Research on order scheduling based on improved artificial bee colony algorithm

Xinghua Li, Haozhe Wang*, Xiaoqing She, Huimin Zhang

College of Energy and Mining Engineering, Shandong University of Science and Technology, 266000, Qingdao, Shandong, China

* Corresponding author's e-mail: 1242352290@qq.com

Abstract. In the face of market changes, shortening the cycle and on-time delivery have become the necessary conditions for manufacturing enterprises to win customer orders. Status of order according to the manufacturing enterprise production scheduling based on improved artificial swarm algorithm, in which the minimum cost of production, the objective function is minimum completion time, constraints on capacity, inventory ability, build orders for production scheduling model by using the before and after the improvement of artificial swarm algorithm to build the order of production scheduling model simulation, combined with the actual production status of the company. Through the analysis of the optimization results, the real effectiveness of the improved artificial bee colony algorithm for solving the order scheduling model is verified, which provides a reference for manufacturing companies to carry out the order scheduling optimization event.

Keywords: order scheduling; optimization; improved artificial bee colony algorithm; production by order

1 Introduction

Order oriented production [1] is a production mode in which enterprises organize production and processing activities according to the relevant requirements of customer order information and deliver to customers at the specified time. In order production mode, how to arrange orders reasonably for production is of great significance. Liao Jiawei [2] introduced TOPSIS method to determine order priority, took inventory cost as the target, and arranged production according to order priority order. Wu Shaomin et al. [3] considering order delay cost, inventory cost and load balance of production unit, a mathematical model of order oriented multi-objective scheduling optimization is constructed. MaYL et al. [4] used the multi-elite co-evolutionary genetic algorithm to solve the scheduling model with the maximum completion time and the smallest completion time. QinHB et al. [5] took foundry enterprises as the background, introduced the constraints of processing interval and operation transportation time, constructed a multi-objective foundry production scheduling model to minimize completion time, total production cost and total delivery delay time, and proposed a hybrid

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discrete multi-objective gray Wolf optimization algorithm. Based on the research of scholars, this paper establishes a multi-objective mathematical model for the production scheduling problem, and proves the feasibility of the method by improving the artificial bee colony algorithm.

2 Model analysis and establishment

2.1 Problem description

The order of the assembly production system is scheduled to decompose the order into multiple sub-orders (as shown in Figure 1) before the order is carried out in the production system, and the decomposed order is renumbered, so that there is only one product model in the order in the production system.

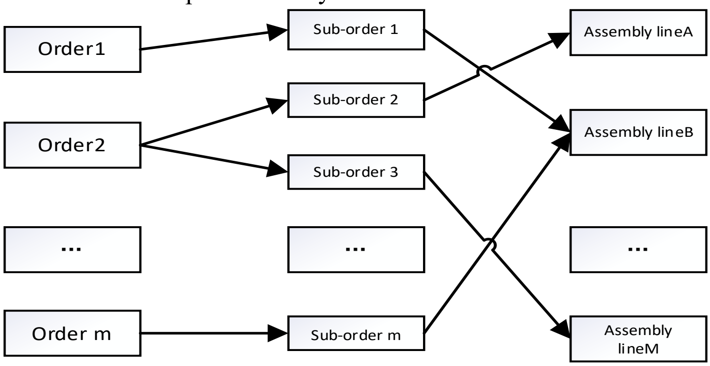

Fig. 1. Order breakdown chart

O is used to represent the decomposed orders. Suppose that m orders enter the production system, and the order set is $i \in O=\{1,2,3...,m\}$and each order has the same assembly process, standard, processing time, delivery time and other related attributes. Each product has *J* processing procedures, which meet the corresponding sequence requirements. In fact, order scheduling is to determine the production and processing arrangement of all orders in the planning period, so that the objective function can achieve the optimal under relevant constraints.

2.2 Assumptions and notations of the model

Set the following assumptions before building the order scheduling model.

(1) Before order scheduling, all order arrival time, processing time, inventory cost, delay cost and other related information are known.

(2) The order has been decomposed into sub-orders before the production schedule, and sub-orders are re-labeled. At this time, the order entering the production system contains only one product, the same product has exactly the same information, and each order has a clear product quantity and delivery time.

(3) The process of processed products is consistent and cannot be stopped during production (unless there is an irresistible disturbance event).

(4) The capacity of each production line is known, including the maximum capacity, production preparation time, equipment maintenance time, etc.

(5) There is no sequence constraint between different order tasks. At time t=0, all machines and products can be processed.

The symbols required in the order scheduling model are as follows:

O: order product set; i: order number, $i \in O=\{1,2,3\ldots,m\}$;

j: the production stage of the order product; J: set of production stages;

t: time period; T: Planning period; MO_i: quantity demanded for order i;

X_{ijt}: the quantity of products to produce order i in phase j of production in period t;

N_{ijt}: determine whether order i is produced in phase j at time t, 0-1 variables;

P_{ij}: Unit cost of processing production for order i in stage j of production;

CP_{ij}: Unit cost of preparation for production of order i in production stage j;

P_i: the quantity of order i completed in advance; CN_i: unit inventory cost of order i;

T_i: complete processing time of order i; T_{ij}: the completion processing time of order i in production stage j; CS_i: unit cost of delayed delivery of order i;

D_i: delivery time of order i; $SDTi$: quantity of delayed delivery of order i;

PTi: judge whether order i has delayed delivery, 0-1 variable;

SP_i: inventory capacity of order i; H: The number of hours in a production cycle;

PT_{ijt}: production preparation time of production order i in production stage j within period t; RT_{ijt}: equipment maintenance time of production order i in production stage j within period t;

F_1: cost of production; F_2: the latest time for completion.

2.3 Mathematical model construction

(1) Objective function.

1) Cost of production: The processing cost, production preparation cost, inventory cost and delay penalty cost are considered comprehensively, denoted by C_1, C_2, C_3 and C_4, respectively, establish the minimum production cost optimization model.

$$C_1 = \sum_{i\in O}\sum_{j\in J}\sum_{t=1}^{T} X_{ijt} \times N_{ijt} \times P_{ij} \quad (1)$$

$$C_2 = \sum_{i\in O}\sum_{j\in J}\sum_{t=1}^{T} N_{ijt} \times CP_{ij} \quad (2)$$

$$C_3 = \sum_{i\in O}\sum_{j\in J}\sum_{t=1}^{T} CN_i \times P_i \quad (3)$$

$$C_4 = \sum_{i\in O}\sum_{t=1}^{T} SDT_i \times CS_i \times (T_i - D_i) \times PT_i \quad (4)$$

$$F_1 = C_1 + C_2 + C_3 + C_4 \quad (5)$$

2) Completion time: refers to the time from the beginning of processing to the completion of processing for all ordered products.

$$F_2 = \sum_{i\in O} T_i \quad (6)$$

The weighting method is adopted to integrate multiple objective functions and obtain the overall objective function:

$$min\ F = min\{F_1, F_2\} = min(\mu_1 F_1' + \mu_2 F_2') \quad (7)$$

$\mu_1 + \mu_2 = 1$, the value μ_1 and μ_2 is measured according to the importance of the performance evaluation index of the enterprise. F_1' and F_2' are normalized according to F_1 and F_2 converted to the minimum value [0,1].

$$F_1' = \frac{F_1 - F_1^{min}}{F_1^{max} - F_1^{min}} \quad (8)$$

$$F_2' = \frac{F_2 - F_2^{min}}{F_2^{max} - F_2^{min}} \quad (9)$$

(2) Constraints.

1) Capacity constraint: the production and processing time, preparation time and equipment maintenance time shall not exceed the specified production cycle.

$$\sum_{i\in O}\sum_{j\in J}\sum_{t=1}^{T} X_{ijt} \times N_{ijt} \times T_{ij} + PT_{ijt} \times N_{ijt} \le H - \sum_{i\in O}\sum_{j\in J}\sum_{t=1}^{T} RT_{ijt} \quad (10)$$

2) Inventory capacity constraint: the order products stored cannot exceed the maximum storage capacity of the corresponding warehouse at any time.

$$\sum_{i\in O} P_i \le SP_i \quad (11)$$

3) Variable constraints: Variables N_{ijt} and P_i in the objective function and constraint conditions are 0-1 decision variables, as shown in Equations (12) and (13). Equation (14) indicates that the continuous variables in the optimization model are non-negative values.

$$N_{ijt} = \begin{cases} 1, order\ i\ was\ produced\ in\ time\ t \\ 0, no\ order\ i\ within\ the\ time\ t \end{cases} \quad (12)$$

$$P_i = \begin{cases} 1, delayed\ delivery\ of\ order\ i \\ 0, no\ delayed\ delivery\ of\ order\ i \end{cases} \quad (13)$$

$$0 \le SDT_i, P_i \le MO_i \quad (14)$$

$$MO_i = \sum_{i\in O}\sum_{j\in J}\sum_{t=1}^{T} X_{ijt} \quad (15)$$

3 Algorithm design

The main improvement of artificial bee colony algorithm is the establishment of double space [6]. Double space refers to adding another space knowledge space when solving the main space. The final optimal solution is found by population exchange and transmission between the knowledge space and the main space, and the specific steps are as follows.

(1) Establishment of principal space

1) Fitness function design.

The fitness *f(x)* of the established target value is shown in Equation (16).

$$f(x) = \begin{cases} \frac{1}{1+F}, F \geq 0 \\ 1 + |F|, F < 0 \end{cases} \tag{16}$$

2) Coding and parameter initialization.

According to the order production scheduling problem, the problem is transformed into the problem of order production line processing sequence arrangement. The order is numbered from 1 to *N*, and each order number appears *M* times in the code. If the process code string is [3 2 4 3 2 1 4 3], the first number 3 represents the first process of order 3, and the seventh number 4 represents the second process of order 4, and so on.

Determine the initial parameters: set the number of unknowns of the bee colony algorithm, the number of workers (observers), the maximum number of iterations, the range of parameters to be solved, and the number of iterations to be abandoned.

3) The stage of leading bees

4) The stage of follow bee

The optimization algorithm follows the law of natural selection, and the degree of adaptation of each solution to the environment is expressed by its fitness. The larger the fitness, the more chance it has to be selected by the bystanders as the object of honey collection. To implement this process, a roulette algorithm is used in which each follower bee produces a number P_i,

$$P_i = rand(1) \tag{17}$$

$$S_i = min(f(j) > P_i) \tag{18}$$

$$f(j) = (\textstyle\sum_{x=1}^{j} f(x) \,/ f(end)) \tag{19}$$

5) The stage of scout bee

(2) Establishment of knowledge space

(3) Exchange between knowledge space and main space

(4) Search for final solution

4 The example analysis

4.1 Data acquisition

S company is a typical order oriented production enterprise, choose one of the production lines to analyse. Orders are ordered according to the principle of first come, first production. The order information is shown in Table 1.

Table 1. Order information table of a planning cycle

Order number	Product model	Quantity demanded	Unit-price	Unit inventory cost	Unit delay penalty cost
O-1	MS 382	50	2649	10	132
O-2	MS 180	90	1097	10	55
O-3	MS 193T	40	1497	10	125
O-4	MS 170	130	699	10	35
O-5	MS 461	30	2899	10	145
O-6	MS 661	20	3019	10	151
O-7	MS 271	60	2190	10	110
O-8	MS 231	90	1529	10	76
O-9	MS 362	50	2499	10	125
O-10	MS 251	40	1789	10	89
O-11	MS 211	20	1149	10	57
O-12	MS 291	50	2319	10	116

As can be seen from Table 1, taking the order with a total demand of 670 as an example, in order to show the production schedule clearly, the overall order quantity will be reduced by 10 times. At the same time, the production cycle is reduced by 10 times.

The production processing time, product processing unit cost, production preparation time are shown in Tables 2, 3, and 4.

Table 2. Product processing timetable

Production processes	Production processing time/min											
	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12
1	3.8	3	3.2	3	3.8	4	2.3	3.2	3.6	3.5	3.2	3.6
2	2.5	2.1	2.1	2.1	2.5	2.8	2.5	2.2	2.5	2.3	2.2	2.5
3	1.4	1.4	1.4	1.3	1.4	1.5	1.4	1.3	1.3	1.3	1.4	1.5
4	2	1.5	1.5	1.5	2	2	1.8	1.6	1.9	1.6	1.5	2
5	2.5	2.4	2.4	2.3	2.6	2.6	2.4	2.4	2.5	2.4	2.3	2.4
6	1.5	1.4	1.4	1.5	1.8	1.8	1.5	1.5	1.5	1.5	1.5	1.5
7	1.5	1.4	1.4	1.4	1.6	1.8	1.6	1.5	1.5	1.5	1.5	1.6
8	2.8	2.5	2.5	2.4	2.8	3	2.5	2.5	2.6	2.5	2.4	2.5
9	3.3	3	3	3.6	3.8	3.6	3.5	3.3	3.3	3.2	3.8	3.3
10	2	1.8	1.8	1.6	2	2.1	1.9	1.8	2	2	1.8	2

Table 3. Product processing unit cost table

Production processes	Product processing unit cost /yuan											
	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12
1	10	10	11	9	10	13	11	10	10	11	10	12
2	52	22	28	17	55	65	35	30	47	32	23	42
3	41	13	16	10	46	51	28	18	37	23	13	32

4	64	21	29	12	68	72	56	32	62	45	23	57
5	52	17	25	10	56	64	38	28	46	31	18	41
6	62	22	27	16	68	71	53	35	58	38	22	55
7	75	30	45	17	78	82	63	43	72	48	36	65
8	90	38	48	23	94	98	82	56	88	64	41	85
9	72	35	39	14	73	76	60	42	68	56	32	63
10	12	12	12	12	12	12	12	12	12	12	12	12

Table 4. Production preparation time table

Production processes	Production processes time/s											
	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12
1	2	1	2	1	2	2	2	1	2	1	1	1
2	3	3	1	2	5	3	2	2	3	2	2	2
3	3	2	2	1	3	5	3	3	3	2	3	3
4	3	1	2	2	4	4	2	2	4	3	2	3
5	4	2	3	1	3	4	4	1	3	3	3	2
6	4	3	2	2	3	3	3	3	2	2	3	4
7	3	1	1	1	4	4	3	2	4	3	1	5
8	3	2	3	2	3	3	2	3	4	3	1	3
9	4	2	3	1	4	4	3	2	3	2	2	2
10	1	1	1	1	1	1	1	1	1	1	1	1

4.2 Scheduling model solving

The related parameters of ABC algorithm and improved ABC algorithm for solving order scheduling problem are set as follows: number of bee colony 50, number of iterations 500, limit of control times 10. Other related parameters. The maintenance time of the device is 1 minute every 30 minutes. When the equipment breaks down, the maintenance cost is 300 yuan each time. Matlab was used to run ABC algorithm and related programs of improved ABC algorithm, and the change of objective function value was obtained as shown in Figure.2.and.3., and production schedule Gantt chart as shown in Figure.4. and. 5..

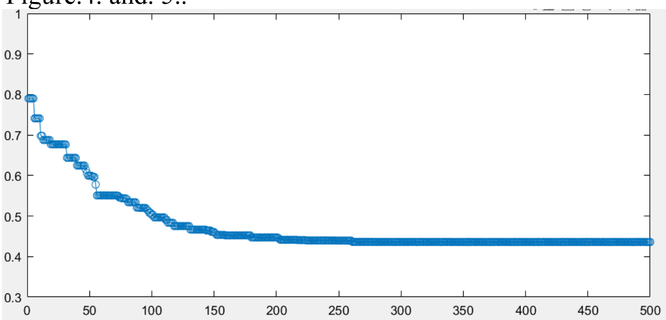

Fig. 2. Iterative graph of ABC algorithm

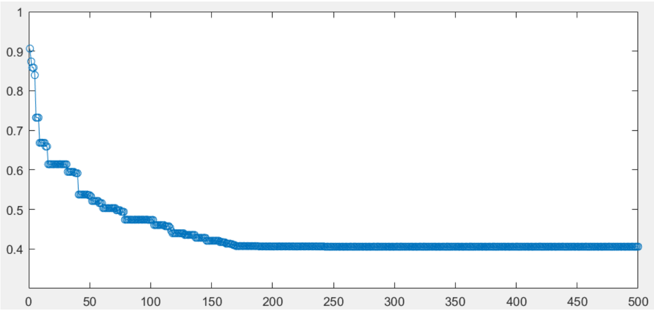

Fig. 3. Iterative graph of improved ABC algorithm

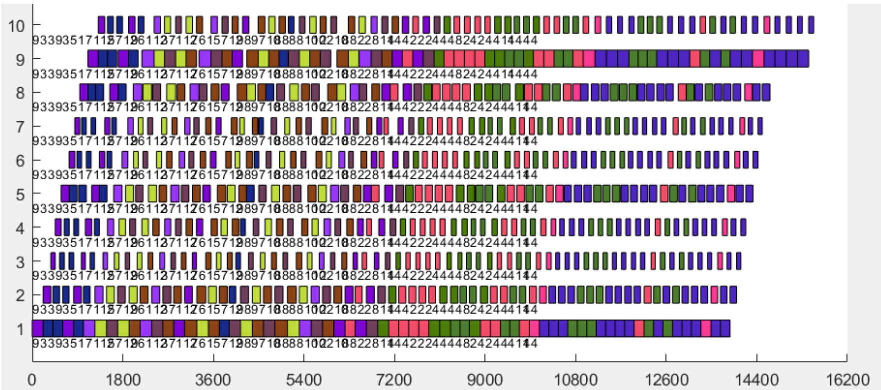

Fig. 4. ABC Algorithm order scheduling gantt chart

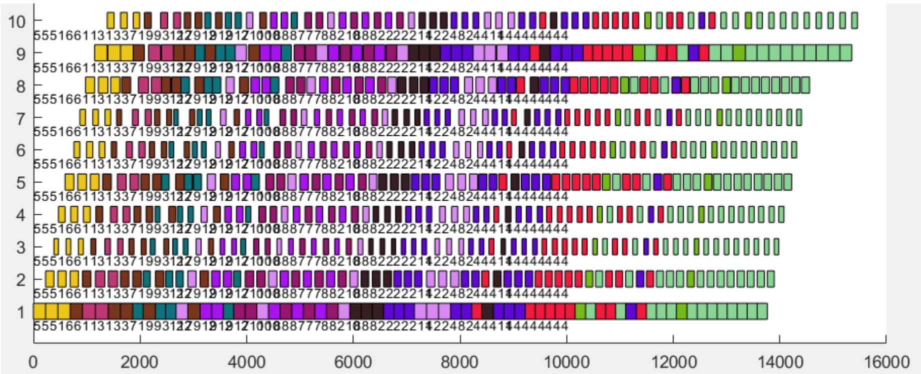

Fig. 5. Improved ABC Algorithm order scheduling gantt chart

According to Figure 2 and 3, the fitness function value solved by ABC algorithm reaches the optimal value at 258 iterations, and the improved ABC algorithm reaches the optimal value at 245 iterations. The improved ABC algorithm has a faster iteration speed and a smaller fitness function value.

As Figure 4 shown, the order scheduling sequence solved by ABC algorithm is 9-3-3-9-3-5-1-7-1-12-5-7-12-9-6-1-12-3-7-1-12-7-6-1-5-7-12-9-7-10-8-8-8-8-10-10-2-2-10-8-8-2-2-10-8-8-2-2-10-8-11-4-4-4-2-2-2-4-4-4-8-2-4-4-11-4-4-4-4.

As Figure 5 shown, the order scheduling order solved by the improved ABC algorithm is 5-5-5-1-6-6-1-1-3-1-3-3-7-1-9-9-3-12-12-7-9-12-9-12-9-12-7-10-10-10-6-8-8-8-7-7-7-8-8-2-10-8-8-8-2-2-2-2-2-11-4-2-2-4-8-2-4-4-11-4-4-4-4-4-4-4-4-4.

The results of S company's production schedule system were obtained and compared with the results of ABC algorithm before and after the improvement. The comparison of the three scheduling schemes is shown in Table 5.

Table 5. Comparison of three production scheduling schemes in initial state

Schedule system			ABC algorithm			Improved the ABC algorithm		
Order completion order	Final completion time	Cumulative life Production cost	Order completion order	Final completion time	Cumulative life Production cost	Order completion order	Final completion time	Cumulative life Production cost
O-1	2398	2780	O-3	5204	1260	O-5	1993	1772
O-2	4231	4958	O-6	6411	2554	O-6	2760	3053
O-3	5045	6178	O-1	6621	5394	O-1	4371	5923
O-4	8173	8222	O-5	6855	7200	O-3	4951	7183
O-5	8979	9964	O-12	7281	9648	O-9	6720	9899
O-6	9466	11225	O-9	7897	12314	O-12	6935	12373
O-7	10857	13938	O-7	8104	15077	O-7	9023	15161
O-8	12841	16802	O-10	10081	16623	O-10	9817	16705
O-9	13976	19381	O-8	13383	19547	O-8	12592	19629
O-10	14823	21199	O-2	13977	21725	O-2	12786	21771
O-11	15321	21792	O-11	14660	22243	O-11	13468	22289
O-12	16434	24718	O-4	15529	24338	O-4	15413	24325
Total	16434	24718	Total	15529	24338	Total	15413	24325

According to Table 5, the production cost obtained by the improved ABC algorithm is the lowest among the three production scheduling plans, which is 24,325 yuan. And the completion time is the smallest, 15413s.The production cost obtained by the improved ABC algorithm is 13 yuan less than that obtained by ABC algorithm, and 393 yuan less than that obtained by scheduling system. The minimum completion time is 16s less than ABC algorithm, 1021s less than the scheduling system. Using the improved ABC algorithm to solve the problem, a planning period can save 3930 yuan, about 2.8 hours, a month can save 51090 yuan, 36.4 hours.

5 Conclusion

Reasonable production scheduling scheme can effectively use resources and equipment, improve production capacity, save production costs, improve on-time delivery rate, and quickly respond to market changes. According to the problem analysis of the current order scheduling situation of manufacturing enterprises, this paper builds an order scheduling model with the lowest production cost and the minimum completion time as the objective functions, and the constraints of production capacity and inventory capacity. The improved artificial colony algorithm is used to simulate the constructed order scheduling model. Combined with the actual production status of Company S, the real effectiveness of the improved artificial bee colony algorithm to solve the order scheduling model is verified through the analysis of optimization results, which provides a reference basis for manufacturing companies to optimize order scheduling events.

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