Research of Production Scheduling Based on Theory of Constraints

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***Abstract*-An improved DBR scheduling method is proposed based on discrete system simulation method. The simulation model is established to identify bottleneck resources and determine the buffer. The improved simulated annealing is used to optimize and determine the DBR control parameters. The example results confirm the accuracy and validity of presented method.**

Keywords-theory of constraints; production scheduling; DBR(drum-buffer-rope); simulation; improved simulated annealing

I. INTRODUCTION

For manufacturing enterprises, production management is an important part of enterprise management, production scheduling is the key problem in production management. Therefore, the formulation of reasonable and scientific production scheduling, production workshop to control WIP, delivery satisfaction and improve production efficiency plays a very important role. The literature [1-2] the use of resources and supply chain constraints to restrict the product, solve the problem of formulating production planning. The heuristic algorithm proposed in paper [3] hybrid process enterprise production plan. Put forward in the literature [4] optimization model of production planning based on genetic algorithm. Literature [5] presented an improved quantum particle swarm optimization algorithm to solve the problem of production planning optimization, convergence instability problems often occur but when solving the optimization. Literature [6] presented an improved quantum particle swarm algorithm, and has a faster convergence speed and robustness. This paper takes a machine tool plant bed production planning as the research object, established a production plan model, and applies the improved simulated annealing algorithm to solve, so as to effectively improve the efficiency of system simulation.

II. DBR PLANNING AND CONTROL METHOD BASED ON SIMULATION

A. Bottleneck Identification Based on Simulation

In this paper, consider using discrete system simulation method to solve the problems of the application of DBR method in the current bottleneck identification and other issues, in order to improve the effective implementation of DBR production control, its basic steps shown in figure 1.

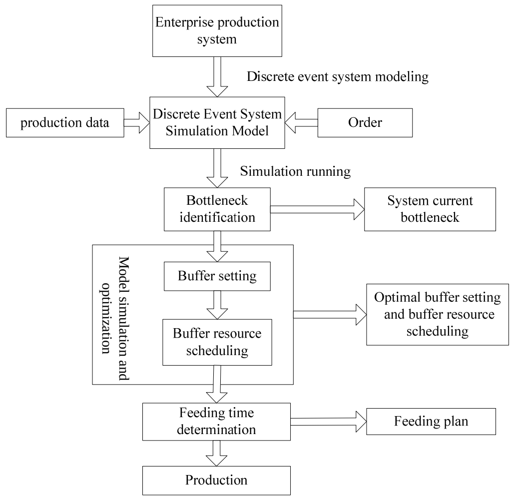

FIGURE I. DBR CONTROL METHOD BASED ON DISCRETE EVENT SIMULATION

Calculation of buffer setting using the following formula diagram:

$$TB_i = (1+R)\sum_{j=1}^{n} P_{ij} \tag{1}$$

In the formula, TBi is the I order of the buffer, R wide put coefficient, n number of processes of the buffer, processing time and preparation time required for the Pij I order corresponds to the product of article J procedure, using the following formula:

$$P_{ij} = O_i * p_{ij} + S_{ij} \tag{2}$$

In the formula, the amount of Oi needed for the I orders of the product, Pij for the first I order products required in the processing procedure of J time, Sij is the first I to the order in the j process of the preparation time of production.

According to the above formula can calculate shipping bottleneck buffer, buffer and assembly buffer size as follows:

$$BC_\mathrm{i} = (1+R)\sum_{j=1}^{k-1} P_{ij} \tag{3}$$

$$BS_\mathrm{i} = (1+R)\sum_{k+1}^{n} P_{ij} \tag{4}$$

$$BA_i = (1+R)\sum_{i=1}^{r} P_{il} \quad (5)$$

In the formula, BCi is the bottleneck buffer, BSi said shipping buffer, BAi as the assembly buffer, k of the time schedule procedure is bottleneck, Pil required for process flow production assembly parts I of the orders of the article l procedure processing time, R for the production of the assembly process the number of processes.

In order to ensure the utilization of bottleneck resources as high as possible, use the FCFS principle of machining in the non bottleneck resources on the contention situation. Get each order in the bottleneck of the start time, the start time of the bottleneck resource bottleneck buffer time minus the feeding time is obtained:

$$MT_i = ST_i - BC_i \quad (6)$$

B. The Optimization Mode

The actual cost of production in this paper,access to 3 key factors influencing the production cost of the enterprise: the average order delay time, average production flow time and the total completion time. Based on the above factors as objective function to establish the model of production plan cost:

$$\min C = w_1 m_1 * [(1+R)\sum_{i=1}^{n}\sum_{j=1}^{m} O_i * p_{ij} + S_{ij} - \sum_{i=1}^{n} D_i(t)] / n$$
$$+ w_2 m_2 * [(1+R)\sum_{i=1}^{n}\sum_{j=1}^{m} O_i * p_{ij} + S_{ij} - \sum_{i=1}^{n} R_i(t)] / n$$
$$+ w_3 m_3 * \max_{i\in(1,\cdots,n)} [(1+R)\sum_{i=1}^{n}\sum_{j=1}^{m} O_i * p_{ij} + S_{ij}] \quad (7)$$

s.t. pij⩾0 i=1,2,…,r, j=1,2,…,n (8)

Sij⩾0 i=1,2,…,r, j=1,2,…,n (9)

Oi⩾0 i=1,2,…,r, j=1,2,…,n (10)

In the formula, W1, W2, W3 respectively for the average order delay time, average production flow time and the total completion time and cost weight relationship value, w1+w2+w3=1. M1, M2, m3 respectively for the average order delay time, average production flow time and the total completion time.

C. The Solution of The Model Based on Improved Simulated Annealing Algorithm

Because of the traditional SA's (simulated annealing algorithm) slow convergence speed. The improved simulated annealing algorithm proposed by Ingber[7] (VFSA) is used.The solving process is as follows:

Initialization: The initial temperature of T (sufficiently large), the initial solution state S (is the starting point of the iterative method), the number of iterations of L for each T value:

On K=1,... L, do the third step to the sixth step

To generate the new S'

Calculation of increment E=E (S') -E (S), where E (S) as the evaluation function

If the delta E<0 'S is accepted as a new current solution, or with probability exp (delta E/T) received S' as the new current solution;

If the termination condition is satisfied then the output current solution as the optimal solution, end program. The termination condition is usually taken as continuous several new solutions are not accepted termination algorithm

T gradually decreased, and T to 0, and then turn to step second

Finally, when T approaches 0, stop the calculation, the output current solution as optimal solution

III. OPTIMIZATION SCHEDULING EXAMPLE

Effectiveness of the production scheduling in a machine tool factory as an example to verify the machine cantilever method. Product process data and the number of tasks such as table 1, shown in Table 2.

TABLE I. CANTILEVER PROCESSING TIME (UNIT: MIN).

Model	Planing	Milling	End milling	Milling	Grinding
A	103	123	98	64	298
B	54	136	88	124	128
C	54	205	88	88	141
D	103	123	174	53	219
E	54	123	98	112	145
F	55	125	100	125	130

TABLE II. CANTILEVER PRODUCTION PLAN

Model	A	B	C	D	E	F
Quantity	5	25	20	10	15	5
Delivery(h)	25	22	22	22	22	26

With the establishment of the system simulation software Flexsim simulation model (model slightly) , the simulation bottleneck detection using link configuration is as follows : ① sorting order using the principle of delivery of the earliest priority ; ② shipping buffer system is not set up , the bottleneck buffer , the production process According to the order of the production process once were ; ③ into the workpiece using a combination of bulk quantities of orders , and a number of artifacts to leave the production line approved before entering the workpiece machining processes in which finished on into the next process .

Data analysis of simulation runs to get , grinders idle lowest rate of 18 %. In fact , due to the small number of units grinder equipment , long processing time , which restricts the output of the system and become the bottleneck process .

After the establishment of the current bottleneck in the system , the next step is to determine the optimal objective under the premise of how to determine a reasonable DBR production control parameters (buffer coefficient , bulk transport , the introduction of the order , etc.) . Table 3 for each order processed on the grinder process start time and end time processing . As can be seen from Table 3, there is a bottleneck process simultaneously processing two orders of circumstances , in Table 4 is the principle of priority ordering delivery conducted using.

TABLE III. START AND END TIMES OF THE BOTTLENECK PROCESS(UNIT: H).

Order form	End Time	Start Time
A	24.7173	23.0615
B	12.4004	8.8568
C	14.7361	11.5961
D	18.4562	16.0140
E	19.0844	16.6696
F	25.0097	24.2875

TABLE IV. SORTED BOTTLENECKS START AND END TIME(UNIT: H).

Order form	Feeding time
B	0
C	1.2551
D	10.0988
E	11.0429
A	20.5815
F	22.1298

The start time of the bottleneck process orders minus bottleneck buffer time to get an order of feeding time . As shown in Table 5.

TABLE V. FEEDING TIME FOR EACH ORDER

Order form	Feeding time
B	0
C	1.2551
D	10.0988
E	11.0429
A	20.5815
F	22.1298

The average delay time of the order , the average flow time, total completion time with the coefficient of variation of the buffer in Figure 2 , Figure 3 ,and Figure4 respectively. Contents shown in Table 6 for different combinations of batch performance system .

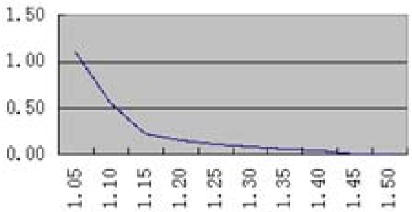

FIGURE II. THE AVERAGE DELAY TIME OF THE ORDER WITH THE BUFFER COEFFICIENT CURVE

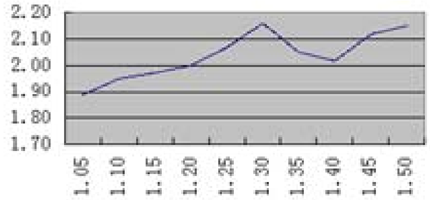

FIGURE III. HE AVERAGE FLOW TIME CURVE CURVE OVER THE BUFFER COEFFICIENT

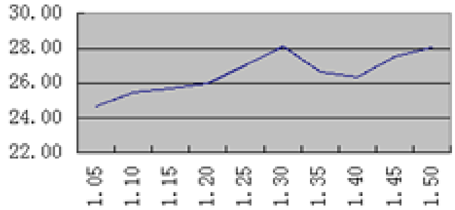

FIGURE IV. THE TOTAL COMPLETION TIME OF THE BUFFER COEFFICIENT CURVE

TABLE VI. PERFORMANCE UNDER DIFFERENT COMBINATIONS OF BATCH SYSTEMS(UNIT: H).

Combination of batch	The average delay time of the order	The average flow time	The total completion time
5	0.25	1.64	26.27
10	0.10	2.56	25.68
15	0.08	3.19	25.53
20	0.02	3.63	25.41
25	0	4.21	25.28

By the improved simulated annealing algorithm and simulation software combines want to give different buffer coefficient and 7 for optimal system performance indicators configuration combinations batch system performance indicators in the following table.

TABLE VII. OPTIMAL PARAMETERS IN THE SYSTEM AVERAGE ORDER LATENCY , MEAN FLOW TIME AND TOTAL COMPLETION TIME

Indicators / parameters	Numerical
Buffer coefficient	1.20
Combination of batch	10
Collations	Early delivery priority
The average delay time of the order	0.1661
The average flow time	2.00
The total completion time	26.0128

IV. CONCLUSION

The bottleneck resources are identified by establishing and running the simulation model. The buffer coefficient, combination batch and other control parameters are optimized with an improved simulated annealing algorithm. Therefore, the scheduling of bottleneck resources and the execution order of production order are determined. Taking a production process and production tasks as an example, the proposed methods is proved to be effective.

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