iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** IV **Month of publication:** April 2026

DOI: https://doi.org/10.22214/ijraset.2026.79441

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

Fabrication of Three Axis Pneumatic Modern Trailer

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Abstract: ***The three-axis pneumatic modern trailer is a compact and cost-effective material-handling system designed to overcome the limitations of conventional single-axis hydraulic trailers. Unlike traditional models that allow only rear tilting, the proposed system enables multi-directional unloading (rear, left, and right) using a single pneumatic cylinder. The design incorporates a hinge mechanism, universal joint, and essential pneumatic components to ensure smooth operation. Fabricated using mild steel, the prototype demonstrated reliable performance, low maintenance, and reduced noise during testing. The results indicate that the system is an efficient and economical alternative to hydraulic trailers, with potential for future enhancements such as automation and IoT-based monitoring.***

Keywords: Three-Axis Trailer, Pneumatic Actuation, Multi-Directional Tilting, Material Handling Systems, Pneumatic Cylinder

I. INTRODUCTION

Efficient transportation and unloading of bulk materials are critical operations in industries such as construction, agriculture, mining, and waste management. Conventional trailers generally employ single-axis hydraulic mechanisms that allow only rear-end tilting. Although reliable, these systems face limitations in confined spaces, narrow pathways, and uneven terrains, where multi-directional unloading is required. As a result, frequent repositioning of the vehicle becomes necessary, leading to increased time consumption, higher fuel usage, and reduced operational efficiency. To overcome these challenges, this study proposes a three-axis pneumatic modern trailer capable of unloading materials in three directions—left, right, and rear. The system utilizes a pneumatic cylinder integrated with a hinge mechanism and a universal joint to achieve controlled multi-directional tilting. Compared to traditional hydraulic systems, the pneumatic approach offers advantages such as lower cost, minimal maintenance, cleaner operation, and improved safety. The proposed design enhances flexibility, reduces operator effort, and provides an efficient and reliable solution for modern material-handling applications.

II. METHODOLOGY

The methodology of the project follows a systematic and structured sequence of steps. Initially, the design of the system is developed using **SolidWorks**, where all components and assemblies are modelled to meet the project requirements and objectives. This is followed by the selection of suitable components, including a pneumatic cylinder, a 5/2 hand-operated control valve, and a universal joint, ensuring proper functionality of the system. After component selection, the fabrication process is carried out, which involves operations such as cutting, welding, and grinding to construct the physical model. Once fabrication is completed, the system undergoes testing to evaluate its performance, efficiency, and reliability under working conditions. Finally, the results are obtained and analysed to assess the effectiveness of the developed system.

III. DESIGN AND CALCULATIONS

Figure 1: 3D Design of Three Axis Pneumatic Modern Trailer

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The design of the three-axis pneumatic trailer is developed using **SolidWorks** to ensure accuracy and proper assembly. The system consists of a rigid base frame and a hinged top platform that acts as the load-carrying surface. A pneumatic cylinder is mounted between the base and platform to provide the lifting and tilting action. Multi-directional movement is achieved using removable pin hinges and a universal joint, allowing tilting in different directions. The structure is reinforced with cross members for strength, and a 5/2 hand-operated control valve is used to regulate airflow for controlled operation.

Cylinder diameter (D) = 40 mm = 0.04 m
Force developed by cylinder:

$$F = P \times A$$

Area of piston:

$$A = \frac{\pi D^2}{4}$$

$$A = \frac{\pi(0.04)^2}{4} = 1.256 \times 10^{-3}\ m^2$$

At 6 bar pressure

$$F = 6 \times 10^5 \times 1.256 \times 10^{-3}$$

$$F \approx 753.6\ N$$

Load Carrying Capacity
Using:

$$Load = \frac{F}{9.81}$$

$$Load \approx 76\ kg$$

IV. COMPONENETS USED FOR FABRICATION

A. GI Pipes

The frame is constructed using 25 × 25 × 2 mm square GI pipes, offering a good balance of strength, rigidity, and lightweight design. The hollow sections provide sufficient load-bearing capacity, while the 2 mm thickness resists bending and impact during operation. The galvanized coating protects against corrosion, enhancing durability and reducing maintenance in harsh conditions**.**

Figure 2: GI Square Pipe

B. Pneumatic Cylinder

The system uses a pneumatic cylinder with a 40 mm bore and 160 mm stroke, providing sufficient force and displacement for lifting and tilting the trailer platform. The bore size ensures adequate thrust, while the stroke length allows effective angular movement of the load bed. This combination delivers smooth, controlled operation and reliable performance in multi-directional tilting.

Figure 3: Pneumatic Cylinder

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C. 5/2 Hand Lever Control Valve

The system uses a 5/2 lever-operated pneumatic valve to control airflow direction in the circuit. It has five ports and two positions, making it suitable for double-acting cylinders. The lever allows easy manual switching to extend or retract the cylinder. This ensures simple operation, quick response, and reliable control of the tilting platform.

Figure 4: 5/2 Control Valve

D. Flow Control Valve

A flow control valve in pneumatic systems is used to regulate the rate of airflow, thereby controlling the speed of pneumatic actuators such as cylinders. It typically includes an adjustable knob or screw that restricts or allows airflow as required. By controlling the air flow, it ensures smooth, stable, and precise movement, preventing sudden or jerky operation and improving overall system efficiency.

Figure 5: Flow Control Valve

E. Universal Joint

The universal joint enables flexible motion transmission during multi-directional tilting of the trailer. It accommodates angular misalignment between connected components for smooth operation. It ensures effective force transfer without stress or binding in the mechanism. This improves stability, durability, and overall efficiency of the three-axis system.

Figure 6: Universal Joint

F. Hinges

Pin removable hinges are used to provide flexible and detachable pivot connections between the frame and tilting platform. They allow smooth rotation for multi-directional tilting (left, right, and rear). The removable pin enables easy assembly, maintenance, and replacement. This improves practicality, durability, and ease of operation.

Figure 7: Hinges

V. FABRICATION PROCESS

Metal fabrication is the process of cutting, shaping, and assembling metal materials to create structural components and parts. It involves operations such as cutting, drilling, welding, grinding, finishing operation & painting to achieve the desired shape and strength. In this project metal fabrication is used to construct the frame, trailer platform, and mounting structures, ensuring durability, stability, and proper alignment of all components. The fabricated parts are designed to withstand applied loads and provide reliable performance of the system

A. Cutting

Cutting operation in metal fabrication involves removing unwanted material from metal pieces to obtain required shapes and sizes for trailer components like the frame and brackets. In this project, square pipes are cut to required dimensions and prepared for welding. Cutting is done using tools such as hacksaw and cutting machines. Proper measurement and accurate cutting ensure correct fitting, strength, and ease of assembly. Edges are finished after cutting to remove burrs and ensure safety

Figure 8:Cutting

B. Drilling

Drilling operation in this project involves making precise holes in metal brackets and hinges to facilitate proper assembly. Holes are drilled on the brackets for securely holding the pneumatic cylinder, and additional holes are made to modify and align the hinges. The operation is carried out using a drilling machine with suitable drill bits, ensuring accuracy and proper fit. After drilling, burrs are removed to achieve smooth surfaces and safe handling.

Figure 9: Drilling

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C. Welding

Welding operation in this project is used to join metal components such as the frame, brackets, and supports of the three-axis pneumatic trailer. The cut and prepared parts are aligned properly and welded using suitable welding methods to ensure strong and permanent joints. After welding, the joints are cleaned to remove slag and ensure strength and safety

Figure 10: Welding

D. Grinding

Grinding operation in this project is carried out to smoothen the cut and welded surfaces of metal components. It is used to remove sharp edges, burrs, and excess weld material to improve surface finish and ensure safe handling. Grinding also helps in achieving proper fitting of parts and enhances the overall appearance and quality of the fabricated trailer.

Figure 11: Grinding

E. Painting

Painting operation in this project is carried out to protect metal components from rust and corrosion and to improve the overall appearance of the trailer. After proper surface cleaning, paint is applied evenly on all parts to ensure durability, smooth finish, and longer service life.

Figure 12: Painting

F. Finishing operation

Finishing operation in this project is carried out using a wire brush for surface cleaning, polishing, and removal of rust. This process improves surface quality and prepares the metal components for painting or further treatment, ensuring better appearance and durability.

Figure 13: Finishing operation

VI. FINAL PRODUCT AND OPERATION

Figure 14:Final Product

Figure 15:Trailer Tilting Towards Rear, Left and Rear Side

The prototype of the three-axis pneumatic modern trailer was tested to evaluate its overall performance, stability, and functionality. The pneumatic system was checked to ensure smooth and controlled operation of the cylinder for tilting in three directions—left, right, and rear. Load testing was conducted to verify the trailer's ability to handle the required weight safely. All components such as the frame, brackets, and hinges were inspected for proper alignment and strength. The testing results confirmed that the prototype operates efficiently and meets the design requirements

VII. RESULT AND DISCUSSION

The three-axis pneumatic trailer was successfully fabricated and tested under working conditions, demonstrating effective multi-directional tilting in left, right, and rear directions using a single pneumatic cylinder. The prototype was capable of lifting and unloading a load of approximately 25 kg, with smooth and controlled operation. All structural components, including the frame, brackets, and hinges, performed reliably without any failure, indicating proper design and fabrication. The system exhibited stable performance along with advantages such as compact design, low maintenance, and ease of operation compared to conventional hydraulic systems.

The theoretical load capacity of the system was calculated to be approximately 76 kg; however, the actual load achieved during testing was lower due to practical limitations. Factors such as friction in moving parts, air leakage, pressure losses, and the compressibility of air contributed to reduced efficiency. Additionally, the use of a tilting mechanism instead of direct vertical lifting introduced a lever arm effect, increasing torque requirements and reducing effective force. Despite these limitations, the system proved to be reliable and efficient for light-load applications, successfully validating the feasibility of pneumatic actuation in a three-axis trailer system.

VIII. CONCLUSION

The three-axis pneumatic modern trailer was successfully designed, fabricated, and tested, achieving multi-directional tilting (left, right, and rear) using a single pneumatic cylinder. The system demonstrated smooth, stable, and reliable operation, with advantages such as simple construction, low maintenance, and elimination of hydraulic fluid-related issues. Although the actual load capacity was lower than the theoretical value due to factors like friction losses, air leakage, pressure drops, and mechanical inefficiencies, the prototype effectively validated the concept. Overall, the project proves that pneumatic actuation is a feasible and cost-effective solution for light-load multi-directional material handling systems, with potential for further improvement and wider industrial applications.

IX. ACKNOWLEDGEMENT

We would remember with grateful appreciation, the encouragement and support rendered by the authority of Eranad Knowledge City Technical Campus, especially Mr. ADARSH.T.K., Principal, Eranad Knowledge City Technical Campus, Manjeri, to successfully complete this project and Michael Shell and other contributors for developing and maintaining the IEEE LaTeX style files which have been used in the preparation of this template.

We express our deepest sense of gratitude to Mr. Sajan C., Head of the Department of Mechanical Engineering, project coordinator Mr. Anoop KJ., Assistant Professor, Department of ME and project guide Mr. Anoop KJ., Assistant Professor, Department of ME for their keen interest and constant encouragement with our work during all stages.

We greatly acknowledge all other staff members of the department and all our friends and well-wishers, who directly or indirectly contributed in this work and Michael Shell and other contributors for developing and maintaining the IEEE LaTeX style files which have been used in the preparation of this template. Our heartfelt thanks to my family members for their kind cooperation in completing this project and last but not least, we are indebted to God Almighty for being the guiding light throughout this project and helped us to complete the same within the stipulated time

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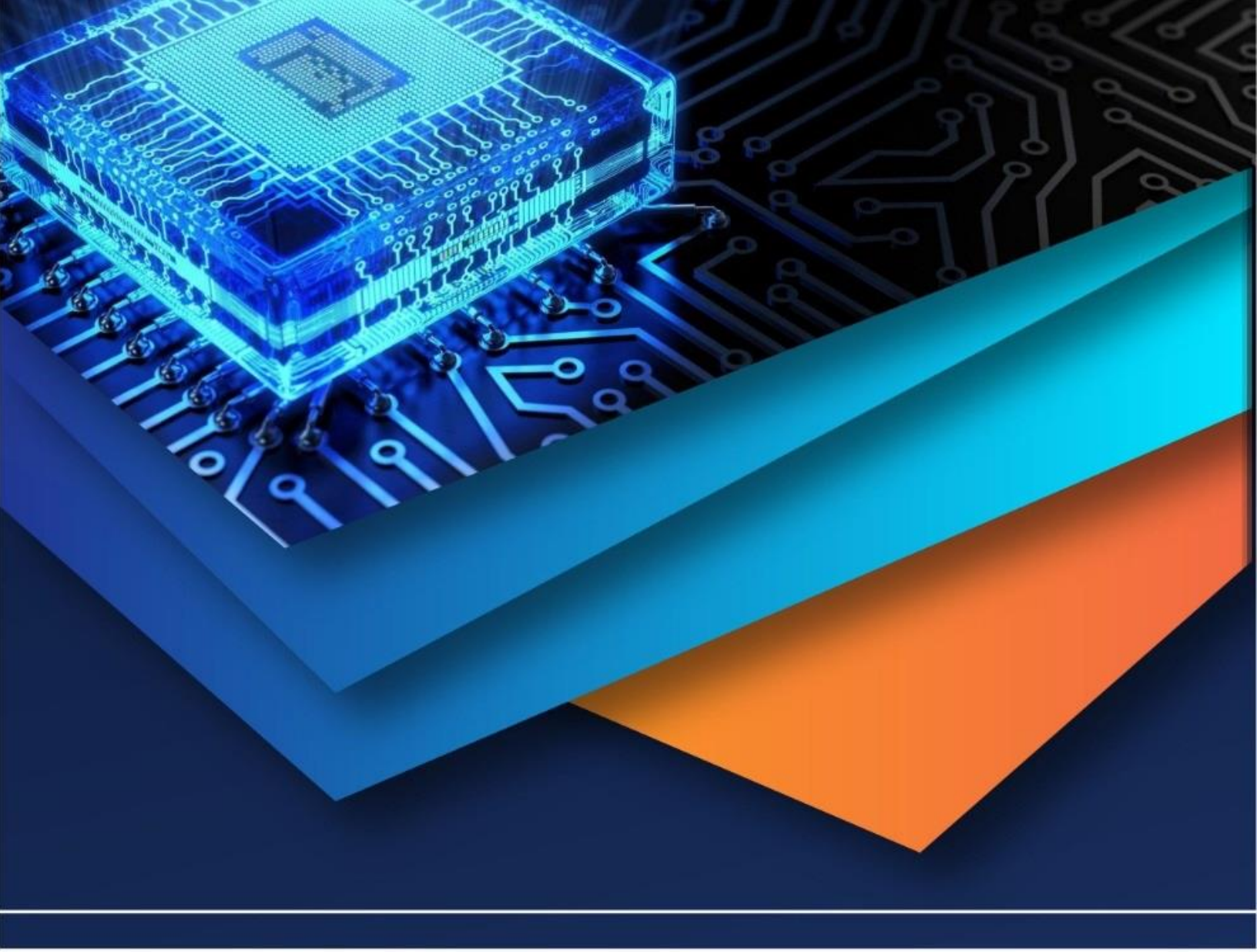

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