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Design Development of Semi-Automated Barrel Lifting and Tilting Trolley

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Abstract: The aim of this study is to presents the design and development of a semi-automatic barrel lifting and tilting trolley. The purpose of this project is to enhance efficiency and reduce manual labor in industries that involve the handling and transportation of heavy barrels. The trolley incorporates a lifting mechanism using a linear actuator, while tilting is achieved through manual rotation facilitated by a chain and sprocket system for precise positioning. Safety features, such as a quick-release grip attached to the barrel cradle, prevent unwanted sliding during lifting and tilting operations. The development process includes four phases: conceptual design, preliminary design, detailed design, and engineering analysis. Among the three proposed trolley designs, one was selected based on the requirements and specifications. The initial step in developing a trolley mechanism involved utilizing existing patents and researching available machines in the market. This process served as inspiration for generating ideas for the design concept. Once the best design concept was determined, it was then implemented and modelled using SolidWorks software. Selected designs undergo a sustainable analysis using the Life Cycle Assessment (LCA) tool in SolidWorks. Additionally, structural analysis was conducted using Ansys to assess the structural integrity of the selected design. Findings from this design and analysis process provide valuable insights for efficient and safe barrel handling in industrial settings.

Keywords: Design, Safety Feature, Sustainable Analysis, Structural Analysis, Enhance Efficiency, Barrel

1. Introduction

Raw materials and production of goods are handled in 210L in various industries. The barrels are handled by hand. At work, barrels are manually moved, lifted, loaded, tilted, and so on. It takes longer and can be unsafe to move a heavy load by hand. It comes from 210L and is liquid. A drum is loaded onto a horizontal stand. To address the material handling issue, the business needs efficient material handling equipment [1].

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Manual handling of large barrels in the manufacturing environment poses risks to productivity and worker safety [2]. Moving and tilting heavy barrels manually can lead to contact stress and physical dangers. Accidents related to physical work can have serious consequences for both employers and employees. To address these concerns, ergonomic improvements should be made by modifying and enhancing designs. A recommended solution is the implementation of semi-automatic systems such as hydraulic, pneumatic, or linear actuator mechanisms. These systems can effectively lift and tilt drums weighing at least 210 kg, considering factors like cost, durability, and long-term usability.

The manual handling of heavy barrels in an industry poses risks to worker health and safety, as well as increasing labor costs and potential errors. Work-related musculoskeletal disorders and accidents are prevalent due to the physical strain involved in lifting and tilting these heavy loads (Straker, 1997). To address this, a portable lifting and tilting device can be produced to reduce the burden on workers and improve overall productivity and safety. The current process requires multiple workers and can result in severe injuries if the heavy drum falls.

Manual handling activities like lifting, lowering, and carrying can lead to musculoskeletal disorders and cause significant global health issues [3].

Traditional methods for maintenance work involving fluid transfer also require unnecessary movements and increase the difficulty of the task. Expensive material handling equipment like forklifts may not be feasible for small industries due to cost and licensing requirements. Therefore, an improved drum lifter design using mechanical mechanisms can enable a single worker to lift and tilt the drum without heavy physical exertion.

2. Methodology

Throughout the design and development of the semi-automated barrel lifting and tilting trolley, the research flowchart shown in Figure 1 is used to represent the overall workflow. The workflow for designing the semi-automated barrel lifting and tilting trolley follows a systematic process as depicted in the flowchart. Initially, the task clarification phase ensures a clear understanding of the requirements and objectives. Once clarified, the conceptual design stage begins, where high-level ideas and concepts are developed. These ideas are then further refined in the embodiment design phase, focusing on the specific details and functionalities. In the subsequent concept generation step, various design concepts are explored to determine the most suitable approach. The chosen concept is then translated into a product architecture, outlining the overall structure and components. Design configuration is performed to define the specific configuration parameters for the trolley.

To further refine the design, three sketch ideas are generated to explore different visual and functional aspects. Following this, parametric design is employed to create a flexible and adaptable model that can be easily adjusted as needed. Detail design involves the meticulous consideration of each component and its interaction within the system. During this phase, careful product material selection is made for the lifting and tilting unit, frame and housing, electrical and electronic components, and circuit diagrams. To validate the design, modelling and simulation are conducted using SolidWorks software, ensuring the trolley's functionality and performance.

Furthermore, structural analysis using ANSYS Workbench software is performed to assess the trolley's structural integrity and safety. This analysis helps identify Von-Mises stress, total deformation, factor of safety and buckling analysis of the chosen design. Throughout the workflow, close collaboration between design engineers, stakeholders, and experts is crucial to ensure the trolley meets all requirements and specifications. By following this comprehensive flowchart, the design of the semi-automated barrel lifting and tilting trolley can be systematically executed, resulting in a robust and efficient product.

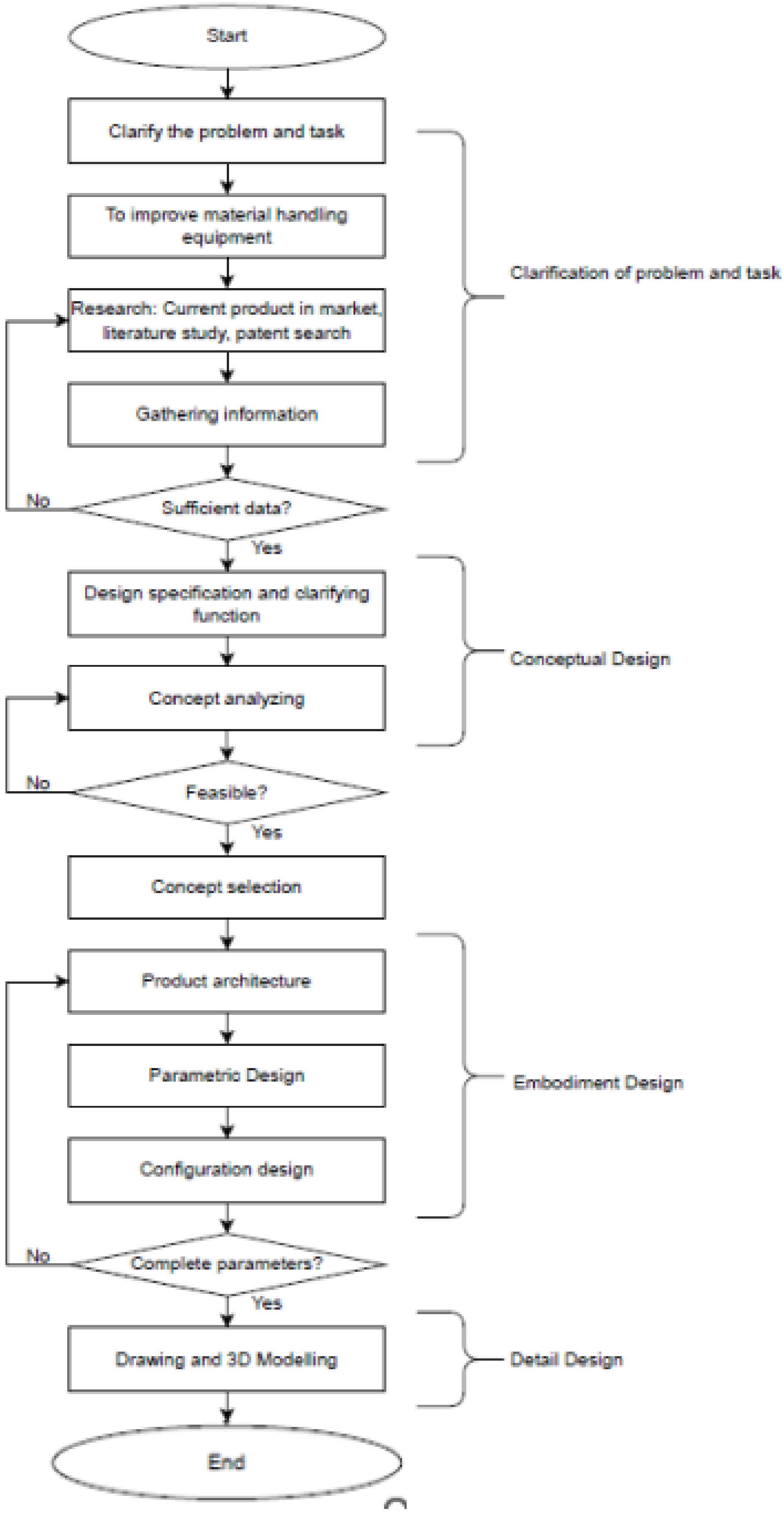
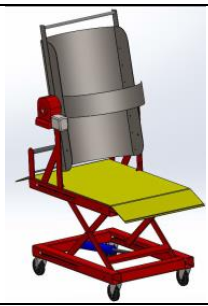


Figure 1: Flow chart of the design process of the trolley

3. Design Process

This topic presents the design and engineering analysis process to develop the semi-automated barrel lifting and tilting trolley using the correct engineering design process. It undergoes several steps before the chosen design can be developed. By choosing the design from the three-design idea, only one design need to choose depends on the objective and meet the product requirement and specification.

Table 1: Concept generation

Product Characteristic	Design Idea 1	Design Idea 2	Design Idea 3
			
Type	Scissors Lifting with motor tilting barrel	Double actuator for lifting and over lift to tilt the barrel	Long reach barrel lifting and tilting
Dimension	792mm x 1380mm x 1778mm	1096mm x 2053mm x 1710mm	880mm x 1580mm x 1654mm
Weight	164.86kg	314.13kg	118.39 kg
Material	Mild Steel	Plain Carbon Steel	ASTM A500
Function	- The barrel is lift using scissors lifting mechanism. - Gearbox motor is utilized to tilt the barrel	- The barrel is lifted by using double actuator. - To tilt the barrel, the actuator must over lift to tilt the barrel.	- Can be use for long reach the barrel for easy placement. - The height of the boom can be adjusted using motor actuator. - To tilt the barrel, manual hand sprocket is used.

3.1 Product Design Specification

The basic portion and reference document for the market or research-available design and product serve as the foundation for the product design specification and its constituent parts. The following are the specifications' requirements for the semi-automatic drum lifting and tilting trolley.

Table 2: Product Design Specification

Introduction	
Title: Designing Semi-Automatic Barrel Lifting and Tilting Trolley Design problem: Lifting and Tilting the Barrel Purpose: To increase productivity and make the work more professional	
Design Needs and Requirements	
Performance function	▪ Can lift up to 210 Kg of barrel. ▪ Minimum workload required for worker.

Operation environment	▪ Carried out at manufacturing plant.
Economic	▪ Should less routine servicing ▪ More economic life at least 7 years.
Geometric limitation	▪ Lift high limit at 1800mm ▪ Can long reach at 1200mm ▪ Tilting the barrel 360 degree
Maintenance	▪ No maintenance required during economic life. ▪ Easy to maintain
Safety	▪ High stability to avoid it buckling. ▪ The trolley boom is rigid and minimize the swing motion
Ease to operate	▪ Reduce manpower at least 1 person can handle the trolley. ▪ Automatic lifting using motorized hydraulic actuator.
Sustainability	▪ Energy-efficient, lowering operational power consumption.

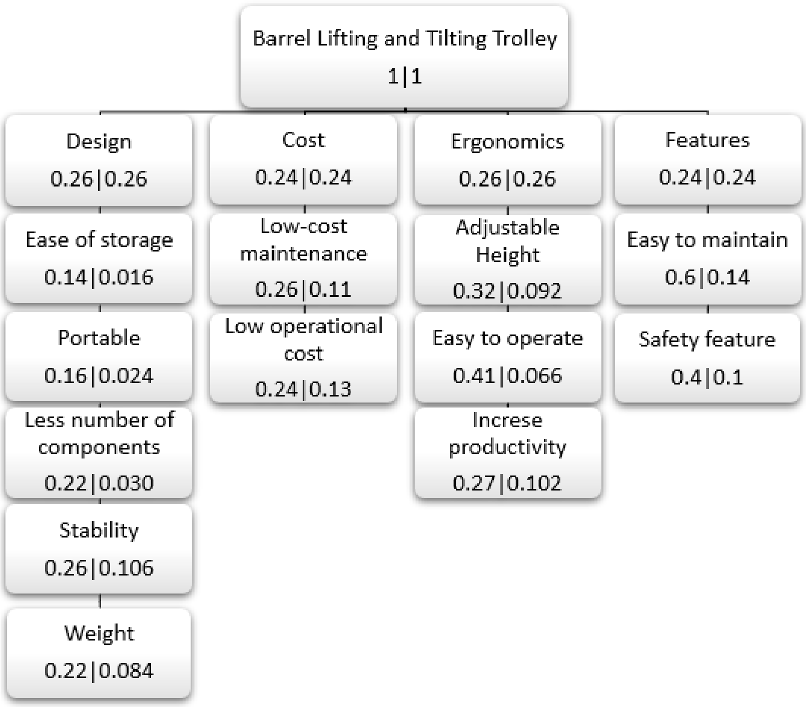


Figure 2: Objective Tree Diagram

3.2 Evaluation Matrix - Weighted Rating Method

To evaluate different options that have multiple aspects to consider, we can use a method called weighted rating. This method assigns weights to each aspect based on their importance and calculates a score for each option. From figure above We can conclude that Idea 3 was chosen through matrix evaluation form because it achieves the design requirements need.

Table 3: Evaluation Matrix

Criterion	Weight Index	Idea 1		Idea 2		Idea 3	
		Rating	Score	Rating	Score	Rating	Score
Design							
Ease of storage	0.016	4	0.064	3	0.048	4	0.064

Portable	0.024	4	0.096	3	0.072	4	0.096
Less number of components	0.030	1	0.030	3	0.090	4	0.120
Stability	0.106	3	0.318	4	0.424	4	0.424
Weight	0.084	3	0.252	1	0.084	5	0.420
Cost							
Low-cost maintenance	0.110	3	0.330	1	0.110	4	0.440
Low operation cost	0.130	2	0.260	2	0.260	3	0.390
Ergonomics							
Adjustable height	0.092	4	0.368	2	0.184	5	0.460
Ease to operate	0.066	2	0.132	3	0.198	4	0.264
Increase productivity	0.102	3	0.306	3	0.306	3	0.306
Features							
Ease to maintain	0.140	2	0.280	3	0.420	4	0.560
Safety feature	0.100	2	0.200	4	0.400	4	0.400
Total	1		2.636		2.596		3.944

3.3 Product Architecture

Product architecture, often known as system-level design, is the process of designing and assigning physical elements or entities to a product's function. Typically referred to as modules, physical components are defined and assembled to satisfy the overall product need specification.

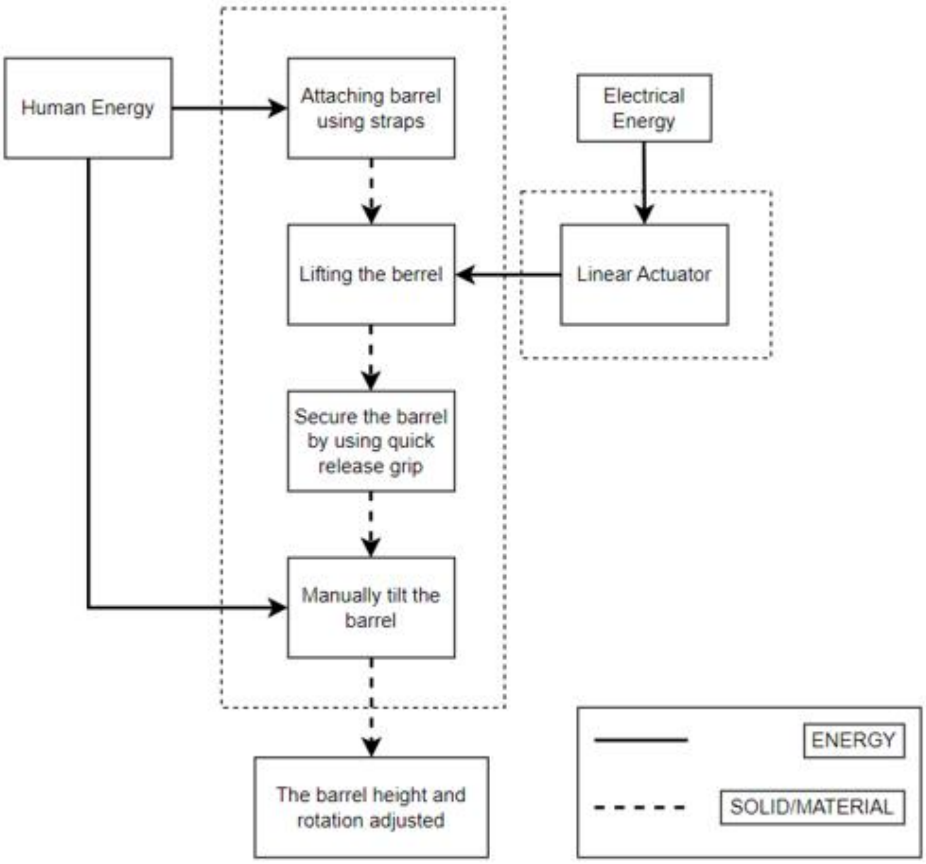


Figure 3: Element Cluster

3.4 Modelling

After all the sub-assembly concepts have been finished, they are combined to create the overall concept design for the semi-automatic barrel lifting and tilting trolley. An isometric view of the entire cart is shown in Figure 4.9.

Figure 4: Overall Design

3.5 Simulation

Sub-assemblies for the trolley are simulated in this section using the SolidWorks software called motion analysis. The following describes how each mechanism on each sub-assembly moves during the simulation process:

(i) Lifting and tilting mechanism
(ii) Folding mechanism

The semi-automatic drum lifting and tilting trolley utilizes a ratchet strap for locking the barrel into the cradle mount. The ratchet strap offers easy one-handed tensioning, quick-release buckle for tightening and loosening, and can withstand loads of up to 2 tons.

Figure 5: The barrel is attach using ratchet straps

The motor actuator is employed to extend or retract the drum lifting and tilting trolley. To prevent barrel sliding, a quick clamp grip is used to secure it. With a maximum extension of 1780mm, the trolley facilitates easier lifting and placement at elevated locations or onto trucks.

Figure 6: Lifting the barrel

The manual tilting of the barrel is facilitated by the tri-wheel handle. The driven sprocket ensures efficient energy usage during the tilting process. The ability to tilt the barrel is beneficial for quick extraction of its contents. Additionally, the orientation of the barrel can be adjusted to either horizontal or vertical arrangement as desired.

Figure 7: Tilting the barrel

To fold this trolley, first of all, the pin on the foot of the trolley and the actuator bracket must be released.

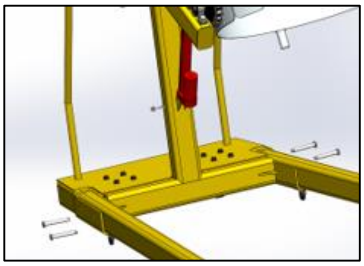


Figure 8: Disassembly of Clevis Pin

After that, pull the leg frame to align the pin holes in the front. Insert a pin in that hole and another pin in the second hole. The second pin functions as a support for the leg backwards.

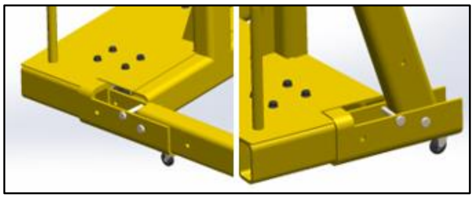


Figure 9: Shows the function of clevis pin when folding the leg

After completing the process, the boom and barrel cradle can be lowered. Therefore, it is easy to store in narrow places and can reduce storage space.

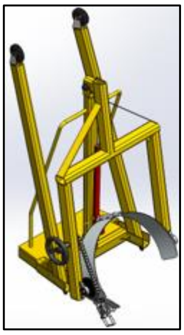


Figure 10: Fully folded trolley

3.6 Engineering Analysis

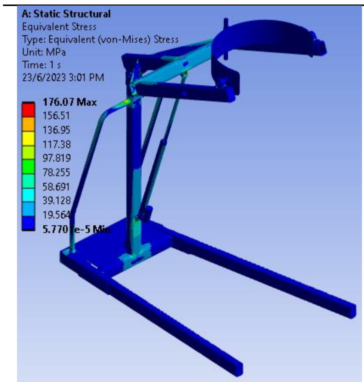
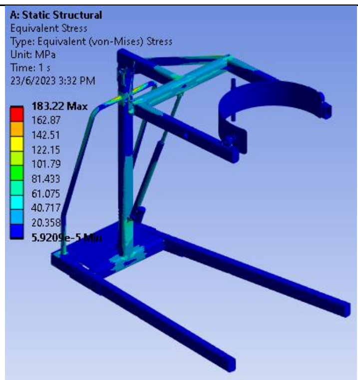
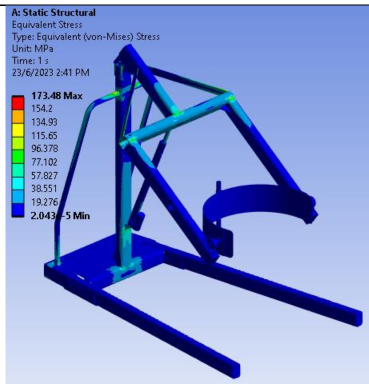
The analysis involved calculating various parameters such as torque, thrust force, wheel calculations, bolt and nut selection, material selection and circuit selection. These calculations aided in selecting appropriate component specifications to ensure product reliability and cost-effectiveness. The final product design specification was derived from this analysis. The table below presents the Final Product Design Specification for reference:

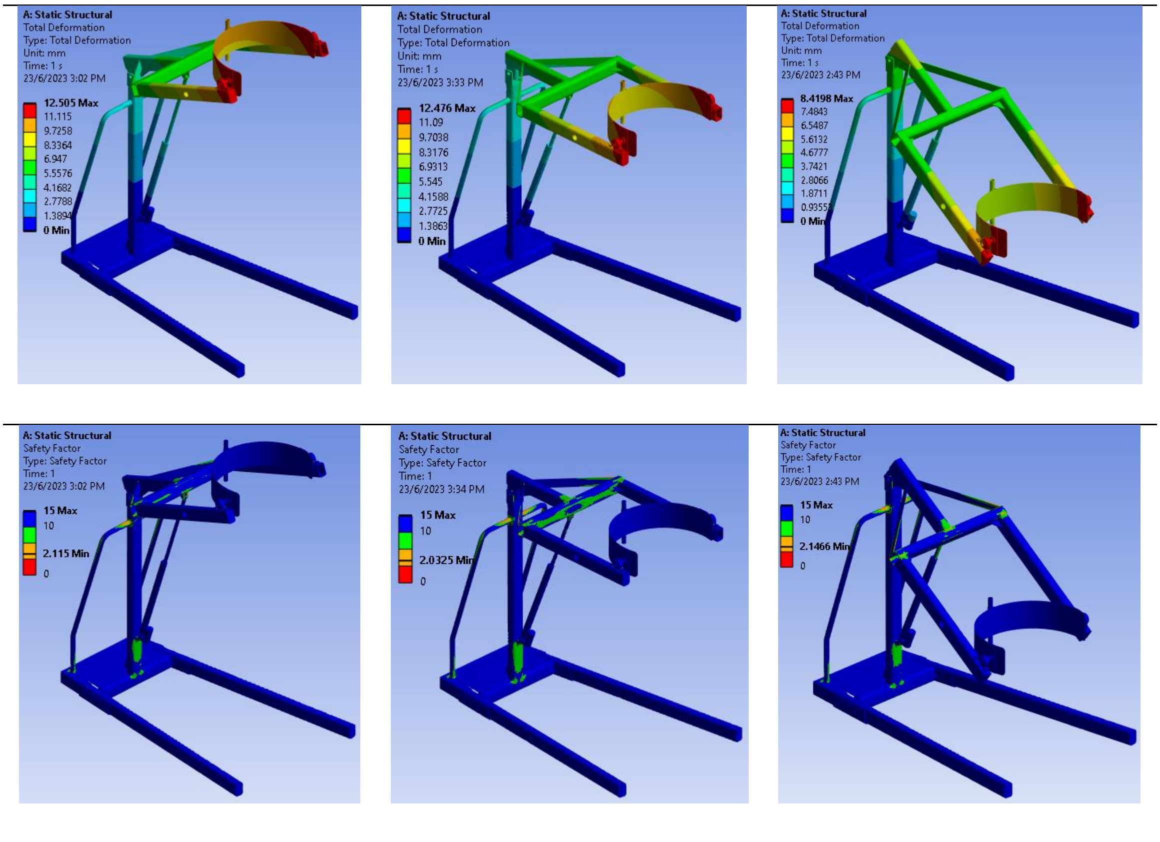
Table 4: Full Product Specification

Product Specification	Description
Specification of actuator	• Stroke: 500 mm • Input Voltage: 12V • Max dynamic load: 6800 N • Max no load speed: 61 mm/s • Max full load speed: 37 mm/s • Total length with extend: 759.5 mm
Weight of the product	118.39 kg
Dimension	895mm x 1583mm x 1755mm
Price	RM8771.02

3.7 Structural Analysis

Ansys Workbench was employed to conduct structural analysis on three positions of the trolley barrel cradle under a full load of 2060N, with a barrel weight of 210kg. The configuration of the barrel lifter was treated as a rigid structure, and the component contacts were defined as bound connections. The analysis focused on evaluating equivalent stress (Von Mises), total deformation, factor of safety (FOS) and buckling analysis.

High Position	Middle Position	Low Position
		



According to the analysis, the trolley experiences the highest Von Mises stress when the barrel is lifted to the middle height (183.22 MPa), followed by the high-lift position (176.07 Mpa) and the low-lift position (173.48 Mpa).

The analysis revealed that the high-lift position caused the largest total deformation (12.505 mm), followed by the middle lift position (12.476 mm). The low lift position exhibited the least deformation (8.4198 mm). These findings indicate that the trolley undergoes significant structural displacement when the barrel is lifted to a higher position.

The factor of safety (FOS) measures the margin of safety against failure in a structural design. The analysis revealed that the low lift position had the highest FOS (2.1466), followed by the high lift position (2.115) and the middle lift position (2.0325). These results indicate that the trolley design offers an acceptable level of safety in all lift positions, with the low lift position providing the highest margin of safety.

The analysis predicts that the structure will experience buckling, especially on linear actuators. The total deformation observed in this mode is 1.0472mm, indicating the magnitude of the buckling displacement as shown in figure below.

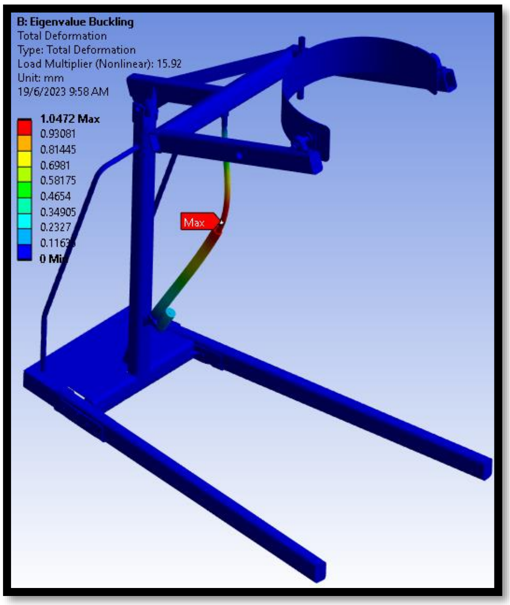


Figure 11: Buckling analysis

Based on the structural analysis of the lifting trolley and barrel inclination, it can be concluded that the trolley design ensures a satisfactory level of safety across all lifting positions. The stress levels do not exceed the maximum yield of the materials used, and the minimum factor of safety for each position surpasses the threshold value of 1.0. Therefore, the design is deemed reliable and meets the required safety standards.

4. Conclusion

The semi-automatic barrel lifting and tilting trolley design has effectively met its objectives by addressing specific product requirements and specifications. An in-depth structural analysis using Ansys has yielded positive outcomes, validating the design's structural integrity. The engineering analyses conducted have been successfully accomplished, resulting in optimal performance and safety. With its user-friendly operation, the trolley proves to be efficient and can be operated by a single individual. In summary, this project has delivered a sturdy and practical solution for lifting and tilting barrels, demonstrating the successful application of engineering principles and design considerations.

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