Design of a Carton Box Orientation Changing Machine for an Industrial Cologne Packing Process

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Abstract. The cologne packing process presents considerable challenges due to the flammable nature of the liquid and the fragility of the glass bottles. Cologne packing typically involves two primary stages: packing individual cologne bottles into carton boxes and subsequently packing carton box stacks into corrugated boxes. This research specifically addresses the second stage, focusing on the design of a simple, efficient carton box orientation changing machine that can be integrated into existing automated packing lines. The proposed mechanism is capable of changing the orientation of carton boxes at a rate of 60 pieces per minute without causing bubble formation inside the cologne bottles. It is designed to handle three common bottle sizes: 50 ml, 100 ml, and 200 ml and change the orientation of carton boxes by 90 degrees. Currently available systems face persistent challenges related to product quality and operational efficiency, particularly in the carton box orientation changing process. Frequent misalignment, jams and manual handling reduce product quality and throughput, while rigid mechanisms cause high maintenance and downtime. Moreover, limited adaptability to varying carton sizes restricts their use in flexible production environments. These shortcomings highlight the need for a more efficient, reliable, and adaptable design solution. Existing mechanisms frequently damage carton boxes or deform the packaging and form bubbles inside the bottle, leading to increased product rejection rates and reduced customer satisfaction. This paper provides a comprehensive review and critical evaluation of current orientation changing methods, identifying their key limitations. The newly proposed mechanism offers a solution that minimizes physical damage to the packaging, enhances the overall quality of the packed product, and improves system efficiency. Furthermore, integrating this mechanism into the existing packing lines has the potential to replace three manual labor positions, contributing to labor cost reduction and process optimization.

Keywords: Carton box, Corrugated box, Orientation changing mechanism

1 Introduction

In modern manufacturing industries automation processes play a significant role. Through automation process can achieve consistent product handling and reduce operational cost. When considering the cologne packing process there are two main stages. Those are carton box packing process and the corrugated box packing process. At the first stage final product is packed into carton boxes. Most of the industries use automated packing machines for this process [1]. The next step is to pack those carton boxes in large corrugated boxes for easy handling and transportation. This process is more complex than the first step. Most of the methods currently used in the industry for changing the orientation of the carton boxes such as twist conveyor, box flipping mechanism may damage the carton boxes. This will affect to the appearance of the final output and therefore these items will be rejected in the quality checking process.

For packing carton boxes in corrugated boxes first need to change the orientation of the output of the automated carton box packing machine. Then need to form a stack of carton boxes. After that need to pick and place this stack. The most common industrial use for this pick and place method is a collaborative robot arm [2]. Finally place those carton box stack in a corrugated box and tap.

This research mainly focuses on the changing orientation of the carton boxes which gives as the output of automated carton box packing machine. Here mainly consider the quality of the final output, cost effective method and easy mechanism which reduce the generation of form. In literature review explores existing methods and technologies used in the industry to change the orientation of the carton boxes.

Twist conveyors are the most common method to change the orientation of the product. There are different types of twisted conveyors in the market. The most common type is the twisted chain conveyor. In this method change the orientation without the use of any external devices. These are commonly used for foolproof product reorientation and reoriented by any angle up to 90˚ degrees. Main features of this product are can rotate the product 90˚ degrees in 60 linear inches and all within a 96 inches footprint, no need any additional automation or no disruption in conveyance and can be used for slight incline and decline applications. However, these conveyors required more space for the installation process [3].

Box flipping mechanism is another most commonly used mechanism for changing the orientation of boxes. In this method box automatically flip and rotate products when the product travels along the conveyor belt. By using this method can flip boxes 90˚or 180˚ degrees. In here, grip the box by frame with fingers and by using linear actuators rotate it. However, this mechanism can only flip one box at a time [4].

The twisting plate is the simplest way that can be used to change the orientation of boxes. These plates include two twisted guide plates along the conveyor. The length of the twisted plate changes because of the size and weight of the carton box. When the box is moved forward this twisted plate applies force on it to rotate. After carton boxes are entered to the twisted plate on conveyor these conveyors will be guide by plates. Plates gradually twist and this twisting angle can be adjusted to 90˚or 180˚ degrees. While using this method need to consider the space requirement because it requires a longer conveyor section for smooth rotation and for the friction of boxes [5].

The turning table method mostly uses a rotating hammer or plates to change the orientation of boxes. While using a rotating hammer it strikes the side or edge of the box. That force will impact while the conveyor continues moving. Advantages of this method are can be used for high-speed production lines; hammer speed and impact force can be adjusted for different orientations and it only requires less space. However, it is not suitable for fragile items due to impact force [6].

2 Methodology

The proposed design focuses on automating the carton box handling process in cologne packing lines, specifically addressing the challenges in orientation change and stacking for final packaging.

A detailed study of the existing manual and semi-automated packing processes was conducted to identify inefficiencies in orientation change, stacking, and final packing. Performance requirements such as throughput 60 cartons/min, gentle handling to avoid bubble formation, and seamless integration with the upstream carton packing machine were established.

The overall system was divided into four functional subtasks which are receiving cartons, orientation change, stack formation, and pick-and-place transfer. For each subtask, alternative mechanisms were explored such as roller conveyors, belt conveyors for transfer, mechanical and pneumatic orientation systems, and the most feasible solutions were selected through a morphological chart and evaluation matrix.

The methodology is structured around four key sub-tasks essential for the development of the new system as follows:

Receiving Cartons from the Automated Carton Packing Machine: The system is designed to receive individual carton boxes directly from the automated carton packing machine. A conveyor mechanism ensures the smooth transfer of cartons to the orientation changing unit while maintaining continuous flow and synchronization with upstream processes.

Changing the Orientation of the Carton Box: An orientation changing mechanism is developed to reorient 90 degree each carton box to the required position for efficient stacking and packing. The system ensures the reorientation is completed without causing internal agitation that could lead to bubble formation within the cologne bottles.

Forming a Stack: After orientation, the cartons are sequentially arranged and stacked into predefined configurations suitable for placement into corrugated boxes. The stacking process is carefully controlled to prevent misalignment and to ensure stability during subsequent handling.

Picking and Placing the Stack into Corrugated Boxes: The final sub-task involves transferring the formed stack into a corrugated box using a pick-and-place system. This step is automated using collaborative robot arm to minimize manual intervention and maintain the required packing speed of 60 pieces per minute.

Finally, the selected mechanisms were modeled using CAD (SolidWorks) to ensure dimensional compatibility, smooth flow, and structural stability. The orientation unit was designed with synchronized motion control to achieve 90° re-orientation without disturbing bottle contents. The stacking system was designed for alignment accuracy, while the collaborative robot arm was programmed to achieve reliable pick-and-place operations.

a. Design Specifications

The proposed carton box orientation changing mechanism is designed to meet specific operational and performance requirements suitable for integration into an automated cologne packaging line. The system is expected to handle a maximum output of 60 pieces per minute, ensuring compatibility with high-speed industrial production lines because the conveyor is configured to deliver cartons at a rate compatible with the upstream packing machine, ensuring continuous flow without bottlenecks and the orientation change is achieved within a fraction of a second using high-speed MJ linear actuators, which provide fast and precise movement. Also, these actuators can be configured as required through PLC modules, enabling optimization of stroke length and speed to minimize cycle time. During stacking, actuator speeds are synchronized with conveyor motion to prevent accumulation delays. The collaborative robot used for pick-and-place operations has a high joint speed and repeatability accuracy, ensuring that the formed stack can be transferred reliably into corrugated boxes within the required cycle time. This machine operates on a standard three-phase power supply with an electrical requirement of 400 V, 50 Hz. The mechanism is designed to achieve a precise rotation angle of 90 degrees, enabling accurate orientation of the carton boxes without causing damage or misalignment. The system must be capable of handling carton box stacks with a weight range between 1.08 kg (for 50 ml box single layer) and 2 kg (for 100 ml box single layer), ensuring stability and consistent performance across various product sizes.

weight of single layer of 50 ml boxes= weight of one box x number of boxes in one stack
$= (6.5/48) * 8$
$= 1.08$ kg

weight of single layer of 100 ml boxes= weight of one box x number of boxes in one stack
$= (12/48) * 8$
$= 2$ kg

Table 1 shows the specifications for three different cologne bottle sizes:50ml, 100ml and 200 ml. For both the 50 ml and 100 ml bottles, 48 individual carton boxes are packed into a single corrugated box. In contrast, due to their larger size, only 12 cartons of the 200 ml bottles can be accommodated per corrugated box. The input feeding speed of the carton boxes into the system is maintained at 60 pieces per minute for the 50 ml and 100 ml bottles, whereas the speed is reduced to 25 pieces per minute for the 200 ml bottles to facilitate careful handling and prevent potential damage during processing.

Table 1. Details of packing boxes

Size	Number of cartons in one corrugated box	Input carton speed(pcs/min)	Corrugated box weight(kg)
50 ml	48	60	6.5
100 ml	48	60	12
200 ml	12	25	5

b. Components of Design

Flexible conveyor
The output of the cartooning machine is delivered into the flexible conveyor, where the boxes are aligned horizontally and transported cartoon boxes forward.
Pushers
There are two pushers used in the system, pusher number 1 is used to change the orientation of the boxes horizontally to vertically and the other one is used to place the boxes

frequently vertically in the stacking stable. One movement of the pusher can place of carton boxes vertically in the stacking table. The pushers are actuated by help of the linear actuators.

Stack stopper

Stack stopper act as a gate and help to form a set of carton boxes and pushes them into the Stack stable.

Angle plate

The angle plate helps guide the boxes down smoothly into the pocket. The cartoon boxes move slides in the angle plate and place them vertically in the pocket.

Linear actuators

There are four actuations in the system, those are pusher number 1, pusher number 2, stack stopper and pocket actuations. Linear actuators play a critical role in the pick-and-place operation. Specifically, an XY linear actuator system from MJ Unit is employed to handle the precise movement of the prepared carton stacks. This actuator system is equipped with a suction pad mounted on the Y-axis actuator, which securely grips the carton stacks during transfer. The XY linear actuator enables controlled, accurate motion in both the horizontal (X-axis) and vertical (Y-axis) directions, facilitating the smooth transfer of the carton stacks from the stacking table into the corrugated boxes positioned on the roller conveyor. The use of this actuator ensures high positioning accuracy and reliable handling of the product, contributing to the overall efficiency and consistency of the packing process.

Pocket

The function of the pocket is to collect vertically and stabilize the cartoon boxes, after that process pocket moves away to form the stacks.

Stacking table

This is the final resting place of the stacked boxes. In here, carried out the boxes next pick and place process.

c. Specifications of components

Roller conveyor

The effective length of conveyor roller is 450 mm and the maximum corrugated box width is 320 mm.

Pneumatic actuators

The system uses two pneumatic actuators, a stack stopper actuator with a 16 mm bore and 80 mm stroke, and a tightening actuator with a 16 mm bore and 10 mm stroke.

Pusher

The system considers surface contact coefficients of 0.2–0.6 (plastic–cardboard) and 0.2–0.45 (SS–cardboard). Actuation is achieved using an MJ 50M with 400 W servo motor for stack forming, an MJ 50 with 400 W servo motor for the pocket holder, and MJ 70 + MJ 70M with 750 W servo motors for pick-and-place.

3 Results and Discussion

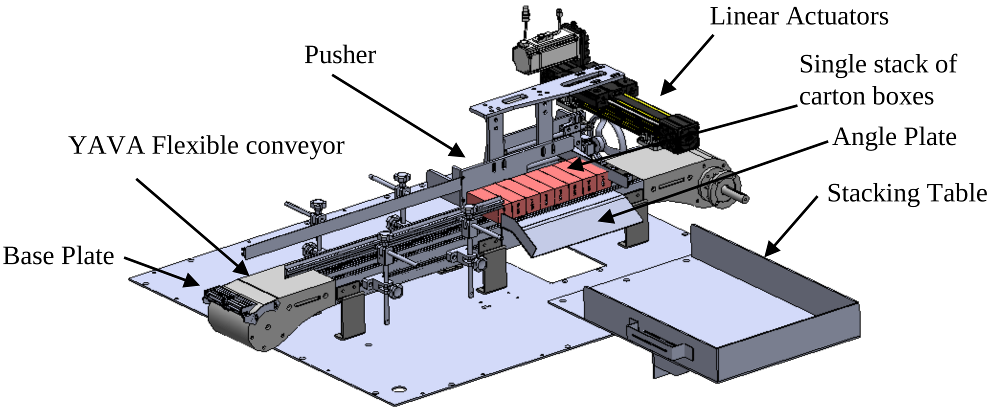

Fig. 1. Solid model of the design

Horizontally oriented carton boxes are discharged from the end of the cartoning machine and transferred to the YAVA flexible conveyor, which has an operating width of 180 mm. These cartons are sequentially received by the conveyor and guided toward a stopper positioned at the end of the conveyor to form linear stacks. The quantity of cartons within each stack is monitored and controlled using proximity sensors installed along the conveyor.

Once the required number of cartons is accumulated, pusher 1 is actuated to transfer the linear stack toward an angled plate. As the stack moves along the angled plate, the orientation of the carton boxes is changed from horizontal to vertical. To prevent the carton boxes from toppling during this transition, the stack is directed into a specially designed pocket that temporarily holds the cartons in position. Following stabilization, the pocket is actuated backward, releasing the vertical stack onto the next stage. Subsequently, pusher 2 is actuated to transfer the oriented stack onto the stacking table for further processing.

Simultaneously, corrugated boxes are formed using a Fairinon FR5 collaborative robot (cobot) equipped with a suction pad. The cobot assembles the corrugated boxes and places them onto a roller conveyor. The availability of a box in the correct position is detected using proximity sensors, which signal two tri-rod pneumatic cylinders to stop the box accurately at the designated location.

While the box is stationary, a pick-and-place system is engaged to transfer the prepared carton stacks into the corrugated box. This operation is performed using an XY linear actuator from MJ Unit, equipped with a suction pad mounted on the Y-axis actuator to securely handle the stacks.

Once the carton stack is successfully placed into the corrugated box, the pneumatic stoppers are released, and the fully packed box is conveyed to the top flap forming and taping station, completing the packing process.

a. Efficiency

Table 2. Efficiency calculation

Packing rate (Manual)	40 pieces /min
Packing rate (Automated system)	60 pieces /min
Increased packing rate	33.33 %

b. Return of Investment (ROI) Analysis

Table 3. ROI calculation

Allocated budget	LKR 10,000,000.00
Expected cost	LKR 10,000,000.00
Amount of the salary for the employee per month	LKR 60,000.00
Number of employees per shift	3
Number of shifts per day	1
Total number of employees per day	3
Monthly employee cost	LKR 180,000.00
Yearly employee cost	LKR 2,160,000.00
Pay Back Period (Years)	4.6

By integrating the proposed automated system, these three manual positions can be fully eliminated from the packing process, leading to significant annual labor savings. Based on the total investment and the yearly cost reduction, the payback period is calculated to be approximately 4.6 years. This indicates that the initial investment in the new automated system will be recovered through labor cost savings within this period.

The return on investment (ROI) analysis demonstrates that the project is financially justifiable, as it offers long-term cost benefits, increased operational efficiency, and reduced dependency on manual labor, while simultaneously improving product handling quality and process consistency.

4 Conclusions

The cologne packing process presents unique challenges due to the fragility of glass bottles and the flammable nature of the liquid product. This research successfully addressed these challenges by developing a simple, efficient, and cost-effective carton box orientation changing mechanism that can be integrated into existing automated packing lines. By automating the manual process, the system establishes a continuous flow operation, eliminating inconsistencies associated with human handling. The use of high-speed MJ actuators with PLC control and a collaborative robot for pick-and-place ensures reliable performance and enables the system to achieve the target throughput of 60 pieces per minute.
In addition, the system is designed with food-grade stainless steel (SS) to meet hygiene and safety requirements, while the adoption of higher GSM cartons provides improved strength, reducing the risk of bubble formation and physical damage to packaging during handling. The modular design also allows adjustment for multiple carton sizes, enhancing the flexibility of the packing process.

Beyond technical performance, the design offers substantial operational benefits by reducing manual labor, achieving significant cost savings, and providing an estimated payback period of 4.6 years. Overall, this solution not only mitigates the existing limitations in cologne packing but also delivers a sustainable, safe, and economically viable advancement for modern automated packaging lines. Future work may focus on further enhancing flexibility and incorporating advanced control technologies to accommodate an even wider range of packaging configurations.

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