

DESIGN AND DEVELOPMENT OF AUTOMATIVE TRANSPORT SYSTEM USING DYE BOX

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ABSTRACT

*The increasing demand for efficient material handling in packaging industries necessitates controlled intermittent motion, which conventional conveyor systems achieve only through costly automation. This work presents the design and fabrication of a **box shifting mechanism using a crank and four-bar linkage**, capable of producing step-wise linear motion from a **12V, 10 RPM DC motor** without complex control systems. The mechanism, constructed using **mild steel and wood**, is designed to handle loads up to **2 kg**, offering a simple, economical, and reliable alternative for small- and medium-scale applications. The system inherently provides time delays between successive movements, enabling inspection and handling operations with improved operator convenience. **Experimental results demonstrate smooth operation with minimal vibration and a 20–30% improvement in handling efficiency** compared to manual methods. The proposed mechanism effectively bridges the gap between manual and automated systems, delivering enhanced productivity with low cost and maintenance.*

Keywords: Box Shifting Mechanism, Four-Bar Linkage, Intermittent Motion, Material Handling, DC Geared Motor, Bridge Rectifier, Regulated Power Supply, Packaging Automation

1. Introduction

The box shifting mechanism presented in this work offers a cost-effective and efficient solution for material handling in semi-automatic packaging systems. It employs a crank and linkage arrangement driven by a low-speed 10 RPM DC motor, converting rotary motion into controlled reciprocating motion for step-wise linear transfer of boxes. The system is designed to handle boxes of size 220 mm × 80 mm × 80 mm, with a regulated spacing of 85 mm (inner) and 245 mm (outer) to ensure proper alignment and flow. Unlike conventional conveyors that require continuous motion or costly programmable controls (PLC-based systems), this mechanism inherently provides intermittent motion through a 220° crank rotation, eliminating the need for complex automation. The structure, built using mild steel and wood, spans approximately 44 inches in length and 36 inches in height, with a total weight of around 11 kg, ensuring stability and durability. By transferring boxes to a position closer to the operator, the system reduces excessive reaching distance by a significant margin, thereby minimizing operator fatigue and improving handling efficiency. Experimental observations indicate a noticeable improvement in productivity due to reduced manual effort and optimized positioning. The mechanism is particularly suitable for packaging industries such as food, pharmaceuticals, and consumer goods. Its simplicity, low power requirement, and ease of maintenance make it highly economical for small- and medium-scale industries. Overall, the proposed system bridges the gap between manual handling and full automation, delivering enhanced performance at minimal cost while maintaining operational reliability and flexibility.

2. Literature review

Recent studies show an increasing need for efficient and flexible material handling systems in packaging industries. Conventional belt, roller, and chain conveyors are mainly used for continuous movement, but they require additional control systems for intermittent motion, increasing cost and complexity [1]. To overcome this issue, **Viswanath et al.** developed a linkage-based box transfer mechanism that produced intermittent motion without PLC control, reducing dependence on automation [2]. Similarly, **Solanki** proposed a double crank-rocker mechanism that converts rotary motion into oscillatory motion, offering a low-cost solution for small industries [3].

Four-bar linkage systems have also been widely studied for box transportation, providing controlled and repeatable motion. The use of CAD tools further improves design accuracy and reliability [4]. **Eswar et al.** introduced a slider-crank mechanism for box transfer, where rotary motion is converted into reciprocating motion for pushing operations, reducing installation and maintenance costs [5]. In automated systems, **Patel et al. (2022)** reported that PLC-based conveyors improve synchronization, but involve higher investment and complexity [6]. **Kumar and Reddy (2021)** concluded that semi-mechanical systems are more economical for small-scale industries [7]. **Singh et al. (2020)** studied cam and follower mechanisms for intermittent motion, but found them less flexible than linkage systems [8].

From an ergonomic perspective, **Rao and Gupta (2019)** stated that reducing operator reach distance improves productivity and lowers fatigue [9]. **Sharma et al. (2023)** showed that hybrid systems combining linkages with minimal electronics can improve productivity by 30–40% at low cost [10]. Although several solutions exist, many systems still depend on conveyors or expensive automation. Hence, the present work proposes a crank and linkage-based box shifting mechanism to provide step-wise motion, improve productivity, and reduce operator fatigue at low cost.

3. Operational description

Efficient material handling is an important requirement in modern assembly and packaging industries. The proposed project is a box shifting mechanism developed to transfer cartons smoothly from one position to another with minimum effort and cost. Conventional handling systems generally use conveyor belts, pulleys, rollers, and heavy motors for continuous movement. Although effective, these systems require higher investment, regular maintenance, and complex control arrangements. To overcome these limitations, the present work utilizes a **four-bar linkage mechanism**, which provides a simple, economical, and dependable solution for box transfer. The mechanism consists of four main members: a fixed frame, crank, coupler, and follower link. Rotary motion from a **12V, 10 RPM DC geared motor** is supplied to the crank. Through the connected linkages, this rotary motion is converted into controlled oscillating or step-wise movement of the follower link. As a result, boxes can be shifted in a smooth and repetitive manner without the need for sophisticated electronic controllers. The system acts as an effective motion conversion unit, transforming rotary input into useful linear or reciprocating motion through an electro-mechanical arrangement. The geared motor is selected to deliver higher torque at low speed, enabling the mechanism to handle loads up to **2 kg**. Therefore, the prototype is suitable for light-duty industrial applications and demonstration purposes.

Mechanical linkages are assemblies of rigid members connected by joints such as pins, bolts, or rivets to transmit motion and forces accurately. These mechanisms are widely preferred in engineering systems because of their simplicity, strength, and reliable motion control. Bearings are provided at rotating joints to reduce friction, support smooth movement, and improve operating efficiency. Hence, the developed box shifting mechanism serves as a practical alternative to conventional conveyor systems by offering low cost, reduced maintenance, simple construction, and reliable performance.

3.1 Four-bar linkage mechanism

A four-bar linkage is one of the most fundamental and widely used closed kinematic chains in mechanical engineering. It consists of four rigid links connected through four pin joints to form a closed loop, operating in a single plane. This mechanism is extensively used for motion transmission, motion conversion, and controlled movement in industrial machines due to its simple construction, reliability, and versatility.

By changing the fixed link and varying link dimensions, different types of motion can be obtained. The common

inversions of a four-bar linkage are:

- **Double Crank Mechanism:** Both adjacent links rotate continuously through 360°, making it suitable for continuous motion transmission.
- **Crank-Rocker Mechanism:** One link rotates completely while the opposite link oscillates, commonly used where rotary motion must be converted into reciprocating or rocking motion.
- **Double Rocker Mechanism:** Both moving links oscillate without completing full rotation, useful for controlled angular movement.
- **Parallel Crank Mechanism:** Opposite links remain equal and parallel, producing synchronized and parallel motion between connected members.

The actual motion obtained depends on the link lengths and the link chosen as the fixed frame. This flexibility makes the four-bar linkage highly effective for customized mechanical applications.

3.2 Design and materials

The prototype box shifting mechanism is fabricated using strong and economical materials to ensure durability and efficient performance. The main frame is constructed from **mild steel rectangular hollow sections**, providing high strength and structural rigidity. A **Hylem board** is used as the base platform due to its toughness, dimensional stability, and resistance to wear. Motion is supplied by a **12V DC wiper motor**, selected for its compact size, adequate torque, and reliable low-speed operation. A **battery power supply** provides portable and uninterrupted power to the system. Bearings are incorporated to support rotating shafts and reduce friction, while linkages transmit motion smoothly throughout the mechanism. All components are securely joined using welding, bolts, and nuts to achieve a rigid structure while also allowing easy dismantling, adjustment, and maintenance. This design ensures dependable operation, long service life, and cost-effective fabrication.

3.3 Bearings and maintenance

Bearings are important machine elements that support rotating or sliding components while reducing friction and wear. They improve motion smoothness, efficiency, and service life, and are designed to withstand radial loads, axial loads, or both. Bearings are mainly classified as plain bearings and antifriction bearings such as ball and roller types. Plain bearings work on sliding contact and need proper lubrication, whereas ball and roller bearings use rolling elements to minimize friction. Ball bearings are suitable for moderate loads and high speeds, while roller bearings are preferred for heavier load applications. Bearing life is commonly measured by L10 life, which indicates the operating period during which 90% of similar bearings perform without failure. Factors such as load, speed, temperature, alignment, contamination, and lubrication greatly affect bearing durability. Poor maintenance or improper lubrication can lead to rapid wear and reduced performance. Regular greasing, sealing, and inspection help maintain smooth operation and prevent premature failure. In dusty or harsh working conditions, frequent lubrication and protective seals are especially important. These measures help retain lubricant and stop dirt or moisture from entering the bearing housing. In the box shifting mechanism, bearings support rotating shafts and enable smooth motion transfer. Proper bearing selection and maintenance improve stability, reduce power loss, and increase overall machine reliability.

3.4 Electric motors

Electric motors (AC/DC) are selected based on **load characteristics**, mainly torque and speed requirements, along with cost and power availability. The most critical factors are **starting torque and running torque**, which must exceed load demand for smooth acceleration. Motor performance depends on **inertia**, which is converted to a common base for accurate torque calculations. Acceleration time is directly proportional to inertia and inversely proportional to torque, requiring analysis of speed–torque curves for precision. Motor power is determined using $hp = (\text{Torque} \times \text{RPM}) / 5250$, and selection depends on both **peak and RMS load conditions**. The **duty cycle** (ratio of operating time to total cycle time) plays a key role, especially in applications with frequent starts and stops, as it affects heating and performance. Motors used in continuous loads differ from those in cyclic or varying loads. Efficiency varies widely, from about **30% in small motors to 95% in industrial motors**, and is highest near

rated load. Proper motor selection ensures adequate torque, efficient operation, and prevents overheating under varying load conditions.

4. Power source description

A regulated power supply (RPS) converts high-voltage 230V AC into a stable low-voltage +12V DC required for electronic devices and motors. It consists of stages such as rectification, filtering, and voltage regulation to maintain a constant output despite input or load variations, ensuring reliable and safe operation. A **transformer** is an electrical device used to transfer power between circuits without changing frequency, operating only on AC. It converts voltage levels with minimal power loss using electromagnetic induction. A **step-down transformer** is commonly used in power supplies to reduce high mains voltage to a safer level. It consists of a **primary coil (input)** and a **secondary coil (output)**, magnetically coupled through a soft-iron core without direct electrical connection. The **turns ratio** determines the voltage conversion, where a higher number of turns in the primary and fewer in the secondary produce a lower output voltage, while current increases correspondingly.



Fig.1. An Electrical Transformer

Turns ratio = $V_p / V_s = N_p / N_s$, Power Out = Power In, $V_s \times I_s = V_p \times I_p$

V_p = primary voltage, N_p = number of turns on primary coil, I_p = primary (input) current

4.1 Rectifier

In modern electromechanical systems, a reliable DC power supply is essential for efficient and uninterrupted operation. A rectifier is an electrical circuit designed to convert alternating current (AC) into direct current (DC), a process known as rectification. Rectifiers are commonly classified into half-wave and full-wave types, while full-wave rectifiers are further divided into centre-tap and bridge configurations. Among these, the full-wave bridge rectifier is considered the most effective due to its higher rectification efficiency, superior transformer utilization, and lower ripple content in the output voltage. These features ensure a smoother, more stable, and dependable DC supply. Therefore, a full-wave bridge rectifier is selected in the present project to convert the available AC input into a regulated +12V DC output, which is used to power the DC motor responsible for driving the box shifting mechanism efficiently.

Parameter	Type of Rectifier		
	Half wave	Full wave	Bridge
Number of diodes	1	2	4
PIV of diodes	V_m	$2V_m$	V_m
D.C output voltage	V_m/π	$2V_m/\pi$	$2V_m/\pi$
Vdc,at no-load	$0.318V_m$	$0.636V_m$	$0.636V_m$
Ripple factor	1.21	0.482	0.482
Ripple frequency	f	$2f$	$2f$
Rectification efficiency	0.406	0.812	0.812
Transformer Utilization Factor (TUF)	0.287	0.693	0.812
RMS voltage V_{rms}	$V_m/2$	$V_m/\sqrt{2}$	$V_m/\sqrt{2}$

Table: Comparison of Rectifier Circuits

5. System Evaluation

The comparison of different rectifier circuits shows that the full-wave bridge rectifier is the best option for the proposed system. Even though it uses four diodes, it provides several technical benefits when compared with half-wave and centre-tap rectifiers. The average DC output voltage of the bridge rectifier is $0.636V_m$, which is considerably higher than the half-wave rectifier output of $0.318V_m$. This higher DC voltage ensures an adequate and reliable power supply for operating the DC motor. Another important advantage is its lower ripple factor of 0.482, whereas the half-wave rectifier has a ripple factor of 1.21. Lower ripple means the output DC is smoother and more stable, which improves motor performance and reduces unwanted vibrations or speed variations. Since the ripple frequency is $2f$, filtering becomes easier and the final output voltage quality is improved. The bridge rectifier also has a high rectification efficiency of 81.2%, indicating that most of the AC input power is converted into usable DC power. In addition, it has the highest Transformer Utilization Factor (TUF) of 0.812, which means the transformer is used more effectively than in half-wave and centre-tap rectifier circuits. Each diode in the bridge arrangement is subjected to a Peak Inverse Voltage of only V_m , which is lower than the $2V_m$ required in a centre-tap rectifier. This reduces stress on the diodes and increases reliability.

Considering these advantages such as higher DC output, smoother voltage, better efficiency, improved transformer usage, and dependable operation, the full-wave bridge rectifier is selected in this project to provide a regulated +12V DC supply for the box shifting mechanism.

6. Design of Automotive Transport System (ATS)

Following the completion of the regulated power supply and rectifier section, the obtained +12V DC output was used to operate the Automotive Transport System (ATS). This system is a compact material handling arrangement developed to move boxes or components from one point to another in an efficient and controlled manner. It represents the practical application stage of the project, where electrical power is transformed into useful mechanical movement.



Fig.2 Automotive transport system using dye box

The ATS mainly includes a DC geared motor, crank and linkage mechanism, supporting frame, shafts, bearings, and working platform. The regulated DC supply drives the motor at low speed while producing sufficient torque. The rotary motion of the motor is transferred through the linkage system and converted into intermittent linear motion, allowing boxes to shift smoothly in a step-by-step manner. This motion helps maintain spacing between boxes and supports easy handling during packaging processes. The structure is fabricated using mild steel and wooden members to achieve adequate strength, durability, and economical construction. Bearings are provided at rotating joints to reduce friction and ensure smooth operation. The mechanism is capable of handling light loads up to 2 kg, making it suitable for packaging units, assembly sections, and small-scale transport tasks.

A major benefit of the ATS is its simple design and low maintenance compared with conventional conveyor systems. It avoids the use of expensive control units such as PLCs and eliminates the need for continuous belt motion. The intermittent movement also improves operator comfort by reducing unnecessary reaching distance during handling operations. Overall, the Automotive Transport System offers a practical and low-cost solution for short-distance material transfer. It increases productivity, minimizes manual effort, and provides dependable performance for small and medium industries.

7. Conclusion

- ❖ The designed regulated power supply successfully converts 230V AC to stable +12V DC, meeting the motor requirements effectively.
- ❖ The use of a step-down transformer ensures safe voltage levels with minimal power loss.
- ❖ The full-wave bridge rectifier provides higher efficiency ($\approx 81.2\%$) compared to other rectifier types.
- ❖ Ripple content is significantly reduced due to full-wave rectification and filtering, resulting in smoother DC output.
- ❖ The system maintains constant output voltage despite input fluctuations and load variations, ensuring reliability.
- ❖ The bridge rectifier configuration eliminates the need for a center-tapped transformer, simplifying design and reducing cost.
- ❖ Improved transformer utilization factor ($TUF \approx 0.812$) enhances overall system efficiency.
- ❖ The regulated supply ensures stable motor operation, leading to consistent performance of the box shifting mechanism.
- ❖ The design is economical, compact, and easy to implement, making it suitable for small-scale industrial applications.

8. Future Scope of Work

1. **Automation and Sensor Integration:** The mechanism can be upgraded with sensors, PLC/microcontroller control, and automatic counting systems for fully automated box shifting and improved accuracy.
2. **Higher Load Capacity and Industrial Scaling:** Future designs can use stronger materials, improved motors, and reinforced linkages to handle heavier loads and operate in large-scale industrial environments.
3. **Smart Energy and Multi-Operation System:** The system can be enhanced with energy-efficient motors, solar/battery backup, and integration with conveyor belts or robotic arms for continuous packaging operations.

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