Design and Application of Robotic Package Stacking for Train Loading in Ports

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Keywords: bulk grain, train loading, package stacking, robot, efficient.

Abstract. With the improvement of scientific and technological progress and production automation level, package stacking robot for train loading was quickly applied. In this paper, according to the work site of the actual demand, a new train loading system based on the robotic technologies was designed and put into use in the project application. Functions of bulk loading, weighing, bagging and stacking were combined in a bulk grain train delivery line. The operations showed that the new system could greatly increase the efficiency of train loading. The loading time for each carriage was reduced to 5minutes. The application of robotic package stacking for train loading firstly introduced a new operation process and will provide technical supports for the port unmanned intelligent operation in future.

Introduction

In the railway transportation of bulk grain such as soy bean and corn, the capacity of the train can't be made best use because of the limitation of carriage volume and material weight. The situation will not only cause loss for the cargo owner but also reduce the effective utilization of the railway transportation lines.

In order to solve the problem, the usual method is mainly consisted of two stages. The first stage is to fill the bulk cargo into the carriage, occupying 75% capacity of the carriage; the second stage is to load the bagged material into the carriage, reaching the rated load. Both workers and equipments are engaged in the bagged material loading process. The bagged materials are firstly lifted to the carriage and then are stacked by workers. The operation modes are divided into three aspects such as truck cranes, bridge cranes and car loaders combined with workers. The traditional mode could be used for solving the shortfall problem but it could cause series of problems, for example low efficiency, serious damage to the cargo and shortage of workers.

With the development of stacking robots, studies were carried out to improve the performance of robots [1]. Dynamics analysis and simulation method was introduced to the areas of stacking robots [2-4]. In the stacking robot, control was optimized in recent years [5]. In this paper, To meet demands of efficient energy-saving and environment friendly train-loading process and to break the bottleneck of the train-loading technology, a new robot assisted train-loading system was put forward in this paper. The system was carried out in the project and the performances were testified. The train loading system was designed based on the stacking robot. The performance was investigated in the engineering application. The comparisons of different train loading systems were summarized.

Design of the train package stacking system

With the expansion of production scale and automation level increasing, the flexibility and reliability of package-stacking robots are fast upgraded which greatly facilitated the application of the robots [6, 7]. Because the grasping technology and the modular design of the robots were slowly developed and the types of the train carriage are diverse, the application of stacking robots in the train loading area was not popular. In the year of 2013, a robotic package stacking system for train loading was designed by China Waterborne Transport Research Institute. The system was applied in the robotic stacking train

loading in the world in Rizhao Jurong Port Terminals with a annual handling capacity of 1.85 million tons. The system was firstly used in the bulk grain train transportation line combined functions such as shunting, loading，flattening and dispatching. The system could be used for bulk grain and bagged grain and be compatible for all-climate and modern flow production. Due to the new technology, traditional train loading process was upgraded. The time for each carriage loading was reduced to 5 minutes, which significantly increased the efficiency of train loading.

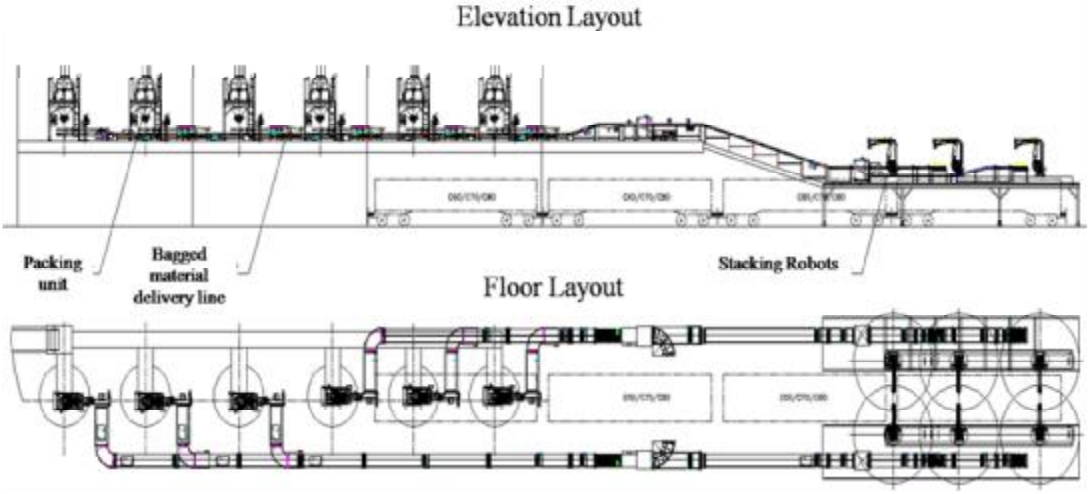

Figure 1 the structure of the robotic package-stacking for train loading system

The package stacking train loading system was consisted of three parts: the packing units, bagged material delivery lines and stacking robots as shown in Figure 1. The packing unit combined functions such as weighing, quantitative filling and bag sewing. The bulk grain in the upper silo was filled in the bags and the bags were put in the delivery line. Six dual-balance packing machines were arranged in the horizontal direction. The packing machine could fill 600 to 1200 bags per hour with weighing range from 50 to 100 kilogram.

The bagged material delivery line was composed of bag-inverting machines, parallel belt conveyors, turning belt conveyors, climbing belt conveyors, weighing machines, bag handling machines, material leakage conveyors, shunting belt conveyors and shaping machines. Before the bags were handled to the stacking robots, the sealed bags had to be delivered, inverted, converged, tested, shaped and shunted. In the converging process, differential speed conveying was adopted to guarantee the distance of adjacent bags.

The stacking robots were essential parts of the whole system. They could carry out the stacking operation for the bagged material in accordance with specific types of train carriage. Six stacking robots covered the whole working area. Each robot is responsible for a specific region according to the procedures. Intelligent control was applied to ensure the stacking process reasonable and orderly.

Figure 2 the workshop scenarios of robotic package-stacking

Characteristics of the train package stacking system

According to the storage process, the port bulk grain silo storage system could be divided to silo charging, storage and silo discharging. Limited by lifting technology, transfer space, bag transportation and system operation economy, Ability of silo discharging process is not as strong as that of silo charging. The unequal silo charging and discharging abilities obviously affected the turnover efficiency of silos.

Stacking train loading is an important way for the silo discharging process. The efficiency, energy consumption and economical efficiency have direct influence on the performance of the silo discharging system. So far the tradition train loading operation mode is the car loader combined with workers which restricts the efficiency of silo discharging. The robotic package stacking for train loading changed the traditional mode, greatly improving the efficiency and working environment of the port. There are several characteristics for the robotic package stacking of train loading system.

(1) Working environment was greatly improved and working region was made best use of.

Due to the robotic package stacking system for train loading, the stream line for bulk grain railway transportation was achieved. Before the system was put into use, the stacking process was undertaken by manpower and need enough space to facilitate the transport equipments and lifting equipments. The robotic package stacking system solved the key technologies for the bulk grain train loading stream line shown in Figure 3.

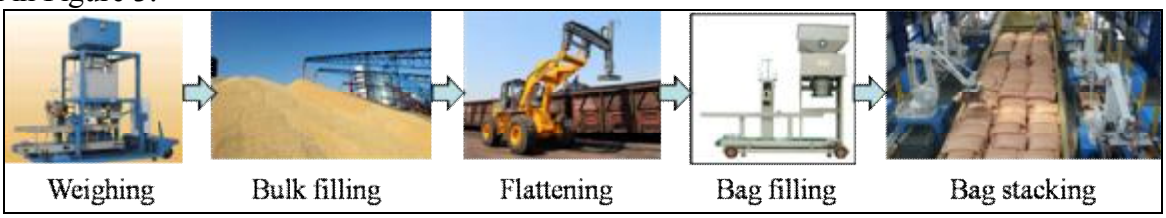

Figure 3 the flow chart of bulk grain train loading

The intelligent train loading line based on stacking robots provided seamless connections for train shunting, bulk grain loading and bagged grain loading to improve the automation level of train loading. All the machines and equipments were arranged in the train loading tower with a dimension of 105 meters in length and 10.5 meters in width. The layout made best use of the space of the port and narrowed the working region. Besides, the working environment could be greatly improved.

(2) The robotic package stacking train loading system ran automatically and automation of package stacking was greatly improved.

The robotic package stacking train loading system was controlled intelligently, achieving the automatic vehicle recognition. The intelligent control system could achieve functions such as vehicle recognition, start-stop waiting, system dispatching, and package stacking operation commanding. During the working process, the intelligent control system first identified the type of the train carriage and condition and then the related information was sent to the bulk grain transportation line. After assuring of the information, the system entered the train loading mode. In this mode, the robotic package stacking system and the bulk grain loading system cooperated with the train dispatching unit to finish the specific procedure. The train dispatching system is responsible for the train displacement and location. The bulk grain loading system could achieve the material weighing, loading and flattening, providing the stacking platform for the package stacking.

(3) The robotic package stacking train loading system provides chances for the bulk grain handling innovation.

The whole system is suitable in the area of the small bag stacking train loading for the entire carriage after the proposed bagged materials and bulk materials loading and related process optimization. In other words, if the bulk material was not needed, the system could be used for small bagged material stacking for train loading.

In future, after continuous optimization and improvement of the robotic package stacking train loading system, it can be used for the high added goods truck loading, directly changing the traditional truck loading process.

Technical and economic performance analysis for the package stacking

The aim for the intelligent train loading system is to realize the automatic train loading of bulk material and bagged material loading. This mode of train loading greatly improved the efficiency of port handling, solving the problems of the traditional port handling method such as low efficiency, complex production process and tedious production origination. Table 1 showed the technical and economic performance comparisons of different package stacking methods.

Table 1 Technical and economic performance of different package stacking

Index	Truck crane	Bridge crane	Train loader	Intelligent train loading system
Equipment configuration for each carriage	Tire truck crane with capacity of 25tons	Bridge crane with capacity of 10 tons	Continuous special train loader	Six robots
Operation time for each carriage	30～45min	20～30min	15～25min	5～10min
Manpower for package stacking	6～8 workers	6～8workers	2～3 workers	No workers
Construction expense for package stacking system	$ 80,800～120,000	$ 194,000～283,000	$ 162,000～242,000	$ 404,000～485,000
Energy consumption index for package stacking	8.1kg standard coal/1000 bags	5.8kg standard coal /1000 bags	4.0kg standard coal /1000 bags	2.8kg standard coal /1000 bags
Maintenance cost	High	High	Medium	Low

The bulk grain train loading transportation line was testified in the Rizhao Jurong Port practical operation. However, there is still optimization room for the robotic package stacking system for train loading in subsequent use and design. Some aspects need improving in future.

(1) It is better to apply the transfixion form for the railway line layout. This kind of arrangement helps to facilitate shunting. The empty carriages can be moved in and out from two ends where loading efficiency and transport volume can be further raised.

(2) In the engineering construction, the method of train traction needs improving. The end integral traction for the train is a better way for the frequent movement. In the end integral traction, hood hanging and releasing together with air duct is unnecessary, thus time for the carriage preparation is reduced and efficiency is improved.

(3) Further research, for example the multi-unit highly efficient auto packing line and intelligent manipulator on operation mode and adaptability, intelligent manipulator curve optimization and layout optimization of operation line, can be greatly enhance the application of intelligent train loading system.

Conclusions

In this paper, based on the essential technology of the robotic package stacking system, an automatic train loading production line with functions of bulk material loading, weighing and package stacking was designed and put into use in the project engineering. Compared to the traditional train loading line, on one hand, this new system could provide more efficient, energy-saving, environment-friendly and economical solution train loading line. On the other hand, the operation lines and production processes

are different from the traditional train loading line. As technologies of the robotic package stacking system develops, the new system will enlarge related applications in the bulk grain train loading area, raising the automation level of grain storage and transportation. In future, with the development of vehicle recognition, locating and working region locating technologies, the robotic package stacking system can be used for bulk material truck loading, entirely enhancing the technical level of bagged material loading.

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