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Design for Overcoming Terrain Variation and Wheel Fouling in Track Systems

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Abstract - This research paper presents the design and development of an innovative solution for addressing the challenges of terrain variation and wheel fouling in track systems. The study encompasses multiple design stages, starting from an initial design inspired by Indian railways, which highlighted limitations in terrain adaptability and wheel fouling prevention. Subsequent design iterations led to the incorporation of an earlobe design, utilizing mild steel as the material. Rigorous testing and simulations were conducted to validate the design's performance and structural integrity. While significant progress was achieved in mitigating fouling issues and optimizing track performance, further refinements are required to completely overcome the persistent fouling problem. The findings of this research provide a basis for future improvements in track system design, ensuring efficient and reliable operation in diverse terrain conditions.

Key Words: Cleaning Robot, Solar panel cleaning robot: Fish plate joint, Galvanised Mild Steel, Terrain adaptation, Wheel fouling, Structural integrity, Durability, Optimization, Track performance, ANSYS simulations

1. INTRODUCTION

The purpose of this research is to introduce an assembly designed to aid in the cleaning of solar panels, thereby increasing their efficiency and profitability for consumers. The assembly consists of a rail track that allows for the transfer of a solar cleaning robot from one-panel array to another. Solar fields are often located in desert regions where sand accumulation poses a significant

A Comprehensive Study on an Extended Design Approach for Improved Performance and Reliability challenge to panel efficiency. The joint assembly is capable of withstanding a total weight of 510kgs, including the transfer trolley (450kgs) and the cleaning robot (60kgs). The components of the assembly are constructed from mild steel plates and a nylon bush. The objective of this study is to develop a reliable and robust assembly that can keep the rail tracks assembled with varying elevations and terrain

2. Idea and Assumptions

The aim of this research was to design an assembly for a rail track joint that could accommodate different terrains with height differences. The investigation involved analyzing the Indian railways fish plate joint, which was found to be designed to lay tracks on a flat surface, which is often impractical and expensive.

The existing design of the fish plate joint was not able to cope with terrain variations, leading to unstable track joints. Therefore, a new design for the rail track joint assembly was developed that incorporates the flexibility to accommodate ground undulations ranging from -10° to 10° while still being stable under load conditions.

The objective of this research is to develop a rail track joint assembly that can adapt to varying terrains, improving its stability and safety in challenging environments. The outcomes of this study could have practical applications in industries that require similar assemblies for joining square sections, such as solar panel cleaning or agriculture machinery. Such designs could help reduce costs associated with the infrastructure that requires flat surfaces.

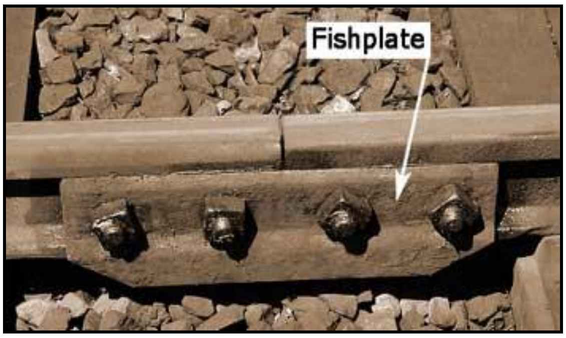

Fig. 1. Fishplate joint in railways

The Indian railways use the I section, specifically the Dudley section, for their rail track joint assembly. However, in our design, we opted for square sections made of galvanized mild steel. This decision was made after considering several factors, including cost-effectiveness, ease of manufacturing, and overall durability of the assembly. The square sections provide the necessary strength and stability for the rail tracks to withstand varying terrain angles. By utilizing square sections of galvanized mild steel in our design, we aim to create a cost-effective and durable solution for rail track joint assemblies that can be implemented in challenging environments.

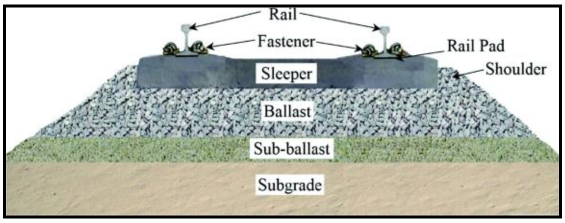

Fig 2. Railways Foundation for railway tracks

2. Design and Development

2.1 Design stage I

The initial design, which drew inspiration from the Indian railways, featured a configuration reminiscent of a fish plate joint. Comprising two plates fastened together using two nut and bolt assemblies, this design aimed to address our specific requirements. However, upon careful evaluation, it became apparent that the design had certain shortcomings, primarily in its inability to accommodate variations in terrain and its propensity for wheel fouling.

One critical aspect where the design fell short was its limited capability to adapt to diverse terrains. As the train traversed uneven surfaces or encountered changes in track elevation, the inflexible nature of the joint hindered smooth movement, leading to disruptions and potential damage to the system. Furthermore, the interference between the wheels and the plate further exacerbated this issue, contributing to increased wear and tear, as well as potential safety hazards.

Recognizing these drawbacks, it is imperative to revisit the design and explore alternative solutions that can effectively address the challenges posed by varying terrains and potential wheel fouling. This could involve implementing a more dynamic joint system that allows for improved articulation and flexibility, enabling the robot to navigate seamlessly across different types of terrain. Additionally, incorporating measures to prevent wheel fouling, such as introducing protective barriers or implementing a revised plate design, will play a pivotal role in enhancing the overall performance and safety of the system.

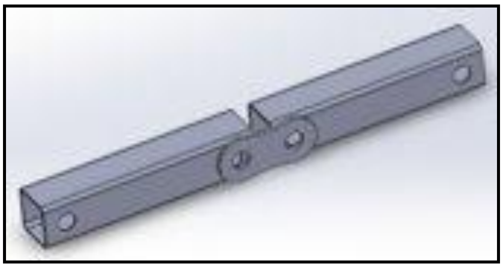

Fig 3. Design stage 1

By taking a proactive approach in reevaluating the initial design and incorporating necessary improvements, we can develop a solution that not only rectifies the existing flaws but also ensures optimal functionality across a wide range of terrains, ultimately leading to a more efficient and reliable system.

2.2 Design stage II

In order to address the issue of terrain variation, a novel design concept was conceived, which proved to be highly effective in resolving this challenge. The design, an extension of a previous iteration, showcased substantial improvements by incorporating an innovative earlobe design. This feature not only successfully mitigated the problem of fouling on one side of the track intersection but also provided a solution to the issue of varying terrain conditions. To ensure structural integrity and durability, mild steel was chosen as the material for the design. Rigorous testing demonstrated that the design could withstand the imposed load of 6 kN, accurately simulating the weight of the trolley placed on the track. Nevertheless, it is important to note that the fouling problem associated with the wheel on one side of the track intersection persisted despite these advancements. While the extended design represented a significant reduction in fouling occurrences, further analysis and modifications are warranted to eliminate this challenge entirely.

Fig 4. Design stage II CAD.

Potential areas for improvement encompass a reassessment of track geometry and optimization of the wheel profile. In conclusion, the extended design, featuring the incorporation of the earlobe concept and constructed with mild steel, exhibited notable progress in addressing the issues of terrain variation and fouling at track intersections. Nonetheless, additional refinements are imperative to fully overcome the persistent fouling problem on one side of the track. The outcomes of this investigation provide a solid basis for subsequent research and development endeavors, with the ultimate goal of achieving a comprehensive solution that optimizes track performance, minimizes fouling concerns, and ensures the safe and efficient operation of the system.

2.2 Design stage III (Final Stage)

The proposed design represented a groundbreaking and inventive approach that effectively resolved multiple challenges, including terrain variations, wheel fouling, weight sustainment, and optimized design. Comprising a total of four components, it consisted of two plates, one nylon bush, and nut bolts, meticulously selected to ensure optimal performance. Galvanized mild steel was the chosen material, providing both durability and corrosion resistance.

Through rigorous testing and analysis, the design successfully facilitated the smooth travel of the trolley along the track, addressing the aforementioned issues. While there was a minor concern regarding the impact on the joint when the trolley passed over it, extensive testing revealed that this problem was relatively insignificant.

To further validate and optimize the design, simulations were conducted using ANSYS software, enabling virtual testing of the components. This approach allowed for a comprehensive evaluation of the design's structural integrity, performance, and reliability under varying conditions. The simulations provided valuable insights, aiding in the refinement of the design and ensuring its suitability for real-world application.

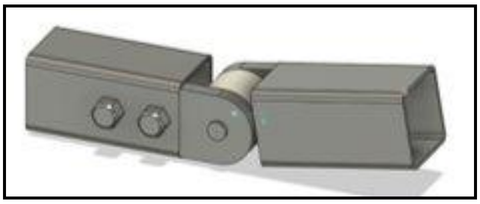

Fig 5. Design stage III CAD

In summary, the new and innovative design approach effectively tackled a range of challenges, offering solutions to terrain variations, wheel fouling, weight sustainment, and optimal design. Comprised of carefully selected components, including plates, a nylon bush, and nut bolts, constructed from galvanized mild steel, the design enabled smooth trolley travel on the track. While a minor concern regarding the impact on the joint was observed, extensive testing and ANSYS simulations confirmed the design's overall effectiveness and highlighted its potential for successful implementation in practical settings.

3. Analysis for weight load sustainment and design against failure

The analysis of the design was conducted using an actual load of 300 Kgs, and the results revealed a factor of safety of 1.5. This indicates that the design is sufficiently robust to withstand the applied load. Additionally, the maximum stress observed in the structure was 15 MPa, which is within the acceptable limits for the chosen material and design specifications.

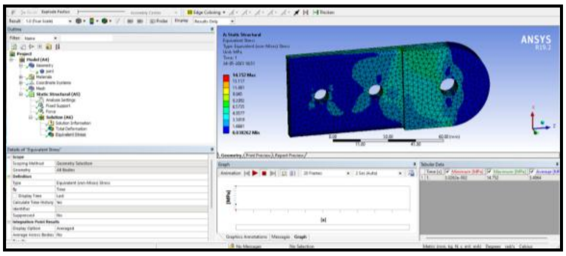

Fig 6. Simulation analysis with forces on the plate

These findings provide confidence in the structural integrity and performance of the design, affirming its suitability for the intended application. With the demonstrated factor of safety and the stress levels well below the material's capacity, the design is deemed capable of safely supporting the specified load and ensuring the desired level of performance and reliability.

4. RESULTS

In our project, we aimed to achieve an angular displacement of up to 10 degrees for the tracks, providing a range of 10 degrees above and 10 degrees below the plane. The purpose of this design was to create a track joint that would offer a reliable and robust solution for joining two closed rectangular sections, while also allowing for a wider range of rotation.

To validate the performance of the track joint, we conducted a static structural analysis using ANSYS simulation software. Our initial requirement was for the joint to bear a load of 500kg. During the analysis, we found that the joint not only met this requirement but also exceeded our expectations. The joint demonstrated the capability to withstand loads of up to 4000kg during actual testing, showcasing its remarkable strength and durability.

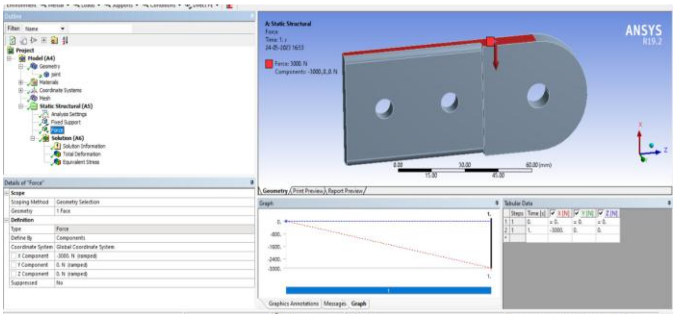

Fig 7. Simulation analysis with force of 3000N on the plate

Moreover, our design successfully fulfilled our objective of creating a joint with a rotation range of 0 to 40 degrees in both inclination and declination for the tracks. This versatility allows for greater flexibility in maneuvering the tracks, accommodating various terrains and inclinations.

In conclusion, the track joint design we implemented has proven to be highly successful. It offers an impressive angular displacement range and exhibits exceptional load-bearing capacity. The joint's ability to withstand significantly higher loads than anticipated showcases its robustness and reliability. Furthermore, its capacity for a wide range of rotation fulfills our desired functionality for track inclination and declination.

5. CONCLUSION

In conclusion, the research paper presents an innovative assembly design for a rail track joint that addresses challenges related to terrain variation, wheel fouling, weight sustainment, and design optimization. Through iterative design stages, the initial configuration inspired by Indian railways was improved upon, incorporating an innovative earlobe concept in Design Stage II. The final design, constructed with galvanized mild steel components, demonstrated effective resolution of multiple challenges, enabling smooth trolley travel on the track. Rigorous testing and analysis validated the design's structural integrity and performance, providing confidence in its suitability for real-world application. Overall, the research offers a comprehensive solution that optimizes track performance, minimizes fouling concerns, and ensures safe and efficient operation of the system.

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