Analysis of Bulk-to-Container Conversion Processes and Equipment Applied in Multimodal Transport

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Abstract

By analyzing and summarizing various application cases of bulk-to-container conversion, this paper clarifies its promoting effect on the growth of container throughput and the development of multimodal transport. On the basis of systematically summarizing the development and evolution of bulk-to-container conversion processes and equipment, the basic technical requirements for bulk-to-container conversion operations are summarized, the advantages and applicable scenarios of different equipment and processes are analyzed, and the future development direction of bulk-to-container conversion operations oriented to multimodal transport is proposed.

Keywords

Multimodal transport, bulk-to-container conversion, container transshipment, technical requirements.

1. Introduction

In 2023, five competent departments including the Ministry of Transport jointly issued the *Action Plan for Promoting the High-Quality Development of Rail-Water Intermodal Transport (2023-2025)*, which proposed to actively promote the bulk-to-container conversion of bulk such as grain, chemical fertilizer, copper concentrate, bauxite, cement clinker, and coal. Port supervision authorities in most provinces and municipalities of China have continuously accelerated the implementation of the bulk-to-container conversion strategy in the container transport industry. By adopting containerized transport for bulk and breakbulk cargo, the time required for cargo gathering at ports has been shortened, the efficiency of logistics transport has been improved, and the operating costs of logistics enterprises have been reduced. Meanwhile, the expansion of bulk-to-container business has led to a significant growth in container throughput and the transport efficiency of specific cargo types [1].

Weifang Port of Shandong Port Group has expanded containerized transport for more than ten types of cargo, including petroleum coke, soda ash, and crude salt, through bulk-to-container conversion, achieving a year-on-year increase of 550% in its monthly container throughput. Rizhao Port of Shandong Port Group focuses its bulk-to-container business on grain, coal coke, iron ore, and other commodities, and its fully automatic bulk-to-container operation system for coke is the first of its kind in China. Fuzhou Port has developed bulk-to-container operations for more than ten types of cargo sources, such as limestone, high-carbon ferrochrome, and quartz sand. In the third quarter of 2023, the throughput of loaded containers for bulk-to-container conversion reached 11,541 TEU, a year-on-year surge of 512%. Nansha Grain General Terminal Company of Guangzhou Port focuses on the bulk-to-container conversion of grain. In October 2024, its monthly grain container loading volume increased by 158% year-on-year, setting a new single-month record. As a national demonstration project for integrated water-road-rail multimodal transport, Shuifu Port in Yunnan has significantly reduced the transport cost of bulk commodities such as phosphate ore by adopting the "bulk-to-container conversion + rail-water intermodal transport" model. Its cargo throughput and container operation volume

have increased year by year, making it an important logistics node in the upper reaches of the Yangtze River.

It is evident that bulk-to-container conversion plays a crucial role in port multimodal transport and has achieved remarkable results in promoting the growth of port container throughput. Meanwhile, statistics from the China Container Industry Association show that bulk commodities account for more than 70% of the total railway freight volume in China, while the overall proportion of bulk-to-container conversion for railway bulk commodities is less than 10%. Therefore, bulk-to-container conversion is expected to become the main growth driver of China's domestic container market, which also indicates that the technologies and equipment related to bulk-to-container conversion will continue to play an important supporting role in advancing the high-quality development of multimodal transport.

2. Bulk-to-Container Conversion Technology and Equipment

Bulk-to-Container Conversion refers to a transportation mode that transforms the traditional bulk transportation pattern for bulk cargo and breakbulk cargo, by loading such cargo into standard containers for shipment. This mode fully leverages the advantages of containerized transportation, including minimal cargo damage, low pollution, and high loading/unloading efficiency. By virtue of the mature container transportation system and the strengths of multimodal transport in terms of cost, efficiency, environmental protection, reliability, and management, it enables low-cost, efficient, and convenient transportation of bulk goods. In terms of cargo sources for bulk-to-container conversion, dry bulk commodities dominate, such as bulk grain, coke, chemical fertilizers, ores, and sand and gravel aggregates [2, 3].

It is generally accepted that the longer the transportation distance, the lower the unit cost. In terms of ocean freight alone, bulk carrier transportation is slightly cheaper than container transportation, presenting a minor cost advantage. However, when considering the subsequent storage, transportation, and distribution processes, as well as the occupation and utilization efficiency of terminal resources, from the perspective of the entire logistics chain, the overall cost borne by cargo owners is actually higher. Taking into account comprehensive logistics costs and port service transformation, foreign ports adopted bulk cargo containerization at an earlier stage.

2.1. Bulk-to-Container Conversion Processes

Direct loading and container pit loading were the most prevalent methods for inland grain container stuffing. While low in cost, they had prominent drawbacks: extremely low operational efficiency, underutilized container capacity, and high labor intensity. Hence, these methods are gradually being phased out by alternative processes.

2.1.1. Loading Tower Process

Through continuous research and process improvement, Dalian Port developed a special truck operation process for bulk grain container loading. By deploying 8 special trucks for bulk grain container loading and purchasing supporting lifting equipment such as bucket elevator, belt conveyors and hopper tower, the vertical tower loading process greatly improved the loading efficiency, with an average rate of 7-8TEU/h, and effectively solved the problem of insufficient loading capacity.

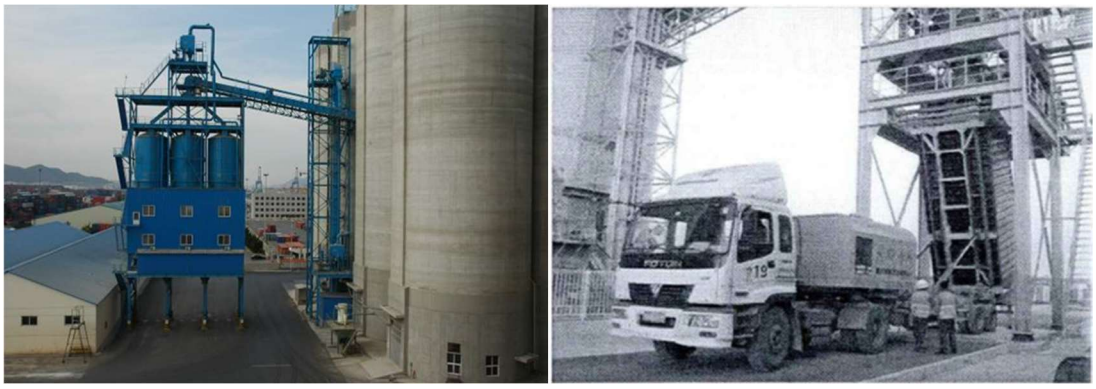


Fig. 1 Loading tower process

The advantages of the loading tower loading process lie in its combination of the characteristics of traditional bulk grain transportation and container transportation. It addresses several challenges in container loading, while improving loading efficiency, enabling the efficient completion of bulk grain loading and unloading processes within containers. It achieves a high degree of automation, reducing the demand for labor. However, its disadvantages include high capital investment and operational costs. Additionally, the large drop height increases material breakage, making it difficult to guarantee the quality of grain.

2.1.2. Automated Bulk-to-Container Conversion Process

Rizhao Port of Shandong Port Group is the largest shipment port for coke bulk cargo and container transportation in China, with an annual waterborne volume of coke exceeding 13 million tons. Previously, the bulk-to-container conversion operations for coke were conducted in an open-air manner, which suffered from issues such as increased cargo fines, significant environmental pressure, and potential safety hazards caused by human-machine intersection. To address these problems, a new "bulk-to-container conversion" process system featuring "process-oriented, modular, intelligent, and green" characteristics was newly designed. This system has achieved new breakthroughs in strengthening dust suppression during operations, reducing cargo breakage, improving loading efficiency, and enhancing automation levels [4].

Fig. 2 Automated bulk-to-container conversion process

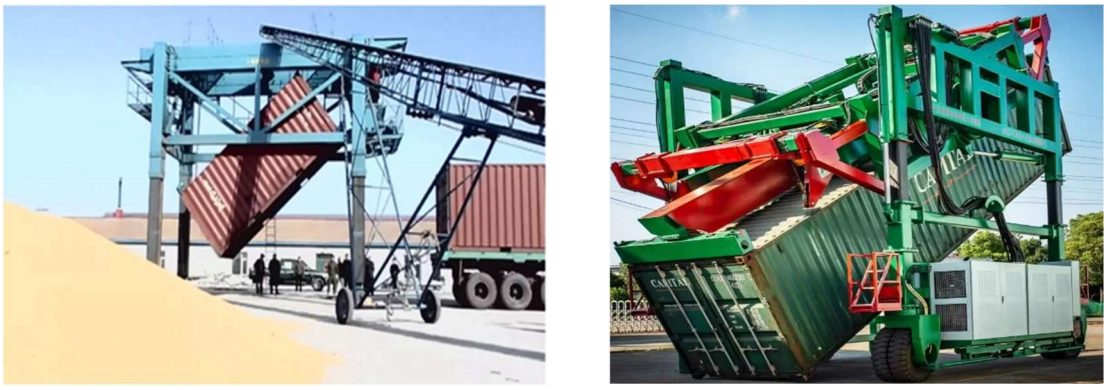
The system mainly consists of five system modules: unloading, stacking, reclaiming, container loading, and horizontal transportation. It encompasses closed operation areas including a 360-meter-long, 75-meter-wide process greenhouse, strip silos, an automatic unloading and dust removal room, and underground corridors. The annual designed operation capacity reaches up to 160,000 TEUs. It can reduce the coke breakage rate by 6%, cut costs by 60 RMB per ton for customers, and achieve a dust suppression rate as high as 97%.

2.2. Bulk-to-Container Conversion Equipment

2.2.1. Container Gantry Tilting Machine

The container gantry tilting machine is a special lifting equipment specifically designed for bulk cargo conveying with containers, integrating lifting and tilting functions. It can effectively reduce the packaging cost of bulk cargo transportation, meeting various requirements of bulk grain transportation such as full-process mechanization, low breakage and spillage rate, stable schedule, and no need for ship waiting for small-batch transportation.

This equipment integrates three core functions including flexible equipment transportation, container hoisting and container tilting, which can fully satisfy the inland bulk cargo container loading demands. Without the support of auxiliary hoisting equipment, its outriggers can be retracted for direct transportation via standard container trailers, enabling convenient container loading operations at multiple working sites. It can substitute reach stackers to complete container hoisting work and cut down the procurement cost of high-price equipment. Combined with the hoisting function, the tilting function can realize 90° container tilting without auxiliary facilities, and bulk cargo can be directly loaded into containers through belt conveyors [5].



(a) mounted gantry tilting machine (b) movable gantry tilting machine

Fig. 3 Container gantry tilting machine

2.2.2. Versatile container Tilting Machine

(a) single-station equipment (b) double-station equipment

Fig. 4 Versatile container Tilting Machine

This equipment is available in two working models: single-station and double-station. For the single -station equipment, it lifts and tilts containers in situ, and therefor occupies a smaller site, comparable to the width of a single lane, can be easily moved with a forklift. For the double-station equipment, after picking up the container, it moves horizontally to tilt the container, and after loading, it moves horizontally to return the container.

2.2.3. Integrated Bulk-to-Container Conversion Machine

Reach stackers are commonly used for container handling. By developing the container tilting function on this basis, they can realize container loading/unloading onto vehicles, short-distance handling, stacking, and tilting loading/unloading operations, making them a multi-functional integrated machine particularly suitable for "bulk-to-container and container-to-bulk" operations.

Fig. 5 Integrated bulk-to-container conversion machine

The common feature of such equipment is that a single machine can tilt the empty container to a certain angle for bulk loading, and move the full container to the container truck, which doesn't require the cooperation of truck movement or handling machinery. Therefore, reducing operation steps, reducing supporting machinery, avoiding transfer, developing new equipment integrating multiple functions, and using a single machine to complete the above multiple actions of bulk-to-container conversion, is an obvious direction for equipment improvement and process optimization.

3. Comparative of Bulk-to-Container Conversion Modes

Table 1. Bulk-to-Container conversion modes comparing

Numble	Modes	Technical Characteristics	Applicable Scenarios
1	Direct Loading Process	Low cost, simple operation, but serious dust pollution, low filling rate, low loading efficiency, high labor intensity	Suitable for various materials
2	Loading Tower Process	High initial investment, high loading efficiency, conducive to automated operation and dust control	Suitable for large-batch single bulk cargo operations, requiring conveying processes support
3	Automated Bulk-to-Container Conversion Process	Realizes the full-process automation of unloading, stacking, reclaiming, container loading and horizontal transportation	Suitable for large-batch bulk cargo, especially for high environmental protection requirements
4	Automated Container Gantry Tilting Machine	Integrates lifting and tilting, compact structure, convenient for road transportation	Suitable for small-scale container loading operations of different materials
5	Versatile Container Tilting Machine	Low cost, simple operation, small size, light weight, convenient for mobile transfer	Suitable for different cargo types, can be used alone or in conjunction process flows
6	Integrated Bulk-to-Container Conversion Machine	Integrates container tilting and handling with good mobility	Suitable for small-scale container loading operations of different materials and in different scenarios

The primary requirement of bulk-to-container conversion operations is to facilitate efficient and direct loading, and to realize the tilting of the container through different measures. Operational safety covers two main aspects. For containers, pressure and loading capacity must be properly controlled to keep containers intact [6]. For on-site staff safety, personnel shall be kept away from operating areas as much as possible during work. Remote-assisted operation measures should be applied in core working procedures to effectively ensure overall operational safety. Pollution control is also very important. During the unloading and container loading process of bulk materials, dust escape will occur, and necessary dust removal measures should be taken for control. The characteristics and applicable scenarios of different operation modes and equipment are compared below.

4. Summary

Currently, the application of bulk-to-container conversion is not confined to ports but also widely adopted in railway yards, logistics parks, warehouses, and storage yards, fully exerting its supporting role in promoting the growth of container throughput and leveraging the advantages of multimodal transport. China's multimodal transport is in a stage of high-quality development driven by policy guidance, technological empowerment, and industrial coordination, forming a development pattern of "closed-loop policy support, improved infrastructure, technological innovation-driven, and regional coordinated promotion". It has become an important pillar for reducing the overall social logistics cost, constructing a unified national market, and smoothing the circulation of the real economy, while also providing broad application scenarios for the processes and equipment of bulk-to-container conversion.

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