Optimization of Material Distribution Scheduling Based on Mixed Distribution Strategy

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Abstract. In order to effectively solve the scheduling problem of mixed flow assembly line material distribution, an optimization method of material distribution scheduling based on mixed distribution strategy was proposed. Firstly, the mixed distribution strategy is described, and the distribution strategy of materials is divided by taking the refrigerator assembly line as an example. Then the problem of mixed distribution strategy is simplified and a mathematical model is established for scheduling optimization. The construction of the model is different from the existing calculation of material consumption based on working hours. This model is based on the quantity of products on line, making the actual material consumption more accurate. Finally, an example is given to verify the feasibility of the model.

Keywords. Mixed-flow assembly line, Material scheduling, Mixed distribution strategy, Loading Occupancy.

1. Introduction

With the continuous development of product diversification and customer customization, mixed-flow production has become an important means for processing and manufacturing enterprises to quickly respond to customers' individual needs [1]. However, the rapid increase in product types and the rapid decrease in production batches have led to a rapid increase in the types of materials and frequency of distribution required during the production process. This has placed higher requirements on the efficiency of line-side material distribution. Research has important theoretical significance and practical value.

In recent years, the issue of material distribution strategies for mixed-flow production lines has attracted the attention of many scholars at home and abroad. Johansson [2-3] first divided the material distribution strategy into batch supply, continuous supply, kitting as the feeding policies and sequential supply. There are many related researches on material distribution strategies [4-6]. At present, most literatures will mention two main distribution strategies, namely line stocking and kitting. In the face of the choice of two strategies, there was a lot of controversy in the academic community initially [7-9]. In the subsequent research, it was found that both strategies have advantages and disadvantages, and no one strategy can be applied to all materials. Therefore, this paper combines line-edge and full-set two kinds of distribution strategies, and optimizes the material distribution scheduling for the combined mixed distribution strategy.

A large number of scholars have carried out related research on the optimization of material distribution scheduling. Yan Zhengfeng et al [10] optimized the material scheduling path based on the fuzzy time window theory, and solved the optimal distribution path on the premise of given the distribution time window. Ling Lin [11] established a time-varying material distribution optimization model by setting penalty costs. Li Aiping [12] proposed an optimization method for the division of
material scheduling stations in a mixed assembly line workshop. Li Shaobo [13] proposed an improved particle swarm optimization algorithm to solve the shortest path problem of material distribution. To sum up, scholars have made some achievements in the study of material distribution scheduling optimization problems, but they still have the following problems: the existing literature rarely involves the scheduling optimization of two or more distribution strategies; the existing scheduling most optimization studies use standard man-hours to calculate the material consumption rate. However, in actual production, there will be different production rates at different times and downtime, which will lead to inaccurate material consumption calculations.

Therefore, this article takes the freezer assembly line as an example. According to the characteristics of the material itself, the material is first divided into line-side strategic distribution or integrated strategic distribution, and then the material receiving station is integrated (the station with the material receiving point becomes the material receiving station). Position), set the RFID code at the first station of the assembly line, determine the consumption of each material according to the number and model of the products on the line, and according to the real-time data of each material distribution station, with the constraint of the load capacity of the distribution vehicle. The maximum load is the goal, and the distribution path of the material is planned to improve the distribution efficiency.

2. Scheme Description and Mathematical Model

2.1. Description of Hybrid Distribution Strategy Solution

The materials required for the freezer assembly line are mainly divided into three types: smaller types of components, such as temperature controllers; larger types of components, such as food baskets; and a single type of universal standard components, such as screws and nuts. Due to the large variety of small-volume components, they can be delivered using kitting; most of the large-volume components cannot be placed in a kit box, so they are distributed using a line stocking; because of the single type, the universal standard parts are All-in-one strategies increase costs, so line-edge strategies are used for distribution.

In kitting distribution, only the first station needs to receive materials. Therefore, the station that uses the line-side strategy for material delivery and the first station that uses the kitting for material delivery constitute all the material receiving stations. As shown in the figure 1, S indicates a station, T indicates a delivery vehicle, a rectangle is a line-edge strategic station, and a diamond is a set of strategic stations. Therefore, the stations that need to receive materials are: 1, 2, 3, 4, 5, 6, 8, 9, 11, 12, 13, 14, 15, 16.

![Figure 1. Delivery location.](image-url)

There are two kinds of existing material distribution scheduling studies: calculating the material consumption of each station according to the working hours, and optimizing the vehicle travel path under the constraints of a given time window; adding an RFID code scanning step at each material demand station to convert the material Consumption is synchronized with the material distribution center. The first solution is feasible in an ideal production environment. However, in actual production, downtime will occur, and the measurement man-hours may not necessarily match the actual
production man-hours. Therefore, the solution for calculating material consumption using man-hours is not accurate; although the second solution can accurately reflect the material consumption situation on the site to the material distribution center, each material consumption station will scan the code to increase labor and equipment costs.

Therefore, in order to minimize costs, RFID scanners are now installed only at the line. The corresponding bar code is pasted on the cabinet, scanned before going online, and the model information enters the material information database. The database has detailed information about the materials required for this model of freezer. The model of the freezer on the production line is sorted. The product requirements database is updated every time a product passes.

2.2 Model Construction

The timely and accurate delivery of materials to the line-side inventory area is a necessary condition to ensure that each consuming station can obtain the required materials within a specified time and ensure the normal operation of the production line. For the materials required for product production, the types and quantities of materials required for a single product on the same production line are the same. We calculate the number of materials consumed by a single product and calculate the amount of each material consumed. According to the size of the loaded material box, we ensure that there is no shortage of materials. And within the carrying range of the transport vehicle, to transport more materials to the maximum extent, it is necessary to divide the material consumption stations into station groups for joint distribution. Set the following mathematical parameters:

L —— Material Consumption Station Number;
N —— Sum of material consumption stations;
i —— Production to i-th product;
j —— j-th delivery;
Lorry —— Loading capacity of transport vehicles;
b_n —— Unit material box volume at station n;
C_n —— Quantity of the material in the unit packing box of station n;
C0_n —— Material quantity required for unit product at station n;
Max_n —— Maximum line-side material quantity at station n;
Min_n —— Minimum line-side inventory at station n;
lack_i,n —— Quantity of missing materials produced to the i-th product station n;

Ac_n —— Cumulative material delivery quantity for station n;
Tran_n —— Collection of the j-th transport;
Tran_j,n = 0,1,2,...,k —— Number of boxes representing the j-th distribution to the n-station distribution materials;
D_n —— Distance between consumption stations and material distribution center;
V —— Trailer running speed;
Y_n —— Number of station n materials consumed by station n service time;
M —— Loading rate;
The model is as follows:
Objective function:
Formula (1) calculates the missing quantity of materials produced to each station. Formula (2) is the objective function and the maximum load factor. Formula (3) is used to determine whether the set minimum line-edge inventory is reasonable. Formula (4) is the constraints on the maximum load of the vehicle ensure that the vehicle will not be overloaded.

2.3. Model Solving

A heuristic rule algorithm is established based on the above model. According to the daily production plan, input the daily production volume, bicycle capacity, total station number, station number and other data into the program. As the product is consumed, if there is an amount of consumed material greater than or equal to the vehicle load, the vehicle is loaded. Transportation and update the material requirements list; if there is an emergency shortage of material at the station, regardless of whether the vehicle is fully loaded, loading and transportation will be performed and the material requirements list will be updated. When the number of iterations reaches the total daily production volume, the calculation is stopped and the loading rate of each vehicle transportation is output. The program flowchart is shown in Figure 2, and MATLAB is used to solve the calculation.

![Figure 2. Algorithm logic.](image-url)
3. Case Analysis
In order to verify the effectiveness of the above method, an automobile company's engine mixed-flow assembly line is taken as an example for verification. From right to left, there are three parts: the engine head line, the engine interior line, and the engine exterior line. This article studies the production line of the freezer assembly line. The two pre-assembly lines correspond to one assembly line. The stations of the two production lines of the pre-assembly line are distributed separately. There are a total of 18 material distribution stations, and a line edge is set next to each consumption station. In the inventory area, the material distribution center is located on the right side of the entire assembly line, as shown in figure 3.

![Figure 3. Delivery routes.](image)

Each transport vehicle is composed of three car bodies driven by a battery head. Three types of standard material boxes are provided: A material box ($25 \times 40 \times 20$), B material box ($50 \times 80 \times 20$), and C material box ($50 \times 80 \times 60$) are used to place boxed materials, and the key pieces of materials to be distributed are divided into three categories according to the different boxes. One car body can be equipped with 12 A material boxes or 3 B material boxes or 1 C material box, and three cars can be matched with three kinds of material boxes. Set the initial maximum and minimum inventory of line edges, and use the formula (3) for verification after the results are obtained.

The algorithm program was compiled and solved with Matlab, and the results shown in figure 4 were obtained. In the running result of the program, the first row represents the station numbers corresponding to the 18 stations, and the first column is the distribution frequency. A total of 1,000 freezers need to be dispatched 21 times a day, and the numbers represent the number of boxes of materials to be distributed. It can be seen from the operation results that each time 3 to 7 stations are distributed, 85.7% of the distribution can achieve a loading rate of 100%, and the rest of the distribution can also achieve a loading rate of more than 80%.
In the actual production and operation process, the loading capacity of the delivery vehicles is not fully utilized, the average full load rate of the delivery vehicles is low, and there is a waste phenomenon. According to this plan, the distribution station group is arranged, and the service time required for each station is 3 minutes, and the time required for each distribution is calculated. Compared with the unoptimized initial scheme and the scheme divided according to the principle of adjacent stations, the average full load rate of the delivery vehicles is effectively improved, and the waste of production resources is reduced.

4. Conclusions
This paper studies the material distribution scheduling problem of mixed distribution strategy. Firstly, the materials are reasonably divided into line stocking materials and kitting materials, and then the material distribution stations are integrated to convert complex problems into common assembly line material scheduling optimization problems to be solved.

In view of the material scheduling problem of the assembly line, the existing two solutions are inadequate. Therefore, this article proposes a material distribution scheduling optimization scheme based on the number of products on-line. According to the actual production consumption of the material, the maximum load rate of the vehicle is the target, and the maximum load of the vehicle and the line side materials are not lower than the safety stock as the limiting conditions. A mathematical model is established and solved. Taking a freezer assembly line as an example, the full load rate of distribution vehicles was increased without affecting the production of the production line, which proved the feasibility of the scheme.

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