

Design and Fabrication of a Hydraulic Transmission Jack for Heavy-Duty Truck Maintenance

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ABSTRACT

This study presents the design, fabrication, and testing of a hydraulic transmission jack specifically tailored for lifting and handling truck transmissions in automotive repair facilities. The device utilizes a foot-operated hydraulic system to provide efficient and safe lifting capabilities, addressing the ergonomic and safety challenges associated with manual handling of heavy transmissions during removal and installation procedures. Through systematic design calculations, material selection, structural analysis, and prototype assembly, the jack achieves a lifting capacity of 2000 kg with a height adjustment range of 190–810 mm, suitable for medium to heavy-duty truck applications. Comprehensive performance testing demonstrated reliable operation under maximum load conditions, with no structural failure, hydraulic leakage, or stability issues observed during extended hold tests and offset load scenarios up to 1500 kg. The prototype was fabricated at approximately \$300, representing 35–50% cost savings compared to commercially available models while maintaining comparable performance characteristics. The foot-pedal hydraulic operation enables hands-free lifting with controlled positioning, significantly reducing physical strain on mechanics and potentially decreasing workplace injuries. Stability tests confirmed adequate resistance to tipping under asymmetric loading conditions, while the 45 kg overall weight and caster-mounted base provide acceptable portability for workshop environments. This innovation contributes to advancing mechanical engineering applications in vehicle maintenance by demonstrating that effective ergonomic solutions can be achieved through practical design approaches using readily available materials and components, making specialized lifting equipment more accessible to small-scale repair facilities, particularly in developing economies where capital investment constraints limit access to commercial equipment.

ARTICLE HISTORY

Received 25 April 2025
Accepted 1 December 2025
Published 10 December 2025

KEYWORDS

Hydraulic System;
Transmission Jack; Truck
Maintenance; Lifting
Mechanism; Automotive
Engineering.

1. Introduction

In the automotive industry, particularly for heavy vehicles such as trucks, the removal and installation of transmissions pose significant challenges due to their weight and bulkiness, often exceeding 500 kg for medium to heavy-duty applications. Traditional methods often involve manual lifting or basic mechanical aids, which can lead to serious workplace injuries and operational inefficiencies. Manual material handling in automotive workshops has been identified as a major ergonomic concern, with studies showing that improper lifting techniques and inadequate equipment contribute to musculoskeletal disorders among mechanics and technicians (Suhimi & Rahman, 2024; Sultan *et al.*, 2021). The physical strain associated with transmission removal and installation not only affects worker health but also reduces productivity and increases maintenance downtime, which is particularly critical in regions with growing trucking industries where vehicle availability directly impacts logistics efficiency. The heavy vehicle industry is undergoing significant transformation driven by sustainability concerns, technological advancement,

and increasing operational demands. Research has shown that the heavy vehicle sector faces unique challenges compared to the light automotive industry, including longer service life, higher maintenance requirements, and more complex supply chain dynamics (Saidani *et al.*, 2018; Shekarian *et al.*, 2024). As the industry moves toward sustainable practices and circular economy principles, there is growing emphasis on improving maintenance operations and reducing environmental impact throughout the vehicle lifecycle. The electrification of heavy goods vehicles and adoption of alternative fuels are reshaping the industry landscape (Kluschke *et al.*, 2019; Rohith *et al.*, 2023), while economic and environmental considerations continue to drive innovation in maintenance practices and equipment design (Ravigné & Da Costa, 2021; Delgado *et al.*, 2017). In this context, developing efficient and ergonomically sound maintenance equipment becomes crucial not only for worker safety but also for supporting the broader sustainability goals of the heavy vehicle industry. In Vietnam specifically, the automotive and heavy vehicle sectors are experiencing rapid growth, creating increased demand for professional maintenance services and appropriate workshop equipment. Recent studies on Vietnamese truck manufacturing have focused on weight reduction and structural optimization (Truong *et al.*, 2021), while research on material handling at major logistics hubs like Sai Gon Port has highlighted significant ergonomic challenges in cargo operations (Nguyen, 2024). The dynamics of heavy mechanized equipment, including lifting mechanisms, have been studied to improve deployment efficiency and safety (Thang *et al.*, 2024; Hong *et al.*, 2024).

However, there remains a gap in accessible, cost-effective solutions for transmission handling in small to medium-sized repair facilities, which constitute the majority of service providers in developing economies. Ergonomic assessments in the German and Malaysian automotive industries have demonstrated that investing in proper equipment and workplace design significantly improves worker comfort, reduces injury rates, and enhances overall productivity (Thun *et al.*, 2011; Sultan *et al.*, 2021), suggesting that similar interventions could benefit Vietnamese workshops. A transmission jack is a specialized tool designed to support and maneuver transmissions during service, providing stable positioning and controlled movement during the critical phases of removal and installation. Recent innovations in hydraulic jack technology have demonstrated the potential for improved safety and efficiency in automotive maintenance. Automated hydraulic jacks have been developed to reduce manual effort and enhance precision (Patil *et al.*, 2017), while inbuilt hydraulic jack systems for four-wheelers have shown promise in integrating lifting capabilities directly into vehicle design (Banakar *et al.*, n.d.). On-board hydraulic jacks have been successfully implemented in various applications, demonstrating the versatility and reliability of hydraulic systems for heavy lifting tasks (Guan *et al.*, 2022). These developments highlight the benefits of hydraulic power in lifting applications, including precise control, high force-to-weight ratio, and the ability to maintain loads safely for extended periods. However, most existing research focuses on general-purpose jacks or vehicle-integrated systems, with limited attention to specialized transmission handling equipment suitable for workshop environments in developing countries. This research addresses this gap by focusing on developing a hydraulic-based transmission jack specifically tailored for truck transmission maintenance, with emphasis on cost-effectiveness, ease of use, and safety enhancement. The device aims to improve workplace ergonomics by eliminating manual lifting, reduce the risk of transmission damage during handling, and increase operational efficiency in repair facilities. By combining established hydraulic principles with practical design considerations for workshop environments, this study seeks to create a solution that is both technically robust and economically accessible to small-scale automotive service providers. This paper outlines the complete design process, from conceptualization through theoretical calculations, material selection, prototype fabrication, and performance testing, to create a practical and cost-effective solution that

contributes to safer and more efficient vehicle maintenance practices in the growing Vietnamese automotive service sector.

2. Methods

2.1 Design Requirements and Specifications

The design process began with a comprehensive requirements analysis based on typical truck transmission specifications and workshop operational needs. The jack was required to support a maximum load of 2000 kg, which covers most medium to heavy-duty truck transmissions. The adjustable height range was specified from 200 mm to 800 mm to accommodate various vehicle ground clearances and transmission positions during removal and installation. Safety features were prioritized, including overload protection mechanisms, stability controls, and secure locking systems to prevent accidental lowering during operation. Additional design considerations included portability for workshop mobility, durability for long-term use under demanding conditions, and ease of operation to minimize physical strain on mechanics.

2.2 Material Selection

Material selection was critical to ensure structural integrity while maintaining reasonable weight and cost-effectiveness. High-strength steel AISI 1045 was selected for the main frame components due to its excellent combination of strength, toughness, and machinability. This medium carbon steel provides a tensile strength of approximately 570-700 MPa and yield strength of 310-415 MPa, making it suitable for bearing heavy loads with adequate safety margins. Hydraulic components, including the cylinder, pump, valves, and connecting hoses, were selected based on their pressure ratings and compatibility with standard hydraulic fluids. All hydraulic components were rated for operating pressures exceeding 100 bar to ensure safe operation with appropriate safety factors. Caster wheels were specified with load ratings sufficient to support the combined weight of the jack and maximum payload, with locking mechanisms to ensure stability during lifting operations.

2.3 Hydraulic System Design

The hydraulic system was designed as a single-acting configuration, consisting of a hydraulic cylinder, manual pump, fluid reservoir, release valve, and connecting hydraulic lines. The single-acting cylinder design utilizes hydraulic pressure for the lifting stroke, while gravity and the weight of the load facilitate the lowering motion when the release valve is opened. This configuration was chosen for its simplicity, reliability, and cost-effectiveness compared to double-acting systems. The manual pump was integrated with a foot pedal mechanism to enable hands-free operation, allowing mechanics to maintain control of the transmission while simultaneously operating the jack. The reservoir was sized to contain sufficient hydraulic fluid for the full stroke length with additional capacity to account for thermal expansion and air bleeding during initial setup.

2.4 Theoretical Calculations

Hydraulic force calculations were performed to determine the required cylinder dimensions and operating pressure to achieve the desired lifting capacity. The fundamental relationship between hydraulic pressure, piston area, and lifting force is expressed by:

$$F = P \times A$$

Where:

- F = Lifting force (N)
- P = Hydraulic pressure (Pa)
- A = Piston cross-sectional area (m²)

With a selected piston diameter of 50 mm (0.05 m) and design operating pressure of 100

bar (10 MPa or 10,000,000 Pa), the theoretical lifting capacity was computed as follows:

$$A = \pi \times r^2 = \pi \times (0.025)^2 \approx 0.001963 \text{ m}^2$$

$$F = 10,000,000 \text{ Pa} \times 0.001963 \text{ m}^2 = 19,635 \text{ N}$$

$$m = \frac{F}{g} = \frac{19,635}{9.81} \approx 2,001 \text{ kg}$$

This calculation confirmed that the selected cylinder dimensions and operating pressure would provide the required 2000 kg lifting capacity with a small margin for safety. Additional structural calculations were performed to verify frame strength, including bending moment analysis for the support arms and stress analysis at critical weld joints to ensure the frame could safely support the maximum load without deformation or failure.

2.5 CAD Modeling and Design Optimization

The complete jack assembly was modeled using computer-aided design (CAD) software to visualize the design, identify potential interference issues, and optimize component placement. The 3D model included all structural members, hydraulic components, fasteners, and moving parts. Finite element analysis (FEA) was considered for critical load-bearing components to validate stress distributions and identify areas requiring reinforcement. The CAD model facilitated dimensional verification, assembly sequence planning, and generation of detailed fabrication drawings for workshop production. Design iterations were performed to optimize the balance between strength, weight, and manufacturability, with particular attention to welding accessibility and ease of assembly.

2.6 Prototype Fabrication

The prototype was fabricated in the university workshop using standard metalworking equipment, including cutting tools, welding machines, drilling equipment, and finishing tools. Steel components were cut to specified dimensions using angle grinders and band saws, with edges deburred to ensure safe handling and proper fit-up during welding. The main frame was assembled using MIG welding techniques, with critical joints receiving full-penetration welds to maximize strength. Hydraulic components were installed according to manufacturer specifications, with proper sealing and secure mounting to prevent leaks and ensure operational reliability. The foot pedal mechanism was fabricated from steel plate and connected to the pump via a mechanical linkage designed to provide adequate leverage for comfortable operation. Caster wheels were mounted to the base frame with reinforced brackets to distribute loads evenly. Final assembly included hydraulic fluid filling, system bleeding to remove air pockets, and adjustment of the release valve for controlled lowering speed.

2.7 Testing and Performance Evaluation

Comprehensive testing was conducted to evaluate the prototype's performance, safety, and reliability under simulated operational conditions. Load testing involved progressive loading from 500 kg to the maximum rated capacity of 2000 kg, using calibrated weights arranged to simulate the weight distribution of an actual truck transmission. Lifting time, stability under load, hydraulic pressure consistency, and operator effort required for pumping were recorded for each load increment. Stability tests were performed with offset loads to evaluate the jack's resistance to tipping under non-centered loading conditions, which commonly occur during actual transmission handling. Hydraulic system integrity was assessed through extended hold tests, where maximum loads were maintained for 30-minute periods while monitoring for pressure loss, fluid

leaks, or structural deformation. Operational ergonomics were evaluated by having multiple users operate the jack and provide feedback on ease of use, pedal force requirements, and overall handling characteristics. Similar testing approaches have been documented in previous hydraulic jack design studies for automated systems in light vehicles, providing validation for the testing methodology employed in this research:



Figure 1. Example of commercial hydraulic transmission jack design
Source: TUFFIOM Hydraulic Transmission Service/Floor Jack (Amazon)

3. Results

3.1 Lifting Performance and Operational Characteristics

The constructed prototype demonstrated successful lifting performance across the full range of tested loads. The jack successfully lifted loads up to the maximum design capacity of 2000 kg without structural failure or excessive deformation. The stroke time for full extension from minimum to maximum height was measured at 15 seconds under no-load conditions, increasing to approximately 22 seconds under maximum load conditions. This lifting speed was considered acceptable for workshop applications, where controlled movement is prioritized over rapid operation to ensure safety and precision during transmission positioning. The number of pump strokes required for full extension was counted at 48 strokes under maximum load, with each stroke requiring moderate foot pressure that was consistently rated as comfortable by test operators. The lowering operation, controlled by the release valve, allowed for smooth and gradual descent with precise positioning capability, taking approximately 8-10 seconds for full retraction under load.

3.2 Stability and Safety Performance

Stability testing was conducted to evaluate the jack's resistance to tipping under various loading conditions, which is critical for safe operation in workshop environments where loads may not always be perfectly centered. The prototype showed no tipping or instability under offset loads of up to 1500 kg positioned 100 mm from the centerline of the support platform. This performance exceeded the minimum safety requirements and demonstrated adequate stability margins for practical use with truck transmissions, which often have irregular weight distributions due to their complex geometry. The wide base design, measuring 600 mm x 500 mm, combined with a low center of gravity, contributed significantly to the observed stability. Load distribution tests confirmed that all four caster wheels maintained ground contact under maximum load conditions, ensuring balanced support. The locking mechanisms on the caster wheels effectively prevented unwanted

movement during lifting operations, with no observed slippage or rolling during any test scenario.

3.3 Physical Specifications and Portability

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3.4 Hydraulic System Performance

The hydraulic system demonstrated reliable and consistent performance throughout all testing phases. Hydraulic pressure remained steady at the design operating pressure of 100 bar (10 MPa) during lifting operations, with no significant pressure fluctuations observed. Extended hold tests, where maximum loads were maintained for 30-minute periods, showed no measurable pressure loss or fluid leakage from any hydraulic connections, seals, or the cylinder itself. This performance indicates proper sealing and component quality, which are essential for long-term reliability and safety. The hydraulic fluid temperature remained within acceptable limits even after repeated lifting cycles, suggesting adequate heat dissipation and appropriate fluid viscosity selection. The release valve provided smooth and controllable lowering action, with no sudden drops or jerky movements that could compromise safety or damage the transmission being handled. System bleeding was straightforward during initial setup, and no air re-entry was observed during subsequent operations.

3.5 Cost Analysis and Comparison with Commercial Models

A detailed cost analysis of the prototype fabrication revealed a total material and component cost of approximately \$300 USD. This cost breakdown included: steel materials for the frame (\$85), hydraulic cylinder and pump assembly (\$120), caster wheels and mounting hardware (\$35), hydraulic fluid and miscellaneous components (\$30), and welding consumables and finishing materials (\$30). Labor costs for fabrication were not included in this analysis as the work was performed in the university workshop as part of the research project. Comparative analysis with commercially available transmission jacks of similar capacity revealed that equivalent models typically retail for \$600-\$900 USD, indicating that the prototype achieved similar performance at approximately 35-50% of the commercial cost. This significant cost advantage makes the design particularly attractive for small-scale repair facilities and workshops in developing economies where capital investment in specialized equipment may be limited. The performance comparison showed that the prototype matched or exceeded commercial models in key parameters including lifting capacity, height range, and stability, while offering comparable operational characteristics in terms of lifting speed and ease of use.

3.6 Performance Summary

Table 1 summarizes the key performance specifications achieved by the prototype compared to the initial design requirements:

Parameter	Design Requirement	Achieved Performance	Status
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Maximum lifting capacity	2000 kg	2000 kg	Met
Minimum height	200 mm	190 mm	Exceeded
Maximum height	800 mm	810 mm	Exceeded
Stroke time (no load)	-	15 seconds	-
Stroke time (max load)	-	22 seconds	-
Stability (offset load)	1500 kg	1500 kg (no tipping)	Met
Overall weight	<50 kg	45 kg	Met
Hydraulic hold test	30 minutes	No leaks observed	Met
Fabrication cost	<\$400	~\$300	Exceeded

The comprehensive testing results demonstrate that the prototype successfully meets all design requirements and performs reliably under simulated operational conditions representative of actual workshop use:



Figure 2. Example of heavy-duty transmission jack in operational use
Source: Transmission Jack Manufacturers/Suppliers

4. Discussion

The results demonstrate that the hydraulic transmission jack effectively addresses the critical limitations of manual handling in truck maintenance operations. By integrating a robust hydraulic system with ergonomic design features, the device significantly reduces physical strain on mechanics, potentially decreasing workplace injuries associated with heavy lifting tasks. This finding aligns with ergonomic research in automotive workshops, which has identified manual material handling as a primary source of musculoskeletal disorders and workplace discomfort (Suhimi & Rahman, 2024; Sultan *et al.*, 2021). The foot-pedal operation enables hands-free lifting, allowing mechanics to maintain control of the transmission while simultaneously operating the jack, thereby improving both safety and operational efficiency. The successful lifting of 2000 kg loads with minimal operator effort demonstrates that hydraulic assistance can effectively eliminate the physical demands that contribute to long-term health problems among automotive technicians (Nguyen, 2024). Compared to existing hydraulic jack designs documented in recent literature, this transmission jack offers distinct advantages for workshop environments. While inbuilt and onboard hydraulic jack systems have been developed for integration into vehicle chassis to provide self-lifting capabilities (Guan *et al.*, 2022; Venkatesh *et al.*, 2021; Banakar *et al.*, n.d.), these designs are vehicle-specific and cannot be adapted for transmission handling tasks. The standalone workshop jack developed in this study offers greater versatility and adaptability across different truck models and

maintenance scenarios. Previous research on automated hydraulic jacks has focused primarily on reducing manual pumping effort through electric or pneumatic actuation (Azeeza *et al.*, 2023; Patil *et al.*, 2017), which improves convenience but increases system complexity and cost. The manual hydraulic system employed in this design strikes a balance between operational efficiency and economic accessibility. Structural analysis approaches used in previous hydraulic jack research (Venkatesh *et al.*, 2021; Sainath *et al.*, 2014) provided valuable validation methodologies that informed the design calculations and testing protocols employed in this study. The cost-effectiveness of the prototype, with a fabrication cost of approximately \$300 compared to commercial models priced at \$600-\$900, makes it particularly suitable for small-scale garages and repair facilities in developing countries where capital investment constraints often limit access to specialized equipment. This economic advantage is significant in the context of the heavy vehicle industry in regions like Vietnam, where the maintenance sector is dominated by small to medium-sized enterprises with limited financial resources (Truong *et al.*, 2021). From a sustainability perspective, improving maintenance efficiency and equipment longevity contributes to the broader goals of the heavy vehicle industry's transition toward circular economy principles (Saidani *et al.*, 2018; Shekarian *et al.*, 2024). By enabling safer and more efficient transmission servicing, the jack supports extended vehicle service life and reduced maintenance-related downtime, which are critical factors in sustainable fleet management. As the heavy vehicle sector increasingly focuses on environmental performance and operational efficiency (Rohith *et al.*, 2023; Ravigné & Da Costa, 2021), maintenance equipment that enhances service quality while minimizing resource consumption becomes increasingly valuable. Despite the successful performance demonstrated in testing, several limitations warrant consideration. The primary limitation is the dependency on manual pumping, which could lead to operator fatigue during extended maintenance sessions. This could be addressed in future iterations by incorporating an electric or pneumatic pump system, similar to automated hydraulic jack designs (Azeeza *et al.*, 2023), though such modifications would increase system complexity and cost. The 2000 kg capacity, while adequate for most medium-duty trucks, may be insufficient for the heaviest commercial vehicles, suggesting that scaled versions with higher capacity could expand applicability. Future enhancements could involve sensor integration for automated safety checks, including load cells to monitor weight distribution, pressure sensors to detect hydraulic system anomalies, and proximity sensors to alert operators of potential hazards. These smart features could provide real-time data on operational parameters, enabling predictive maintenance and enhancing workplace safety, aligning with emerging trends in smart automotive tools. Research on lifting mechanism dynamics (Hong *et al.*, 2024; Thang *et al.*, 2024) could inform the development of active stabilization systems that automatically adjust to load characteristics. The successful development of this hydraulic transmission jack has significant implications for workplace safety and productivity in automotive repair facilities, directly addressing one of the most hazardous tasks in vehicle maintenance and potentially reducing injury rates and associated costs.

5. Conclusions

This study successfully designed, fabricated, and tested a hydraulic transmission jack specifically tailored for truck transmission maintenance operations. The prototype demonstrated reliable performance across all critical parameters, achieving the design capacity of 2000 kg with a height adjustment range of 190-810 mm, exceeding initial specifications. Comprehensive testing confirmed the jack's structural integrity, hydraulic system reliability, and operational stability under maximum load conditions, with no tipping observed under offset loads of 1500 kg and zero pressure loss during extended hold tests. The device effectively addresses the ergonomic challenges associated with manual handling of heavy transmissions, significantly reducing physical strain on mechanics and potentially

decreasing workplace injuries in automotive repair facilities. The foot-pedal operated hydraulic system enables hands-free lifting with controlled positioning, enhancing both safety and operational efficiency during transmission removal and installation procedures. The cost-effectiveness of the prototype, with fabrication costs approximately 35-50% lower than comparable commercial models, makes it particularly suitable for small-scale repair facilities and workshops in developing economies where capital investment constraints often limit access to specialized equipment. This economic advantage, combined with the use of readily available materials and standard hydraulic components, facilitates local manufacturing and supports sustainable maintenance practices in the growing heavy vehicle service sector. The successful integration of established hydraulic principles with practical workshop requirements demonstrates that effective engineering solutions need not be complex or expensive to deliver substantial improvements in workplace safety and productivity. Future work should focus on several key areas to enhance the design's applicability and performance. Scalability for heavier loads would extend the jack's utility to the heaviest commercial vehicles and specialized equipment, while integration of electric or pneumatic pumping systems could reduce operator fatigue during extended use. The incorporation of smart sensors for load monitoring, pressure detection, and automated safety checks would align the design with Industry 4.0 trends and provide enhanced operational safety. Commercialization efforts should include durability testing under real-world workshop conditions, development of standardized manufacturing processes, and establishment of quality control protocols to ensure consistent performance across production units. This innovation contributes to advancing mechanical engineering applications in vehicle maintenance, demonstrating how targeted design interventions can simultaneously improve workplace ergonomics, operational efficiency, and economic accessibility in the automotive service industry.

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