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Design and Fabrication of Box Transport Mechanism Using Four Bar Link Mechanism

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***Abstract*: This paper presents the design and fabrication of a box transport mechanism employing a four bar linkage. The mechanism aims to efficiently transport boxes within industrial environments. The design utilizes the principles of kinematics and mechanical engineering to achieve a robust and reliable system. The paper details the conceptualization, design process, fabrication techniques, and experimental validation of the proposed mechanism. The final model will be constructed using CAD software, eliminating any errors that may have occurred during graphical synthesis.**

***Keywords*: Box transport, Four bar linkage, Mechanism design, Fabrication, Industrial automation**.

Introduction: In industries, there's a growing demand for intermittent package movement alongside continuous motion. Our project aims to develop a mechanism using mechanical linkages to achieve this stop-and-move motion. Unlike conveyor systems, our system introduces a time delay between package movements, allowing for alterations or other interventions. This design advantage reduces costs compared to conveyor systems, which require costly programmed modules for intermittent stopping of the belt. The prototype design comprises an electric motor, shafts, and a fabricated frame and platform for moving packages efficiently.

Design Methodology: The design process involved conceptualizing the mechanism, considering factors such as load capacity, speed, and reliability. The four bar linkage configuration was chosen for its simplicity, versatility, and ability to provide controlled motion. Kinematic analysis was conducted to optimize the mechanism's performance.

Objective: Fabricate a box transport mechanism capable of moving objects from one location to another, encompassing project planning and execution. Gain proficiency in fabrication techniques within a mechanical workshop and become adept in utilizing various mechanical machine tools, as well as measuring instruments.

Working principle: In this study of mechanisms, a four-bar linkage, also known as a four-bar, is the simplest movable closed-chain linkage. It consists of four links connected in a loop by four joints. Planar four-bar linkages are the most common and are constructed with four one-degree-of-freedom joints: revolute joints (R) and prismatic joints (P). The ground link is fixed relative to the viewer, while the crank link can rotate fully and the rocker link cannot. A slider connects to the ground via a prismatic joint and is sometimes considered a crank with an infinitely long pivot. A floating link, or coupler, connects two other links and is often called a connecting rod in a single slider-crank mechanism.

Linkages can be classified based on their primary functions:

- Function generation: determines the relative motion between linked frames.
- Path generation: defines the path of a tracer point.
- Motion generation: controls the motion of a coupler.

Four simple planar linkages are identified by function:

Reverse-motion linkage (Fig. 1a) A reverse motion linkage converts rotary motion to reciprocating motion, or vice versa, using a toggle action. It's made of linked joints in a specific arrangement. When activated, it reverses the direction of motion. Engineers use kinematics and dynamics principles, along with simulations and prototypes, to design and optimize these mechanisms for applications in automotive, and machinery robotics. Facilitates the movement of objects or force in opposite directions by utilizing the input link as a lever. However, if the fixed pivot is off-center, the output link's movement differs from that of the input link. Strategic positioning of the fixed pivot enables the linkage to generate specific mechanical advantages. Moreover, this linkage can rotate through 360°.

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Push-pull linkage (Fig. 1b). Enables both pushing and pulling actions within a system using interconnected rods, levers, or cables. It's widely used in applications like vehicle throttle control, steering systems, lifting mechanisms, and machinery controls. Design and analysis focus on component arrangement, material strength, and motion efficiency, employing principles of mechanics, kinematics, and dynamics for optimization.

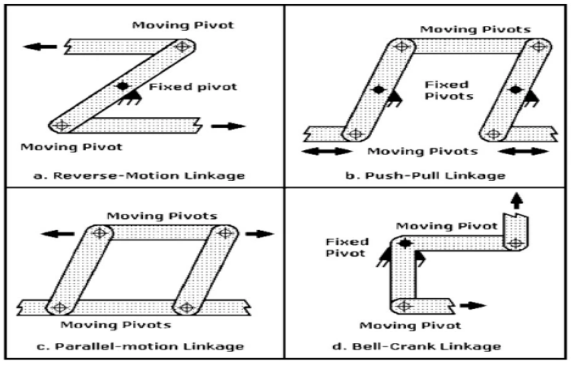

Fig. 1- Functions of four basic planar linkage mechanisms

Parallel-motion linkage (Fig. 1c) enables objects or forces to move in the same direction while maintaining a fixed distance between them. Applications of parallel-motion linkage include pantographs used in electric trains to draw power from overhead cables and drawing tools for manual replication of original drawings. Additionally, it can be employed to keep tool trays horizontal when toolbox covers are opened.

Bell-crank linkage (Fig. 1d) changes the direction of objects or force by 90°. Initially utilized in doorbells, it has since been adapted for bicycle brakes. By pinning two bell cranks bent at 90° in opposite directions, the mechanism forms tongs. Converts motion around a fixed pivot point into a different direction or type of motion. It consists of a lever connected to a fixed pivot and another lever or link attached to its free end. When one end is moved, the other moves differently. Used in various systems to change motion direction, transmit forces, or create mechanical advantage. Design involves lever lengths, angles, and forces, optimized using mechanics, kinematics, and dynamics principles for specific applications.

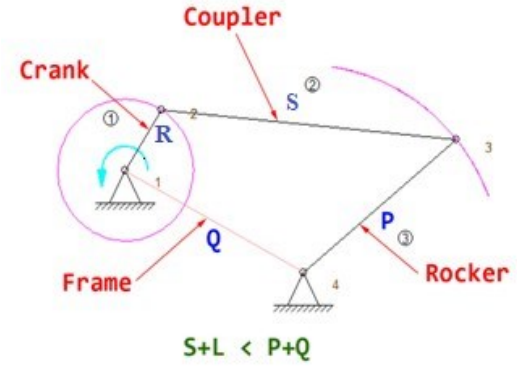

Fig. 2- Crank rocker

Literature Review: Linkages are mechanisms formed by connecting two or more levers together. They can change the direction of a force or make multiple objects move simultaneously. Various fasteners like pins, bolts with nuts, and rivets are used to connect linkages, allowing them to move freely. There are two main classes of linkages: simple planar linkages and specialized linkages. These linkages can perform tasks like describing straight lines or curves and executing motions at different speeds.

Shiva Krishna Y,etal.(2022) This paper presents the design and fabrication of a box transport mechanism to meet the growing demand for intermittent movement of packages in modern industries. Unlike conventional conveyor systems, which offer continuous motion, our mechanism provides a stop-and-move motion using carefully engineered mechanical linkages. This innovative approach introduces flexibility, allowing for on-the-fly alterations to packages or repositioning for various purposes. The prototype design incorporates an electric motor, precision-engineered shafts, and a lightweight yet robust aluminum frame.

Patel Bhautik ,etal.(2021) This project aims\or the utilization of kinematic synthesis (type, dimensional and number) to fabricate a working physical model of an eight link transport mechanism. The mechanism to be developed in its simplest form would perform the function of transporting boxes/articles which are being fed onto two rails and are moved ahead one by one. Transport mechanisms generally move material and their application lies in various industries-

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manufacturing, assembly, packaging etc. In this project we apply the path generation synthesis and coupler curve synthesis and study to fabricate our model.

Shrikant R. Patel, etal. (2018) The research work on the kinematic and dynamic analysis has been reviewed in this paper. Methodology for different mechanism, kinematic analysis is important to understand the position, velocity and acceleration of each +linkage during the working of mechanism. The essentiality of dynamic analysis is to understand dynamic behavior of each link, during the working of mechanism.

P.R.Kothule,etal.(2013)There has been a serious demand for intermittent movement of packages in the industries right from the start. The objective of this study is to design a mechanism that delivers this stop and move motion using the mechanical linkages. The advantage of this system over the conveyor system is that the system has a time delay between moving packages and this delay can be used to introduce any alterations in the package or move the package for any other purpose and likewise. While in the normal conveyor mechanism such actions cannot be performed unless programmed module is used to produce intermittent stopping of the belt which is basically costly.

Ulhas Patil ,etal.(2011) This project aims for the utilization of kinematic synthesis(type, dimensional and number) to fabricate a working physical model of an eight link transport mechanism. The mechanism to be developed in its simplest form would perform the function of transporting boxes/articles which are being fed onto two rails and are moved ahead one by one.

Experimental Set Up:

Linkage: A mechanical linkage is a system of interconnected components designed to manage forces and movement. It consists of rigid links connected by joints, which provide ideal movement like rotation or sliding. Ideal joints have degrees of freedom (DOF), representing the parameters associated with their movement. Linkages are designed to transform input force and movement into desired output force and movement. The ratio of output force to input force is the mechanical advantage, while the ratio of input speed to output speed is the speed ratio. In an ideal linkage, the speed ratio and mechanical advantage are equal.

M S Frame: mild steel and stainless steel differ primarily in their alloying materials, with mild steel containing carbon and stainless steel incorporating chromium. This results in stainless steel having very high corrosion resistance and a stain-resistant surface, while mild steel requires galvanizing to prevent corrosion. Mild steel has a low carbon content (under 0.25%) and is characterized by its low strength and hardness. It is often used for structural and mechanical components that do not require high strength.

D C Motors: are rotary electrical motors that convert direct current (DC) electrical energy into mechanical energy. They rely on magnetic fields produce force, and most types have mechanisms to periodically change the direction of current within the motor. They were among the first widely used motors, powered by existing DC lighting systems. Their speed can be controlled using variable voltage or by adjusting current strength in field windings. Small DC motors are found in tools and appliances, while universal motors, lightweight brushed motors, are used in portable tools and appliances.

Nuts and Bolts: are fundamental fasteners used in various applications, providing reliable connections in structures, machinery, and everyday items. Bolts, versatile and sturdy, are essential in construction projects like buildings and bridges, as well as in everyday objects such as furniture and vehicles. Threaded studs or bolts offer strong connections for electrical components and security fixtures like door locks. Nuts, with threaded holes, are paired with bolts to fasten parts together, relying on friction, bolt stretching, and part compression for stability.

Crank-Rocker Mechanism: - The four bar linkage is the simplest and often times, the most useful mechanism. As we mentioned before, a mechanism composed of rigid bodies and lower pairs is called a linkage. In planar mechanisms, there are only two kinds of lower pairs --- revolute pairs and prismatic pairs. The simplest closed-loop linkage is the four bar linkage which has four members, three moving links, one fixed link and four pin joints. A linkage that has at least one fixed link is a mechanism.

DESIGN:

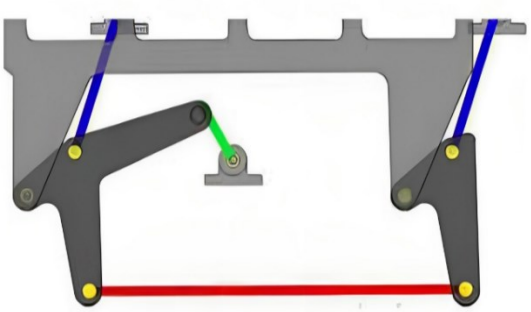

Fig. 4- Box Transport Mechanism

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In the given fig. 3 value of d is the predetermined value and we have to determine the crank radius r for a given value of rocker P

Let the oscillation of rocker P degree at point B From the triangle ABC d=2AC

d=2R Sin(Q/2) Q/2=Sin-^{l}(d/2R)

Q=2 Sin-^{l}(d/2R) where d is the displacement in mm.

From crank and rocker motion

r =(R*3.14321/180)*Sin^{-l}(d/2R)

In this work, the crank for displacement d=215mm, at the rocker radius R=250mm.

Crank radius is given by,

r= (250*3.14321/180)*sin^{-l}(215/(2*250))

r= 111.18mm

Determining degree of freedom

Degree of freedom is the number of input required to get constrained output in a chain.

According to kutzback's equation

F= 3(L-1)-2J-H where

F is the degree of freedom.

L is the no of links.

J is the no of binary joints.

H is the no of higher pair.

hence

F=3(8-1)-(2*10)-0

F=1

Step Down Speed

$N_1D_1=N_2D_2$

where

N_1=Rotating speed of the pulley 1 in rpm.

N_2= Rotating speed of the pulley 2 in rpm. D_1=Diameter of the pulley 1 in mm.

D_2= Diameter of the pulley 2 in mm.

The N_1 is the speed of motor and it is connected with pulley. Pulley speed 1440rpm is constant throughout the mechanism. The pulleys are taken by the standard diameter in the market.

N_1=1440 rpm,

D_1=8mm,

D_2=24mm

N_2=480rpm

The velocity of the box transport mechanism,

$U = \pi DN / 60$

Where, u=Step down speed in m/s

$=(\pi * 8 * 1440)$

u=603 mm/s

u=0.6 m/s

Conclusion: The project introduces a novel box shifting mechanism, departing from conventional conveyor systems by employing kinematics links and a motor. Designed for light-duty operations, it targets small-scale industries like soap manufacturing and biscuit packaging, handling boxes weighing 5 to 10 kg. This innovation promises to accelerate production speed and efficiency in such industries. Moving forward, the focus will be on developing accurate mathematical models and simulations to enhance kinematics, dynamics, and motion analysis, paving the way for further advancements and modifications tailored to specific requirements.

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Application and Future Scope:

Application: -

1. Transferring the boxes from one place to another for the requirement of worker within the industry.
2. Heavy tools easily transport to one work station to another work station.
3. Creating a balance line in the assembly line.

Future scope: - We have tried easy and simple to use prototype design which will revolutionize the concept of box transfer mechanism. As it is easy to use and fabricate small scale industries will be able to utilize this product for the betterment in the plant management. As transporting boxes from the assembly line will get more manageable industries could easily increase their production rate and so their revenue. Further advancements and modifications can be done as per the requirements as well as scale of the use.

Conclusion: The project introduces a novel box shifting mechanism, departing from conventional conveyor systems by employing kinematics links and a motor. Designed for light-duty operations, it targets small-scale industries like soap manufacturing and biscuit packaging, handling boxes weighing 5 to 10 kg. This innovation promises to accelerate production speed and efficiency in such industries. Moving forward, the focus will be on developing accurate mathematical models and simulations to enhance kinematics, dynamics, and motion analysis, paving the way for further advancements and modifications tailored to specific requirements.

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