Design and Application of an Integrated Push-type Loading System

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Abstract. In order to improve the loading efficiency of large-volume and standardized bulk materials, Anqiu Boyang Machinery Manufacturing Co., Ltd. has designed and manufactured a set of overall propelled loading system for bulk goods based on the modular design theory according to the customized demands of beer manufacturers. This integrated loading system is based on modular design principles and is customized to meet the specific needs of clients (e.g., breweries). To ensure positioning accuracy and system stability while taking into account characteristics such as material form, volume, weight, and gripper type, a Kawasaki CP500L four-axis palletizing robot. Additionally, when there are significant changes in the loading environment, parameters of the conveying system, palletizing robot, and pushing system can be appropriately adjusted according to the specific load size or material type. In extreme cases, replacing the palletizing robot with one that has higher load capacity can ensure loading efficiency and operational stability.

Taking the beer loading process as an example, we compared and analyzed the loading efficiency, construction investment cost, labor cost, operation cost and other indexes of the overall propelled loading system and the conveyor belt transportation assisted manual loading operation. The results show that: the loading efficiency of the overall propulsive loading system is 3 times higher than that of the conveyor belt transportation auxiliary manual loading mode, and it can save 92.20% of the labor cost per year.

Keywords: bulk materials; loading efficiency; loading systems; economic efficiency; transit speed; automation

1 Introduction

Classification number: TP278 Literature identification number: B

With the implementation of the plan to multiply residents' wage income, and the phenomenon of rising labor costs has become a major problem [1-3]. The global automated trolley loading and unloading system (ATLS) expected to reach 1.5 billion yuan in 2028 will reach 1.5 billion yuan in 2028, with a compound annual growth rate

A. Mallik et al. (eds.), *Proceedings of the 2025 6th International Conference on Management Science and Engineering Management (ICMSEM 2025)*, Atlantis Highlights in Economics, Business and Management 4,
https://doi.org/10.2991/978-94-6463-845-5_19

(CAGR) of 14.6% over the period of 2022-2028 [4], the global automated trolley loading and unloading system (ATLS) market has a broad application prospect in the future.

To a beer production enterprise warehousing site, for example, the traditional conveyor belt transportation auxiliary manual loading operations need to be 6-9 hours to complete a 35-ton box truck loading work, To achieve the automation requirements of the product transfer loading process, Anqiu Boyang Machinery Manufacturing Co., Ltd. has customized a set of bulk cargo overall propulsion loading system.

2 Integral Propulsion Loading System Design

- client need

1. Modular design, easy to assemble, disassemble and maintain;
2. The mechanical strength of the loader system is sufficient, and the system has reliable stability and is easy to operate;
3. The loading efficiency is not less than 280 barrels/h;
4. Layer and full pallet loading modes are adjustable;
5. The loading speed is adjustable and controllable;
6. No more than 2 people per system in manual intervention positions during operations;
7. Loads are automatically counted and saved.

- schematic design

We have determined the propulsion loading system in which the materials are distributed and transported by conveyor belts, the palletizing robots pick up and palletize, and the movable lifting palletizing platform carries the stacks. The bulk material loading process is shown in Figure 1.

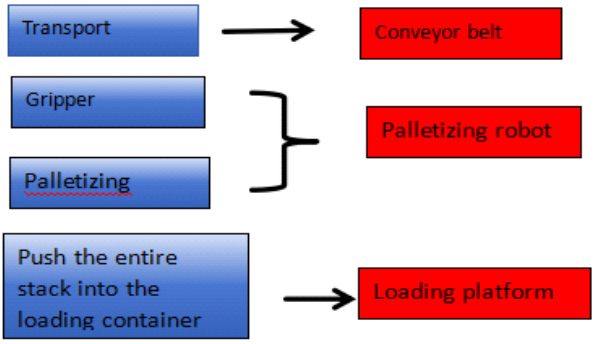

Fig. 1. Flow chart for loading bulk materials

- modeling

According to the cargo loading scheme,the final overall propulsive loading system consists of conveyor system, palletizing robot, intelligent control system, ground running system, lifting system, locking device, pushing system and material stopping device. layout scheme shown in Figure 2.

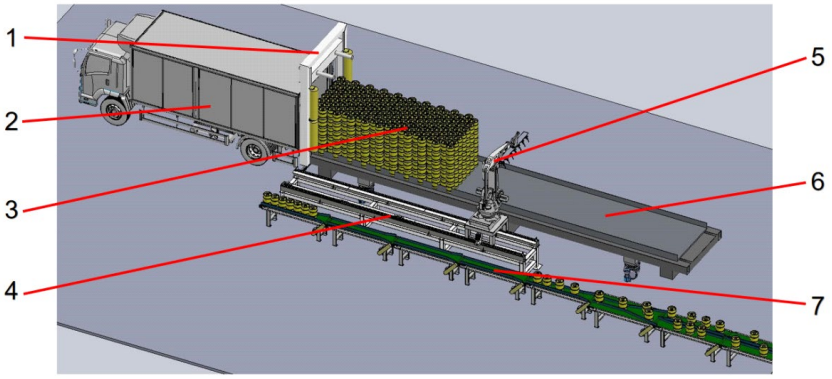

Fig. 2. Layout scheme of integral propulsion loading system (1.Stopping device 2. Box wagon 3. Material stacking, 4.Robot moving track 5.Palletizing robot 6.Pushing platform 7.Conveyor system)

- conveying system

The wine barrel conveying system is mainly composed of three parts: motor, chain plate and frame, and its three-dimensional design is shown in Figure 3.

Fig. 3. Three-dimensional diagram of the conveyor system

- clamping device

The picking and palletizing process of the kegs is done by L 4-axis robot with a robotic gripper device. The robot is fixed on the slide base, and cooperates with the slider and rack . The pneumatic gripper is supported on the concave wall above the kegs by the principle of three-point centering, and the guide bar aligns the upper and lower kegs . The design is shown in Figure 4.

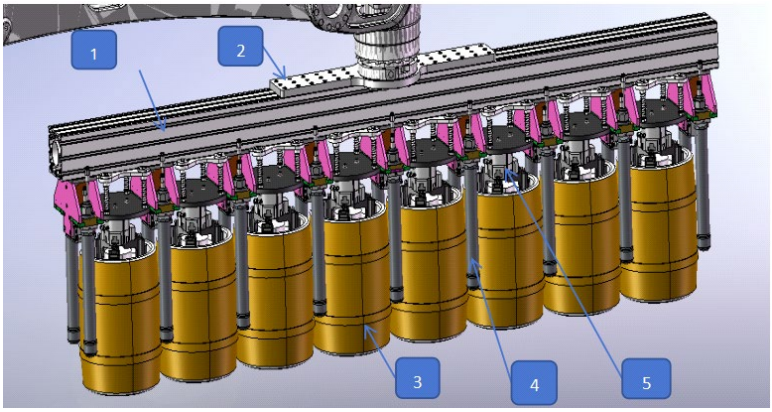

Fig. 4. Clamping device(1.Aluminum profile main beam 2.Robot coupling plate. 3.Wine barrels 4.Guide rods 5.Pneumatic gripper)

- Unwind stopper and gantry design

The main function of the rewinding baffle is to block the wine barrels when the push plate is loaded into the truck to prevent the wine barrels from falling loose and dumping. The pulleys on both sides of the baffle plate are embedded in the groove of the gantry column to realize the up and down movement of the rewinding baffle with the transmission device on the gantry, the three-dimensional drawing of the rewinding baffle plate is shown in Fig. 5, and the three-dimensional drawing of the gantry is shown in Fig. 6.

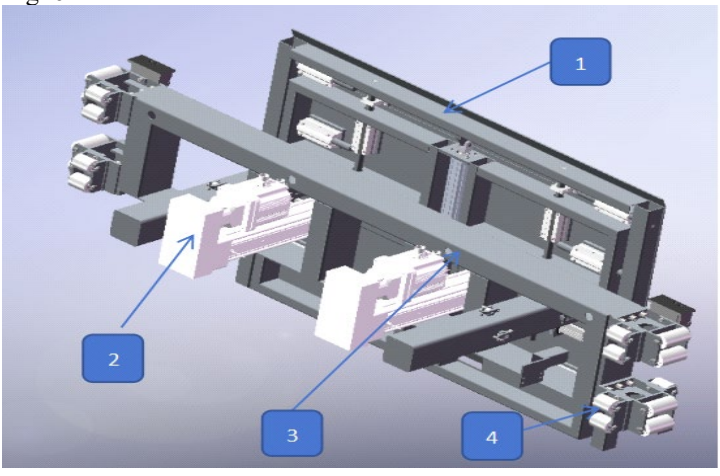

Fig. 5. Three-dimensional model of the withdrawal baffle (1.Baffle plate 2.Baffle moving electric cylinder 3. Sliding bracket 4.Sliding roller)

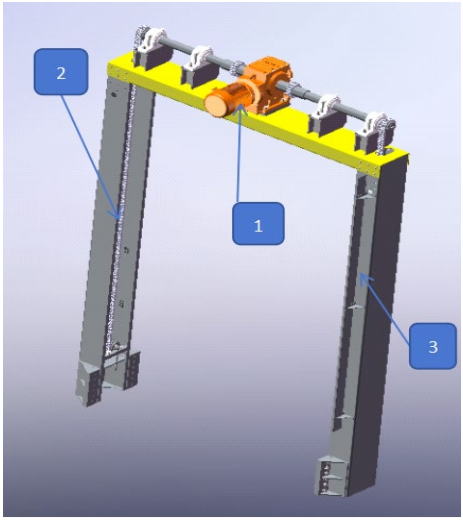

Fig. 6. Three-dimensional model of the gantry (1.Baffle Lifting Drives 2.Lifting Chain 3.Columns)

1.7Main structure and push plate design

The main body of the overall propulsion loading system can realize the main body lifting and lowering, the main body moving forward and backward, the main body moving left and right, and the main body angle rotation movement function under the support of the mobile bracket, the main role of the push plate to provide a loading platform for the push plate to move forward to provide the power, and the installation of the push plate can be installed in the transmission chain under the action of the goods into the carriage. The three-dimensional model shown in Figs. 7, 8 and 9.

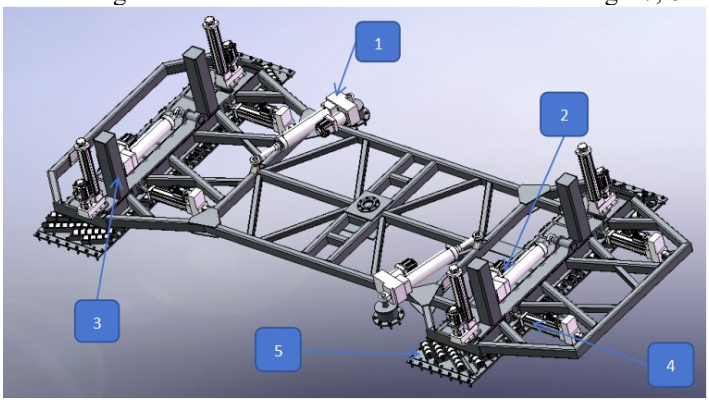

Fig. 7. Moving bracket for loading system(1.Main body angle rotation 2.Main body left/right movement 3.Main body left/right movement)

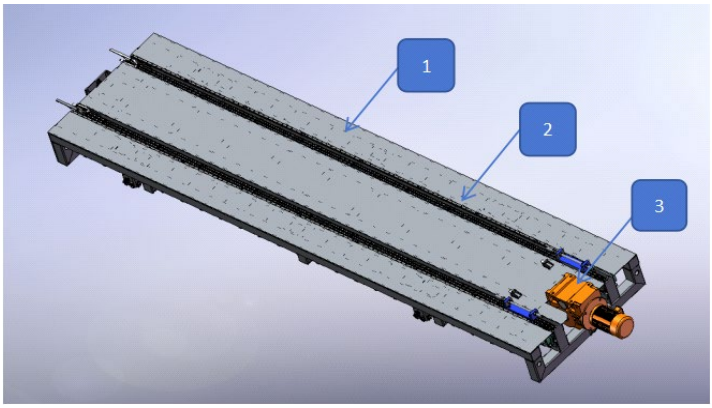

Fig. 8. Main structure of loading system1.Shelf 2.Pusher Drive Chain 3.Pusher Drive Chain

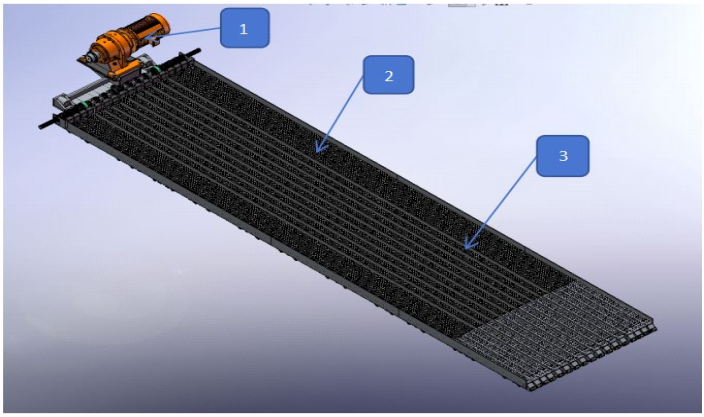

Fig. 9. Pusher plateMaterial Chain Conveyor Drives 2.Material chain conveyor 3.Pusher plate

3 Integral Propulsion Loading System Application Effect

3.1 Comparative Analysis of Loading Efficiency

Taking the cargo loading and transferring process of a beer production enterprise as an example, the traditional manual loading operation mode takes about 6-9 hours to load with a load capacity of 35 tons under the operation of 5-8 workers.Furthermore, loading efficiency is significantly affected by factors such as operational space constraints, loading duration, personnel proficiency, personnel coordination, and working environment [5-7].The loading efficiency of the overall propelled loading system mainly depends on the picking-palletizing efficiency of the palletizing robot and the number of single clamps. The Kawasaki 4-axis robot moves at of 300 rounds/hour, and the maximum loading capacity of the manipulator clamping is12,000L per hour, it takes about 3.5 hours to complete the loading task with load capacity of 35 tons.

The beer loading process of the overall propulsion loading system is shown in Figure 10.

Fig. 10. Operational process of practical application of integral propulsion loading system

3.2 Comparative Analysis of Economic Benefits

(1) Construction investment costs

The beer production enterprises, Adopting the procurement cost of other equipment of the overall propelled loading system is 350,000 yuan, and the total construction investment cost is 416,000 yuan, and the occupied site can be saved for 200m^2.

(2) Labor costs

According to the current market price of 30 yuan / t to pay labor costs [8], the annual labor costs of about 1 million yuan. Using the system, only one person can complete and the salary of 6500 yuan , the annual labor costs of 78,000 yuan.

operating cost

Costs of the two type system loading operation are shown in Table 1.

Table 1. Investment and operating costs of integral propulsion loading system vs. manual operation

sports event	manual work	Fully integrated propulsion loading system
Construction investment (million yuan)	19.80	41.60
Labor costs ($ million)	100	7.80
System maintenance costs ($ million)	0.20	0.50
Cost of energy consumption (million dollars)	5.54	16.63
add up the total	125.54	66.53

Note: Construction investment, equipment energy consumption and system maintenance costs are based on meeting a daily loading capacity of 100 tons

From Table 1, compared with the traditional manual operation, the overall propulsion loading system can save 92.20% of the labor costs, the traditional way of operation of a year's labor costs can be fully covered by the overall propulsion loading system of all construction costs and annual operating costs in total.

4 Conclusion

Comparative analysis of economic benefits can be seen from the results of the use of the overall propulsion loading system, the beer production enterprises of the vehicle transfer loading labor costs from the original 1 million yuan per year down to 78,000 yuan per year, the improvement of loading efficiency also saves the loading space, which can support the expansion of the enterprise's production capacity by three times under the premise of continuing the construction and application of the automated loading operation system.

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