Design And Development of Lifting Machine

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Abstract-This research focuses on the design and development of a lifting machine that operates using a lead screw mechanism. The primary objective is to lift a 100 kg load — specifically a power panel — from a lower position onto a conveyor belt at a height of 4 to 5 feet, commonly used in automated systems. The lifting system incorporates a lead screw-driven mechanism supported by a ball table to facilitate the horizontal sliding of the power panel. The methodology includes conceptual design, part selection based on manufacturing standards, and structural analysis through simulation.

A static structural simulation was performed to evaluate the system under varying loads (50 kg, 100 kg, and 150 kg). The results showed maximum von Mises stresses of 53.06 MPa, 128.9 MPa, and 156.1 MPa, respectively. Corresponding displacements were 0.2070 mm, 0.4243 mm, and 0.6420 mm. The factor of safety (FOS) based on von Mises stress was found to be 4.7 at 50 kg, 1.9 at 100 kg, and 1.6 at 150 kg. These results validate the structural stability and load-handling capacity of the design under the intended working conditions.

Key words-Lifting Machine, Lead Screw, Automation, Von Mises Stress, Structural Analysis, Load Handling, **FEA**.

1. INTRODUCTION:

Lifting machines are essential tools in a wide range of industries, from manufacturing and construction to warehousing and logistics. These machines are designed to simplify the process of elevating heavy loads, reducing the physical strain on workers and enhancing overall operational efficiency. By mechanising the lifting process, such machines not only increase productivity but also ensure the safety of operators by minimizing the risk of injury associated with manual handling.

One of the most reliable mechanisms for controlled lifting is the lead screw mechanism. The principle of a lead screw system lies in its ability to convert rotational motion into linear motion. When a rotational force is applied to the screw, it drives the nut along the axis of the screw, creating a smooth and precise lifting or lowering motion. This mechanism is highly valued for its simplicity, precision, and ability to generate significant mechanical advantage, making it ideal for applications where fine control over the lifting process is required. The lead screw's self-locking feature also ensures that loads remain securely in place even when the drive system is not actively engaged, enhancing safety during operation.

The lead screw-based lifting machine offers several advantages. Its mechanical efficiency ensures that heavy loads can be lifted with minimal effort, while its ability to provide accurate and stable movement makes it suitable for applications that demand precision. The inherent simplicity of the design reduces the need for complex components, leading to lower maintenance costs and improved reliability. Additionally, the lead screw's robustness ensures a long operational life, even under heavy-duty conditions.

However, despite the well-known benefits of lead screw mechanisms, certain research gaps remain. Existing studies have primarily focused on manual or semi-automated systems, with limited exploration into their application in fully automated vertical lifting machines (Singh & Sharma, 2022) [1]. Furthermore, although some motorized lifting designs have been proposed, they often lack critical safety features and ergonomic considerations (Naik et al., 2015) [2]. There is also a scarcity of compact, cost-effective lifting systems tailored for small to medium-scale automation environments (Jadhav & Thakare, 2022) [3]. In addition, material selection and optimization of the load-bearing capacity remain underexplored, especially under varying load conditions (Pandey & Kulkarni, 2020) [4].

This research addresses these gaps by designing a lead screw-nut based lifting machine for use in automated systems, particularly for lifting loads vertically from a lower to a higher position. The proposed system emphasizes precision, safety, and affordability, making it ideal for industrial automation where reliability and compactness are crucial.

To validate the performance of the design, a finite element analysis (FEA) simulation was carried out.

The results demonstrated the structural integrity of the machine under different load conditions:

- At 50 kg load, the maximum von Mises stress was 53.06 MPa, with a displacement of 0.2070 mm and a factor of safety (FOS) of 4.7.
- At 100 kg, the stress increased to 128.91 MPa, displacement was 0.4243 mm, and FOS dropped to 1.9.
- At the maximum tested load of 150 kg, stress reached 156.1 MPa, with a displacement of 0.6420 mm, and a FOS of 1.6.

These results confirm that the design remains within acceptable stress limits and safety margins under typical operational loads, while also highlighting the limits for safe usage. The study thus contributes a viable, durable, and efficient solution for vertical load handling in automated systems.

2. METHODOLOGY

1.1. Conceptual Design Using 3d Cad Modelling.

The conceptual design phase was conducted using Computer-Aided Design (CAD) software to explore and visualize potential solutions prior to detailed development. Three different design concepts were created and evaluated to determine the most effective configuration in terms of safety, functionality, and structural performance. These designs are presented in Figures 1 through 3.

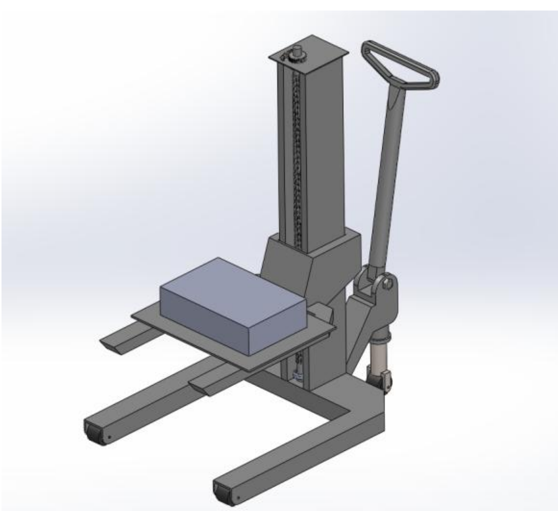


Figure 1: Concept Design One

Concept 1 (Figure 1): This initial design lacked a properly selected linear rail system for the sliding mechanism. The absence of an appropriate linear guide posed a significant safety concern, as the mechanism would not operate reliably under load. This limitation made the design unsuitable for further consideration.

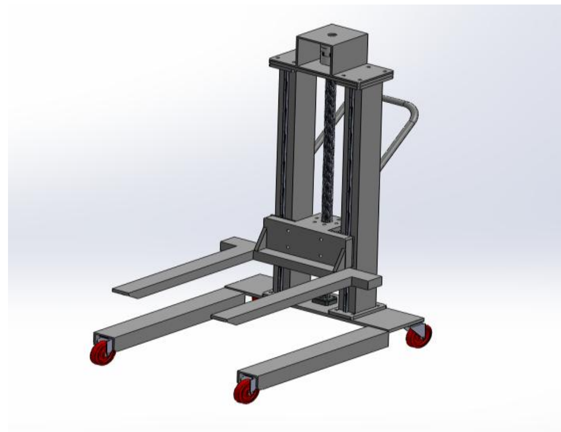


Figure 2: Concept Design Two

Concept 2 (Figure 2): In this iteration, a linear rail was included to improve the sliding function. However, the placement of the gearbox and motor at the top of the structure resulted in an uneven weight distribution. This configuration risked instability and potential imbalance during operation, especially under dynamic conditions.

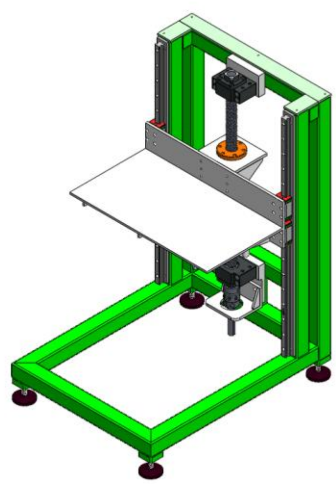


Figure 3: Concept Design Three

Concept 3 (Figure 3): The final concept addressed the shortcomings of the previous designs. The gearbox and motor were repositioned to a lower part of the structure, thereby lowering the center of gravity and enhancing stability. Additionally, a limiting switch was integrated into the design to improve operational safety by preventing over-travel or mechanical.

1.1. MATERIAL SELECTION

Component	Material	Standard/Spec
Frame Structure	Mild Steel Square Tube	IS 2062 Grade A
Base Plate & Mounts	Mild Steel Flat Plate	IS 2062, 6–10 mm thick
Moving Platform (Table)	Mild Steel Sheet	IS 2062, ~5 mm thick
Guide Support Plates	Mild Steel Plate	IS 2062
Brackets & Fixtures	Mild Steel	IS 2062
Foot Pads Mounts	Mild Steel Plate + Nut Inserts	IS 2062

1.2STANDARD PART MATERIAL

COMPONENT	MATERIAL
Lead Screw	Carbon Steel (C45/EN8)
Nut	Phosphor Bronze
Bearings (Pillow Block, Linear)	Chrome Steel (SAE 52100)
Motor	Aluminum Housing + Copper Windings
Gearbox	Cast Iron Housing, Alloy Steel Gears
Coupling	Aluminum or Mild Steel
Linear Guides	Hardened Steel Rails
Fasteners	High-Tensile Steel (Grade 8.8)

3 TOOLS AND MATERIALS PREPARATION

A thorough search was conducted to identify and select appropriate tools and materials required for the manufacturing process. Material selection was based on factors such as strength, durability, cost, and compatibility with available machining processes.

1.3 COMPONENT SOURCING AND PART IDENTIFICATION

After determining the necessary components, a sourcing phase was undertaken to procure standard parts and materials. This step also involved identifying any custom parts that needed to be manufactured in-house.

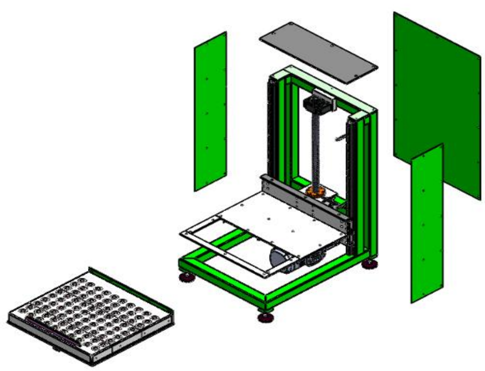
1.4 MACHINING AND FABRICATION PROCESSES

The selected concept was fabricated using suitable machine processes, including cutting, drilling, and shaping. The operations were carefully planned and executed to ensure dimensional accuracy and quality of finish. Safety protocols and proper machining practices were followed throughout.

4.RESULTS AND DISCUSSION

The outcomes of the fabrication process were assessed to determine if the final product matched the intended design. Any deviations or challenges faced during machining were analysed, and possible improvements were noted.

5.FINAL 3D CAD MODELLING



(a)

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	SQ PIPE FRAME BL-01 R2		1
2	RAIL MOUNTING PLATE BL-01 R2	AL PROFILE 45x45; L=830	2
3	SUPPORT UNIT MOUNTING PLATE-2 BL-01 R2		1
4	FOOT MOUNTING BLOCK BL-01 R2		4
5	FRAME TOP PLATE BL-01 R2		1
6	LEAD SCREW BL-01 R2		1
7	GEARBOX MOUNTING BRACKET BL-01 R2		1
8	RAIL HGR25R950C R2		2
9	SUPPORT UNIT BK30 R2		2
10	COUPLING als-055-r-25b-25b R2		1
11	GEARBOX SHAFT BL-01 R2		1
12	GEARBOX W63_U_19_P80 B5B3, 2POLE MOTOR 1HP R2		1
13	LEVELING FOOT M16X120		4
14	BALL TABLE BASE PLATE BL-01 R2		1
15	LMK16LUU R2		2
16	STOPPER PLATE BL-01 R2		1
17	GUIDE ROD BL-01 R2		2
18	TABLE TOP SHEET BL-01 R2		1
19	BALL TABLE SUPPORT PLATE BL-01 R2		2
20	Ball trasfer Unit NEW R2		90
21	REAR SIDE GUARD UHMW PLATE BL-01 R2		1
22	UHMW PLATE BL-01 R2		1
23	LEAD SCREW NUT BL-01 R2		1
24	LIFTER BACK COVER BL-01 R2	Bottom panel; Electrical cabinet	1
25	TOP PLATE BL-01 R2		1
26	BELOW MOUNTING PLATE BL-01 R2		1
27	SPACER FOR BELLOW BL-01 R2		1
28	LEAD SCREW MOUNTING BRACKET BL-01 R2		1
29	SPACER FOR BELLOW-1 BL-01 R2		1
30	STOPPER ROD BL-01 R2		1
31	LIMIT SWITCH MTG PLATE BL-01 R2		2

(b)

Figure 4: (a)Exploded View and (b)Bill of Material (BOM) for lifting equipment.

In the final phase of the methodology, the complete 3D CAD model of the hoisting equipment was developed using SolidWorks. This included all structural members, supports, and joints necessary for realistic simulation. After assembly, the model underwent Finite Element Analysis (FEA) to evaluate its strength and safety under different loading conditions.

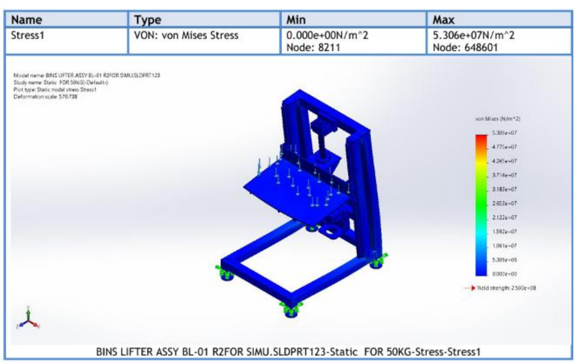
6. SIMULATION SETUP

The simulation was performed under static conditions to replicate the actual working load scenarios. The material assigned was mild steel, with fixed supports applied to the base and load applied at the lifting point. Three different loads were tested: 50 kg, 100 kg, and 150 kg, to assess performance under varying operational conditions.

1.1. VON MISES STRESS ANALYSIS:

Table 1: Comparison Of Maximum Von Mises Stress at Different Load

LOAD (KG)	MAXIMUM VON MISES STRESS (MPA)
50	53.06
100	128.9
150	156.1



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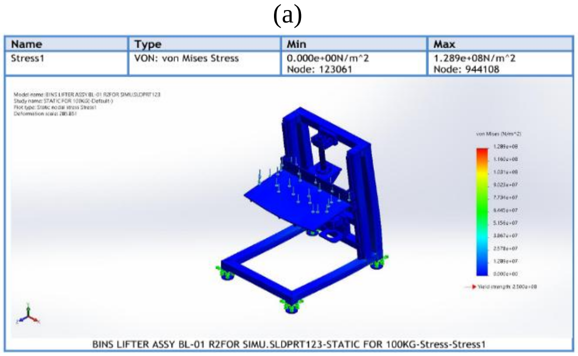

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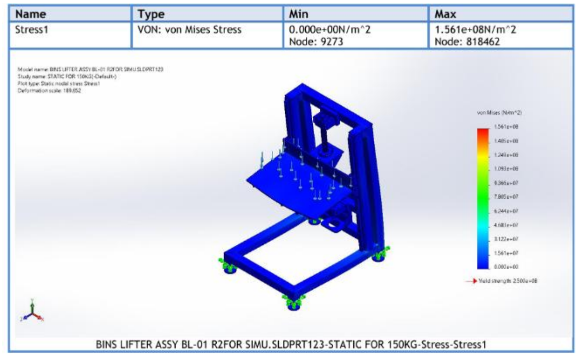


(c)

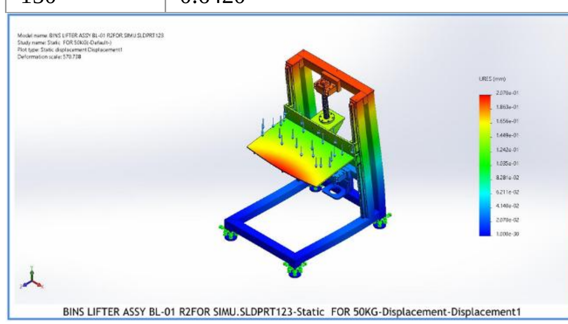
Figure 5: The maximum value of von mises stress for different load:(a) 50kg, (b) 100kg, And (c) 200kg.

At 50 kg, the structure experienced a low stress level of 53.06 MPa, indicating a very safe condition. As the load increased to 100 kg, the stress rose to 128.9 MPa, still within acceptable limits. At 150 kg, the stress peaked at 156.1 MPa, which is nearing the yield strength of mild steel, but still safe under short-term use.

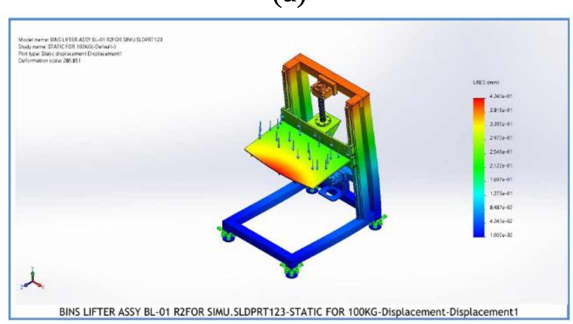
1.1. DISPLACEMENT ANALYSIS:

Table 2: Comparison Of Displacement at the Different Load.

LOAD (KG)	MAXIMUM DISPLACEMENT (MM)
50	0.2070
100	0.4243
150	0.6420



(a)



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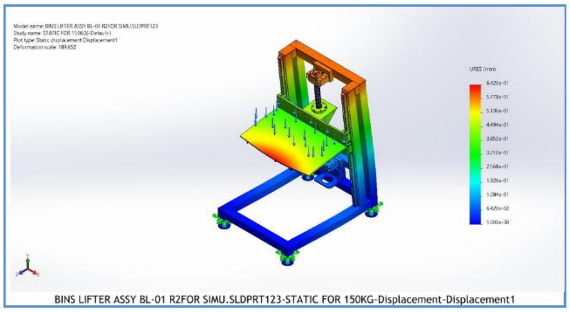


(c)

Figure 6: The maximum value of Displacement :(a) 50kg, (b) 100kg, And (c) 200kg.

Displacement increased linearly with load. At the maximum load of 150 kg, the deflection was only 0.642 mm, which is considered acceptable for structural applications of this nature. The results indicate good stiffness and structural rigidity.

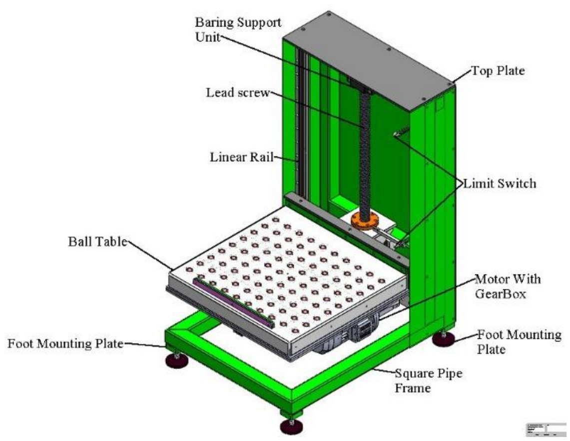
1.1. FACTOR OF SAFETY (FOS):

Table 3: Comparison Of Minimum Value for Factor of Safety at the Different Load.

LOAD(KG)	FACTOR OF SAFETY
50	4.7
100	1.9
150	1.6

The FOS values show that the equipment is highly safe under 50 kg load and remains within acceptable design limits at 100 kg. At 150 kg, the FOS drops to 1.6, suggesting the structure is still safe but approaching its operational limit. This load should be considered the maximum recommended capacity for continuous use.

7. FINAL PRODUCT ASSEMBLY



(a)

The lifting equipment is constructed using a square pipe frame with foot mounting plates to ensure a stable and durable base. The main lifting mechanism consists of a lead screw powered by a motor with gearbox, which raises and lowers the ball table platform. Smooth and accurate vertical motion is maintained with the help of linear rails mounted on both sides of the frame.

At the top of the structure, a bearing support unit and top plate provide alignment and support for the lead screw. A limit switch is installed along the travel path to restrict the lifting range and prevent over-extension of the platform. The ball table features multiple rollers, making it easier to load or unload heavy items with minimal effort.

For mobility and safety, the equipment includes lockable wheels and a fixed handle for manual movement around the workshop. A gear lock system within the winch prevents unintended cable or gear movement, enhancing user safety. Overall, the design offers an adjustable, secure, and user-friendly solution for lifting operations in workshop environments.

(b)

Figure 7: (a)&(b)Final Product Assembly

8. CONCLUSION

The design and development of the lead screw-driven lifting machine were successfully completed, meeting the intended goal of safely lifting a 100 kg power panel to a conveyor height of 4–5 feet. The integration of a ball table allowed for smooth horizontal movement, improving the overall efficiency and usability of the system in a workshop environment.

Through static structural simulation, the lifting equipment was tested under different loads (50 kg, 100 kg, and 150 kg). The analysis demonstrated that the system can reliably support up to 100 kg with a sufficient factor of safety (FOS = 1.9). While the system remained structurally stable at 150 kg, the reduced safety margin (FOS = 1.6) indicates that 100 kg should be considered the recommended maximum operational load.

The complete assembly was achieved by following standard manufacturing practices, including welding, machining, and component alignment. The final prototype enhances workplace safety by minimizing direct physical handling of heavy loads, and offers a compact, mobile, and ergonomic solution for lifting applications in industrial and automated setups.

9. AUTHOR CONTRIBUTIONS

KRISHNA AJAY KOHAR: Conceptualization, CAD modelling, simulation analysis, and report writing.

PAWARA SURESH: Fabrication, assembly, and testing of the final product.

10. CONFLICT OF INTEREST

The authors declare that there are no known financial or personal conflicts of interest that could have influenced the outcome of this project.

11. ACKNOWLEDGEMENTS

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