Research on scheduling of synchronized handling operation of Railway Container Terminals

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Abstract. As an important node of container transportation, the handling efficiency of railway container terminals has a direct impact on the capacity and efficiency of transportation process. In this paper, orbital container gantry crane’s scheduling optimization problem is studied. By research the operation characteristics of gantry crane, considering various constraints, and aiming at the shortest total handling time, an optimization model of synchronous handling operation scheduling is established for improve the efficiency of handling operation at the railway container terminals.

1. Introduction

Container transportation has developed rapidly around the world in recent years. In order to ensure the seamless integration of international and domestic trade, China is also focusing on the development of container transportation. In particular, with the publication of the strategy “The belt and road”, container transportation, which is one of the important modes of transportation for multimodal transport, has become the main development direction of railway freight traffic and modern logistics.

Since the railway freight reform in 2013, container transportation has become an important way for railway transport enterprises to transform into modern logistics and accelerate market-oriented reforms. By expanding the types of container cargo, increasing number of railway container terminals nationwide and creating “China Railway Express” brand and other initiatives to promote the rapid growth of container traffic has become a new bright spot in the development of railway freight traffic. In 2017, the national railway container delivery volume was 10.29 million TEUs, an increase of 37% over the previous year; a total of 3673 CR Express trains are ran over, exceeding the sum of the previous 6 years. With the gradual expansion of the container transportation network coverage and service area, China's railway container transportation has achieved rapid development, and container transportation volume has increased year by year.

There are many scholars have conducted in-depth research on its transportation organization, network planning, network node design, and container port resource scheduling since the emergence of container transportation. Said ENA et al. proposed an optimization method for solving container loading problems by using genetic algorithm, and applied the method to Port-said port of Egypt. The calculation and analysis showed that the container service time of the container terminal (loading or unloading) reduced by 56% [1]. Dotoli et al. proposed a scheme for container yard operation scheduling, which is based on container allocation and freight train composition of the freight yard, and maximizes the available space while considering several constraints [2]. Guo et al. focused on the scheduling problem of railway container cranes. Considering the influencing factors of crane operation time such as safety distance, travel time and interference, a mixed integer programming model was established [3]. Wang Li takes the key resources of the railway container terminals as the research object, defines the
key resources of the railway container terminals, and constructs the key resource scheduling optimization system. For the single loading, single unloading, mixed handling of various conditions, the model with the shortest working time as the objective function [4].

Through the domestic and international research review of the container port station, it can be known that in the research on the handling operation scheduling of the container terminal covers the single loading/unloading modes and mixed handing modes, but there is still a lack of research on the synchronous operation of handing.

In this paper, the crane used in railway container terminal is taken as the research object, and the scheduling optimization problem is studied with the focus on the handling synchronous operation mode. On the basis of the railway container terminals handling operation optimization system, the paper focuses on the multi-line handling synchronous operation scheduling problem, and establishes the handling synchronous operation scheduling optimization model with the shortest handling operation time.

2. Problem formulation

The operation process of the orbital container gantry crane moves the one container from one position to another, and the collection of multiple moving processes is a door handing operation plan. The optimization problem of the crane scheduling is to optimize the operation sequence of the door crane. Because the starting and ending positions are determined for the movement of a single container, the working time and running distance of the door hanger are also determined. Therefore, the research focus of this problem is the connection of the crane in the two effective movement processes.

According to the vertical working range of the orbital container gantry crane (the latter is called crane for short), the number of handling lines, and the type of handling operations, the handling operation mode of the railway container terminals can be divided into the following three cases.

2.1. Scheduling mode of single-loading or single-unloading

In the single-load scheduling mode, the cranes only perform loading or unloading operations during the work. The handling is two sets of procedures. When the uninstall operation is complete, the wrapper operation can be performed and vice versa. In this mode, there is a no-load operation after each heavy-duty operation, so the efficiency of the crane is low.

![Figure 1. Schematic diagram of single loading.](image)

2.2. Scheduling mode of hybrid handling

In the hybrid handling mode, the cranes carry out the loading and unloading operations at the same time, but two operations are respectively for different handling lines; for a certain handling line, only loading or unloading operations exist. Otherwise, there are both loading and unloading operations, but there is no intersection between container positions that related to two operations. In this mode, the crane can continue to pack the same loading line or unload the other loading lines after one loading operation.
2.3. Scheduling mode of synchronous handling
In the synchronous scheduling mode, the cranes simultaneously perform loading and unloading operations. The order of the two operations can be cross-over as needed. And one or more container positions on the handling line involve two operations. In this mode, the crane can continue to pack or unload the same loading and unloading line after one loading operation.

3. Scheduling model and algorithm of synchronous handing
The handing operation of the container crane is the process of loading or unloading one container from one working position to another, and the starting and ending point of the moving process is two container’s working positions. In order to describe the movement process and moving distance between the two container’s working positions of the crane, this paper assumes that the position of each wagon corresponds to the bay position of the yard when the train stops, and the working position of the yard and handing line is arranged in rows and columns. The reference is represented by two-dimensional coordinates, and the geometric center point of the work position is taken as the corresponding point of the two-bit coordinate, and the movement of the container between the two work positions is expressed as the movement between the two points.

3.1. Assumptions
Assume that the handling process meets the following conditions:
(1) All the containers operated during handling belong to the same container type, and the track door crane moves each container at a uniform speed;
(2) The track door crane can only operate one container at a time during the operation;
(3) Each handling line is a single-layer container train;
(4) From the beginning to the end of the handling task, the position of each container is no longer
adjusted, and the coordinates of the starting and ending working positions have been determined;
(5) The track door crane adopts a fixed range operation mode, and only one door crane operation is
performed at a time in the fixed range;
(6) No need to re-adjust container position during the handling process.

3.2. Objective function and constraints

(1) Objective function.

The objective function of the model is that the end time of the total handling operation of the container
 crane is the smallest, that is, the time taken to complete the work is the shortest. Because the working
time of each individual container is determined, the minimum total working time required is the same
as the shortest running time between the two jobs.

(2) Restrictions

The scheduling optimization model is subject to the following constraints:

The end time of the total handling task of the crane is equal to the sum of the empty running time
of the crane and the time of completing the loading/unloading operation of each container plus the
start time of the total task.

The loading/unloading operation time of one container is equal to the moving time of the crane
between the corresponding starting position and the ending position of the container.

For a working position of container where both the loading operation and the unloading operation
exist, the container at the position must be unloaded before the other container can be loaded. The
corresponding handling operations have the following constraints: the start time of follow-up loading
operation of the container should be later than the end of the subsequent unloading operation of the
container plus the moving time between the ending position of last container and the starting position
of the next container.

The start time of the subsequent loading/unloading operation should be later than the end time of
the pre-loading/unloading operation plus the empty running time of the track between the two single
tasks. Crane has only one pre-operation operation for each loading/unloading operation; crane has only
one follow-up operation for each loading/unloading operation, both of which are to ensure the crane
handling only one container at a time.

3.3. Algorithm

When the model is built, the starting and ending positions of the containers involved in the handing
process are represented by two-dimensional coordinates, and the movement between the different
working positions during the operation of the track door is simplified as the crane moves between two
points. According to the assumption of the model, the crane is running at the uniform speed, the
shortest objective function time is converted into the minimum horizontal movement distance of the
 crane when solving the multi-job synchronous handing scheduling problem, and the greedy algorithm
is designed. The optimization model is solved to obtain an optimal loading and unloading sequence, so
that the total loading and unloading time is the shortest. The flow chart of the algorithm is shown in
Figure 4.
4. Conclusion
By comparing the characteristics of various handling scheduling methods of the orbital container gantry crane, the handling synchronous scheduling mode is proposed as the optimal mode. The article establishes a synchronous handing scheduling model and designs the algorithm to solve it, and the results verify the optimality of the synchronization mode. This mode improves the handling efficiency of the railway container terminals, thus ensuring the reliability of the entire container transportation system. Provide an operational reference for the railway container terminals.

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References
[1] Said ENA, El-Horbaty ESM. An Optimization Methodology for Container Handling Using Genetic Algorithm [J]. Procedia Computer Science, 65(2015):662-671.
[2] Dotoli M, Epicoco N, Falagario M, et al. Optimization of intermodal rail-road freight transport terminals[C]. Robotics and Automation (ICRA), 2014 IEEE International Conference on. IEEE, (2014) 1971-1976.
[3] Guo P, Cheng W.M, Zhang Z.Q, Zhang M and Liang J. Gantry Crane Scheduling with Interference Constraints in Railway Container Terminals [J]. International Journal of Computational Intelligence Systems, 6 (2013) 2: 244-260.
[4] WANG Li. Key Resources Scheduling Optimization Theory and Method of Railway Container Terminal [D]. Beijing Jiaotong University, (2014).
[5] TANG Liansheng, GUO Peng. Study of loading/unloading equipment optimization scheduling in railway container terminal [J]. Computer Engineering and Applications, 2(2012):211-214.
[6] WANG Li, ZHU Xiao-ning, YAN Wei, XIE Zheng-yu. Optimization Model and Algorithm of Rail Mounted Gantry Crane Scheduling at Railway Container Terminals [J]. Journal of the China railway Society, 5(2014):8-13.