INTELLIGENT OPTIMIZATION OF MATERIAL DISTRIBUTION IN LARGE-SCALE MIXED FLOW PRODUCTION WORKSHOP BASED ON PATH OPTIMIZATION ALGORITHM

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***ABSTRACT**: Material distribution in the manufacturing workshop determines the normal operation and production cost of the production line. At present, large-scale mixed flow production workshop puts forward higher requirement that material system distribution needs to be finished on time and efficiently for material distribution. Under the manufacturing mode of large-scale mixed flow production, this study, on the basis of path optimization algorithm, explores the intelligent optimization dispatching of logistics distribution in the production workshop, thereby improving the material leveling of the multiple production lines and the efficiency of production logistics. The results show that the optimization of material distribution path is the most important way to save time of distribution and reduce cost. Path optimization algorithm can reduce the vehicle travel distance and iteration times, and the convergence rate of the whole system is higher. In addition, intelligent optimization material distribution based on the path optimization algorithm can greatly reduce the problem of production line stop caused by material distribution. This study provides a theoretical basis for the intellectualization and informatization of material distribution in the manufacturing workshop.*

***KEYWORDS**: manufacturing, material distribution, production workshop, path optimization algorithm, intelligent optimization.*

1 INTRODUCTION

Production efficiency has become a key factor for enterprises to improve their competitiveness and the rhythm of the production workshop directly affects the production cost and delivery cycle of products. For manufacturing enterprises, the most effective method to reduce the product cost is to optimize the layout of production equipment, improve the production process and reduce the production logistics cost (Zuo & Zhang, 2013). Material distribution in the production workshop is a process in which materials produced by enterprises flow in the production process. According to rough statistics, material distribution or transportation in the production workshop accounts for more than half of the total time while the actual production time consumes relatively less (Azadeh et al., 2013; Liu et al., 2017). In the production process of large-scale mixed flow production workshop, reducing the auxiliary time for material distribution can improve the production efficiency of enterprises. There is a huge space for improvement for the logistics distribution system of the production workshop (Asadollahi et al., 2014). The distribution frequency and time accuracy of the intelligent optimization path process will be stricter than that of the general logistics optimization problem. Besides, material distribution in mixed flow production workshop is more complicated than that of a single production workshop in terms of decision-making target, research object, topology structure, material type and cost factor (Simpson & Martins, 2011).

Products of large-scale mixed flow production workshop are characterized by high complexity and numerous varieties, and the production process is complicated and changeable and is affected by many factors. Material distribution needs to be carried out strictly according to the time. That material distribution is not delivered timely, the quantity is insufficient or the distribution time is too early and the quantity is too large will affect the normal operation of multiple production lines (Nahas, 2014; Ramezani et al., 2017). Along with the development of intelligent information technology, the information technologies, such as intelligent identification and intelligent perception are gradually applied to the production workshop, which can realize the tracking of material state and the optimization of intelligent distribution. The level of automation and informatization determines the market competitiveness of enterprises to some extent for the production workshop of enterprises (Wu et al., 2019). In the actual manufacturing process, the product types of the large-scale mixed

flow production workshop change frequently and there are many material types to be distributed, so it is difficult to grasp the demand status of the line-edge material in real time and accurately or to achieve optimization of the distribution path (Montoya-Torres, 2011). Under the manufacturing mode of large-scale mixed flow production, this study, on the basis of path optimization algorithm, explores the intelligent optimization dispatching of logistics distribution in the production workshop, thereby improving the material leveling of the multiple production lines and the efficiency of production logistics. This paper provides a theoretical basis for the intellectualization and informatization of material distribution in the manufacturing workshop.

2 ESTABLISHMENT OF MATERIAL DISTRIBUTION PATH OPTIMIZATION MODEL IN MIXED FLOW PRODUCTION WORKSHOP

Material distribution involves material flow activities in the production workshop. The integrity of production activities is completed through a series of processes such as loading, unloading or handling of raw materials from a material storage area by using suitable distribution tools or methods (Naeem et al., 2013). In the traditional production workshop, material distribution mainly includes circulation distribution, direct distribution and emergency distribution. Fig. 1 shows the organization structure and work flow of the production workshop center, and the whole organization structure consists of planning and control section, production department, process technology department, materials section and warehouse. The planning and control section is responsible for the preparation of the daily production plan for products, and the work flow is roughly divided into material sub-package, instruction of each production line, issuance of materials, assembly and replacement of materials, and check of materials. Timeliness and accuracy are the most basic characteristics of material distribution, both reducing the inventory at the line edge and making the quantity or weight of materials required to be distributed on time (Yan et al., 2012). On large-scale mixed flow production lines, the goal of material distribution path optimization is to require the shortest travel distance, the shortest total delivery time, the least time window penalty cost and the smallest number of delivery forklifts (Nahas, 2017).

At present, as the demand or requirement for products is continuously improving, the production line is continuously increasing or extending, thereby increasing the number of production line station points. This will increase the type and quantity of production line material demand and raise higher requirements for material distribution in the production plant (Zhang et al., 2012). Fig. 2 shows the factors affecting material distribution in the production workshop, including station information of material distribution, tooling process information and plant layout information. Material distribution can be conducted according to the importance of the workshop station, reasonable distribution schemes of demand quantity and distribution time, which can also reduce the line-edge inventory and greatly improve the production efficiency of the production workshop.

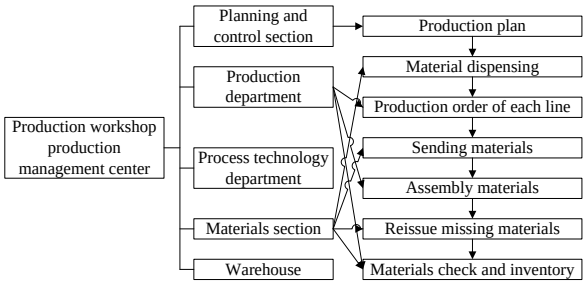


Fig. 1 Organization structure and workflow of manufacturing workshop Center

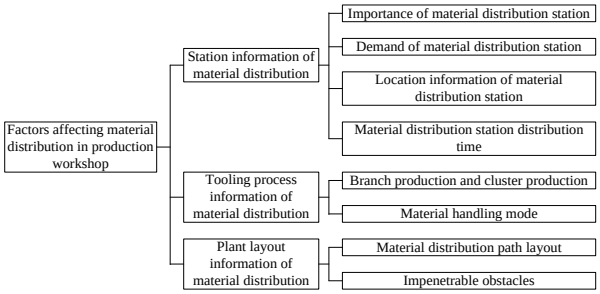


Fig. 2 Factors affecting material distribution in production workshop

3 INTELLIGENT OPTIMIZATION OF MATERIAL DISTRIBUTION IN MIXED FLOW PRODUCTION WORKSHOP

The production of large-scale mixed flow production workshop is divided into continuous production and discrete production. The high production efficiency of mixed flow production line requires fast production switching time with higher flexibility, which can adapt to the market demand of product diversification. Mixed flow production workshop needs to rely on the production of large quantities of products and advancement of equipment and tooling, and material distribution needs to strongly depend on reasonable production plan and assistant management of production

logistics. In the process of material distribution in large-scale mixed flow production workshop, material distribution is realized by means of mutual cooperation such as manufacturing information visualization, timely line-edge material distribution and material early-warning, so as to realize the real-time transmission of information. Common material distribution in mixed flow production includes three types: planned management distribution type, plate management distribution type and emergency demand management distribution type.

Fig. 3 is the material distribution flow of the production workshop, making the material distribution list according to the material demand plan and production plan of products. The continuity, balance, coordination and timeliness of the whole flow all affect the production efficiency and production cost of products. Material distribution includes material distribution plan, material sorting and distribution. The optimization of the material distribution path is the most important way to save distribution time and reduce cost. The optimization of material distribution involves the optimization of production line transportation and the optimization of material transportation (vehicle scheduling and vehicle transportation route, etc.). This study, based on the path optimization algorithm, realizes continuous production of mixed flow production line by optimizing two paths of production line and material transportation. Path optimization involves many factors, such as material transportation distance, transportation time, number of dispatched vehicles, vehicle full load rate and service efficiency. The path optimization algorithm can realize the tradeoff solution between non-parallel targets. Fig. 4 is a mixed intelligent algorithm flow considering path optimization, in which uncertain constraints during transportation are simulated with an algorithm network by setting each node on the optimization path as clear information. The path optimization algorithm is used to find the approximate optimal solution in the model.

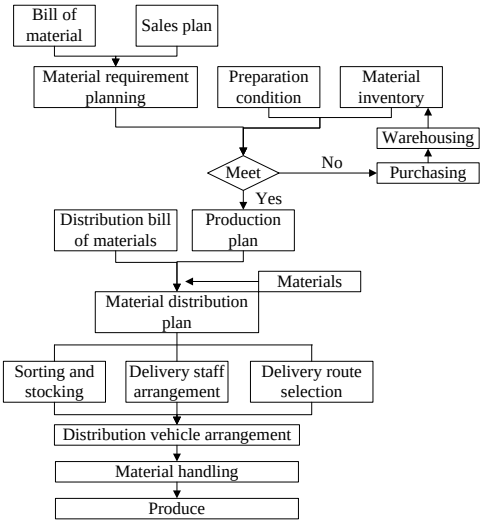


Fig. 3 Material distribution process of production workshop

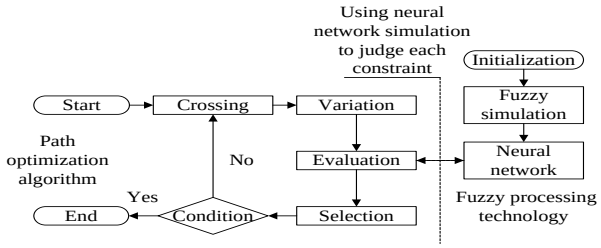


Fig. 4 Hybrid intelligent algorithm flow considering path optimization

4 REALIZATION OF INTELLIGENT OPTIMIZATION MODULE OF MATERIAL DISTRIBUTION BASED ON PATH OPTIMIZATION ALGORITHM

4.1 Correlative optimization of material distribution and production sequence in large-scale production workshop

Materials on the assembly line of large-scale mixed flow production workshop are divided into general materials, key materials and characteristic materials according to the demand characteristics. General materials generally refer to the materials required by all the assembly lines of mixed flow production workshop, with fast consumption speed and large required amount. Therefore, it is the key materials and characteristic materials that play a decisive role in material distribution. In order to achieve intelligent optimization of material distribution in the production workshop, the usage rate of various materials required by the mixed flow production line shall be kept unchanged. To explore the relevance between material distribution and production sequence in large-scale mixed flow production workshop, this study takes a mixed flow

product production line as an example. Table 1 is the planned production capacity and material requirement list of a product. A total of four products are produced on the mixed flow product line, and the required material type for each product is shown in Table 1. Fig. 5 is a comparison of the material distribution demand curve of the production workshop, in which the maximum deviation value and the change of the ideal demand curve of the two distribution schemes are given. In either scheme, there is a deviation from the ideal supply curve, and the distribution requirement can be met by increasing or decreasing the inventory amount of materials. Table 2 is a horizontal comparison of distribution modes according to the material distribution station classification in the production workshop, showing that higher distribution efficiency, vehicle utilization rate and station satisfaction can be obtained by selecting comprehensive distribution.

Table 1. Planned production capacity and material requirement list of a product

Product	Planned demand	Demand ratio	Material type		
			Type 1	Type 2	Type 3
1	4500	39.13%	4	8	6
2	1300	11.30%	0	8	5
3	3000	26.09%	7	4	0
4	2700	23.48%	4	0	9
Total	11500	100%	15	20	20

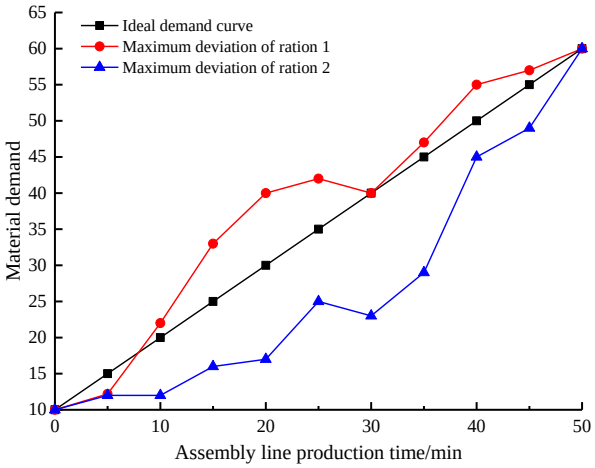


Fig. 5 Comparison of material rationing demand curve in production workshop

Table 2. Horizontal comparison of distribution modes according to the classification of material distribution stations in production workshop

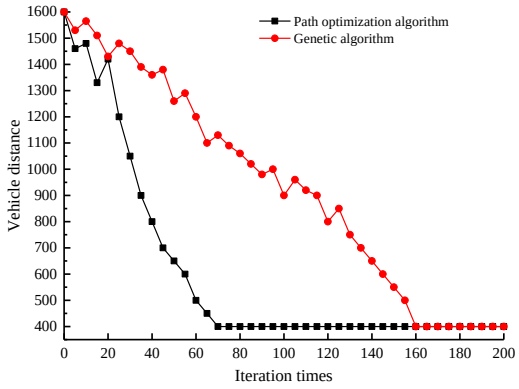
Delivery mode	Distribution efficiency	Distribution tool utilization	Station satisfaction	Applicable scenario
Station direct delivery	Low	Low	High	Key station, bottleneck station and mass material, etc
Single material distribution	Medium	High	Low	Regular planned material delivery
Comprehensive logistics distribution	High	High	High	The above scenarios

4.2 Realization and application of intelligent module of material distribution

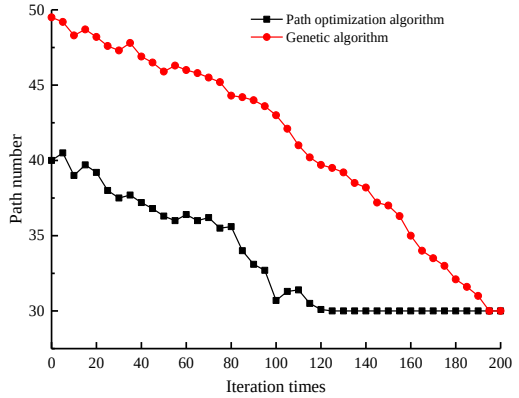
The development of informatization and intellectualization provides the possibility of automation and real-time material distribution in large-scale mixed flow workshop. Based on the example of a large-scale mixed flow production line in Table 1, this study realizes the combination of production organization and planned dispatching by establishing production plan system and equipment collection system in the production workshop, providing intelligent module for material management. In the intelligent optimization of the manufacturing workshop, genetic algorithm is commonly used. This study applies the path optimization algorithm to the intelligent module. Fig. 6 is a comparison of optimization of intelligent

iteration times between path optimization algorithm and genetic algorithm. By using the vehicle travel distance and the number of paths as the iteration process, it is obvious that using path optimization algorithm can reduce the vehicle travel distance and the number of iterations, and the convergence rate is higher than that of genetic algorithm.

Fig. 7 shows the statistics of production line stop factors before and after the implementation of the intelligent optimization of material distribution. Fig. 7 (a) shows that 39.74% of factors cause the production line stop due to material distribution before the intelligent optimization of material distribution. Fig. 7 (b) shows that only 19.35% of factors cause production line stop due to material distribution after the intelligent optimization of material distribution, and the production line stop factors caused by material distribution are greatly reduced compared with those before the intelligent optimization.

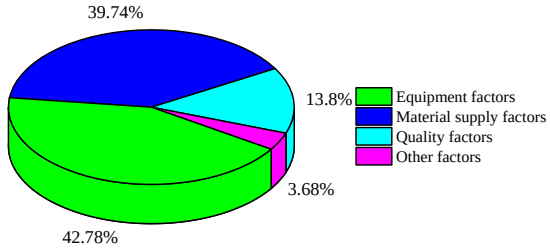


(a)Vehicle distance

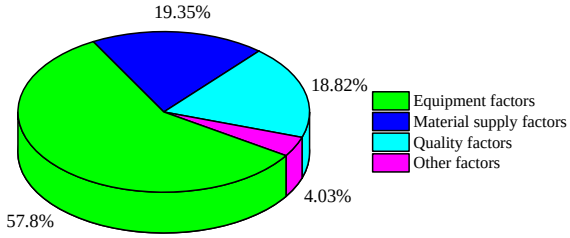


(a) Path number

Fig. 6 Comparison of intelligent iteration times between path optimization algorithm and genetic algorithm



(a) Before intelligent optimization of material distribution



(b)After intelligent optimization of material distribution

Fig. 7 Statistics of production line stop factors before and after the implementation of intelligent optimization of material distribution

5 CONCLUSIONS

Under the manufacturing mode of large-scale mixed flow production, this study, based on the path optimization algorithm, explores the intelligent optimization dispatching of logistics distribution in the production workshop, so as to improve the material leveling of multiple production lines and the efficiency of production logistics. Conclusions have been drawn as follows:

(1) The mixed flow production workshop needs to rely on the production of large quantities of products and advancement of equipment and tooling, and material distribution needs to strongly depend on reasonable production plan and auxiliary management of production logistics.

(2) Path optimization involves many factors, such as material transportation distance, transportation time, number of dispatched vehicles, vehicle full load rate and service efficiency. The path optimization algorithm can realize the tradeoff solution between non-parallel targets.

(3) Higher distribution efficiency, vehicle utilization rate and station satisfaction can be obtained by selecting comprehensive distribution. Intelligent optimization material distribution based on the path optimization algorithm can greatly reduce the problem of production line stop caused by material distribution.

6 REFERENCES

►Azadeh, A., Motevali Haghighi, S., Asadzadeh, S. M., Saedi, H. (2013). A new approach for layout optimization in maintenance workshops with safety

factors: the case of a gas transmission unit. *Journal of Loss Prevention in the Process Industries*, 26(6), 1457-1465.

►Asadollahi, M., Geir Nævdal, Dadashpour, M., Kleppe, J. (2014). Production optimization using derivative free methods applied to brugge field case. *Journal of Petroleum Science and Engineering*, 114(1), 22-37.

►Liu, P., Liu, X., Zhang, Z., Wang, Y., Gui, W. (2017). Production optimization for concentration and volume-limited fed-batch reactors in biochemical processes. *Bioprocess and Biosystems Engineering*, 41(11), 407-422.

►Montoya-Torres, J. R. (2011). Editorial: intelligent optimization for manufacturing operations. *Journal of Intelligent Manufacturing*, 22(5), 765-766.

►Nahas, N. (2017). Buffer allocation and preventive maintenance optimization in unreliable production lines. *Journal of Intelligent Manufacturing*, 28(1), 85-93.

►Nahas, N. (2014). Buffer allocation and preventive maintenance optimization in unreliable production lines. *Journal of Intelligent Manufacturing*, 28(1), 1-9.

►Naeem, M. A., Dias, D. J., Tibrewal, R., Chang, P. C., Tiwari, M. K. (2013). Production planning optimization for manufacturing and remanufacturing system in stochastic environment. *Journal of Intelligent Manufacturing*, 24(4), 717-728.

►Ramezani, A., Maymand, E. M., Yazdanpanah-Samani, M., Hosseini, A., Ghaderi, A. (2017). Improving pertuzumab production by gene optimization and proper signal peptide selection. *Protein Expression and Purification*, 135, 24-32.

►Simpson, T. W., Martins, J. R. R. A. (2011). Multidisciplinary design optimization for complex engineered systems: report from a national science foundation workshop. *Journal of Mechanical Design*, 133(10), 101002.

►Wu, J., Cheng, S., Cao, J., Qiao, J., Zhao, G. R. (2019). Systematic optimization of limonene production in engineered escherichia coli. *Journal of Agricultural and Food Chemistry*, 67(25), 7087-7097.

►Yan, A., Chai, T., Yu, W., Xu, Z. (2012). Multi-objective evaluation-based hybrid intelligent control optimization for shaft furnace roasting process. *Control Engineering Practice*, 20(9), 857–868.

►Zuo, Y. H., Zhang, K. R. (2013). Research on key techniques of intelligent optimization of batch production job shop scheduling. *Advanced Materials Research*, 753-755, 1903-1909.

►Zhang, R., Song, S., Wu, C. (2012). A two-stage hybrid particle swarm optimization algorithm for the stochastic job shop scheduling problem. Knowledge-Based Systems, 27, 393–406.