RESEARCH PROGRESS IN MECHANICAL AND MANUFACTURING ENGINEERING
e-ISSN: 2773-4765

RPMME

Vol. 7 No. 1 (2026) 308-319
https://publisher.uthm.edu.my/periodicals/index.php/rpmme

Design of a Palm Fruit Lifting Device for Truck

Wan Sayyidil Athir Wan Mohd Zulkifli[1], Mohd Azwir Azlan[1]*, Shahrin Hisham Amirnordin[1], Ahmad Fu'ad Idris[1]

[1] *Faculty of Mechanical and Manufacturing Engineering*
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400, MALAYSIA

*Corresponding Author: azwir@uthm.edu.my
DOI: https://doi.org/10.30880/rpmme.2026.07.01.033

Article Info

Received: 10 Dec 2025
Accepted: 9 Mar 2026
Available online: 28 February 2026

Keywords

Palm oil industry, palm fruit lifting, SolidWorks, Lifting Device

Abstract

The manual evacuation of Fresh Fruit Bunches (FFB) in Malaysian palm oil plantations is a labour-intensive process associated with a high prevalence of musculoskeletal disorders (MSDs) among harvesters. While large-scale mechanization exists, there is a critical lack of affordable, portable lifting solutions for smallholders. This project presents the design and simulation of a compact Palm Fruit Lifting Device that eliminates the physical strain of manual loading. Utilizing SolidWorks for 3D modelling and motion analysis, the mechanism was optimized to achieve a maximum lifting capacity of 120 kg and a lift height of 0.5 m. Simulation results validate a lifting speed of 0.78 m/s, ensuring efficient operation without compromising stability. The design incorporates anti-corrosion materials and standardized components to maximize durability in harsh plantation environments. This mechanical solution offers a cost-effective alternative to manual handling, significantly enhancing harvesting productivity while mitigating occupational health risks.

1. Introduction

The palm oil industry remains a cornerstone of Malaysia's economy, playing a pivotal role in global agricultural exports. As of 2024, the sector contributed significantly to national revenue, with export earnings from palm oil and palm-based products remaining a key economic driver [1]. To sustain this growth, agencies such as the Malaysian Palm Oil Board (MPOB) actively promote technological advancements to enhance productivity. However, despite these economic successes, the industry faces critical operational challenges, particularly in the evacuation of Fresh Fruit Bunches (FFB). The process of transferring harvested FFB, which can weigh between 20 to 30 kg each, from the ground to collection trucks is traditionally performed manually. This labour-intensive practice involves repetitive bending, lifting, and throwing, posing severe health risks to workers.

Recent occupational health studies have highlighted an alarming prevalence of work-related musculoskeletal disorders (WMSDs) among oil palm harvesters. A 2025 systematic review indicated that over 88% of harvesters reported pain in the lower back, shoulders, and neck due to awkward postures and heavy manual handling [2]. Furthermore, prolonged exposure to these ergonomic hazards has been linked to chronic spinal injuries and significant productivity losses, as workers experiencing physical fatigue show a reduction in daily harvest output [3]. Consequently, there is an urgent industry-wide push to transition from manual labour to mechanized solutions to safeguard worker well-being and maintain operational efficiency.

To address these issues, various mechanical lifting technologies have been introduced. The market currently offers heavy-duty solutions such as hydraulic high-lift trailers and mobile conveyors, which are capable of handling multi-ton loads. Research by Thaddeus et al. (2023) emphasizes that implementing such "in-field" mechanization can increase FFB collection speed by over 27% compared to manual methods [4]. Additionally, compact transporters, such as the mechanical "tipping device" evaluated by MPOB in 2024, have demonstrated the ability to reduce unloading time by 35% [5]. Table 1 summarises the products currently available in the marketplace.

Table 1 *Available Product in the Market*

Specification	HIAB Jet Grabber - JG7000	Hydraulic Bin	Presco Mobile Conveyor	Palm Oil Dumpster
Figure				
Manufacturer	Multico (M) Sdn. Bhd.	Malaysian Palm Oil Board - MPOB	Presco	Not Specified
Machine Type	Hydraulic Arm	Hydraulic Bin	Conveyor	Lift Chain
Power Source	Engine Motor	Battery	Motor	Motor
Lifting Speed	2.6 m / 300 kg 3.5 m / 210 kg	400 kg/38 sec	12-16 ton/hour	Not Specified
Weight	280 Kg	400 kg	500 kg	Not Specified

However, a gap remains for small-scale independent smallholders who cannot afford high-capital machinery like hydraulic cranes or large tractors. Most existing commercial solutions are designed for large estates, leaving a lack of portable, affordable, and user-friendly lifting aids for smaller operations.

Therefore, this project, in collaboration with HS Agrojaya Empire, aims to bridge this gap by designing a compact "Palm Fruit Lifting Device." Unlike heavy hydraulic arms, this device is engineered for portability and affordability, featuring a 120 kg lifting capacity and a simplified manual-assist mechanism. The objective is to provide an ergonomic solution that eliminates the need for manual lifting, thereby reducing the risk of musculoskeletal injuries while enhancing harvesting efficiency for small- to medium-sized palm oil producers [6].

2. Methodology

This process, which involves steps such as conceptual, embodiment, and detail design, enables engineers to effectively identify solutions to various problems. Notable figures like Pahl and Beitz, George E. Dieter, and Rudolph J. Eggert have proposed several design process methods. For this project, we are utilising the engineering design process outlined by George E. Dieter. This process primarily comprises three design phases: conceptual, embodiment, and detail design.

The first phase, conceptual design, has four stages: defining the problem, gathering information, generating concepts, and evaluating those concepts. The second phase, embodiment design, includes three stages: establishing product architecture, configuration, and parametric design. Finally, the third phase, detail design, consists of a single stage. Figure 1 illustrates the design process flowchart introduced by George E. Dieter.

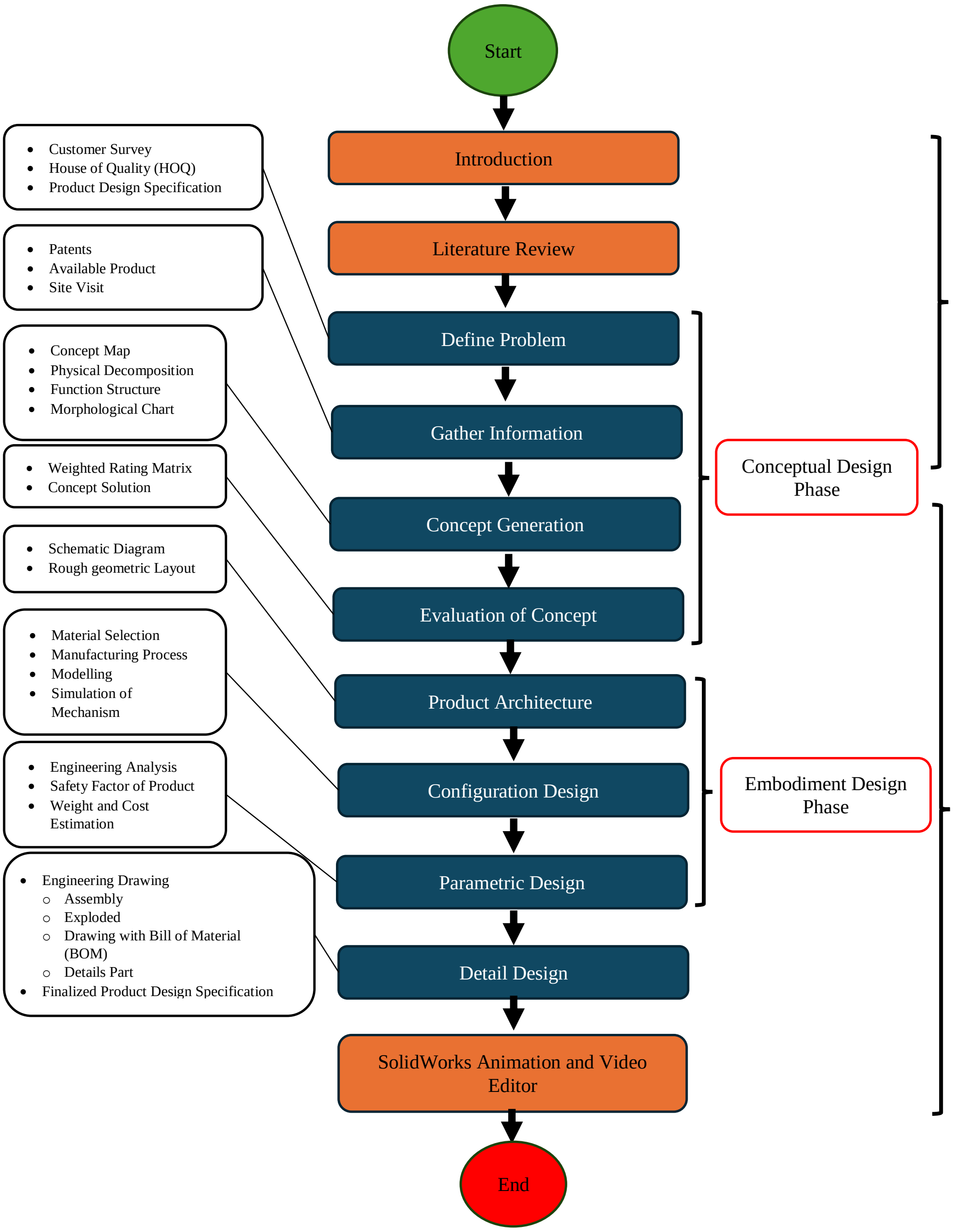


Fig. 1 *Flowchart of the design process*

3. Design Process

The design process is intended to guide students through a systematic sequence of activities aimed at solving a real-life problem with an effective design solution. To assess and understand the customer's need for a lifting machine for heavy palm fruit, a Google Forms online survey was conducted titled "Survey of the Product Design Specification for Palm Fruit Lifting Machine in Palm Oil Plantation". The survey collects valuable input from respondents. An objective tree is employed to analyse the survey results, and relative weighting is utilized to identify the Product Design Specifications (PDS).

The objective tree serves as a clear and straightforward tool for illustrating the requirements that need to be addressed during the design phase of the product. Finalizing the objective tree before proceeding with the design process minimizes the potential for misunderstandings between the customer and the designer. Figure 2 presents the objective tree diagram for a palm fruit lifting device, while Table 2 outlines the product design specifications.

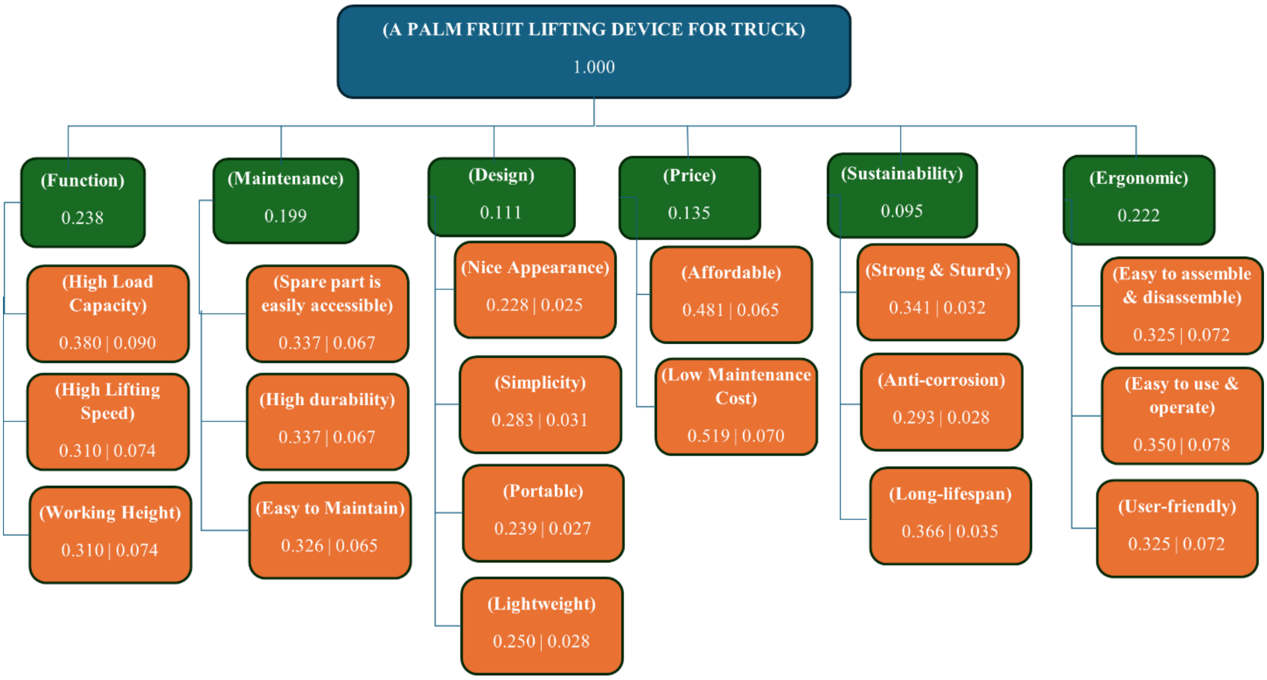


Fig. 2 *Objective Tree of Palm Fruit Lifting Device*

Table 2 *Product Design Specification*

Introduction	
Title	Design of a Palm Fruit Lifting Device for Truck
Design Problem	To transport palm fruit from the ground into the truck in the palm oil plantation industry
Intended Purpose	To enhance the safety and efficiency of transferring palm oil fruit from the ground into the truck
Target Customer	Palm oil plantation company
Special Feature	• Able to control the speed of the machine • Able to monitor the load of the truck using a video cam • Able to adjust the height of the machine from the ground
Customer Requirement	
Functional Performance	• The load capacity of a machine above 100kg • The lifting speed of the machine above 1 m/s • Easy to maintain • The lifting height of the product is above 2m
Design	• The design should be straightforward and appealing, with an even finish that reflects the current market trend • The weight of the machine below 100kg
Price	• The selling price of machines is below RM5500 • Low maintenance cost
Sustainable	• Strong and sturdy • Anti-corrosion • Longer lifespan with more than 10 years
Operating Environment	• Suitable for any type of road surface in the palm oil field
Maintenance, Repair, Retirement	• The machine should have low maintenance and repair needed during economic life • Spare parts are easily accessible
Safety	• The machine is stable and without any failure occur during economic life
Ergonomics	• Easy to assemble and disassemble • Easy to use • User-friendly

3.1 Concept Generation

In this stage, we explored several methods, including morphological charts, physical decomposition, functional decomposition, and brainstorming. The objective was to generate product concepts that can effectively meet the necessary functions. Figure 3 showcases the functional design of the Palm Fruit Lifting Device.

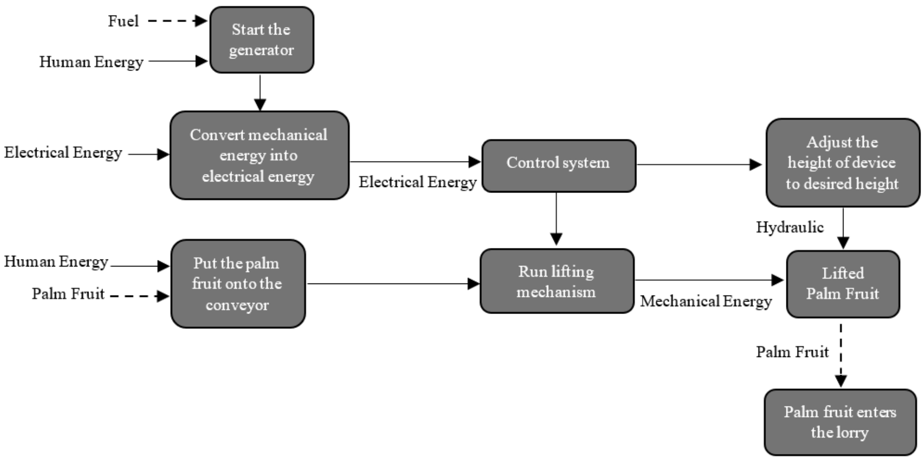


Fig. 3 *Function Structure*

Integrating a weighting factor derived from the objective tree survey with the design requirements, a weighted decision matrix was employed to assess and analyse the concepts among the three alternatives based on the morphological chart. This methodology allows for identifying the most suitable concepts that meet customer requirements. After evaluation, the concept combination that achieves the highest rating will be selected to advance to the next phase. The chosen concept combination is presented in Table 3.

Table 3 *Product Concept Combinations*

No.	Function	Selection Concept
1	Power Source	Generator
2	Lifting Mechanism	Sprocket and Chain
3	Height Adjustment	Hydraulic Cylinder

3.2 Product Architecture

Product architecture plays a crucial role in product development, as it outlines the physical structure and components necessary for the product to fulfil its intended function. This architecture is based on the function structure, which is an integral part of the concept generation process. The primary objective of product architecture is to organize the functional elements into clusters that will form the product's modules. A schematic diagram, such as the one illustrated in Figure 4, is utilized to depict the arrangement and interaction of the physical elements within the product architecture.

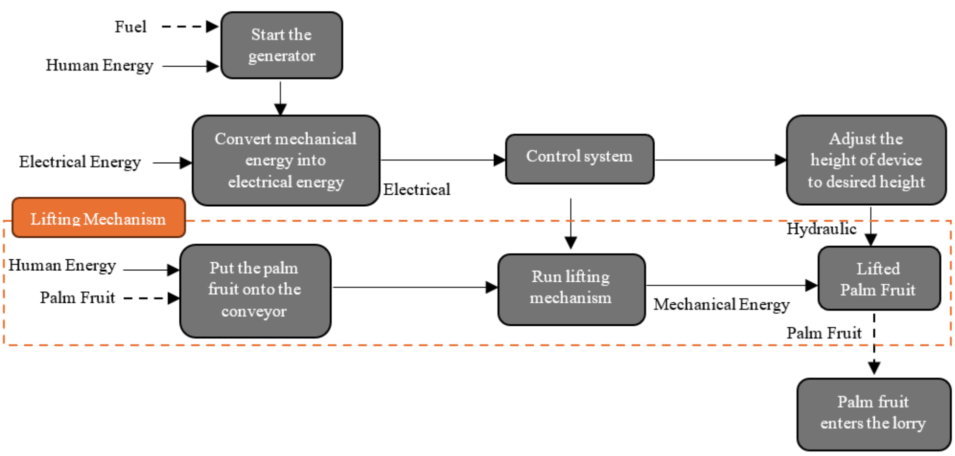


Fig. 4 *Schematic Diagram with Clustered Elements*

3.3 Modelling

The 3D models of this machine were developed using SolidWorks, a sophisticated computer-aided design tool. These models were derived from the concepts selected in the prior stage of the project. The individual components were then integrated to create the final product: a Palm Fruit Lifting Device. Figure 5 illustrates the complete assembly of the device.

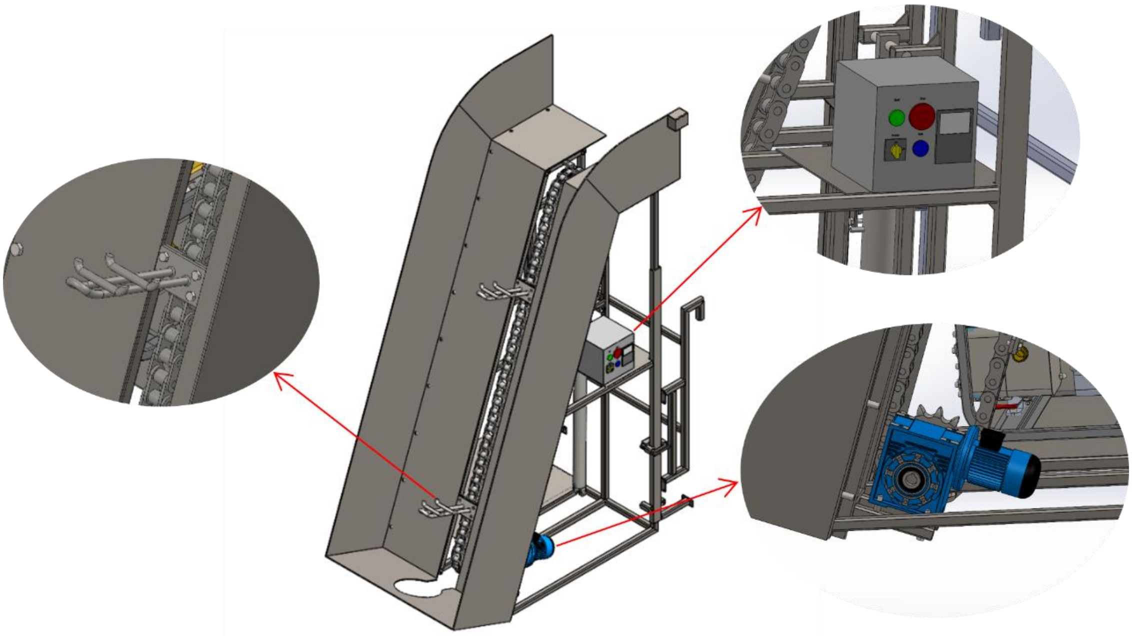


Fig. 5 *Full Assembly of Palm Fruit Lifting Device*

3.4 Power Source

At the bottom right of the conveyor frame is the power source for the system, consisting of a motor and gear assembly that drive the sprocket and chain. The motor powers the sprocket's rotation by turning a connected shaft, which then drives the chain movement. This generates the necessary force to rotate the palm fruit holder along its path. Bearings support the shaft to ensure proper alignment and prevent sagging. Figure 6 shows the sprocket and chain movement operated by the motor.

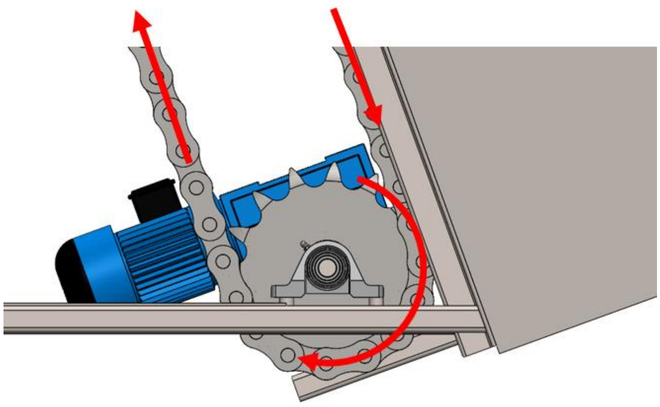


Fig. 5 *Power transmission system of Palm Fruit Lifting Device*

3.5 Lifting Mechanism

The lifting mechanism in this system utilizes a sprocket and chain arrangement designed to elevate materials, such as palm fruit, from a lower level to a higher one. By leveraging gravitational and frictional forces on the palm fruit holder, the palm fruit is placed on an inclined holder that moves upwards, driven by the chains and sprocket mechanism. Figure 6 illustrates the movement and operation of the device for elevating the palm fruit.

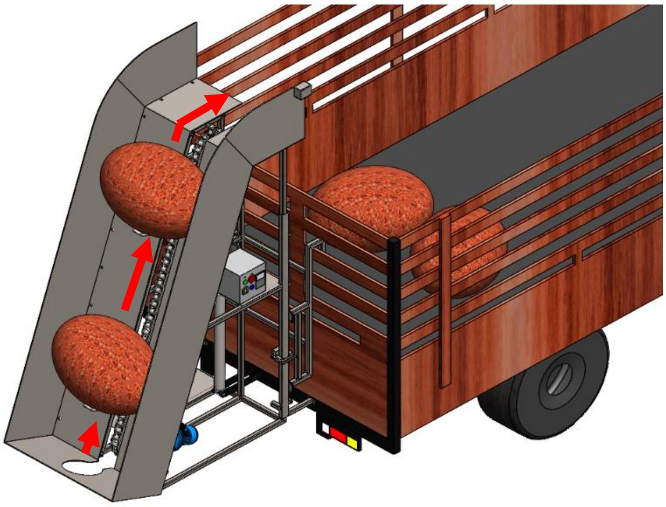
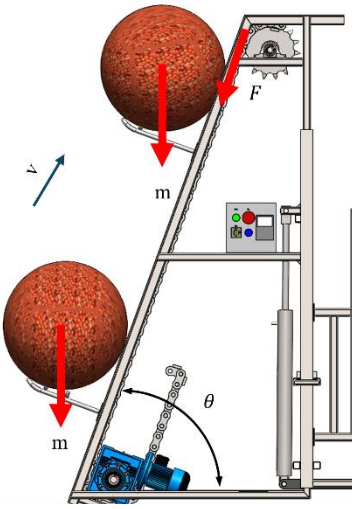


Fig. 6 *Power transmission system of Palm Fruit Lifting Device*

3.6 Motor and Bearing Selection

Selecting the right motor for a machine requires careful calculations to ensure maximum efficiency and minimal energy waste. For the palm fruit lifting device, the motor's kinetic energy powers the sprocket and chain. To begin, the user can determine the motor's required power, which can be calculated using the equation in the next page:



$$P_{req} = Fv = [(m \times g)\sin\theta](v) = [(120 \times 9.81)\sin 70](1) = 1106.20 \ W$$

Power that required to be supplied by the motor:

$$P_{motor} = \frac{P_{req}}{\eta_{m(assumed)}} = \frac{1106.20}{0.75} = 1474.94\ W = 1.474\ kW$$

Based on calculations, the power that required to be supplied is 1.4724 kW. By using these calculations, the suitable gearmotor has been chosen as shown in the figure below:

Ratings -- Motorised unit							Input speed at 1440 rpm - or Reducer			
Motor kW n1 r/min	Motor Frame	Wormgeared Motor Size	Ratio *i*	n2 r/min	T2 Nm	fs	Wormgear Reducer Size	Rated kW 1	T2 Nm	Eff η
1.5kW 1400rpm	90B5	NMRV 075	7.5	187	68.2	2.7	NRV 075	4.06	184.5	0.89
	90B5	NMRV 075	10	140	92.1	2.2	NRV 075	3.25	199.5	0.90
	90B5	NMRV 063	15	94	126.5	1.1	NRV 063	1.65	139.1	0.83
	90B5	NMRV 075	20	70	173.9	1.3	NRV 075	1.88	218.0	0.85
	90B5	NMRV 075	25	56	212.3	1.0	NRV 075	1.47	208.1	0.83
	90B5	NMRV 090	25	56	209.8	1.6	NRV 090	2.43	339.8	0.82
	90B5	NMRV 075	30	47	243.8	1.0	NRV 075	1.48	240.6	0.80
	90B5	NMRV 090	30	47	237.7	1.7	NRV 090	2.57	407.3	0.78
	90B5	NMRV 090	40	35	307.0	1.2	NRV 090	1.76	360.2	0.75
	90B5	NMRV 090	50	28	368.4	0.9	NRV 090	1.38	338.9	0.72
	90B5	NMRV 110	50	28	383.7	1.6	NRV 110	2.35	601.1	0.75
	90B5	NMRV 110	60	24	429.8	1.3	NRV 110	1.9	544.4	0.72
	90B5	NMRV 110	80	18	533.2	0.9	NRV 110	1.34	476.3	0.67
	90B5	NMRV 130	80	18	541.2	1.5	NRV 130	2.26	815.4	0.68
	90B5	NMRV 130	100	14	654.9	1.1	NRV 130	1.7	742.2	0.64

To ensure the motor can lift the palm fruit, we need to verify the gear ratio, check if the chosen gearmotor provides enough torque for the sprocket and chains, and calculate the sprocket's rotational speed. This evaluation will confirm if all components operate efficiently. The required torque is represented in the equation below:

$$T_{req} = F \times r = [(m \times g) \sin \theta] \times r = [(120 \times 9.81) \sin 70] \times 0.1069 = 118.25\ Nm$$

According to the calculation results, the torque provided by the gearmotor sufficient to rotate the sprocket and chain. Next, to determine the rotational speed that required by the gearmotor to achieve 1 m/s, the rotational speed can be calculated by using the equation below:

$$V_{motor} = \frac{2\pi N}{60} \times r = \frac{2\pi(70)}{60} \times 0.1069 = 0.78\ m/s$$

Based on the calculation, the selected gearmotor proven are not able to provide desired speed for sprocket and chain but it is acceptable speed based on the customer satisfaction level. For bearing selection, the equation below is used to select the suitable bearing:

$$F_m = 177.29\ kg = (177.29 \times 9.81) \sin 70 = 1634.3\ N$$

$$L_D = 5\ hours\ \times 300\ days \times 5\ years = 7500\ hours$$

$$x_D = \frac{60(7500)(90)}{10^6} = 40.5$$

Figure 7 below shows possible force that acting on shaft during the lifting process.

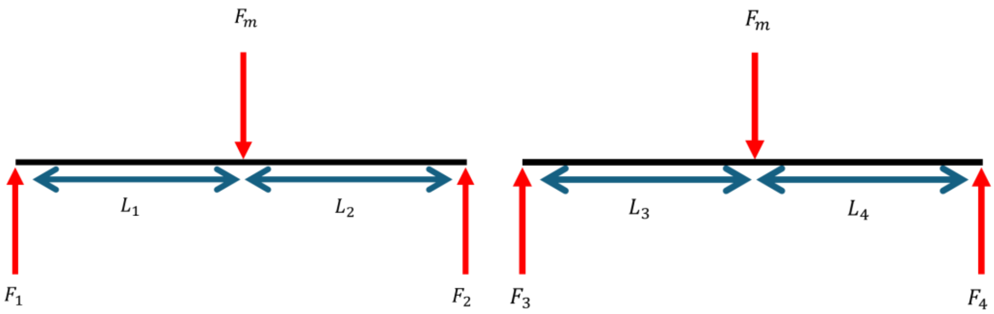


Fig. 7 *Force acting on both shaft*

Based on the static equilibrium of force and moment;

$F_m(L_1) - F_2(L_1 + L_2) = 0$

$1634.3(0.07) - F_2(0.070 + 0.084) = 0$

$114.4 - F_2(0.154) = 0$

$F_2(0.154) = 114.4$

$F_2 = 742.88\ N$

$F_m(L_3) - F_4(L_3 + L_4) = 0$

$1634.3(0.0715) - F_4(0.0715 + 0.0845) = 0$

$116.9 - F_4(0.156) = 0$

$F_4(0.156) = 116.9$

$F_4 = 749.36\ N$

$F_m = F_1 + F_2$

$1634.3 = F_1 + 742.88$

$F_1 = 1634.3 - 742.88$

$F_1 = 891.42\ N$

$F_m = F_3 + F_4$

$1634.3 = F_3 + 749.36$

$F_3 = 1634.3 - 749.36$

$F_3 = 884.94\ N$

To calculate dynamic load rating for bearing, the equation below is used:

$$C_{10} = a_f F_D \left(\frac{x_D}{x_o + (\theta - x_o)\left(\ln\left(\frac{1}{R_D}\right)\right)^{\frac{1}{b}}} \right)^{\frac{1}{a}}$$

For Bearing 1: C_{10} $= (1.5)(0.89142)\left(\frac{40.5}{0.02 + (4.459 - 0.02)(ln}\right.$ $C_{10} = 7.61$ kN	For Bearing 2: C_{10} $= (1.5)(0.74288)\left(\frac{40.5}{0.02 + (4.459 - 0.02)(ln}\right.$ $C_{10} = 6.34$ kN
For Bearing 3: C_{10} $= (1.5)(0.88494)\left(\frac{40.5}{0.02 + (4.459 - 0.02)(ln}\right.$ $C_{10} = 7.56$ kN	For Bearing 4: C_{10} $= (1.5)(0.74936)\left(\frac{40.5}{0.02 + (4.459 - 0.02)(ln}\right.$ $C_{10} = 6.40$ kN

Based on the calculations, the dynamic load rating for Bearing 1 is 7.61 kN, while the dynamic load rating for Bearing 2 is 6.34 kN, the dynamic load rating for Bearing 3 is 7.56 kN and the dynamic load rating for Bearing 4 is 6.40 kN. According to the calculation result, the SKF P2B 30M-TF ball bearing is the best choice for bearing 1, bearing 3 and bearing 4 as shown in Figure 8 while the SKF P2B 20M-TF ball bearing is the most suitable option for bearing 2 as shown in Figure 9.

Research Progress in Mechanical and Manufacturing Engineering Vol. 7 No. 1 (2026) p. 308-319

Designation	Dimensions						Basic load ratings		Limiting speed
							dynamic	static	
	d [mm]	A [mm]	H [mm]	H_2 [mm]	J [mm]	L [mm]	C [kN]	C_0 [kN]	[r/min]
P2B 215-WF	74.613	73	82.55	168.28	216.69	274.64	66.3	49	2 600
P2B 25M-FM	25	38.1	36.51	70.64	104.78	139.7	14	7.8	7 000
P2B 30M-TF	30	44.6	42.86	83.34	120.65	165.1	19.5	11.2	6 300
P2B 35M-FM	35	45.8	47.63	93.66	127	166.69	25.5	15.3	5 300
P2B 35M-TF	35	45.8	47.63	93.66	127	166.69	25.5	15.3	5 300
P2B 40M-FM	40	48.8	54	104	137.32	184.15	30.7	19	4 800

Fig 8 *SKF Ball Bearing Catalogue*

Designation	Dimensions						Basic load ratings		Limiting speed
							dynamic	static	
	d [mm]	A [mm]	H [mm]	H_2 [mm]	J [mm]	L [mm]	C [kN]	C_0 [kN]	[r/min]
P2B 20M-TF	20	34	33.34	64.29	95.25	127	12.7	6.55	8 500
P2BC 20M-CPSS-DFH	20	36	33.3	64.6	95	129	10.8	6.55	700
P2BC 20M-TPSS	20	36	33.3	64.6	95	129	10.8	6.55	5 000
P2BC 20M-TPZM	20	36	33.3	64.6	95	129	12.7	6.55	5 000
P2BSS 20M-CPSS-DFH	20	29	33.3	63.5	96.8	127	10.8	6.55	700
P2BSS 20M-TPSS	20	29	33.3	63.5	96.8	127	10.8	6.55	5 000

Fig 9 *SKF Ball Bearing Catalogue*

3.7 Simulation Analysis

Two analyses were conducted on the Palm Fruit Lifting Device, explicitly focusing on the chain assembly, conveyor frame, conveyor supporter, and conveyor path. These analyses included a Von Mises stress analysis and a safety assessment factor. The maximum stress recorded for the chains was 262.90 MPa, followed closely by the conveyor frame at 263.00 MPa, the conveyor supporter at 332.21 MPa, and the conveyor path at 49.32 MPa, as illustrated in Figure 10, Figure 11, Figure 12 and Figure 13. On the other hand, the minimum safety factor was 1.3 for the chains and the conveyor frame, 1.05 for the conveyor supporter, and 7.1 for the conveyor path, all exceeding the recommended threshold of 1. Therefore, the machine is deemed safe, as shown in Figure 10, Figure 11, Figure 12 and Figure 13.

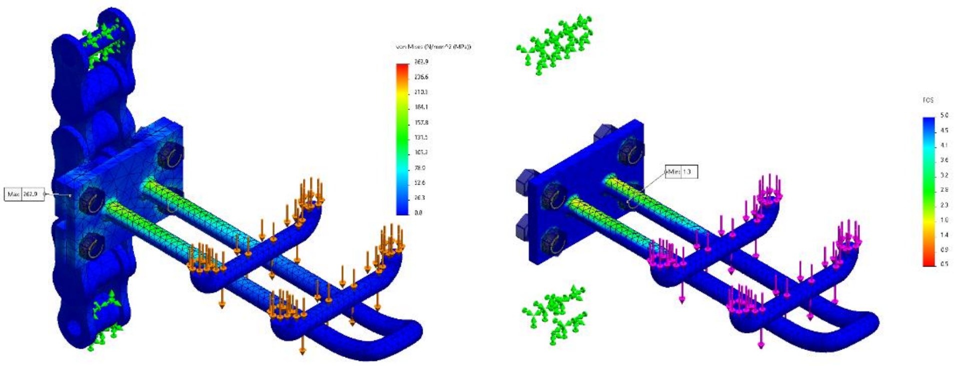


Fig 10 *Von Mises Stress analysis and Factor of safety of chains*

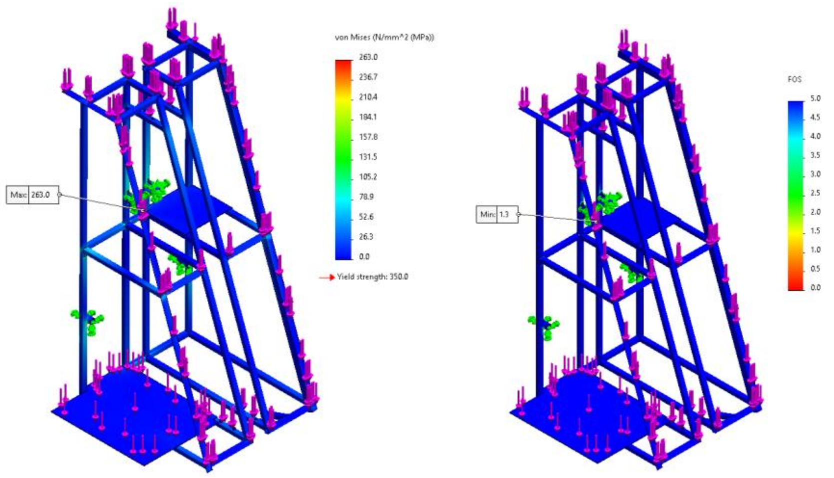


Fig 11 *Von Mises Stress analysis and Factor of safety of conveyor frame*

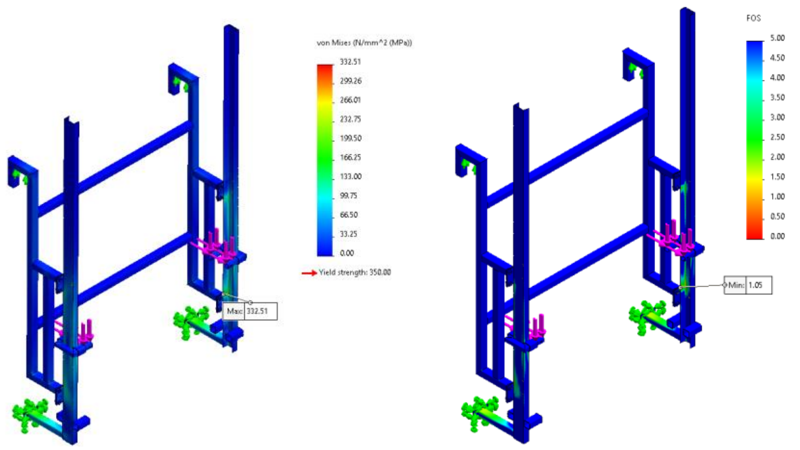


Fig 12 *Von Mises Stress analysis and Factor of safety of conveyor supporter*

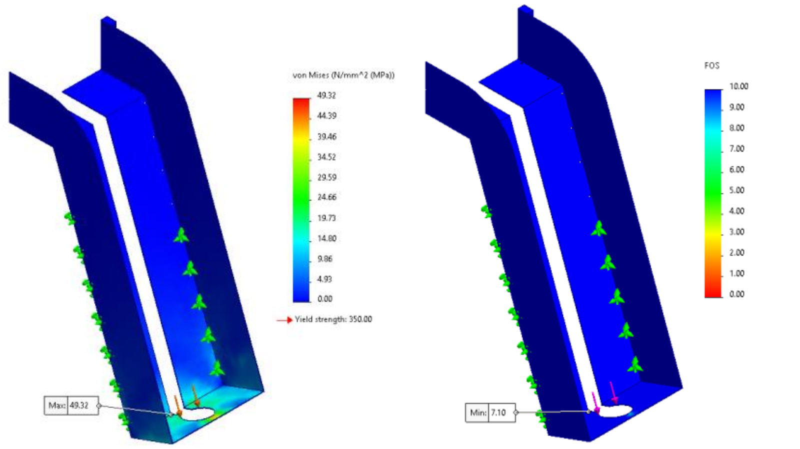


Fig 13 *Von Mises Stress analysis and Factor of safety of conveyor path*

3.8 Product Specification

Product specifications serve as a guide, outlining the specific requirements and details necessary for a product's development. They ensure that the product meets quality standards and fulfils consumer needs. Table 4 in the next page presents the product specifications for the Palm Fruit Lifting Device.

Table 4 *Product Specifications*

Detail	Product Specifications
Load Capacity	120 kg
Dimension	1649 mm (W) X 2342 mm (H)
Lifting Speed	0.78 m/s
Weight	335.40 kg
Power	1.5 kW
Price	RM 22,977.10

4. Conclusion

In conclusion, this project has successfully developed a mechanical Palm Fruit Lifting Device designed to address the critical ergonomic challenges faced by manual harvesters in the Malaysian palm oil industry. By eliminating the need for strenuous manual lifting, the device significantly reduces the risk of musculoskeletal disorders while enhancing operational efficiency during the evacuation of fresh fruit bunches (FFBs). The design process, validated through SolidWorks simulation and kinematic analysis, resulted in a robust mechanism capable of lifting a maximum payload of 120 kg at a controlled speed of 0.78 m/s. Furthermore, the integration of anti-corrosion materials ensures durability and reliability within the harsh environmental conditions of oil palm plantations. Ultimately, this compact and cost-effective solution bridges the gap between manual labour and high-capital machinery, offering a practical alternative for smallholders to improve productivity and safety standards

Acknowledgement

The authors wish to thank the Faculty of Mechanical Engineering, Universiti Tun Hussein Onn Malaysia, who has supported the accomplishment of the research activity.

Conflict of Interest

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

References

[1] Malaysian Palm Oil Board (MPOB), Overview of the Malaysian Oil Palm Industry 2024. Kuala Lumpur: MPOB, 2025.

[2] U. M. Noor and M. I. Z. Ridzwan, "Prevalence of work-related musculoskeletal disorders (WMSDs) and recent initiatives to address them in the oil palm industry: A systematic review," Journal of Oil Palm Research, vol. 37, no. 4, pp. 581–597, 2025.

[3] J. H. Z. Zulkifli et al., "Physiological limits and fatigue analysis of manual fresh fruit bunch loading," International Journal of Industrial Ergonomics, vol. 94, p. 103415, 2023.

[4] D. J. Thaddeus et al., "An overview of the benefits and advantages of implementing mechanisation in the oil palm plantation: A look at fresh fruit bunch (FFB) evacuation," Advances in Agricultural and Food Research Journal, vol. 4, no. 2, p. a0000411, 2023.

[5] M. R. M. Khalid et al., "Performance evaluation of a tipping device for fresh fruit bunch (FFB) loading," Journal of Oil Palm Research, vol. 36, no. 1, pp. 140–145, 2024.

[6] M. S. M. Solahder, "Design and simulation of a compact FFB lifter using finite element analysis," Journal of Mechanical Engineering and Sciences, vol. 17, no. 1, pp. 6401–6412, 2023.