Launch Vehicle Assembly Material Delivery Method

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Abstract: To address the current issues of high demand for personnel and low efficiency in the delivery of materials for launch vehicle assembly, and to improve the accuracy of material delivery and the timeliness of material information statistics, this paper proposes a method for the delivery of assembly materials for launch vehicles. This method adopts the "Automated Guided Vehicle (AGV)+Intelligent Management Scheduling System" approach, transforming the traditional manual receipt and delivery into a combination of AGV delivery and receipt terminals. Through the intelligent management scheduling system, it is possible to achieve the collection, management, tracking, and control of full-process material information. This method can effectively enhance production delivery efficiency, reduce the rate of material distribution errors, and improve the timeliness of information statistics.

Keywords: Assembly; Intelligent Scheduling System; AGV; Material Delivery; Route Planning

1. Background and Current Situation Analysis

Currently, the main method of delivering materials for the assembly of launch vehicles involves assembly scheduling personnel who, based on the assembly cycle plan and combined with production progress information, submit support applications. The material delivery department then sends the assembly materials to the production site according to the station support table. The current method of assembly material delivery primarily involves manual receipt, counting, and distribution of assembly materials, with workshop logistics managers responsible for sub-packaging components and entering support information based on production support. This is followed by scheduling personnel notifying operators to pick up and store the materials at the respective operation stations.

The current method of material delivery requires significant manual intervention and has several disadvantages: (1) It is inefficient, wastes human resources, and affects the progress of the assembly cycle[1]; (2) There are many types of materials in large quantities and the processes are complex, leading to a high error rate in manual material distribution; (3) Material support timing is unified, resulting in a dramatic increase in workload in a short time, which leads to poor timeliness and accuracy of material inventory and product shortages. This, in turn, prevents the scheduling system from adjusting the production plan based on accurate inventory information, ultimately causing a lack of continuity in on-site production.

With the increase in the number of tasks for new-generation launch vehicle models, to address the drawbacks of manual material distribution, this paper proposes a method for the delivery of assembly materials for launch vehicles.

2. Detailed Description of the Material Delivery Method

The method proposed in this paper aims to address three issues: low efficiency in manual delivery, high error rates, and poor timeliness. This method adopts the "Automated Guided Vehicle (AGV) + Intelligent Management Scheduling System" approach for material delivery management. AGVs transport sorted materials to the assembly area along a predefined route, where workers complete the receipt through feedback to the intelligent warehousing management system via terminals. The intelligent management scheduling system can perform real-time statistical processing based on the equipment and worker feedback. Covering the entire process from material receipt, storage, process support, to inventory and dispatch (such as inventory sorting, shortage statistics, etc.), the intelligent management scheduling system tracks all material information, ensuring timely data statistics of material inflows and outflows. Moreover, the system shifts from manual entry of product information to device-reliant input, reducing the workload of personnel while effectively lowering the rate of data entry errors. This not only enhances the efficiency of product circulation but also improves the accuracy of information flow[2-4].

2.1 Composition of the Delivery Method

The launch vehicle assembly pulsating production line requires a wide variety of materials in large quantities, each differing in volume, shape, material, weight, and protective requirements. To accommodate these variations, this method utilizes a "pallet + material box + turnover rack" format to standardize the material delivery process, using "AGV + turnover rack" to automate the turnover of materials of different specifications. The material delivery scheduling system primarily consists of the following functions:

1) Pallet, material box, turnover rack, and RFID technology optimize material management

To ensure materials always meet production needs and that inventory levels meet planned storage volumes, this method uses customized pallet boxes in the sorting phase to complete the assembly and sorting of instruments and standard components. Pallets can be designed with grooves to fit the dimensions of the stored materials, allowing for fixed placement and positioning of materials on the pallet, as well as the packaging of materials on the same pallet; a material box can hold one or more pallets. For standard component materials, multiple pallets can be stacked in one material box to facilitate the packaging of multiple pallets, with the material box then being stored in inventory. During material delivery, warehouse managers uniformly access and place multiple material boxes on the same turnover rack for transportation. Depending on assembly space requirements, multiple turnover racks are used to deliver materials to the appropriate locations. This "pallet + material box + turnover rack" format not only meets assembly requirements but also saves time during on-site assembly.

RFID (Radio Frequency Identification) is a non-contact, non-visual automatic identification technology that identifies target objects and collects relevant data through radio frequency signals without manual intervention, showing great potential in aerospace, logistics, equipment, and other areas of intelligent warehousing and inventory management[5,6]. This method employs RFID tag technology to assign material codes[7] to materials themselves, enabling real-time identification and tracking of material trajectories and driving both operations and data. The introduction of RFID tag technology is a key component in the automation of material management.

2) Automated material storage and retrieval

CTU robots are devices specifically designed to improve operational efficiency in warehouses and logistics centers, particularly suitable for high-density storage and narrow aisle operations. While enhancing picking efficiency, they also ensure the safe storage of materials, ultimately achieving precise storage. To maximize the automation of material turnover and free up labor on a cost-saving basis, the material delivery method proposed in this article aims to implement unmanned operations in all aspects of material management. The use of CTU intelligent picking robots enables automated storage and retrieval of materials, and in conjunction with multi-layer material storage racks, it maximizes space utilization while achieving three-dimensional storage and management of materials.

3) Precision Logistics Delivery

Automated Guided Vehicles (AGV) serve as important logistics transport equipment in smart workshops and logistics systems and have been widely applied[8]. To enhance the material delivery capability of AGVs, this method equips material AGVs with a dedicated management platform to achieve automated driving and scheduling of the material delivery AGVs. It can also monitor the operation of the AGVs themselves, managing and controlling the AGVs safely in real-time if the equipment malfunctions or requires an alarm. Additionally, AGVs can convey commands through system-driven and manual calling methods[9], and they can precisely locate the materials needed for delivery and the stations awaiting delivery, thus ensuring high-quality material delivery[10,11].

4) Line-side Material Buffer Area

In the planning of this method, a line-side buffer area is used as a link between material delivery and assembly. The materials parked in the production line's line-side buffer area are determined based on the production tasks scheduled for that day. The scheduling system plans in advance the materials needed for that day, and AGVs deliver the materials required for each assembly station to the line-side buffer area for temporary storage. The line-side buffer area temporarily stores materials using delivery turnover racks. When assembly work is to be initiated, the operators in the line-side buffer area identify and retrieve the delivery turnover racks, and then push them to the work area for assembly. The line-side buffer area effectively prevents the waste of space and time-consuming searches caused by the excessive piling up of materials on-site.

2.2 Material Delivery Process

As shown below, the launch vehicle assembly material delivery method is depicted in Figure 1:

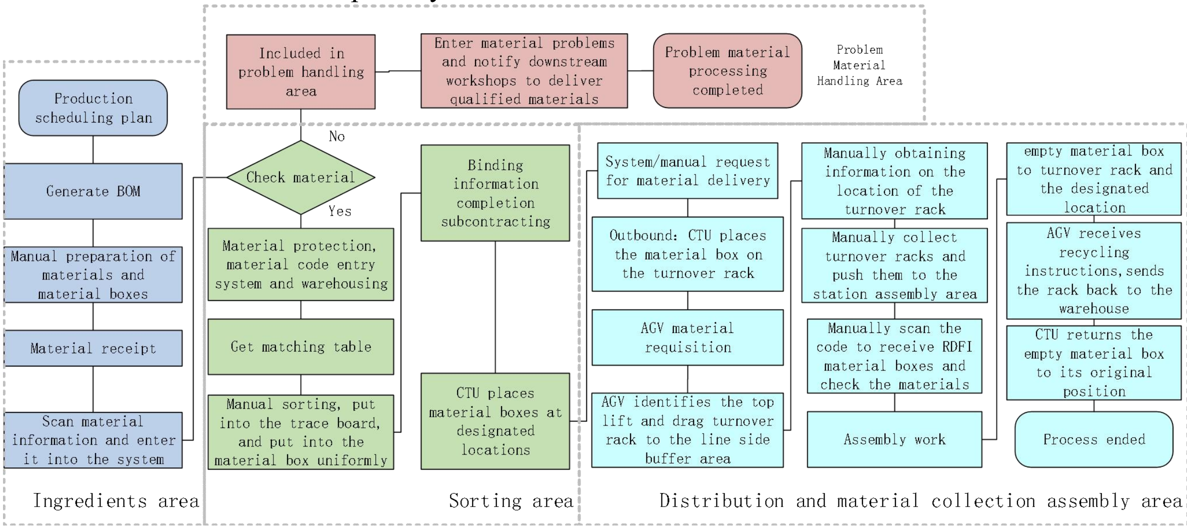

Figure 1. Material Delivery Process

1) Upon arrival of materials in the workshop, the warehouse manager in the product reception area inspects the delivered products, verifying document conformity, material handover quantities, etc. At the same time, the information of the completed handovers is entered into the warehouse management system to complete the reception.

2) After receiving the materials, the warehouse manager performs a visual inspection of the received materials to determine if the products meet the standards. For materials with issues, they are moved to a segregated area for problematic products and recorded. Notification is sent to the upstream workshop/unit to replace the materials with qualified ones. For qualified materials, a material code is assigned based on the certificate of conformity for single delivery products, and for multiple delivery products, each part is individually assigned a material code. The material code is used for entering supporting information into the warehouse management system and allows for quick location of materials based on the code.

3) After material inspection, the warehouse manager retrieves the matching table, sorts the materials according to material requirements, and packages the sorted materials for protection before placing them into pallets. Multiple pallets are then placed into material boxes, and the materials inside the boxes are bound and packaged according to the process sequence indicated in the matching table.

4) Once material sorting and packaging are complete, the intelligent scheduling system sends a command to the CTU intelligent picking robot. The CTU automatically stores the material boxes at specified locations on the material storage racks, completing product storage.

5) When assembly stations require materials, delivery instructions can be sent through the scheduling system or manually. The CTU

intelligent picking robot and the AGV assembly delivery cart simultaneously receive the instruction. The CTU retrieves the material box from the specified location on the material storage rack, places it on the material box delivery turnover rack, and the stealth AGV elevates the delivery turnover rack to transport the materials to the line-side buffer area, waiting for assembly use[12].

6) After the materials reach the line-side buffer area, operators use handheld terminals to obtain the position information of the assembly materials on the turnover racks, retrieve the delivery turnover rack from the line-side buffer area, and manually push it to the assembly station area. Station operators scan to receive the RFID material box, check and confirm before starting the material assembly work.

7) After the assembly work is completed, operators place the empty material boxes on the delivery turnover rack, and under the prompt of the mobile terminal, send the delivery turnover rack back to the designated line-side buffer area. Once in position, the mobile terminal initiates a material recovery command to the AGV, which, upon receiving the command, automatically goes to the line-side storage and returns the delivery turnover rack to the warehouse.

8) After the delivery turnover rack arrives back at the warehouse, a manual call is made for the CTU intelligent picking robot to return the empty material boxes to their original positions, completing the delivery.

2.3 Logistics Route Planning

The logistics route planning area includes the warehouse storage area and the assembly station area. Figure 2 primarily displays the logistics delivery routes between the comprehensive warehouse and various assembly station areas. The planned routes connect the line-side buffer areas of each assembly area, with the production line serving as the layout base, utilizing the space dimensions between each production line to plan AGV delivery routes.

For areas along the delivery route with larger spaces, bi-directional delivery channels are used; for areas with smaller spaces along the delivery route, uni-directional delivery channels are implemented, with bi-directional channels set at both the endpoints and starting points of the linked routes. This route planning ensures both the convenience of material use and the efficiency of logistics delivery.

The logistics route planning is illustrated in Figure 2:

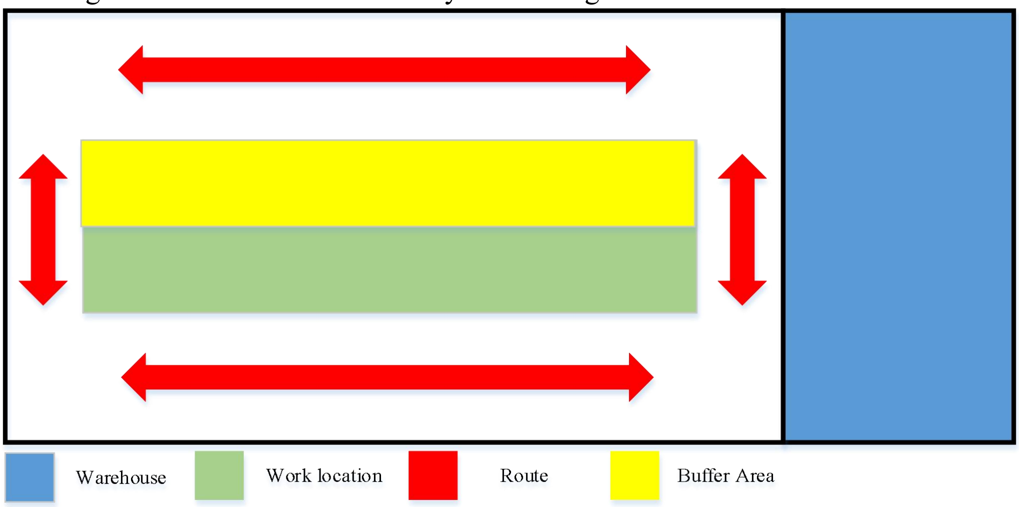

Figure 2. Example of Logistics Path

3. Conclusion

This paper addresses the issues of low efficiency, high error rates, and poor timeliness in the current delivery of assembly materials for launch vehicles by proposing a method for the delivery of launch vehicle assembly materials. This method has the following two improvements:

(1) The delivery method has been improved from traditional manual delivery to a combination of AGV delivery and collection terminals, reducing labor costs and effectively improving the efficiency of warehouse management personnel;

(2) The management method has shifted from manual tallying to a digital management mode, allowing for the collection and management of

complete lifecycle data of products, effectively enabling tracking and control of product information;

Through AGV delivery and an intelligent management scheduling system, this method can effectively improve production delivery efficiency, reduce material distribution error rates, and enhance the timeliness of information statistics.

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