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Design Analysis of a Foldable Wheel Clamp

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Abstract

This project aims to design and develop a foldable wheel clamp that addresses the common limitations of traditional immobilization devices, including excessive weight, bulk, and lack of adjustability. Conventional clamps, typically constructed from heavy steel or cast iron, are cumbersome to transport and often damage alloy wheels during installation and removal. To overcome these shortcomings, the proposed design incorporates lightweight, high-strength materials, an ergonomic form factor, and a telescopic adjustment mechanism compatible with wheel diameters ranging from 14 to 18 inches. A scissor-type folding mechanism enables compact storage, while a linear actuator automates deployment, achieving full extension in approximately 5 seconds. Rubberized contact pads are integrated to prevent wheel surface damage during clamping. The design methodology encompasses conceptualization, functional decomposition, material selection, and iterative validation using Computer-Aided Design (CAD) and Finite Element Analysis (FEA). The concept was evaluated through a weighted decision matrix prioritizing security, portability, and ease of use. Results indicate that the foldable wheel clamp offers significant improvements in robustness, weight reduction, and ergonomic handling, thereby decreasing the time and physical effort required for deployment. Primarily intended for law enforcement and parking enforcement applications, the design presents a modern, user-centric solution for vehicle immobilization. Future work may explore integration with smart locking systems and field validation of the motorized deployment mechanism under real-world conditions.

1. Introduction

A prevalent method of preventing vehicles from moving is tire and wheel clamping, which immobilizes one of the four tires to prevent the vehicle from being driven. Tire clamping serves solely to ensure the vehicle remains immobile and thus reduce the risk of it being moved.

The foldable wheel clamp project aims to provide a practical and effective solution to this ongoing problem. By developing a portable, user-friendly wheel clamp, the project aims to empower vehicle owners to take proactive measures against illegal parking, thereby complementing existing enforcement strategies and improving traffic management in urban areas [1]. Electronic security devices, such as car alarms, immobilizers, and GPS tracking systems, have long been the cornerstone of vehicular theft prevention. However, these systems are vulnerable to tampering. Thieves with access to signal jamming tools or hacking devices can disable alarms and bypass ignition controls with relative ease. Additionally, even when these systems are triggered, law enforcement or passersby often respond too slowly to prevent theft or vehicle damage [2].

The objective of this project is to design a foldable clamp mechanism for varying wheel sizes using SolidWorks. This proposed development of a foldable, adjustable wheel clamp aims to address longstanding issues arising from the removal of conventional wheel immobilization devices. Modern models made of solid steel remain fixed to a single body, making them endlessly bulky and incompatible with a wide range of tire sizes. This causes operational inefficiency, increased physical strain on enforcement personnel, higher itemized equipment costs, and reduced applicability during field operations. This project is a significant focus as it aims to overcome these problems by multifunctionally integrating a foldable design while maintaining a modular structure adjustable to tires 14 up to 18 inches in diameter. Through the integration of folding mechanisms with optimized geometry, the proposed clamp is best suited for mobile enforcement units and compact service vehicles due to spatial savings in storage. This advancement directly improves logistical efficiency and reduces costs associated with storing and deploying multiple clamp variants.

Wheel clamps play a critical role in vehicle parking control and immobilization, but traditional designs, particularly those made from rigid steel constructions, often fail to provide the necessary mobility and safety features for users. The lack of these features in conventional wheel clamps impacts their effectiveness, making them difficult to operate in certain environments [3].

1.1 Study on Component of Wheel Clamp

Traditional wheel clamps consist of three key mechanical components: the chock and ground engagement mechanism, the facing and engaging bar, and the locking system [4]. The chock serves as the foundation, gripping the tire to prevent rotation, and is typically constructed from hardened steel or reinforced polymers to resist tampering and environmental stress. Connected to the chock, the facing and engaging bar wraps around the wheel—with the facing bar positioned against the outer wheel face and the engaging bar securing the inner side. These components are often designed with adjustable or telescopic arms to accommodate various wheel sizes, ensuring a secure and adaptable fit.

The locking mechanism, crucial for immobilizing the engaging bar, ranges from traditional padlocks to advanced integrated systems [4]. Innovations include designs where the vehicle's own ignition key is required to engage or release the clamp, temporarily disabling the ignition and enhancing theft deterrence. The effectiveness of a wheel clamp relies on balancing these components to achieve security, durability, and user convenience, ensuring reliable operation across different vehicle types and conditions.

1.2 Ergonomic and User-Centric Design in Modern Wheel Clamp

Beyond mechanical design, ergonomics and user safety have become a growing focus in recent studies. For instance, a portable, three-arm wheel clamp was presented, specifically designed for medium-sized tires. Their study utilized SolidWorks CAD software and Finite Element Analysis (FEA) to simulate real-world stress conditions. As a result, small-scale teams for parking control and private security personnel spend less energy on the job since clamp operation became stand-up use, making the device lighter and easier to operate. The study noted ergonomic enhancements made with new materials and collapsible frames could reduce deployment time by 40% [6].

1.3 Patent Search

Several patents are reviewed and compared to collect information on existing designs to develop the design concept. Table 1 lists the patents selected for review and comparison.

Table 1 *Patent Search*

No	Patent Name and Number
1	Wheel Clamp for a Vehicle (EP 3835142)
2.	Wheel Clamp (WO 204718 A1)
3.	Vehicle Wheel Clamp (5385038)
4.	Anti-Theft Vehicle Wheel Lock

1.4 Existing Product Comparison

Table 2 shows the existing product comparison.

Table 2 *Existing Product Comparison*

Specification	Caribe Model (Way Ne Hardware)	WCLAMP Series (Welldone Hardware)	3 Forks Lock (66 Happy Tool)
Figure			
Clamp Type	Dual adjustable clamper	Dual adjustable clamper	Heavy-duty U-clamp with tri-fork jaws
Weight	11 kg	13 kg	18 kg
Material	Heavy-duty steel	Mild steel with anti-corrosion finish	Hardened steel, anti-rust coated
Wheel Size	Medium to large	Medium to large	Limited
Locking Mechanism	Dual padlock housing	Mechanical lock with padlock cover	Single lock (integrated into clamp body)
Protective Elements	Rubber-coated hooks, warning plate	Corrosion-resistant finish	Soft-coated claws, painted body

2. Project Flow

2.1 Project Flow Chart

The design process model is a systematic procedure for developing a product or solution from an initial idea to a final design that is suitable for manufacture. Figure 1 shows the overall methodology used to develop the wheel clamp product. The study begins with the introduction and literature review stages, which include the background study, problem statement, objectives, scope, and review of existing wheel clamp products, patents, and commercial designs. Information was collected from journals, articles, textbooks, and internet sources to identify gaps and limitations in current products before defining the design problem.

Next, several design concepts were generated using methods such as component decomposition, function analysis, and morphological charts. The concepts were then evaluated using a weighted rating method to select the most suitable design. The selected concept proceeded through product architecture, configuration design, parametric design, and detailed design stages. Finally, the completed design was developed and visualized using SolidWorks animation and video editing software.

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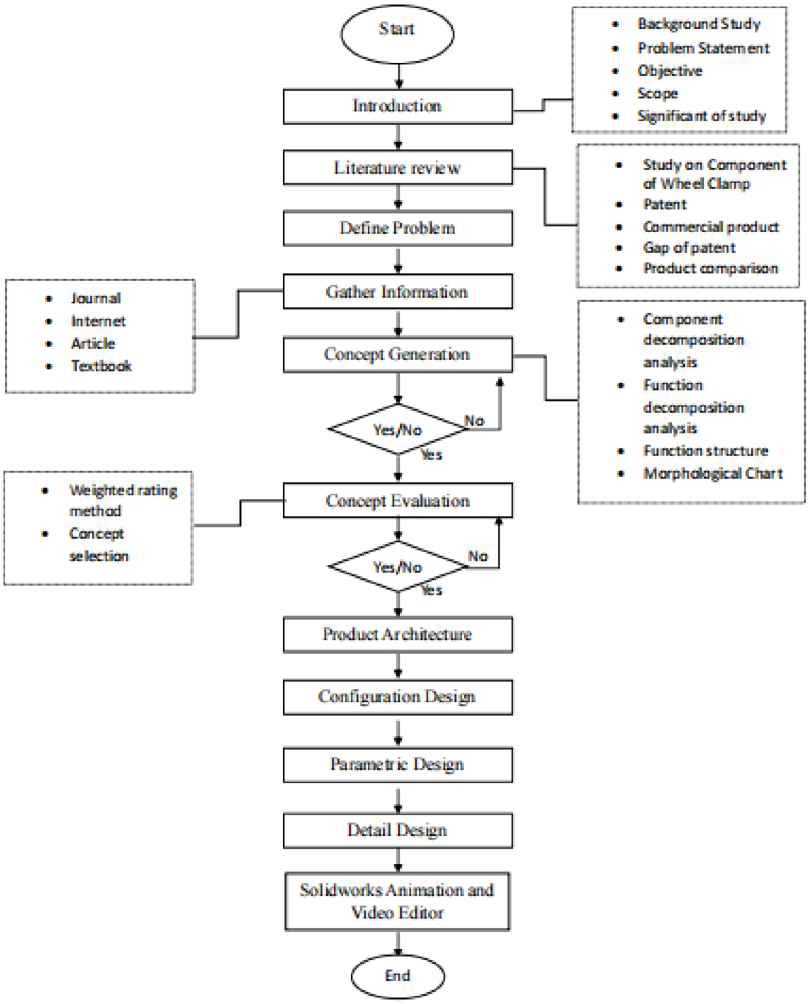

Figure 1 *Design Flow Chart*

2.2 Object Tree

Figure 2 illustrates the functional decomposition of the proposed foldable wheel clamp design. The main objective of the product is to provide secure wheel immobilization while ensuring adjustability, easy storage, transport convenience, and user-friendly operation. Several sub-functions were identified to support these objectives, including strong clamping force, tight tire fitting, resistance to tampering, telescopic arm extension, firm tire grip, foldable structure, convenient carrying handle, automatic folding mechanism, and clear locking feedback. This functional analysis helps guide the development of a practical, secure, and portable wheel clamp design.

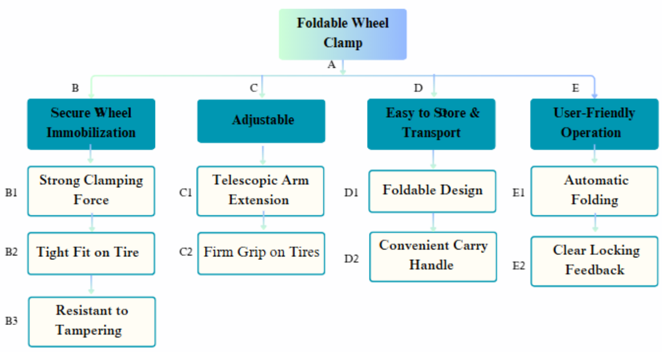

Figure 2 *Objective Tree*

3. Methodology

3.1 Function Structure

All Foldable Wheel Clamp processes, from the initial to the final stage, are generated by referring to the black box shown in Figure 3 below.

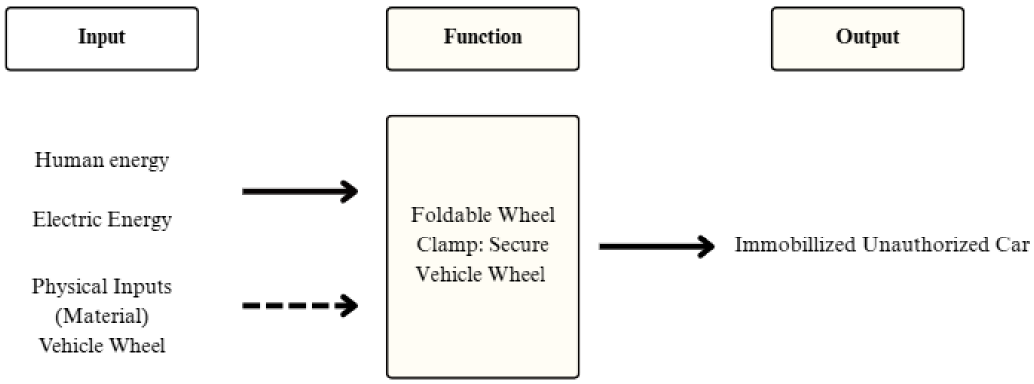

Figure 3 *Black Box Foldable Wheel Clamp*

Morphological chart is a tool for generating and analysing different combinations of components in a table that helps designers to select the most appropriate combination that satisfies the common functionality required in a new product. Evaluation of the combination can be done by a weighted decision matrix, which ranks all the alternative combinations to meet the design goal. Figures 4 to 6 present the development of the proposed foldable wheel clamp design, starting from the initial project sketch to the final 3D CAD model. Figure 4 shows the conceptual sketch used to visualize the basic structure and folding mechanism of the wheel clamp during the early design stage. Figures 5 and 6 illustrate the completed design in folded and unfolded conditions, respectively. The folded configuration highlights the compact structure for easier storage and transportation, while the unfolded configuration demonstrates the operational form of the wheel clamp for securing vehicle tires. The design emphasizes portability, functionality, and ease of use while maintaining effective wheel immobilization.

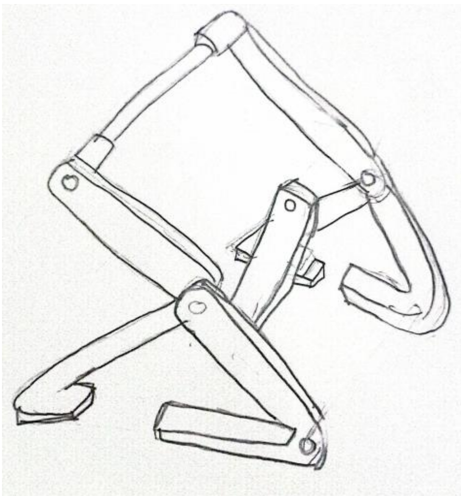

Figure 4 *Project Sketch*

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Figure 5 *Folded Wheel Clamp*

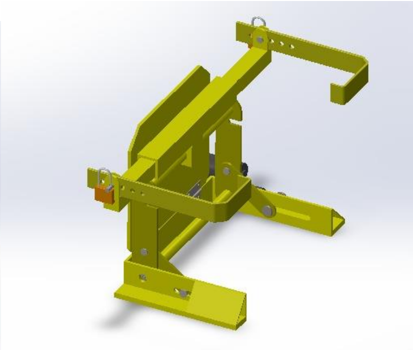
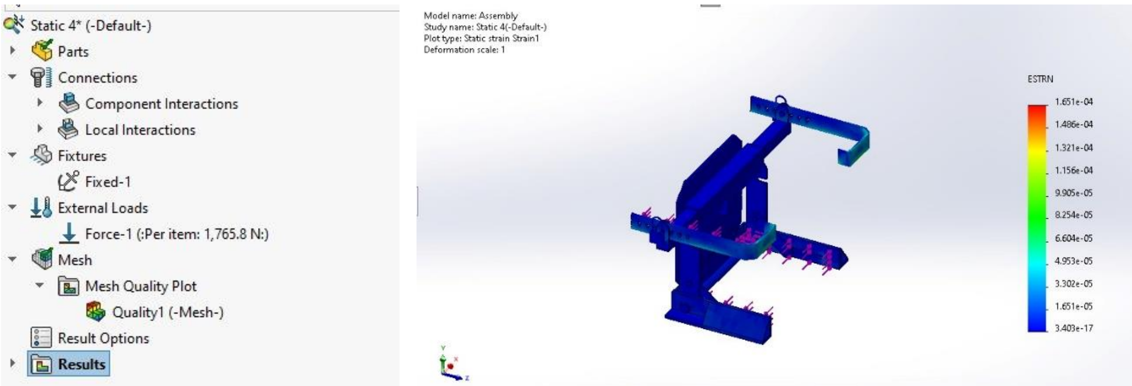


Figure 6 *Unfold Wheel Clamp*

3.2 Simulation

A structural simulation was performed to evaluate the clamp's resistance to human tampering (Figure 7 to Figure 9). A static force of 90 kg (≈ 883 N) was applied to critical clamp components to simulate attempted forced removal. A Factor of Safety (FOS) of 2 was used, meaning the design was validated to withstand at least 1766 N without permanent deformation or failure. The simulation confirmed that the clamp maintains structural integrity under tampering conditions, ensuring reliable immobilization.



(a) (b)

Figure 7 (a) *Simulation Geometry*, (b) *Engineering Strain*

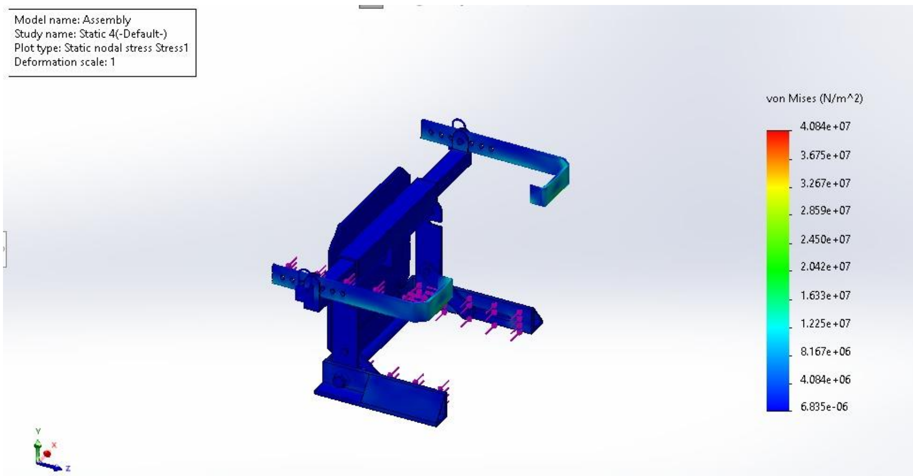


Figure 8 *Von Mises*

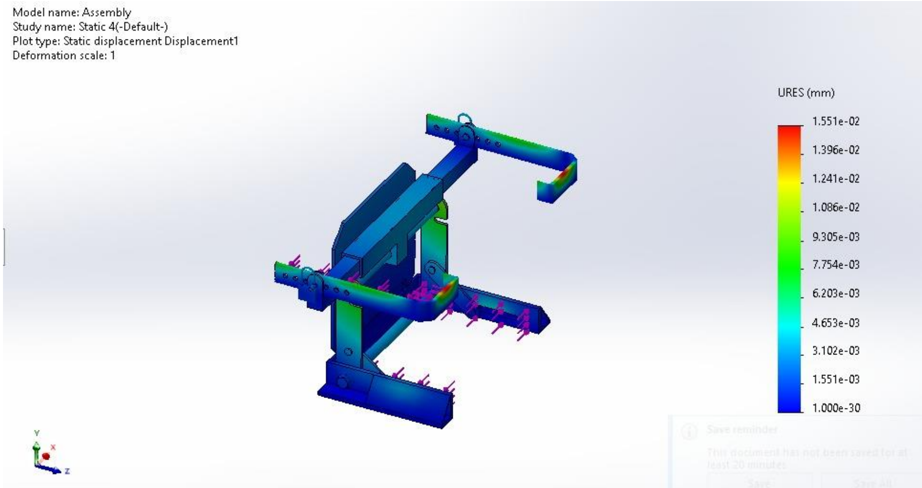


Figure 9 *Displacement*

3.3 Engineering Analysis

This section presents the torque and speed analysis of the linear actuation system implemented in the Foldable Wheel Clamp.

I. Force Requirement

The motorized deployment system is designed to overcome a resistive force of 4.2 kg-f (41.2 N) required to initiate and complete the unfolding motion of the wheel clamp.

$$F_{required} = 4.2\ kg\ \times 9.81\frac{m}{s^2} \tag{1}$$
$$F_{required} = 41.2\ N$$

Applying a safety factor of 2.5 to account for dynamic loads, wear, and environmental conditions:

$$F_{required} = 41.2N\ \times 2.5 \tag{2}$$
$$F_{required} = 103\ N$$

II. Power and Current Analysis

Mechanical Power Output:

$$P = F \times v \tag{3}$$
$$P = 103\ N\ \times 0.015 m/s$$
$$P = 1.55\ W$$

Electrical Power Input (assuming 60% efficiency):

$$P_{elec} = \frac{1.55}{0.6}$$
$$P_{elec} = 2.58\ W$$

Current Draw at 12V:

$$I = \frac{P_{elec}}{V} \tag{4}$$
$$I = \frac{2.58}{12}$$
$$I = 0.215\ A$$

III. Speed and Deployment Time

Linear speed: 15mm/s
Stroke length: 75 mm

$$t = \frac{Stroke}{Speed} \tag{5}$$
$$t = \frac{75\ mm}{15mm/s}$$
$$t = 5\ s$$

IV. Battery Sizing

Energy per Deployment Cycle:

$$E = P_{elect \times t} \tag{6}$$
$$E = 2.58\ W \times 5\ S$$
$$E = 12.9\ J$$

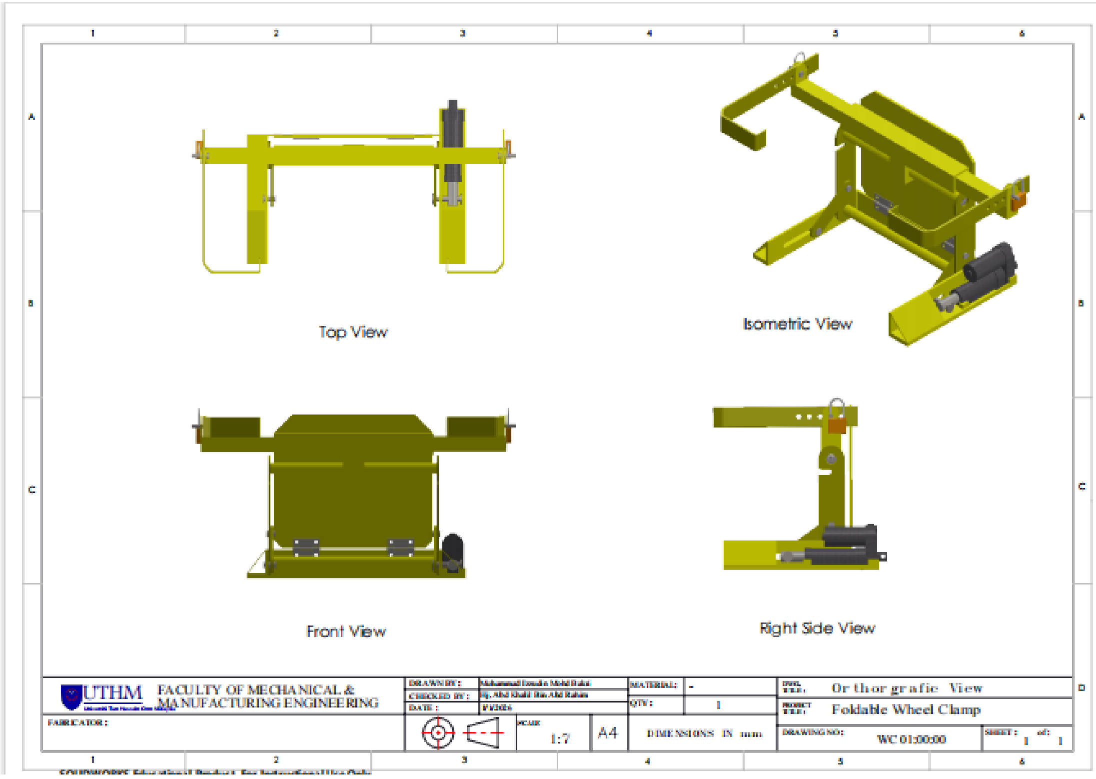
Battery Capacity for 50 Cycles:

$$E_{total} = 12.9\ J \times 50 \tag{7}$$
$$E_{total} = 645\ J$$

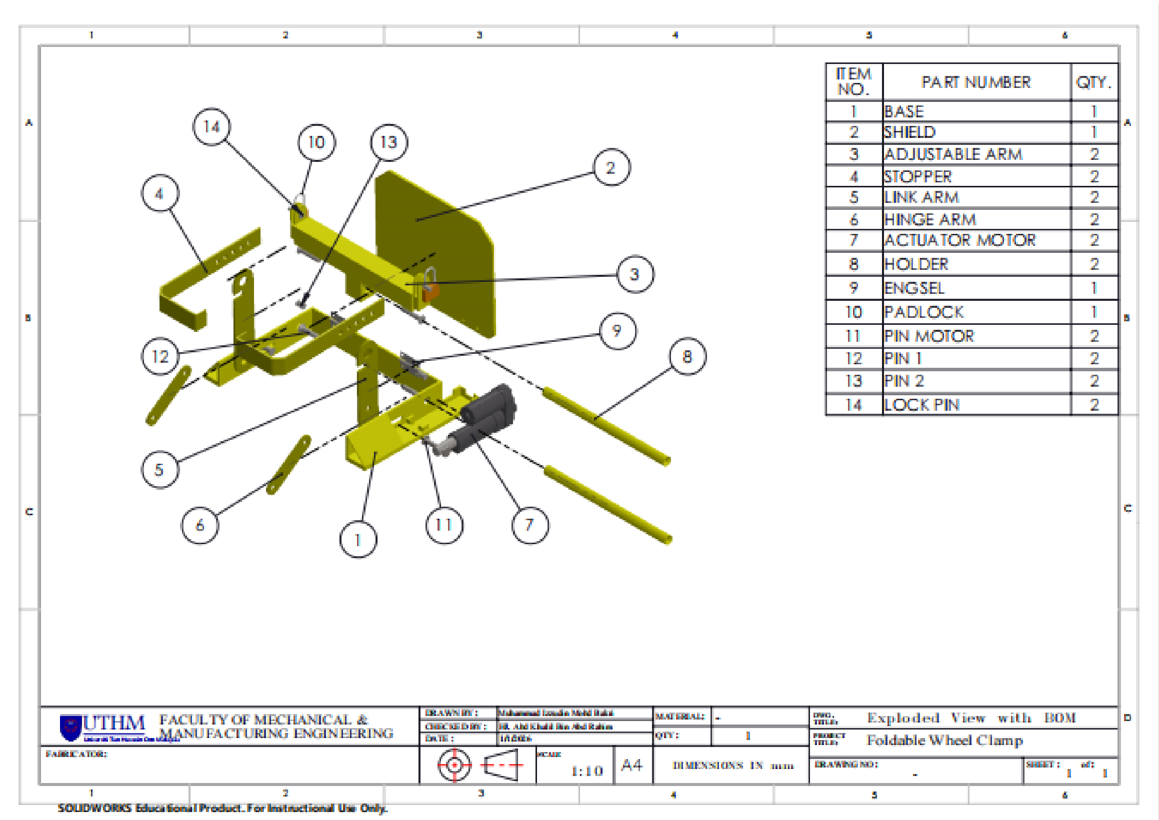
$$Capacity\ (Ah) = \frac{E_{Total}}{V \times 3600}$$
$$Capacity\ (Ah) = \frac{645}{12 \times 3600}$$
$$Capacity\ (Ah) = 0.0015\ \mathrm{Ah}$$

3.4 Engineering Drawing

These technical drawings were created using SolidWorks to fully define the foldable wheel clamp's geometry, dimensions, tolerances, and assembly logic. All components are documented to manufacturer-ready standards, ensuring clarity for fabrication, quality control, and future design iteration. Figure 10 presents the detailed design and assembly configuration of the proposed foldable wheel clamp developed using CAD software. Figure 10a illustrates the orthographic and isometric views, including the top, front, right-side, and isometric perspectives, which provide a comprehensive visualization of the product structure, dimensions, and arrangement of the main components. Meanwhile, Figure 10b shows the exploded view and Bill of Materials (BOM) of the wheel clamp, highlighting the assembly sequence and relationship between components such as the base, adjustable arms, stopper, hinge arm, actuator motor, padlock, and lock pins. The BOM table also lists the part names and quantities required for the complete assembly. Together, these figures support the verification of the design, assembly process, manufacturability, and overall functionality of the foldable wheel clamp system. In addition, the detailed representation of the components helps improve understanding of the product operation and facilitates future fabrication and maintenance processes.



(a)



(b)

Figure 10 *(a) Orthographic and isometric views, (b) Exploded view and Bill of Materials (BOM) of the wheel clamp*

3.5 Product Specification

The finalized product specification was generated after the detailed design and engineering analysis. Table 3 shows the product specification of the Foldable Wheel Clamp.

Table 3 *Product Specification*

Product Specifications	Description
Product Name	Foldable Wheel Clamp
Motor Power	36 W
Maximum Speed	15–20mm/S
Overall Weight	10.8 Kg
Dimension (Unfolded)	410mm X 292mm X 307mm
Dimension (Folded)	410mm X 292mm X 72 Mm

4. Conclusion

The development of the Foldable Wheel Clamp illustrates the principle of compromise in technical design. To achieve a compact and easily storable solution with a folded dimension of only 72mm, a compromise was made on the product's weight 10.8 kg. Further weight reduction was constrained by the necessity for sufficient structural strength. Therefore, this design prioritizes solving the initial problem in reducing bulk and saving storage space by accepting this trade-off in weight. The result is a functional, robust, and significantly more practical product than conventional clamps, demonstrating that optimal design is often the result of a deliberate balance between competing parameters.

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Conflict of Interest

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

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Muhammad Izzudin, Abd Khalil;* ***data collection:*** *Muhammad Izzudin;* ***analysis and interpretation of results:*** *Muhammad Izzudin;* ***draft manuscript preparation*** *Muhammad Izzudin. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] The Star Online. (2025, January 13). *Beefing up enforcement at hotspots*. The Star. https://www.thestar.com.my/metro/metro-news/2025/01/14/beefing-up-enforcement-at-hotspots?utm_source

[2] Mienie, G. (2017, March 1). *Thieves are abusing technology with signal jamming · GeorgeMienie*. GeorgeMienie. https://www.georgemienie.co.za/thieves-abuse-technology-signal-jamming/

[3] Paudel, M., Yap, F. F., & Bastola, A. K. (2020). Safety assessment of personal mobility devices with different wheel size based on their dynamic stability performance. *International Journal of Sustainable Design*, *3*(4), 227. https://doi.org/10.1504/ijsdes.2020.112094

[4] *US5927108A - Wheel lock - Google Patents*. (1998, May 18). Google.com. https://patents.google.com/patent/US5927108

[5] Asus, Z., Ab Rahman, M. A., & Che Daud, Z. H. (2021). *Portable and compact tire-clamping mechanism for medium sized tire*. Journal of Transport System Engineering, 8(1), 36–40. https://www.jtse.utm.my/index.php/jtse/article/view/97