Technological Analysis of Automatic Container Terminal  
Automated Guided Vehicle and Intelligent Guided Vehicle  

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Abstract. Generally, an automated container terminal is divided into three operating areas: wharf apron operating area, horizontal transportation operating area and container yard operating area. Because of the complexity of working conditions, the automation of horizontal transportation area is more difficult than the other two. It is one of the key factors affecting the operation efficiency, total investment, operating cost, environmental safety and handling capacity of automated terminals, and it is also the difficult problem of the automated container terminal process system comparison and selection. This paper will analyze and prospect two important horizontal transport machineries in automated container terminal, and technical suggestions are put forward for constructing automated container terminal and upgrading traditional container terminal.  

Key words: Automatic; Container Terminal; Automated Guided Vehicle; Intelligent Guided Vehicle; AGV; IGV.  

1. Introduction  
In recent years, the process of economic globalization has been accelerating. The total volume of goods in international trade has been increasing rapidly, and both container terminals and shipping enterprises are under a great deal of pressure. Automated container terminal can significantly reduce the labor cost of loading and unloading, improve the loading efficiency and reduce the risk of terminal operation. Therefore, many container terminal began to transform to semi-automatic and fully-automatic.  

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At present, horizontal transport equipment of fully-automatic container terminal in operation almost select automated guided vehicle (AGV). With the successful development and application of auto straddle carrier (ASC), intelligent container truck (ICT) and intelligent guided vehicle (IGV), horizontal transport equipment of automatic container terminal gradually divide.  

This study focus on power supply method, navigation and positioning method and matching coupling method of AGV and IGV to analyze and prospect.
2. Power Supply Method
Lithium battery is the preferred power supply mode for equipment. There are various charging methods, such as trolley conductor designated area charging, trolley conductor opportunity charging and Charging station.

2.1. Charging in Trolley Conductor Designated Area
Battery pack automatic charging in trolley conductor designated area is shown in Figure 1. This method is characterized by simple structure.

![Figure 1. Charging in Trolley Conductor Designated Area](image1)

2.2. Trolley Conductor Opportunity Charging
The equipment runs to the loading area under the rail mounted container gantry crane, and starts charging when arrive the container handling position. When finished loading, the charging is completed. The amount of charge is enough to the equipment for a working cycle. This method will reduce the battery configuration, reduce the weight of the equipment, and reduce energy consumption, as shown in Figure 2.

![Figure 2. Trolley Conductor Opportunity Charging](image2)

2.3. Charging Station
Charging in charging station means replace the battery of equipment. It is required that the battery should provide the energy to keep the equipment running for 8 hours. Therefore Lithium battery pack needs to be equipped with large capacity, at the same time the weight of equipment has also increased, as shown in Figure 3.

![Figure 3. Charging Station](image3)
In the future, with the development of wireless charging technology, wireless charging may become the main choice of AGV charging.

3. Navigation and Positioning Method
The biggest difference between AGV and IGV is navigation and positioning method. Navigation and positioning method of AGV is “magnets + sensor”, and navigation and positioning method of IGV is “satellite + intelligent sensor”.

3.1. Navigation and Positioning Method of AGV
Navigation and Positioning techniques of AGV include dead reckoning and absolute position correction. The hardware mainly includes radio frequency identification antenna, positional magnet, inertial measurement unit and encoder.

   Dead reckoning is to calculate the current position and motion state of the equipment based on the data collected by gyroscopes, speed encoders and corner encoders under the condition that the initial position of the equipment is known. Dead reckoning can quickly calculate the position of the equipment, and the calculated position has a high accuracy in a short time. However, because dead reckoning is solved based on velocity integral, its cumulative error is proportional to time, that is, the longer time passes from the initial position, the greater cumulative error of dead reckoning will be. In order to eliminate the cumulative error, an absolute position reference point should be set for position correction.

   Absolute position correction is achieved by radio frequency identification antenna and positional magnet (Figure 4). Radio frequency identification antenna is installed in the front and rear sides of the equipment, and the positional magnets are buried underground in a grid layout. When AGV passes the positional magnet, the radio frequency identification antenna reads the number of the positional magnet and its absolute position in the antenna coordinate system. The absolute position of the yard coordinate system is obtained by coordinate transformation, so as to eliminate the cumulative error caused by dead reckoning.

![Figure 4. Positional Magnet of AGV](image)

3.2. Navigation and Positioning Method of IGV
With the rapid development of automatic driving, satellite navigation and 5G communication technology, intelligent guided vehicles without positional magnet are developing rapidly.

   In the complex environment of the port, it requires 24-hour operation, which puts forward high requirements on the reliability and stability of the positioning service. It is difficult to achieve reliable and stable effect by using a single navigation method. With the development of navigation technology, it is a new choice to use navigation technology in the horizontal transportation equipment of automatic container terminals.

   As a kind of widely used and independent navigation system, inertial navigation system and satellite positioning system can complement advantages. At the same time, the fusion of other sensors can greatly improve the stability and accuracy of navigation and positioning.

   In addition, the selection of 5G communication and using 4G communication for dual network redundancy can not only effectively guarantee the wireless communication between the equipment and management system, but also effectively improve the navigation and positioning accuracy of the equipment. IGV with satellite positioning system and inertial navigation system is shown in Figure 5.
4. Matching Coupling Method

When loading, the equipment have to wait for the arrival of quayside container crane spreader, or the quayside container crane spreader have to wait for the arrival of the horizontal transport equipment. Reasonable matching and coupling between them is one of the difficulties that affect the operation efficiency of automatic container terminals.

At present, AGV Companion (movable support, Figure 6) and L-AGV support (fixed support, Figure 7) installed on the ground of crane exchange area have neatly solved the matching coupling problem.

5. Trend Analysis

As the most mature equipment of automatic container terminal horizontal transportation equipment, AGV has a certain market demand for the expansion of automated container terminal. However, because of its navigation and positioning method, there is a higher investment of purchasing equipment and civil engineering.

Selecting and using IGV, the existing process layout does not need to make any changes. With the rapid development of automatic driving, satellite navigation and 5G communication technology, application of IGV in building new automatic container terminal and upgrading traditional container terminal has broad prospects.

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