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Sustainable Vehicle Lifting Solutions: Development and Testing of a Pneumatic Scissor Jack

Mohammad Nor Azami Mohd Rafee[1], Nurrul Amilin Zainal Abidin[1]*, Nurul Hanna Mas'aud[1], Nur Aini Sabrin Manssor[1]

[1] *Faculty of Mechanical Engineering,*
Universiti Teknologi MARA (UiTM) Johor Branch, Pasir Gudang Campus, 81750 Masai, Johor, MALAYSIA

*Corresponding Author: nurrul0230@uitm.edu.my
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Abstract

Conventional lifting systems often require manual effort, resulting in inefficient and unstable vehicle lifting operations. An improvised version of a lifting system with better efficiency, safety, and stability is thus needed to address these problems. Therefore, this study focuses on the design and construction of pneumatic scissor lift jacks, aiming to reduce manual labor and increase vehicle lifting performance. The fabricated prototype is integrated with a double-acting pneumatic cylinder, which was designed using SolidWorks and made of AISI 1020 mild steel. A simulation using finite element analysis shows approximately 3.52 MPa Von Mises stress when a 2000 N static load is applied on the lifting platform. Based on the results and data discussion, stress is lower than the material's yield strength, thus confirming that the newly developed lifting system can safely handle the load without permanent deformation. During the lifting and lowering process, there were no unusual vibrations and shaking observed, proving that the system demonstrated a stable and functional performance. In brief, it is recommended to utilize rectangular-shaped mild steel structures instead of the current 1 mm thick plates to enhance the lift's strength and durability. Incorporating an automatic safety lock mechanism when the lift reaches its maximum height extension would be beneficial to prevent accidental lowering and maximize safety for future development.

1. Introduction

To date, research on lifting mechanisms for automobiles and other heavy-load applications has advanced significantly, focusing on improving mechanical design and utilizing machine components to reduce human labor [1]. Recent studies emphasize the significance of lifting systems that offer controlled and stable movement, which reduces the need for physical intervention and thus improves the reliability of such designs [2], [3]. Conventional lifting equipment, like screw and mechanical scissor jacks, is widely employed because of their mobility, affordability, and convenience [1], [2]. Nonetheless, they have several drawbacks that make them unfit for lifting massive or uneven modern vehicles, such as the necessity for a heavy workload for humans, slow performance, and poor stability [3], [4]. To address these issues, many have since come out with pneumatic scissor lift prototypes that incorporate a pneumatic cylinder into a traditional scissor design. These systems effectively substitute manual labor with automated fluid power by employing compressed air to produce the linear motion to expand the scissor arm [5] – [7].

Pneumatic jack development actively promotes sustainable engineering methods in addition to better ergonomics. These systems are in line with the Sustainable Development Goals (SDGs) 9 (Industry, Innovation, and Infrastructure) and 12 (Responsible Consumption and Production) since they use compressed air as a working fluid instead of hydraulic oil, which is known as environmentally toxic [7], [8].

Scissor-type lifts are widely used, but they have a basic geometry problem where as soon as the scissor mechanism is elevated, the distance between its attachment point to the base and the movable platform reduces [9]. The mechanism's base is also observed to be drastically reduced because of this constriction which raises the possibility of overturning and dangerously lowers overall stability [9].

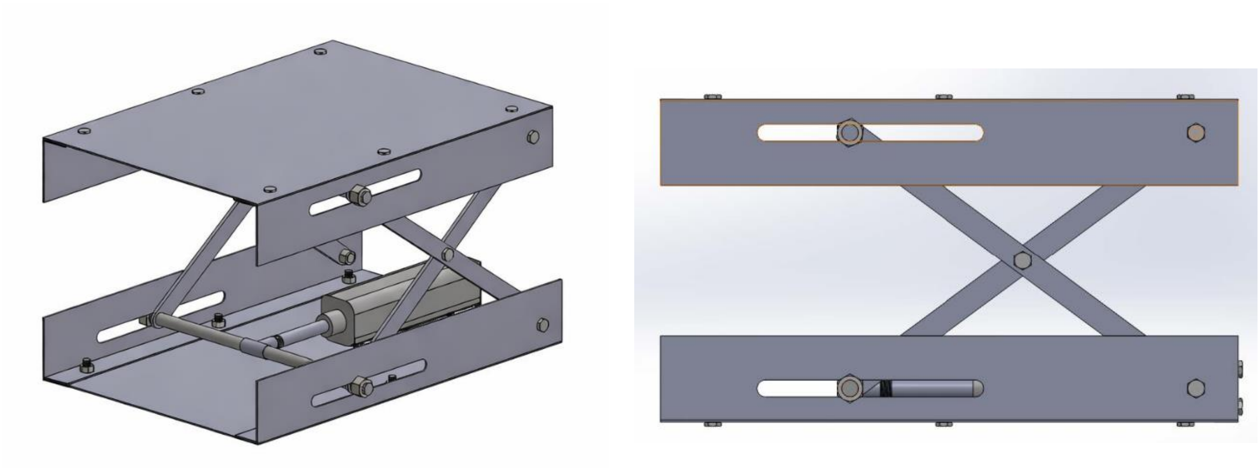
Recent mechanical designs suggest a spatial lever lifting technique to address this issue [10]. The joints that attach the lifting mechanism to the base and the movable platform in this arrangement stay stationary and fixed [10], [11]. Although the studied sources commend pneumatic scissor lifts for removing dangerous hydraulic lubricants, the literature on external control systems draws attention to a significant functional issue where the air is extremely compressible. Because air is compressible, it is much harder to precisely place and maintain a steady load under varying weights [12], [13].

Therefore, this study's primary objective is to develop a pneumatic scissor lift jack that will make lifting a car easier and safer. Most conventional jacks require a person to lift the automobile with a lot of hand power, which can be time-consuming and exhausting. By employing pressurized air and a pneumatic cylinder to do the lifting task, this invention seeks to address that issue.

2. Methodology

2.1 Computer-Aided Design (CAD) and Modelling

The 3D mechanical modeling of the prototype was executed using SolidWorks. The design integrated a traditional scissor lift mechanism with a pneumatic cylinder, where the linear motion of the cylinder's piston was designed to expand the scissor arms [6], [7]. Detailed CAD models were created for each single part, such as the base, lifting platform, threaded rods, scissor arms, and pneumatic holder. Fig.1 below shows the assembled part of the proposed design from the isometric (a) and side view (b). The full dimensions of the proposed design are illustrated in Fig. 2, where the base platform is 360 x 550 mm with the maximum extended lifting height up to 256.89 mm.



(a) (b)

Fig. 1 *The assembled CAD models from (a) An isometric view; and (b) A side view with the base platform of 360 mm x 550 mm, AISI 1020 Mild Steel*

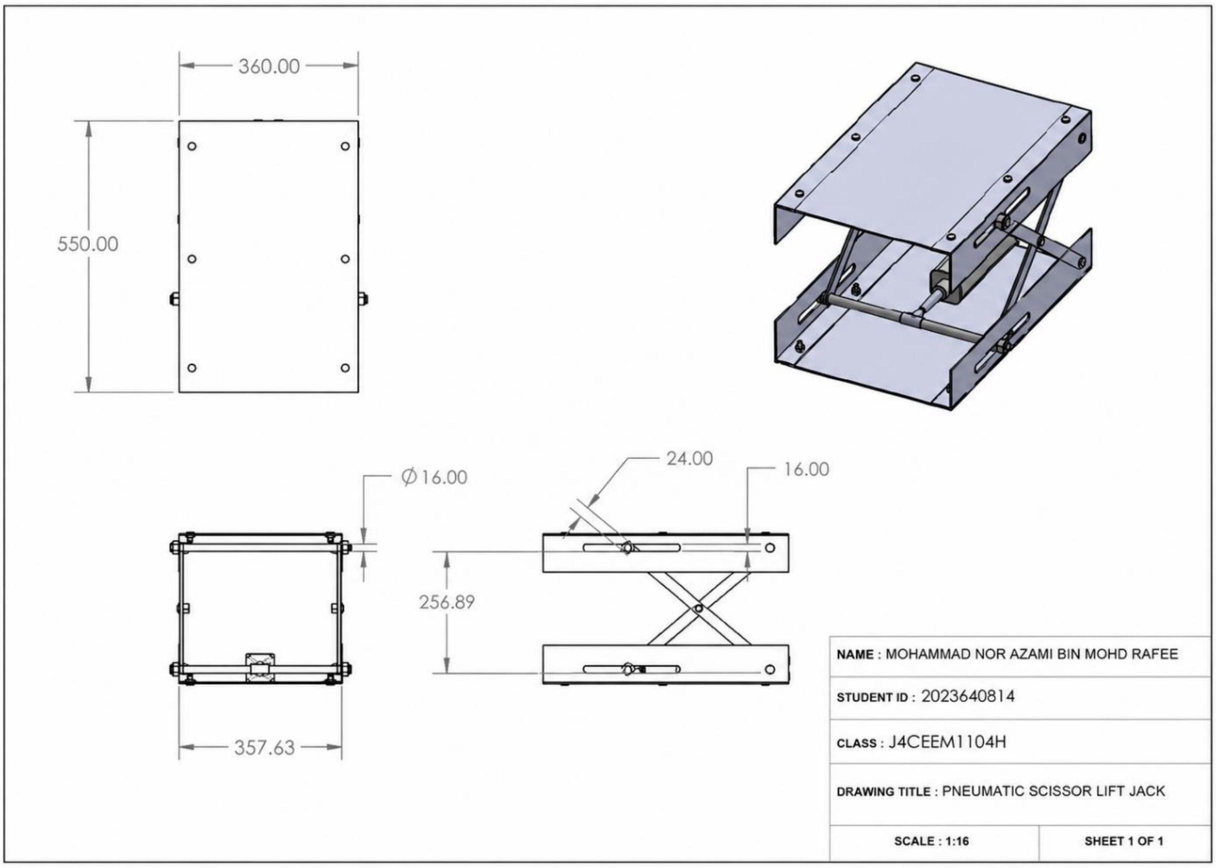


Fig. 2 *The assembly drawing of the proposed pneumatic scissor jack illustrating the dimensions (in mm) of the base platform and the maximum extended lifting height*

2.2 Engineering Calculation and Structural Analysis

Finite Element Analysis (FEA) was used to assure the lift's structural integrity [11]. During a static load simulation, the lifting platform, which is built from AISI 1020 steel with a thickness of 10 mm, was subjected to a 2000 N force. It is shown in Fig. 3 that the contour plot represents the Von Mises stress distribution across the structure. A maximum stress of roughly 3.52 MPa was revealed by the Von Mises stress analysis, while the minimum stress is close to 0 MPa at the fixed support regions.

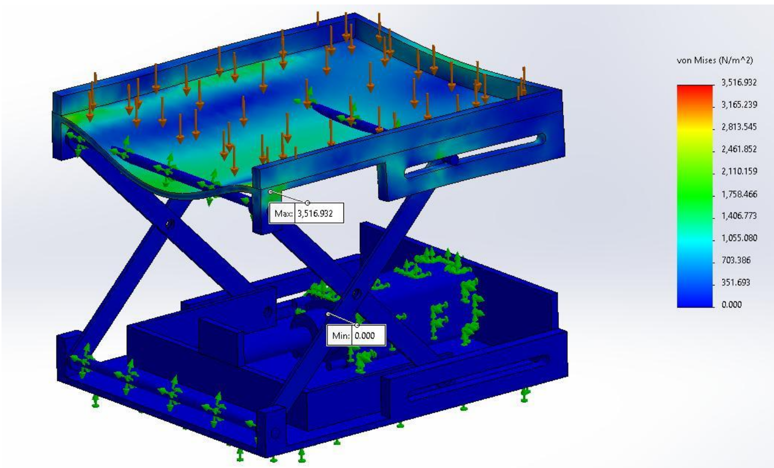


Fig. 3 *Von Mises stress distribution of the scissor lift platform under applied 2000 N static loading conditions, showing a maximum stress of approximately 3.52 MPa*

2.3 Prototype Fabrication and Testing

The final phase of the methodology involved functional testing of the fully assembled prototype, as shown in Fig. 4. An air compressor that was controlled by a directional control valve provides compressed air to the pneumatic cylinder [14], [15]. The system's ability to efficiently convert the pneumatic piston's linear action into the vertical lifting motion was assessed following previous studies [15] – [17]. To confirm structural stability and ensure that there were no air leaks, shaking, or strange vibrations, the lifting and lowering phases were closely observed during the operation in a quiet, confined space.

(a) (b)

Fig. 4 *The fully assembled pneumatic scissor lifting jack integrated with a directional control valve, from (a) Side view;* and *(b) Front view*

3. Results and Discussion

The designed and fabricated pneumatic scissor lift jack, integrated with a double-action pneumatic cylinder, was successfully built from 3D CAD modeling in SolidWorks to a fully manufactured physical prototype. The structural stability and strength were assessed using finite element analysis. From Fig. 3, it is indicated that stress is unevenly distributed throughout the structure. The load-transferring members and platform experience greater bending and compressive forces, leading to a concentration of higher stresses. The typical yield strength of AISI 1020 mild steel is around 294 MPa if it is cold drawn and approximately in the range of 205 to 350 MPa, depending on the manufacturing process and state. Since the induced stress of 3.52 MPa is much lower than the yield strength of 294 MPa, the analysis confirmed that the platform could safely support the load without permanent deformation. This finding demonstrated that the platform is sturdy. Any small bending under load would stay strictly elastic, ensuring that the platform would safely return to its original shape without suffering plastic deformation.

The estimation for factor of safety (FOS) is given as follows:

$$FOS = \frac{stress_{max/ult}}{stress_{working}} = \frac{294}{3.52} \approx 83.5 \tag{1}$$

A very high factor of safety obtained from Eq. 1 suggests that the newly developed pneumatic scissor lifting system is mechanically safe.

Following fabrication, operational testing was conducted by providing compressed air to the pneumatic cylinder. The testing revealed that the pneumatic pressure successfully moved the cylinder's piston in a linear motion, converting the vertical lifting action of the scissor mechanism. Observations made during raising and lowering phases demonstrated that the movement was constant and smooth with no unusual vibrations, indicating how practical and safe the prototype is for its intended use.

3.1 Advantages of the Proposed Project

This newly developed pneumatic scissor lift jack offers several advantages compared to traditional mechanical and heavy hydraulic lifts. By employing pressurized air rather than human mechanical cranking, the method significantly reduces the physical workload required to lift an automobile. As a result, both user comfort and operational speed were significantly improved. Additionally, the prototype developed in this study is portable and easy to store or relocate because of its compact and lightweight design. The simple integration of a double-acting pneumatic cylinder with a typical scissor framework makes the device straightforward and easy to install and maintain over time.

3.2 Suggestions for Future Improvement

For future improvements and recommendations, it is advisable to replace the basic frame of 1 mm thick mild steel plates with rectangular-shaped mild steel to enhance the strength, security, and functionality of the pneumatic scissor lift. This will undoubtedly increase the lift's overall load-bearing strength and durability. It is also recommended to incorporate an automated safety lock that turns on when the scissor lift reaches its highest point. By preventing involuntary lowering in the event of an air pressure decrease, this feature would optimize user safety.

4. Conclusion

The newly designed pneumatic scissor jack lifting system, integrating a double-acting pneumatic cylinder, has successfully displayed the capability of replacing human mechanical labor with fluid power. From the findings, it is wisely said that this project offers significant engineering insights, whose reliable operation depends on accurate joint alignment and perfect load distribution. This proof-of-concept also delivers a solid foundation for developing future automated, ergonomic, and advanced car lifting systems. Additionally, the entire engineering process from 3D CAD modeling to actual manufacturing and testing is validated by this study.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contributions to the paper as follows: ***study conception and design:*** *Mohammad Nor Azami Mohd Rafee, Nurrul Amilin Zainal Abidin;* ***data collection:*** *Mohammad Nor Azami Mohd Rafee;* ***analysis and interpretation of results:*** *Nurrul Amilin Zainal Abidin, Nurul Hanna Mas'aud;* ***draft manuscript preparation:*** *Mohammad Nor Azami Mohd Rafee, Nurrul Amilin Zainal Abidin, Nur Aini Sabrin Manssor. All authors reviewed the results and approved the final version of the manuscript.*

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