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Abstract. Aiming at problems that the flexible scheduling capability of the production line in the existing factory is poor due to islanding effect and existing scheduling methods ignore non-cutting time and dynamic change of time when solve the minimum completion time, this paper studies the optimization of multi-variety and small batch workflow scheduling, and establishes an optimal job flow allocation model based on dynamic time parameters. Taking a flexible flow shop as an example, the model is applied to the implementation, and the EM-PLANT simulation software is used to make digital decision to realize the scientific scheduling of workpiece flow in cyber environment of production line. The simulation results show that the optimal allocation model can reduce the average completion time of workflow and improve production line efficiency.

1. Introduction

The modeling and simulation of machine and logistics behavior in the factory has always been a hot topic among scholars[1]. The digital analysis capability of the factory is also an important part of intelligent manufacturing. As factory modeling and simulation technology matures, modeling and simulation technology begins to play a role in providing decision support. Research based on system behavior for optimal decision making[2] or based on historical and real-time data to predict future behavioral patterns[3] began to sprout. Since the accuracy of decision-making depends on the amount of training data, data analysis based on industrial software has begun to develop in the industry[4].

At present, the decision analysis research on shop scheduling is more and more in-depth and detailed. Markus P. Roessler pointed out the challenges of factory decision making and provided solutions on joint decision-making in production and logistics from a management perspective[5]. Nour El Houda Tellache et al. considered some conflicting operations that could not be processed simultaneously in different robots, and established a mathematical model to provide a polynomial solution to this problem[6]. M. A. Dulebenets et al. considered the difference in the size of cargo carried by different ships and established a mixed integer non-linear model to minimize the total ship run time[7]. XinNianWang establishes the estimation distribution algorithm for solving the minimal completion time of benchmark problems[1]. Although the research on scheduling algorithms is getting more and more in-depth, most scheduling studies only take processing time into consideration, and non-processing auxiliary time is often ignored. Many scheduling studies are based on the benchmark problems[8]. These problems lack the consideration of logistics time and assume that the processing time is constant. It is an idealized mathematical problem and still has a long distance from engineering applications[9].

Based on the above review, it is known that constructing the reasonable mathematical model of

details of factory, and solving the model based on simulation software can achieve the purpose of comprehensively simulating the on-site production status and providing basis for factory behavior decision[10]. The independence between the same type of production line of the factory is still obvious, and the simulation granularity is relatively low, which becomes a bottleneck restricting the further improvement of the production efficiency and logistics efficiency of the factory. Therefore, this paper studies the optimization of the logistics flow based on dynamic time parameters based on EM-Plant software platform.

2. Problem Description

The production lines with the same function in the factory are independent of each other, resulting in poor modularity and flexibility of production lines. The problem is manifested in the following aspects:

- Islanding Effect. The islanding effect means that after the workpiece enters a production line, all production tasks must be completed before it can be shipped out of this production line. Due to the different busy time of each production line equipment, it will encounter the situation the workpiece still stay at waiting area but it cannot be dispatched to the adjacent production line with idle equipment due to islanding effect.

- Non-cutting time of flexible workpiece flow. Flexible workpiece flow refers to the flow of various types of workpieces. Different types of workpieces need to be reloaded before they can be processed by specific equipment. Due to the order of workpiece flow is irreversible, the dynamic reloading time needs to be considered into the distribution process of workpiece flow.

In order to solve the above problems, the rules of the workpiece inflow line are redefined, the workpiece can be exchanged between different production lines of the same function, breaking the islanding effect of the factory. At the same time, the dynamic time parameters such as the reloading time, the cross-line logistics time, the processing time and the buffer waiting time are introduced into the research to establish optimization allocation model.

3. Logistics Optimization Allocation Model

Suppose there are M production lines with the same function in the factory. Each production line has N pieces of processing equipment. L is the number of workpieces in logistics flow. The total time T^o of each workpiece entering and exiting the flexible mixing shop according to one of strategies can be expressed by the following formula:

$$T^o = \sum_{i=1}^{M}\sum_{j=1}^{N}\left(P_{Hij}^o + P_{Gij}^o + P_{Kij}^o\right)X_{ij}^o + S_X^o, (o = 1, 2, \cdots, L)$$
(1)

Where, P_{Hij}^o indicates the reloading time of the o-th workpiece in the j-th equipment of the i-th production line. P_{Gij}^o indicates the processing time of the o-th workpiece in the j-th equipment of the i-th production line. P_{Kij}^o indicates the waiting time of the o-th workpiece in the j-th equipment of the i-th production line. X_{ij}^o indicates whether the o-th workpiece has selected the j-th device of i-th production line for processing. X_{ij}^o can form an N × M size reachability matrix X. When $X_{ij}^o = 0$, it means that the o-th workpiece will not be processed in the j-th equipment of the i-th production line. When $X_{ij}^o = 1$, it means that the oth workpiece will be processed in the jth equipment of the i-th production line. S_X^o represents the total length of the path traveled by the o-th workpiece between devices with element equals 1 in reachability matrix.

Taking a workpiece z as an example, the workpiece needs to be processed from the corresponding

equipment of j=1, 2, ..., N before it can go out of the production line, but z has M options for each device (because there are M identical production lines), the feasible solution for the selection of the workpiece z pass through the production line is shown in Figure 1.
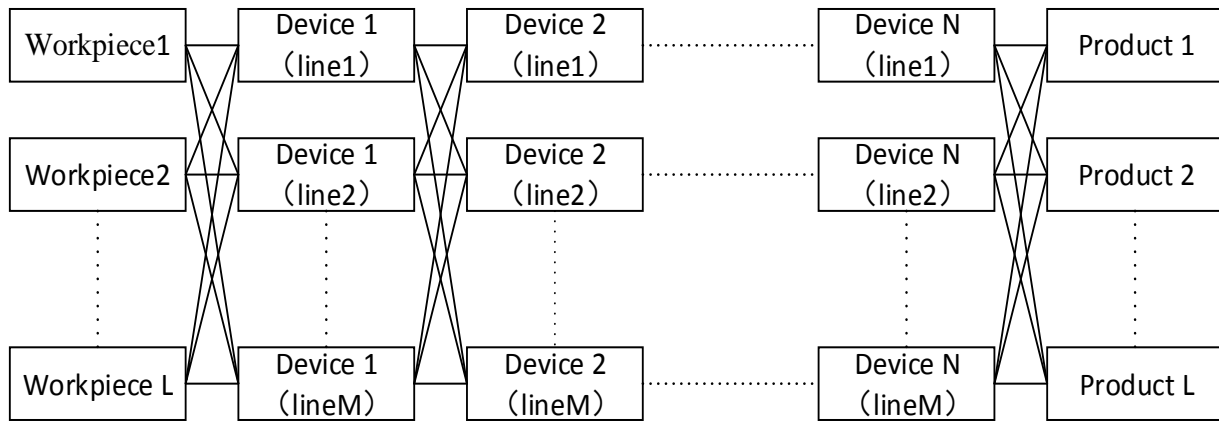

Figure 1. Logistics plan.

According to selection principle of production line, the constraint equation is established as follows:

$$\sum_{i=1}^{M} X_{ij}^{o} = 1, j = 1, 2, \cdots, N \tag{2}$$

$$X_{ij}^{o} = \{0, 1\} \tag{3}$$

The goal of optimal allocation model is to acquire the reachability matrix solution X while it also satisfies the condition of minimizing the total consuming time $\min T^{o}$ and the corresponding constraint equation.

For a workpiece, there are a total of M^{N} feasible solutions under the flexible production rules; for the workpiece flow, there are $O \times M^{N}$ feasible solutions. The time complexity of the algorithm are all the order of magnitude level $o(M^{N})$. Not only that, because the types of workpieces are versatile and the complex environment interferes, the time parameters of each workpiece in the same device appear to change dynamically. For the above reasons, it is impossible to traverse the feasible solution with the traditional heuristic algorithm. Therefore, it is necessary to combine the simulation technology with the heuristic algorithm to solve the dynamic NP hard problem integrally.

4. Case Study
The hybrid flow shop J specializes in the production of various parts of the automotive transmission part. The factory is widely used in unit layout. Each unit uses U-shaped lines to form an independent production line. The production lines with similar processes contents and little difference in processing equipment are arranged together to form several modules, each of which is complete and isolated with each other. The production lines of the original hybrid flow shop are independent of each other, that is, once the workpiece enters a production line, all processing tasks must be completed before the workpiece leaves the production line, therefore the flexibility between the lines is insufficient.

For example, in the besides-star wheel production line, the J factory has five complete besides-star wheel production lines with the same equipment configuration, which are line6, line7, line8, line9 and line10 respectively. When the workpiece enters one of the besides-star wheel production lines, it can only be shipped out after completing all the processes in the production line. Even if some work stations on this production line are occupied, it cannot leave the production line to another idle production line .The factory layout and process flow are shown in Figure 2.
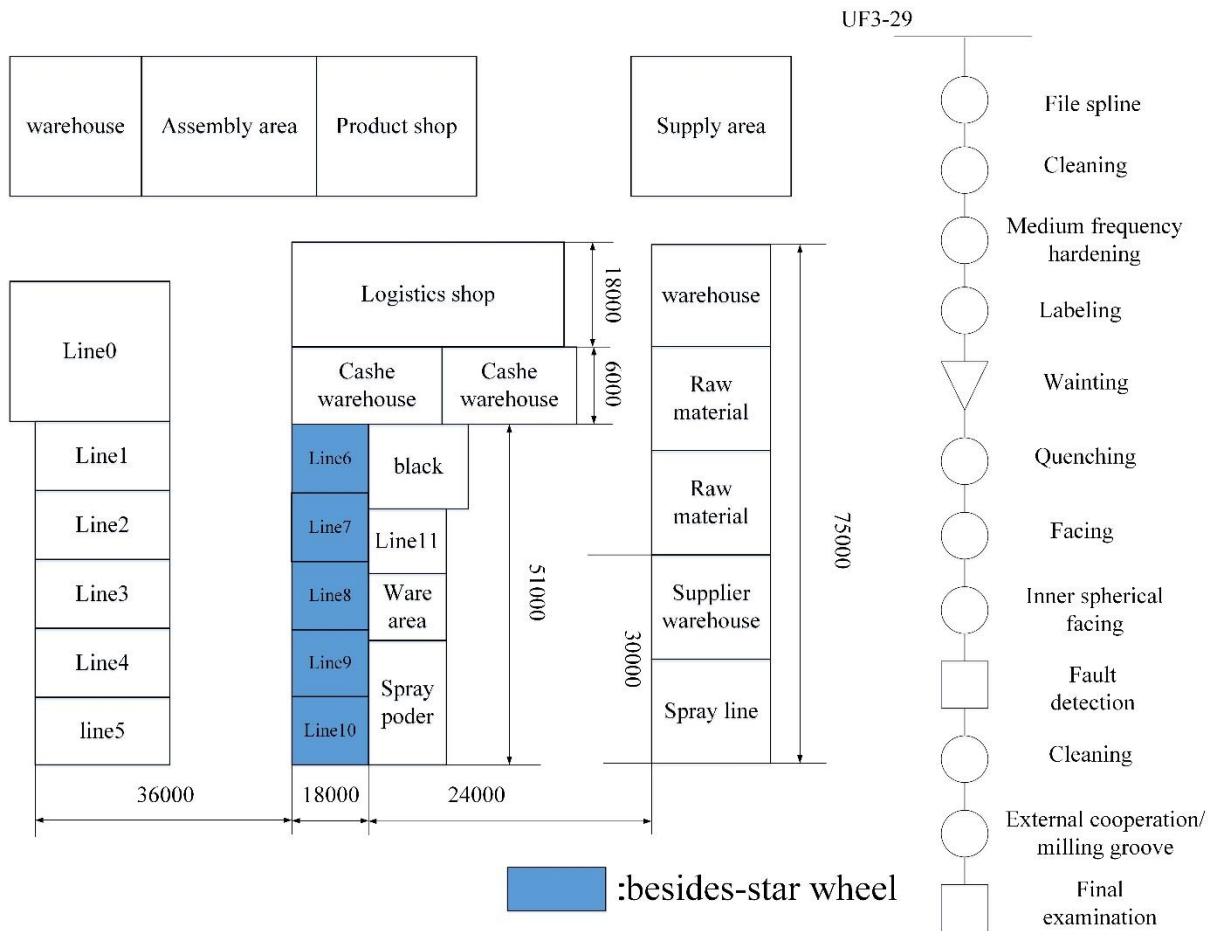
Figure 2. Besides-star wheel production line process.

It is known that there are nine pieces of equipment for each besides-star wheel production line. According to the principle of optimized distribution, the independence between the lines is now removed, and the semi-finished products processed by each equipment can be freely entered into the next equipment of other production lines. Since the flow between the lines is turned on, the time for moving the workpiece between the lines becomes a time factor that cannot be neglected. Since the inter-line logistics cost is significantly higher than the logistics between the devices in the line, it is assumed that the in-line logistics cost is neglected. The line-to-line equipment logistics statistics is shown in the table 1.

Table 1. Logistics statistics table (unit:mm)

Line No	Line6	Line7	Line8	Line9	Line10
Line6	0	10000	20000	30000	40000
Line7	10000	0	10000	20000	30000
Line8	20000	10000	0	10000	20000
Line9	30000	20000	10000	0	10000
Line10	40000	30000	20000	10000	0

This production line produces two typical models of besides-star wheel: UF3-29 and AC2000i. There are only minor differences between the two besides-star wheel process, such as size and spraying

technology. However, it is necessary to change the fixture tools of the besides-star wheel for different equipment. This process is manually completed. The average time for manual reloading is $\bar{t}=1min$. Whether reloading the fixture tools of the besides-star wheel depends on whether the present workpiece type on the processing equipment is consistent with the previous one. Therefore, the reloading time can be calculated by algorithm logic:

$$T^{o}(n)=\begin{cases} \dfrac{1}{\sqrt{2\pi}\sigma}\exp\left(-\dfrac{\left(x-\bar{t}\right)^{2}}{2\sigma^{2}}\right), & s(n)\neq s(n-1) \\ \\ 0 & , s(n)=s(n-1) \end{cases} \tag{4}$$

Where, $s(n)$: the type of workpiece processed at the n-th time step ; $T^{o}(n)$: reloading time at n-th time step ; $\bar{t}$ is the mean time of reloading manually; σ is the time deviation of reloading manually.

After the above resources are defined, the simulation software can be used to solve the optimal reachable set. The simulation is based on the Tecnomatix Plant Simulation 9 version of the EM-PLANT software platform. The simulation time is set from Wednesday, March 1, 2017 to Friday, March 31, 2017. And the daily production plan is 2,700 pieces. The shift change system uses two shifts to ensure that they are running 24 hours a day. Rest time is three times per shift, each break for 15 minutes.

In addition, to simulate device failures, the availability ratio and average repair time are set to simulate the failure. The simulation fault parameters of each device are shown in Table 2.

Table 2. Machine equipment simulation fault parameters

Device	Availability ratio	MTTR
File spline	90%	60min
Quench	90%	50min
Tempering	70%	120min
Facing	90%	50min
Spherical Face	90%	48min
Flaw detection	95%	48min

After the above data is entered into the model, the simulation model of the besides-star wheel production line is established by using EM-PLANT software, as shown in Figure 3.
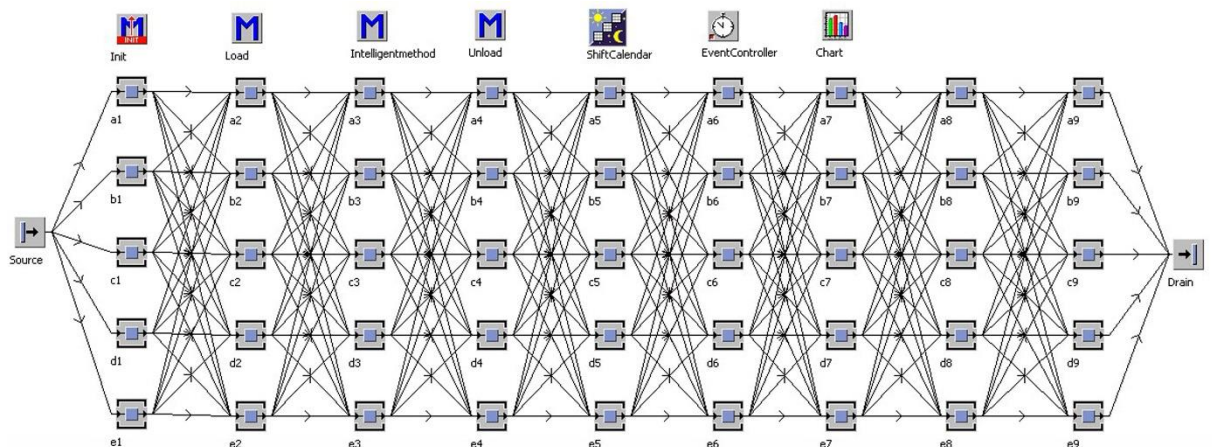

Figure 3. Besides-star wheel production line simulation model

The simulation model 'source' is a workpiece flow generator, which can generate a workpiece flow according to a predetermined flow according to a workpiece flow scheme. The model has a total of 45 machines, and each row representing a simplified model represents all the equipment on a production line (actually it is a U-shaped line). 'Drain' is the output of the workpiece stream. Each arrow line indicates the reachable path of the workpiece flow. 'Method' is the core part of the software, which can control the production line to operate according to the rules in the Method module input code program. The optimized distribution management model is input into the 'Intelligent Method' to simulate an optimal reachable path. Due to the large number of scenarios, the traversal search of the scheme uses genetic algorithms. . After the model is stable, the 'Chart' can be used to observe the operation status of each process.
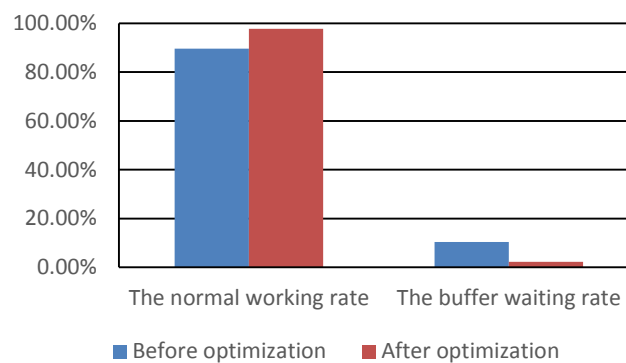

Figure 4. Comparison of workpiece flow optimization indicators before and after improvement

5. Conclusion
In this paper, the EM-PLANT simulation platform is used to combine the simulation technology with the heuristic algorithm to solve the dynamic NP hard problem in an integrated way. The normal working rate and the buffer waiting rate of the workpiece are compared under the condition of line-to-line isolation and inter-line fusion. The simulation comparison results show that the reachability scheme obtained by the optimized allocation algorithm can ensure the overall waiting rate of the workpiece is 2.17%, which is 8.14% lower than that before, as shown in Figure 4. The results verify that feasibility of the model.

Acknowledgement

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