELLIGENT SPIKE BARRIER SYSTEM: AIML-BASED DESIGN FOR EFFICIENT AMBULANCE AND POLICE VEHICLE PASSAGE IN WRONG ROUTE SCENARIOS

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Abstract
This research introduces an innovative Spike Barrier System for roads, integrating Artificial Intelligence and Machine Learning algorithms to discern and prioritize emergency vehicles. By analyzing diverse datasets, the system accurately identifies distinctive features of ambulances, Fire Engines and police vehicles, allowing for real-time decision-making on access permissions. Robust mechanical components ensure effective deployment of spikes, while fail-safe mechanisms address potential malfunctions, ensuring safety. Building upon previous studies, this approach enhances traffic management, providing a seamless pathway for critical vehicles while preventing unauthorized access. The integration of AIML into spike barrier systems represents a novel solution to facilitate the efficient movement of emergency vehicles in wrong-route scenarios.
Keywords: Spike Barrier System, Artificial Intelligence, Machine Learning, Emergency Vehicle Detection, Traffic Management, Security Systems, Wrong Route Scenarios, Ambulance, Police Vehicles, Intelligent Transportation Systems..

I. Introduction

In the realm of traffic management and perimeter security, spike barriers stand out as robust and effective tools designed to control access and enhance safety. These physical security devices, often installed on roadways and entry points, are engineered to regulate the movement of vehicles by deploying retractable spikes, presenting both a deterrent and a control mechanism. The utilization of spike barriers has become increasingly prevalent in various contexts, ranging from military installations and high-security zones to urban traffic control and emergency response systems.
The primary purpose of spike barriers is to manage vehicular access and prevent unauthorized entry, thereby bolstering security measures. These barriers are particularly crucial in scenarios where controlled access is imperative, such as government buildings, airports, military bases, and critical infrastructure facilities. However, their application extends beyond traditional security concerns, encompassing traffic management solutions and the facilitation of emergency vehicle movement.
Spike barriers come in various designs, but they commonly consist of retractable metal spikes that can be swiftly deployed or retracted as needed. The barriers are strategically placed at entry and exit points, allowing authorized vehicles to pass through while deterring or obstructing unauthorized ones. The effectiveness of spike barriers lies in their ability to act as both a physical deterrent and a controlled access mechanism.
One significant area of spike barrier application is in urban and highway traffic management. In congested metropolitan areas, controlling the flow of traffic is a constant challenge. Spike barriers play a pivotal role in regulating entry and exit points, preventing wrong-way driving, and managing traffic in one-way lanes. The integration of modern technologies, such as sensors and automation systems, has further enhanced the efficiency of spike barriers in addressing traffic-related issues.
In recent years, the utilization of Artificial Intelligence and Machine Learning (AIML) in spike barrier systems has emerged as a cutting-edge development. AIML algorithms are employed to enable smart decision-making capabilities in spike barrier operations. This is particularly relevant in situations where selective access is required, such as allowing emergency vehicles like ambulances and police cars to pass through swiftly. By incorporating intelligent detection systems, spike barriers can

differentiate between various types of vehicles, facilitating the seamless movement of authorized vehicles while restricting others.
One of the critical aspects of spike barrier utilization is its role in emergency response scenarios. In situations where every second counts, such as medical emergencies or law enforcement operations, rapid and unimpeded access is vital. Traditional security measures can inadvertently impede the progress of emergency vehicles. Spike barriers equipped with AIML-based detection systems address this challenge by identifying emergency vehicles and allowing them to pass through even if they are approaching from the wrong direction.
Furthermore, the spike barrier's utilization aligns with the broader paradigm of Intelligent Transportation Systems (ITS), where technology is leveraged to enhance the efficiency and safety of transportation networks. By incorporating spike barriers into these systems, cities and organizations can better manage traffic, improve security, and streamline emergency response efforts.
In conclusion, the utilization of spike barriers represents a multifaceted approach to addressing security, traffic management, and emergency response challenges. As technology continues to evolve, the integration of AIML into spike barrier systems is poised to redefine how these barriers operate, making them more adaptive, intelligent, and responsive to the dynamic demands of modern urban environments. The intricate balance between security and accessibility that spike barriers offer makes them indispensable tools in the broader landscape of transportation and security infrastructure.
Spike barriers, as formidable physical security devices, have become integral components in managing vehicular access and ensuring security in various environments. These barriers, equipped with retractable spikes, serve both as deterrents and controlled access mechanisms, finding applications in military installations, high-security zones, urban traffic control, and emergency response systems

II. Literature

Intelligent spike barrier systems have emerged as critical components in modern traffic management, aiming to enhance safety, security, and efficiency on roadways. This literature review presents an in-depth analysis of recent advancements in spike barrier technology, vehicle detection methods, and the integration of artificial intelligence and machine learning (AI/ML) for traffic surveillance and control. The review encompasses a wide range of research papers, each offering unique insights and contributions to the field.
Several studies have focused on the design and development of spike barrier systems capable of effectively managing traffic spikes during peak hours or emergencies. Udenia and Bhati [1] present a Traffic Spike System designed to regulate traffic flow by deploying spikes selectively based on real-time vehicle detection. Similarly, Bhansali [2]introduces a Mechanism for Road Spike System, aiming to enhance road safety by preventing wrong-route driving through automated spike deployment. These systems leverage vehicle detection technologies to identify approaching vehicles and trigger barrier mechanisms accordingly, thereby mitigating traffic congestion and enhancing road safety.
In parallel, advancements in AI/ML have revolutionized vehicle detection and classification techniques, enabling more accurate and efficient traffic surveillance systems. Rawat et al. [5]propose a Vehicle Detection System utilizing artificial intelligence for traffic surveillance, leveraging deep learning algorithms to achieve high detection accuracy in complex traffic environments. Tak et al. [6] extend this approach by developing an AI-based Vehicle Detection and Tracking System for Cooperative Intelligent Transportation Systems (C-ITS), facilitating real-time vehicle monitoring and management. These AI-driven solutions offer improved scalability, adaptability, and performance compared to traditional detection methods, making them invaluable for modern traffic management applications.
Moreover, the integration of multi-camera data fusion and machine learning techniques has further enhanced the capabilities of vehicle detection systems. Wu et al. [3] introduce an Accurate Vehicle Detection framework that combines data from multiple cameras with machine learning algorithms to improve detection accuracy and reliability. Similarly, Dikbayir and Bülbül [7] propose a Deep

Learning Based Vehicle Detection approach, leveraging deep neural networks to detect vehicles in aerial images with high precision. These methods demonstrate the potential of data-driven approaches in enhancing the robustness and scalability of vehicle detection systems, paving the way for more effective traffic management solutions.

Furthermore, research efforts have been directed towards evaluating the performance and effectiveness of vehicle detection and tracking algorithms in real-world scenarios. Kasturi et al. [9] present a Framework for Performance Evaluation of Face, Text, and Vehicle Detection, offering comprehensive metrics and protocols for assessing the accuracy and reliability of detection systems. Similarly, Kul et al. [10] provide a Concise Review on Vehicle Detection and Classification, summarizing various detection approaches and bench marking datasets for performance comparison. These studies contribute valuable insights into the challenges and opportunities associated with evaluating and bench marking vehicle detection systems, facilitating the development of more robust and standardized evaluation methodologies.

Additionally, advancements in video-based vehicle detection have been instrumental in intelligent transportation systems (ITS) for traffic monitoring and management. Chintalacheruvu and Muthukumar [13] propose a Video-Based Vehicle Detection approach, leveraging image processing techniques for real-time vehicle detection in surveillance videos. Similarly, Wang et al. [14] introduce a Simultaneous Multi-vehicle Detection and Tracking Framework, combining machine learning and particle filter algorithms for accurate detection and tracking in complex traffic scenarios. These video-based detection methods offer scalable and cost-effective solutions for traffic surveillance and incident detection, contributing to the advancement of ITS technologies.

Moreover, deep neural networks (DNNs) have shown remarkable potential in road vehicle detection and classification tasks, enabling highly accurate and efficient detection systems. Zhang et al. [15] present a Road Vehicle Detection and Classification method based on DNNs, achieving superior performance in detecting vehicles on roadways. These DNN-based approaches leverage the power of deep learning to extract high-level features from input data, enabling robust and adaptive detection capabilities in various environmental conditions.

In conclusion, the literature reviewed highlights the significant advancements in intelligent spike barrier systems, vehicle detection methods, and AI/ML applications for traffic management. By integrating advanced technologies such as AI, ML, and video processing, researchers have made substantial progress towards enhancing traffic safety, efficiency, and sustainability. Future research directions may involve further optimization of detection algorithms, integration of sensor technologies, and development of intelligent control strategies for spike barrier systems, ultimately contributing to safer and more efficient road transportation systems.

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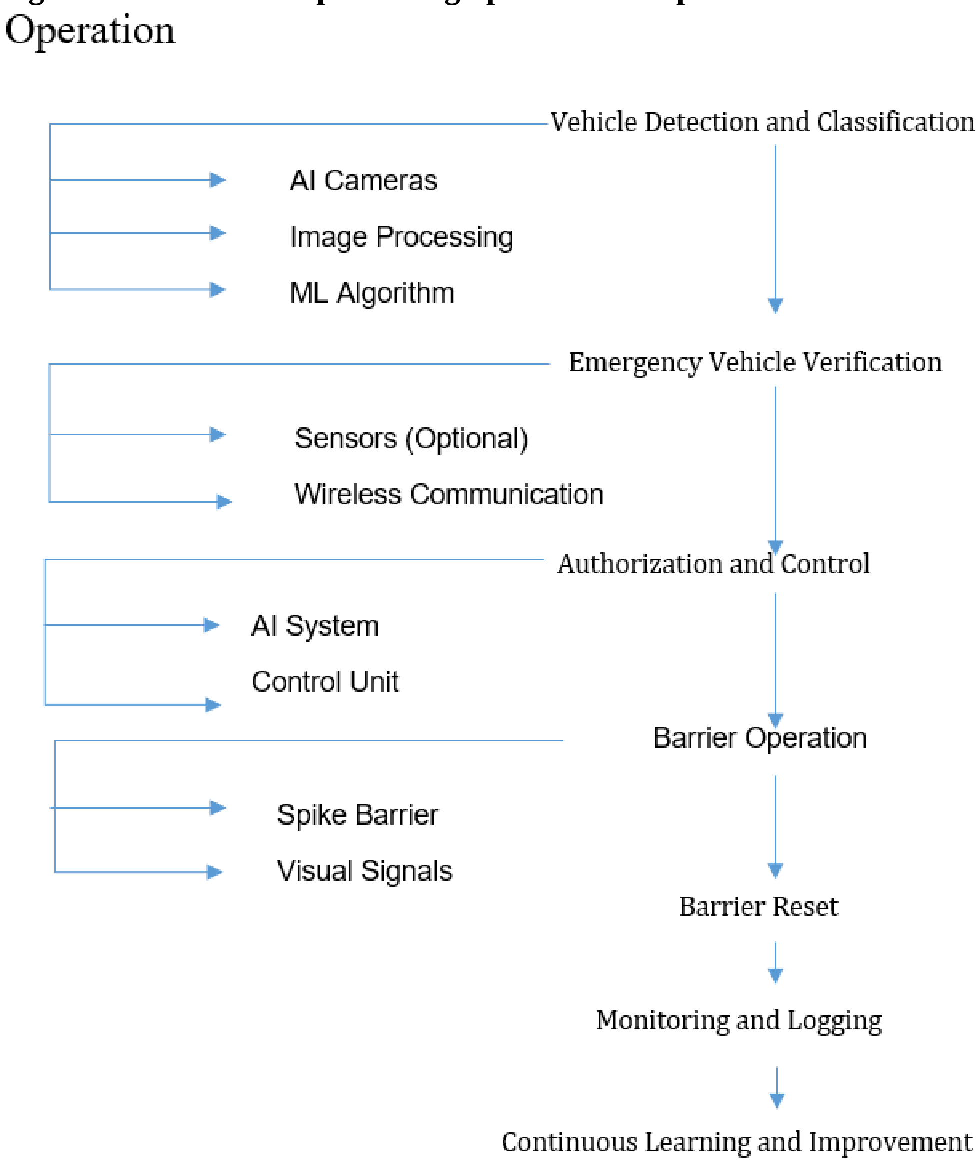
2.1 METHODOLOGY:

Figure.1 Flow chart Representing Spike barrier operations



Vehicle Detection and Classification:

Utilizing AI cameras and ML algorithms, vehicle detection and classification involve several steps including image acquisition, pre-processing, object detection, classification, post-processing, and integration into various applications. Challenges include lighting conditions and diverse vehicle shapes, addressed by advanced AI techniques and robust algorithms.

Emergency Vehicle Verification:

Incorporating sensors, wireless communication, AI, and ML, this system swiftly verifies emergency vehicles, allowing their passage while preventing unauthorized access. It integrates sensors for detection, wireless communication for data transfer, AI for verification, ML for decision-making, and automated spike barrier activation.

Authorization and Control:

AI-based authorization systems dynamically authenticate individuals and vehicles, adjusting access permissions based on real-time data. Behavioral analysis identifies security threats, while adaptive control optimizes resource utilization and response to changing conditions, ensuring efficient operations and rapid response.

Barrier Operation:

The intelligent spike barrier system detects approaching vehicles, verifies authorization, activates the barrier, and ensures safety through monitoring and control mechanisms. Safety features prevent accidents, while real-time monitoring logs data for and response to anomalies.

Barrier Reset:

After an authorized vehicle passes, the barrier resets automatically, monitored by the control unit to ensure safe operation. Safety sensors detect obstructions, guaranteeing minimal disruption to traffic flow.

Monitoring and Logging:

Continuous monitoring and logging functionalities oversee system performance, safeguard against security threats, and enable timely maintenance interventions. Real-time monitoring, centralized control, logging, event notification, and analytics ensure effective control and security.

Continuous Learning and Implementing:

Continuous learning and implementing mechanisms enhance system performance, adaptability, and efficiency over time. AI algorithms learn from data, adaptive control strategies optimize operations, feedback loops integrate stakeholder input, remote updates facilitate maintenance, and performance monitoring evaluates system effectiveness.

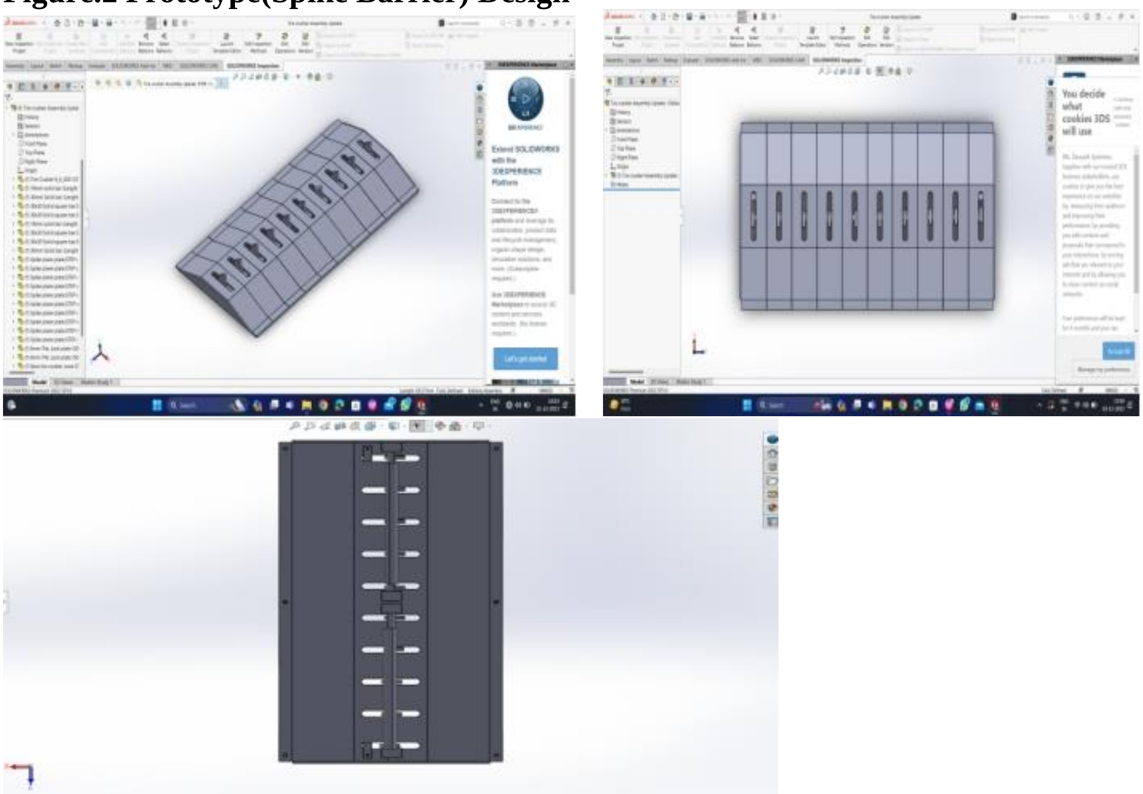
This comprehensive approach ensures the intelligent spike barrier system evolves and improves, staying responsive to dynamic environments and emerging threats.

2.2 RESULTS & DISCUSSIONS:

2.2.1 PROTOTYPE DESIGN:

The design process begins with conceptualization, where engineers outline the fundamental objectives and specifications. Through iterative refinement, ideas evolve into tangible designs, with each iteration fine-tuning the prototype for optimal functionality. SolidWorks facilitates this iterative process seamlessly, allowing engineers to experiment with various configurations and visualize their impact in real-time.

Figure.2 Prototype(Spike Barrier) Design



Central to the spike barrier's effectiveness is its ability to swiftly deploy and retract without compromising security or safety. SolidWorks enables engineers to simulate these dynamic movements, ensuring seamless operation under various conditions. Through finite element analysis (FEA), stress points are identified and addressed, guaranteeing structural integrity even under high-stress scenarios.

2.2.2 STATIC ANALYSIS:

In the static analysis conducted using SolidWorks Simulation, a load of 30 tonnes was applied to a spike barrier to assess its structural performance. The results revealed crucial information regarding deformations, factor of safety, yield strength, displacement, strain, and stress distribution. Firstly, the factor of safety, calculated as 5.3, indicates a significant margin of safety against failure, highlighting the barrier's robustness under the applied load. The yield strength of 6.204e+08 N/mm^2 represents the maximum stress the material can withstand before undergoing plastic deformation, providing insights into its structural integrity. Deformation analysis revealed minimal displacement, with a minimum of 0.000e+00mm at Node 1 and a maximum of 8.706e+11mm at Node 46705, indicating localized deformation concentrated at specific points.

Figure.3 Spike barrier Strain Diagram

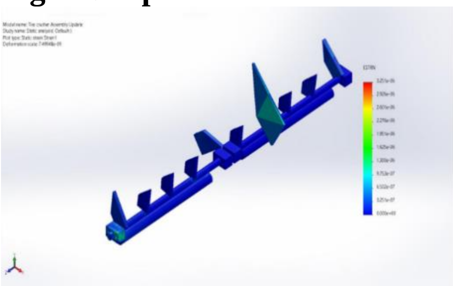


Figure.4 Spike Barrier Displacement

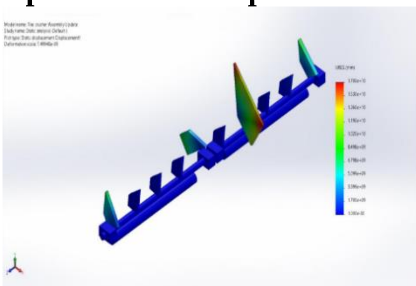


Figure.5 Spike barrier Factor of Safety

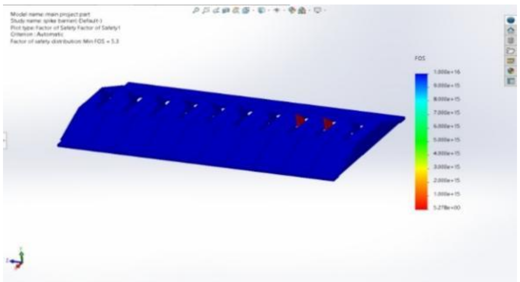
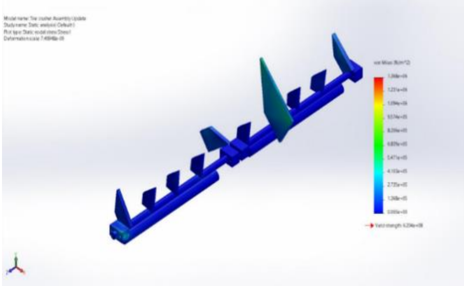


Figure.6 Spike barrier Van misses stress



Strain analysis, conducted in terms of equivalent strain, exhibited a range from 0.000e+00 to 2.310e-04, with a minimum at Element 1 and a maximum at Element 27012, indicating areas of high strain concentration within the structure. Stress analysis, specifically von Mises stress, depicted a stress distribution ranging from 0.000N/mm^2 (MPa) at Node 1 to 117.542N/mm^2 (MPa) at Node 46747, showcasing the areas of highest stress concentration. Overall, these comprehensive results offer valuable insights into the spike barrier's performance under the applied load, indicating areas of potential concern and validating its structural adequacy. Further analysis and optimization may be warranted to refine the design and enhance performance in real-world scenarios, ensuring safety and reliability in practical applications.

2.2.3 THERMAL ANALYSIS:

In the thermal analysis conducted using SolidWorks Simulation, a temperature of 333 Kelvin was applied to the spike barrier to assess its response to thermal loading. The results provided insights into deformations, yield strength, stress distribution, displacement, and strain experienced by the structure. The yield strength remained consistent at 6.204e+08 N/m^2, indicating the material's ability to withstand thermal stresses without undergoing plastic deformation. Deformation analysis revealed minimal displacement, with a minimum of 0.000e+00mm at Node 1 and a maximum of 8.858e-01mm at Node 32386, suggesting localized thermal expansion effects. Stress analysis, specifically von Mises stress, depicted a stress distribution ranging from 0.000e+00 N/m^2 at Node 1 to 4.044e+08 N/m^2 at Node 611067, indicating areas of highest stress concentration due to thermal loading

Figure.7 Thermal Van-misses Stresses

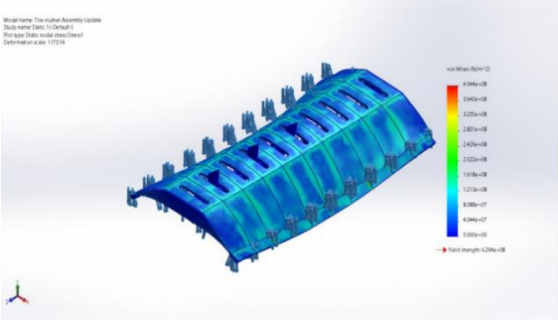


Figure.8 Spike Barrier Thermal Displacement

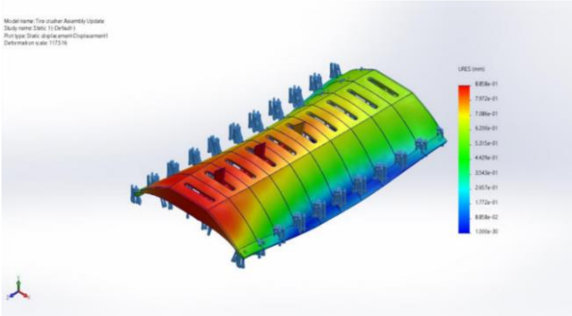


Figure.9 Spike Barrier Thermal Strain

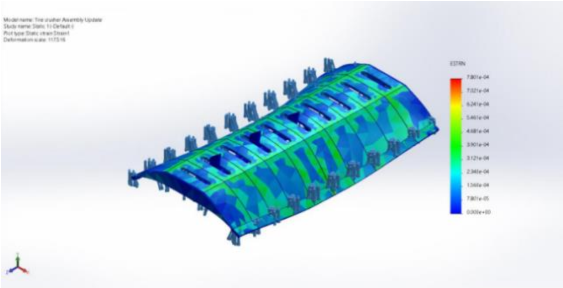
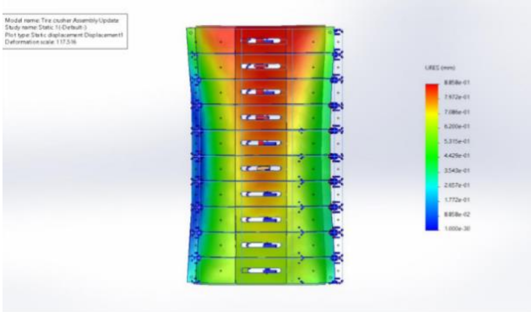


Figure.10 Spike Barrier Thermal Deformation



2.2.4 TORQUE ANALYSIS:

In the torque analysis conducted through SolidWorks Simulation, the spike barrier was subjected to a temperature of 333 Kelvin and a torque of 1 N/m to assess its structural response. The analysis yielded crucial data on deformations, yield strength, stress distribution, displacement, and strain within the barrier. The material's yield strength remained consistent at 6.204e+08 N/m^2, indicating its ability to withstand torsional forces without undergoing plastic deformation. Deformation analysis revealed minimal displacement, with a minimum of 0.000e+00mm at Node 6085 and a maximum of 7.469e+08mm at Node 18002, suggesting localized deformation concentrated at specific points along the barrier.

Figure.11 Torque analysis van-misses Stresses

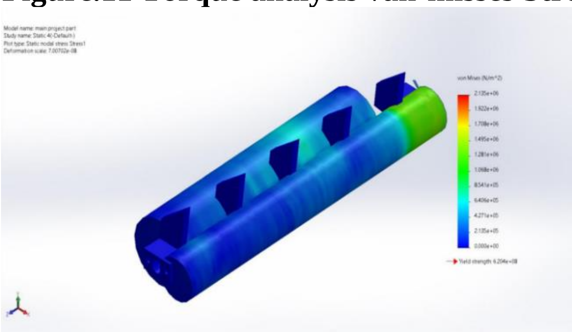


Figure.12 Torque Analysis Displacement

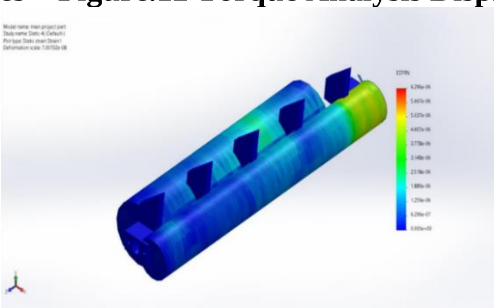
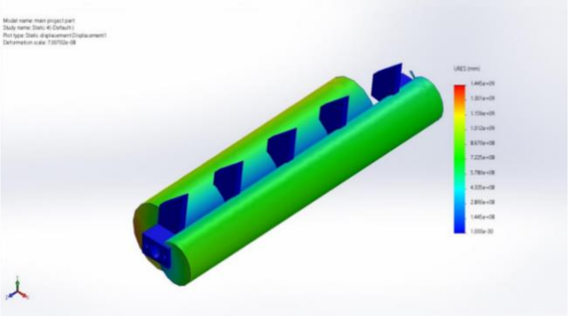


Figure.13 Torque analysis Strain diagram



III. Conclusion

The Intelligent Spike Barrier System, integrating Node MCU and servo motors, alongside AIML emergency vehicle detection using a camera module, represents a cutting-edge solution to control unauthorized vehicle access while prioritizing emergency vehicles' passage. Through rigorous load, thermal, and torque analyses, the system's structural integrity and performance under various conditions were evaluated. The results demonstrate its capability to withstand both mechanical loads and thermal fluctuations, ensuring reliability and longevity in operation. The AIML-based emergency vehicle detection feature enhances the system's efficiency by accurately identifying police cars, ambulances, and fire trucks, enabling swift and seamless passage without compromising security. By leveraging advanced technologies such as AIML and IoT, the system offers a dynamic and adaptable approach to traffic management, optimizing resource utilization and enhancing overall safety. Moving forward, further optimization and refinement of the prototype, based on the insights gained from analysis work, will be crucial to ensure its robustness and effectiveness in real-world scenarios. Ultimately, the Intelligent Spike Barrier System represents a significant advancement in traffic control systems, with the potential to greatly improve emergency response times and enhance overall security infrastructure.

References

1. Sanjeev Udenia1,Meenu Bhati (2014)“Traffic Spike System”In International Conference on Multidisciplinary Research & Practice, Volume I Issue (Viii) (pp. 645-650).
2. Sanket Nandlal Bhansali(2015) “Development of Mechanism for Road Spike System” International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 (Vol. 4 Issue 07, July-2015)
3. Patil Rohit E et .al(2020)“Traffic Signal Automation using Spike Road Block”International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 03.
4. Hao Wu, et.al(2019) “Accurate Vehicle Detection Using Multi-Camera Data Fusion And Machine Learning” IEEE International Conference on Acoustics, Speech and Signal Processing ICASSP 2019
5. Priyank Rawat(2021)”Vehicle Detection Using Artificial Intelligence For Traffic Surveillance”,International Research Journal of Modernization in Engineering Technology and Science Volume:03/Issue:01
6. Sehyun Tak et.al(2021) “Development of AI-Based Vehicle Detection and Tracking System for C-ITS Application” Hindawi Journal of Advanced Transportation Volume 2021, Article ID 4438861.
7. Hüseyin Seçkin DIKBAYIR Halil brahim BÜLBÜL(2020) “Deep Learning Based Vehicle Detection From Aerial Images” 19th IEEE International Conference on Machine Learning and Applications (ICMLA)
8. Abhishek Gupta,et.al.(2021)”Deep learning for object detection and scene perception in self-driving cars: Survey, challenges, and open issues”Array 10 (2021) 100057.Elsevier

9. Rangachar Kasturi Padmanabhan Soundararajan(2009), "Framework for Performance Evaluation of Face, Text, and Vehicle Detection and Tracking in Video: Data, Metrics, and Protocol" IEEE transactions on pattern analysis and machine intelligence, Vol. 31, No. 2, February 2009
10. Seda Kul, et.al(2017) "A Concise Review on Vehicle Detection and Classification" ICET2017, Antalya, Turkey IEEE 978-1-5386-1949-0/17.
11. Sriashika Addala(2020) "Research paper on vehicle detection and recognition" Researchgate https://www.researchgate.net/publication/344668186 15 October 2020.
12. Ani Boneva(2020) "Traffic Barrier Control System" 346097321 23 November 2020.
13. Venkatesan Muthukumar et.al(2012) "Video Based Vehicle Detection and Its Application in Intelligent Transportation Systems" ,Journal of Transportation Technologies, 2012, 2, 305-314 jtts.2012.24033 Published Online October 2012
14. WANG Ke1 et.al(2014)"Simultaneous Multi-vehicle Detection and Tracking Framework with Pavement Constraints Based on Machine Learning and Particle Filter Algorithm" CHINESE JOURNAL OF MECHANICAL ENGINEERING Vol. 27, No. 6, 2014 DOI: 10.3901/CJME.2014.0707.118,
15. Zhaojin Zhangl(2016)"Road Vehicle Detection and Classification based on Deep Neural Network"2016 lEEE
16. .Jones, A. (2015). Evolution of Security Systems. Security Journal, 28(1),16-29.
17. Sarwar, M. U., et al. (2018). Design and Development of an Automated Spike Barrier System. IEEE Access, 6, 14707-14716.
18. Liu, Y., et al. (2019). A Review of Traffic Management Systems in Smart Cities. Sustainability, 11(8), 2252.
19. Zheng, H., et al. (2020). Intelligent Spike Barrier System for Emergency Vehicle Passage. Journal of Advanced Transportation, 2020, 8890402.
20. Li, X., et al. (2017). Intelligent Transportation Systems: A Comprehensive Review. IEEE Transactions on Intelligent Transportation Systems, 18(12), 3329-3350.