SIMULATION BASED CO-SCHEDULING RESEARCH ON GROUP-DISTRIBUTED MANUFACTURING SYSTEM

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ABSTRACT: This paper introduces the characteristics of group-distributed manufacturing mode, and makes some basic assumptions, including scheduling principle and scheduling cycle, etc. On this basis, a co-scheduling model of group distributed manufacturing system is built, and simulation algorithm based on heuristic rules is compiled. Then we make a simulation research on the co-scheduling model through MATLAB. Simulation results show that production cost and production load balance are both optimized distinctly by using the co-scheduling model, which confirms that the co-scheduling model of group distributed manufacturing system is scientific and effective.

KEY WORDS: group distributed manufacturing, manufacturing management, co-scheduling, simulation.

1 INTRODUCTION

Distributed manufacturing mode which has Agile and lean characteristics has become the new direction of the development of the manufacturing production mode in the 21st century (Fumin, 2000; Sichao, 2013). Take Chinese economic development level and manufacturing development phase into consideration, the distributed manufacturing in China is still in the stage of theory and mode studies. However, another kind of similar manufacturing pattern is gradually formed, it is called group-distributed manufacturing mode. In this mode, subordinate manufacturing units belong to the same group company. There exists a large possibility to implement collaboration among these manufacturing units because of relatively small obstacles in the process. It is a production manufacturing mode conforming to the actual needs and actual conditions.

Fewer scholars made in-depth research on group distributed manufacturing system, but the research on distributed manufacturing were common, we could use for reference. G.Q.Huang proposed that man-machine integration global optimization system would be applied to the distributed manufacturing system (Huang, 2001). With the development of distributed model, Chinese scholars also started to pay great attention. Some scholars carried on a thorough analysis on the type and components of distributed manufacturing (Lihua, 2013) (Shijin, 2010).Yang thought distributed manufacturing system is based on the cooperation of each link production and business operation activities through the Internet, and realize the sharing and optimization of enterprise resources (Zhihong, 2002).

X.F. Yao believed that the information of distributed manufacturing system had characteristics such as resource information highly distribution and autonomy, the diversity of data and environmental heterogeneity (X.F. Yao, 2000).

Above all, most of the research is focused on the co-mechanism, and only a minority of researchers studied production co-scheduling problem of distributed manufacturing mode from the viewpoint of production management. Although in practice, group-distributed manufacturing mode has had a long history, research about co-scheduling of group-distributed manufacturing is more rarely at present. In China, the group-distributed manufacturing is a widely used production mode, studying group-distributed manufacturing and its co-scheduling has great significance in theory and practice.

2 PROBLEM DESCRIPTION

2.1 Aims of co-scheduling

Group distributed manufacturing co-scheduling is based on information technology, and it makes full use of information resources and manufacturing resources of the group's manufacturing units, to realize product manufacturing at appropriate speed, low cost. In the process of co-scheduling, real-time, full and accurate information is the foundation, through the establishment of information integration management system for the various manufacturing unit of information resources integration, and on this basis for scientific scheduling, realizes the

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resource sharing, the optimum combination and the reasonable configuration, make the enterprise production operation to achieve the global optimal, improve the market competitiveness of group company. The target of group distributed manufacturing co-scheduling mainly including lower production costs, improve production load balance.

2.2 Primary principles of co-scheduling

Group distributed manufacturing mode of production system is a very complicated system, moreover, it has some unique characteristics, the internal co-scheduling among various manufacturing units has been put forward new requirements, the goal of co-scheduling have taken place some changes compared with the traditional production scheduling. Therefore, when making group distributed manufacturing co-scheduling the principle of adapted with management should be strictly followed to ensure that the co-scheduling is smooth and efficient operation of the production system as a whole.

In group distributed manufacturing mode, the co-scheduling should follow the basic principles: resources and information sharing and combination of collaborative management and distributed management. Resources and information sharing is the foundation of the group distributed manufacturing co-scheduling. The combination of two kind of management model can provide platform and space autonomous production scheduling for group each manufacturing unit, and worked together to achieve more, optimize the allocation of resources, improve the production efficiency. On the basis of considering the interests of the various manufacturing units, realize the maximization of the interests of the whole group company.

2.3 Mode of co-scheduling

Group distributed manufacturing mode of production system is a very complex system, its constituent units are numerous, the distribution of resources and information has strong dispersion. Only on the basis of information integration, can further implement the effective management of manufacturing activities coordination and dependency and realize the integration of the manufacturing activities and manufacturing process, improve the competitiveness of manufacturing companies (Mckay, 1998).

Based on the group and the characteristics of distributed manufacturing and the co-scheduling target and basic principle of the manufacturing mode, design a group distributed manufacturing oriented co-scheduling mode. The co-scheduling model based on the information integration, by means of a coordinated production scheduling, to realization group company the full use of the internal business information and production information, and on the basis of the information integration of various resources for unified planning and deployment, reduce production cost, improve the efficiency of resource utilization and customer satisfaction and maximize the company's profits and value. Group distributed manufacturing oriented co-scheduling framework model shown in Figure 1.

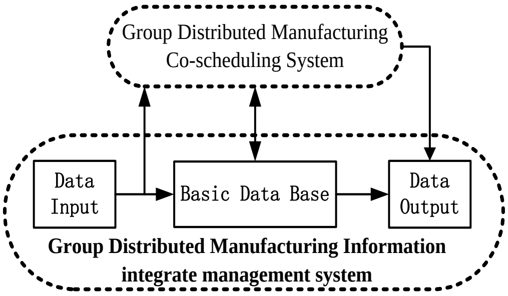

Figure 1. Group distributed manufacturing oriented co-scheduling framework mode

3 CO-SCHEDULING MODEL

Group-distributed collaborative scheduling included two main scheduling methods. The one was centralized co-scheduling. There existed a coordination center in the manufacturing system, and it was responsible for organizing its subordinate manufacturing unit to co-allocate the production task. Coordination center made centralized management of subordinates and released production scheduling command. The other is the cooperative bidding type, which formulated a set of bidding rules in advance in the production system, and the production task allocation and scheduling between various manufacturing units by bidding. This had a relatively high degree of autonomy of course. Given that the present manufacturing industry in our country is still in the growth stage, the enterprise needs to improve management ability and level, the centralized coordination scheduling is easier to carry on and more adapted to the current level of development. Therefore, the centralized collaborative scheduling is used in this paper.

3.1 Model assumptions

(1) Model assumptions. The production scheduling of group-distributed manufacturing enterprise included two hierarchies, the production

task cooperation scheduling among various manufacturing unit and production scheduling within each manufacturing unit. In this collaborative scheduling model, only the production task cooperation scheduling among various manufacturing unit was considered into research.

(2) Scheduling principle assumptions .There were several scheduling principle assumptions to obey. By order of the priority principle of manufacturing unit, only beyond its spare capacity order again by group headquarters operation collaborative scheduling model assigned to other suitable manufacturing unit; each order could only be accepted by a manufacturing unit. Production in time principle, in the process of collaborative scheduling, the time of the customer order completion is not the sooner the better, but before the customer required delivery date; Batch delivery principle, all products in an order was delivered at one time after the completion production.

(3) Scheduling period assumption. Due to the uncertainty of customer orders, assuming a day for a cycle. Start the collaborative scheduling model for scheduling operation the day new customer orders before closing time work every day.

3.2 Conceptual model

The co-operative scheduling of Group-distributed manufacturing model was driven by customer demand. In the environment of group distributed manufacturing, staring the collaborative scheduling model when the new customer demand occurred. The manufacturing units which had received customer orders begin carried on the measurement of its surplus production capacity, and realized the first allocation of production tasks; then, if customer demand is beyond the scope of its own production capacity, the beyond parts of the customer orders would be unified coordination scheduling by the group company headquarters, and realized the redistribution of production tasks. In the whole collaborative scheduling model, customer demand is the core drive of the scheduling model.

The conceptual model was as follow in figure 2.The scheduling is mainly for the first time according to the principle of order intake manufacturing unit priority, it will get new customer orders and accept this order match the residual capacity of manufacturing unit, if by order of the production unit can order volume on schedule to complete the production task, will the customer orders assigned to the manufacturing unit. The rescheduling, was mainly for unfinished in the scheduling in the first time distribution of customer orders. For these orders, by the group headquarters this coordination center according to the specific collaborative scheduling rules, to unified planning and allocation. Finally considering the interests of the group's manufacturing units, on the basis of promoting group company's overall profit maximization.

4 HEURISTIC ALGORITHM

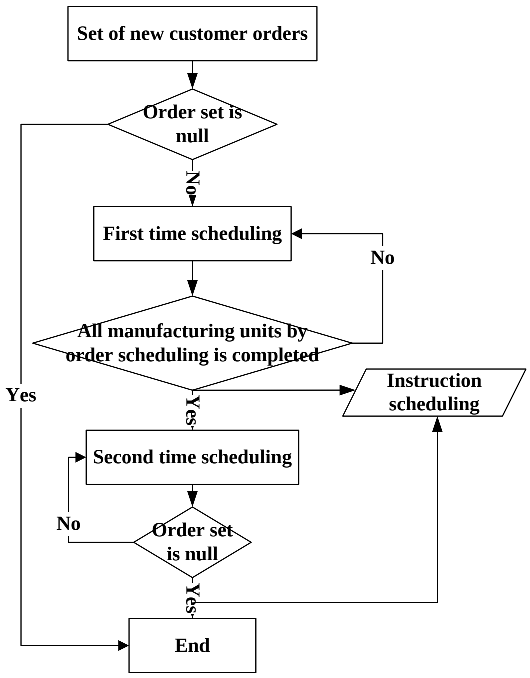

Figure 2. Group distributed manufacturing co-scheduling model

In this paper, research is not focused on a single manufacturing unit or production planning and scheduling problem in the workshop, but on the production task coordination scheduling problem among multiple subordinate manufacturing units in the group-distributed manufacturing model. The scheduling problem was strongly dynamic, and it was difficult to obtain reasonable scheduling command by a single mathematic model (Rodammer, 1998). As a result, collaborative scheduling algorithm based on heuristic rules was used according to the characteristics and requirements of group-distributed manufacturing cooperative scheduling. And the earliest delivery date (EDD) priority should be the scheduling rule, then scheduling the production tasks collaboratively among the group's subordinate manufacturing units. When making the coordination scheduling of production tasks, the priority of the task scheduling was determined according to the urgency of production tasks, and the urgency was determined by the time of delivery of the customer orders requirements.

4.1 Variable definition

The variables of collaborative scheduling model in group-distributed manufacturing enterprise were defined as follows.

(1) Manufacturing unit set $A=\{A_1,A_2\ldots A_n\}$. A_i denotes manufacturing unit i; A_{ai} denotes current production scheduling date of manufacturing unit A_i; A_{ci} denotes the productivity of manufacturing unit A_i per unit time, that is, the number of products per hour; n denotes the total number of group subordinate manufacturing units.

(2) Feasible manufacturing unit set $KX_j=\{A_i\},i\in(1,2\cdots n)$ which is for the rescheduling of customer orders Z_j, K_j denotes the number of feasible manufacturing units for customer order Z_j.

(3) New customer order set $R=\{R_1,R_2\cdots R_n\}$, R_i denotes all customer orders newly undertaken by manufacturing unit i; n denotes the total number of group subordinate manufacturing units.

(4) Customer orders $R_i=\{R_{i1},R_{i2}\cdots R_{imi}\},i=1,2\cdots n$ newly undertaken by manufacturing unit A_i. m_i denotes the total number of customer orders newly undertaken by manufacturing unit i, and customer orders in the set are arranged by the delivery date of order requirements.

(5) Customer order $R_{ij}(t_{ij},r_{ij})$ denotes customer order j undertaken by manufacturing unit i, t_{ij} denotes the delivery date customer order R_{ij} required and r_{ij} denotes the total number of products required by customer order R_{ij}.

(6) Customer order set $Z=\{Z_1,Z_2\cdots Z_m\}$ for rescheduling. $Z_j(zt_j,zr_j)$ denotes individual customer orders not assigned to the manufacturing unit in the first schedule and customer orders in the set are arranged by the delivery date of order requirements; m denotes the number of customer order for rescheduling.

(7) $Q_i(t_i,q_i),i=1,2\cdots n$, denotes the current remaining capacity of manufacturing unit A_i.

(8) $C_j=\{C_{kj}\}$ denotes the final production cost set $C_j=\{C_{kj}\},k\in(1,2\cdots k_j)$ by feasible manufacturing units for rescheduling customer order $Z_j=(zt_j,zr_j)$ without overtime work or delay. C_{kj} denotes the total cost to complete the order by the manufacturing unit k in the final feasible manufacturing units set $KX_j=\{A_i\}$ for customer order $Z_j=(zt_j,zr_j)$ under the condition of none overtime work or delay .

(9) P_1 denotes the labor cost of per unit product at normal working hours; P_2 denotes the labor cost of per unit product at overtime working hours; Y_{ij} denotes the finished products transportation time from the manufacturing A_i to the correspond place of customer order R_j; P_3 denotes the cost in the unit delivery time for per unit products.

(10) Co-scheduling results ZZD, namely production task allocation instruction set generated by co-scheduling.

4.2 Simulation algorithm

According to target of group-distributed manufacturing co-scheduling, the earliest delivery date (EDD) priority rules, co-scheduling concept model and variable definitions, work out co-scheduling algorithm based on heuristic rules. And each phase of the algorithm is described as follow.

(1)First time scheduling

Schedule for the first time to each $R_i(R_i\neq\varnothing)$ in the new customer order set $R=\{R_1,R_2\cdots R_n\}$ .According to the principle of manufacturing unit priority, respectively match all customer orders in the set $R_i=\{R_{i1},R_{i2}\cdots R_{imi}\},i=1,2\cdots n$ with the spare capacity of manufacturing unit A_i by the sequence of delivery time, arrange the manufacturing units which undertake orders preferentially to carry on production tasks, and scheduling algorithm is shown as below.

Step1: let $i=1$;

Step2: if new customer order manufacturing unit A_i set $R_i=\varnothing$ of, directly go to Step8; Otherwise go to Step3;

Step3: let $j=1$;

Step4: calculate spare capacity Q_{ij} of manufacturing unit A_i for customer order $R_{ij}(t_{ij},r_{ij})$ in the set $R_i=\{R_{i1},R_{i2}\cdots R_{imi}\}$, and get current production capacity $Q_{ij}\left(\left(t_{ij}-A_{ai}\right)*8,q_{ij}\right)$ of the corresponding manufacturing unit A_i for customer order $R_{ij}\left(t_{ij},r_{ij}\right)$.

Step5: if $q_{ij}\le r_{ij}$, go to Step6. If $q_{ij}\ge r_{ij}$, it means that manufacture unit volume on can complete customer order $R_{ij}\left(t_{ij},r_{ij}\right)$ on time. According to the sequence priority principle of manufacturing unit adopting orders, assign customer order to the manufacturing unit A_i, and put the scheduling results into co-scheduling result set ZZD. At the same time, update the manufacture resource data of s manufacturing unit A_i and use it as input data for the next customer order when scheduling. And remove the customer order $R_{ij}\left(t_{ij},r_{ij}\right)$ from the customer order set $R_i=\left\{R_{i1},R_{i2}\cdots R_{imi}\right\}$.Go to Step7.

Step6: if $q_{ij}\le r_{ij}$, manufacturing unit A_i cannot complete the production of customer orders $R_{ij}\left(t_{ij},r_{ij}\right)$ on time, then put the customer order into customer order set $Z=\left\{Z_1,Z_2\cdots Z_m\right\}$ for rescheduling. And remove the customer order $R_{ij}\left(t_{ij},r_{ij}\right)$ from the customer order set $R_i=\left\{R_{i1},R_{i2}\cdots R_{imi}\right\}$.

Step7: if $j=m_i$, directly go to Step8; Otherwise, let $j=j+1$, go to Step4.

Step8: if $i=n$, direct go to Step9; Otherwise, let $i=i+1$, go to Step2.

Step9: scheduling for the first time end, go to Step10.

After the scheduling for the first time, three results are gained as follows: scheduling results for the first time set ZZD; customer order set $Z=\left\{Z_1,Z_2\cdots Z_m\right\}$ for rescheduling, $Z_j\left(zt_j,zr_j\right)$ denotes individual customer orders not assigned to the manufacturing unit in the first schedule and customer orders in the set are arranged by the delivery date of order requirements, m denotes the number of customer order for rescheduling; manufacturing resource data set A of various manufacturing units after the completion of the scheduling for the first time.

(2)Second time scheduling

Make scheduling results for the first time, setting ZZD, and manufacturing resource data set A after the first time scheduling and customer order set Z for rescheduling as input data for rescheduling. If customer order set $Z=\left\{Z_1,Z_2\cdots Z_m\right\}=\varnothing$ for rescheduling, retreat to the co-scheduling; otherwise, schedule for each customer order $Z_j\left(zt_j,zr_j\right)$ in set Z according to the sequence. Co-allocation scheduling algorithm to all manufacturing units are described in the below.

Step10:let $j=1$;

Step11:let $i=1$;

Step12: According to customer orders $Z_j\left(zt_j,zr_j\right)$ for second time scheduling in the set of customer order $Z=\left\{Z_1,Z_2\cdots Z_m\right\}$, calculate the spare capacity $Q_{ij}\left(z_{ij},q_{ij}\right),i=1,2\cdots n$ of manufacturing unit i in the manufacturing units set $A=\left\{A_1,A_2\cdots A_n\right\}$. This paper let the spare capacity $Q_{ij}=\left(zt_j-A_{ai}\right)*8-Y_{ij},q_{ij}$ of manufacturing unit i in the manufacturing units set $A=\left\{A_1,A_2\cdots A_n\right\}$.

Step13: if $q_{ij}\le zr_j$, then go to step14; If $q_{ij}\ge zr_j$, then manufacturing unit A_i could complete customer order $Z_j\left(zt_j,zr_j\right)$ on time, manufacturing unit A_i is a feasible manufacturing unit for the customer order. Go to Step15.

Step14: if $q_{ij}\le zr_j$, then manufacturing unit A_i t cannot completes the production of customer order $Z_j\left(zt_j,zr_j\right)$ on time, so manufacturing unit A_i is not feasible for the customer order. Therefore manufacturing unit A_i should not be put into feasible manufacturing unit set $KX_j=\left\{A_i\right\}$ of customer order Z_j.

Step15: if $i=n$, go to Step16;Otherwise, let $i=i+1$, go to Step12.

Step16: if the final feasible manufacturing unit set $KX_j\ne\varnothing$ of customer order $Z_j\left(zt_j,zr_j\right)$ under the condition of none overtime work or delay, go to the condition of none overtime work or delay, go to Step17 directly; if the final feasible manufacturing unit set $KX_j=\varnothing$ of customer order $Z_j\left(zt_j,zr_j\right)$ under the condition of none overtime work or delay, go to Step17directly, go to Step20.

Step17: let $k=1$.

Step18: calculate the final production cost $C_{kj} = zr_j * P_1 + zr_j * Y_{ij} * P_3$ by the manufacturing unit k in the final feasible manufacturing units set $KX_j = \{A_i\}$ for customer order $Z_j = (zt_j, zr_j)$ under the condition of none overtime work or delay. Put the new data C_{kj} into feasible manufacturing units production cost set $C_j = \{C_{kj}\}, k \in (1, 2 \cdots k_j)$.

Step19: if $k = k_j$, then go to Step20; Otherwise, let $k = k+1$, go to Step18.

Step20: gain eventual production cost set $C_j = \{C_{kj}\}, k \in (1, 2 \cdots k_j)$ of feasible manufacturing unit without overtime work or delay delivery for customer order Z_j.

Step21: assign customer order $Z_j(zt_j, zr_j)$ to the corresponding manufacturing unit in Step20 which has the minimum production cost.

Step22: if $j = m$, then go to Step23; Otherwise, let $j = j+1$, go to Step11.

Step23: scheduling end.

After the whole co-scheduling, two results can be gained: final scheduling results set ZZD ; manufacturing resource data set A of various manufacturing units after the completion of co-scheduling.

5 SIMULATION FOR THE CO-SCHEDULING MODEL

5.1 Evaluation index

Based on the above analysis, the goal of group distributed manufacturing co-scheduling includes lowering production costs, improving customer satisfaction and increasing production load equilibrium degree. Therefore, the co-scheduling model evaluation, still with the two indexes as an evaluation basis.

Production costs

For the evaluation index to calculate the cost of production, only consider the production cost of projects that some changes have caused by import of co-scheduling model. Therefore, the production costs including three parts: labor costs, transportation costs, delayed delivery default cost.

Production load equilibrium degree

Production load equilibrium degree is equal to the variance of each manufacturing unit production load rate.

Production load rate = (product quantity/manufacture unit capacity) *100%

5.2 Data for simulation experiment

Input data of co-scheduling model mainly comes from basic database of the information integrated management system and the outside world order data. In this paper, the simulation data is from a steel manufacturing group, the company's main business is to provide specifications for downstream automobile manufacturing enterprises of the same car chassis plate, the company has 8 manufacturing units, received 10 new customer orders for co-scheduling.

New order data

The 10 customer orders are shown in Table 1

Table 1. New order data

Sequence	Symbol	Product numbers	Data of delivery
1	R_{21}	2000	4
2	R_{71}	4000	5
3	R_{12}	18000	6
4	R_{63}	7000	7
5	R_{43}	16000	8
6	R_{62}	10000	9
7	R_{81}	11000	10
8	R_{83}	9000	12
9	R_{41}	12000	13
10	R_{51}	8000	14

Sequence refers to the order in accordance with the delivery date for all new orders are numbered.

(2) Finished goods transport distance data, the distance between manufacture units and customers (described by transit time). The detail data are listed in Table 2.

(3) Manufacturing resource data of manufacture units (shown in Table 3)

Manufacture units sequence refers to all of the staff within group companies in accordance with the rules of manufacturing units are numbered; Production load means the current manufacturing unit has undertaken but did not complete the production task; Capacity means the manufacturing unit can product the number of production per hour; Production scheduling data refers to the current manufacturing unit production task has been to date.

Table 2. New order data(Unit:Hour)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
R_{21}	10	6	8	14	16	19	17	20
R_{71}	15	15	17	14	16	10	6	10
R_{12}	7	10	12	15	14	20	19	21
R_{63}	13	12	15	12	10	5	11	12
R_{43}	12	13	9	5	9	13	15	17
R_{81}	21	20	19	16	21	15	9	8
R_{83}	16	18	20	17	19	13	7	5
R_{41}	12	12	7	6	10	16	15	12
R_{51}	14	14	10	11	8	9	12	16

Table 3. Manufacturing resource data of manufacture units

Sequence	Symbol	Product load	Capacity	Production scheduling data
1	A_1	4000	220	3
2	A_2	1200	180	1
3	A_3	10000	250	5
4	A_4	19200	300	8
5	A_5	7200	160	6
6	A_6	5600	200	4
7	A_7	1000	190	1
8	A_8	20000	210	12

(4) Delayed delivery cost data breach of contract (shown in Table 4)

5.3 Simulation

5.3.1 The running of co-scheduling model

First time scheduling

The results of first time scheduling are shown in Table 5.

From table 5, in first time scheduling customer order R21, R51, R71 are assigned to manufacture A2, A5, A7 respectively, and the corresponding cost are 200600, 803200, 401200 Yuan， every order can be delivery on in time.

When assign each customer orders to the corresponding manufacture unit, synchronous update manufacturing resource data for manufacture unit. After the first time scheduling, the manufacturing resource data of manufacture unit can be obtained, and then, set the data as input for the second time scheduling.

Table 4. Delayed delivery cost of default rates

Sequence	Symbol	Delayed delivery cost (Yuan/unit product/day)
1	R_{21}	1.9
2	R_{71}	0.9
3	R_{12}	1.4
4	R_{63}	2.9
5	R_{43}	2.8
6	R_{62}	3
7	R_{81}	3.2
8	R_{83}	2.4
9	R_{41}	2.7
10	R_{51}	1.1

Table 5. Result of first time scheduling ZZD

Customer order	Manufacture unit	Order product cost	Delayed delivery(day)
R_{21}	A_2	200,600	0
R_{51}	A_5	803,200	0
R_{71}	A_7	401,200	0

(2) Second time scheduling

Choosing the customer orders and the remainder manufacturing resource as the new input data, the result of simulation listed in Table 6.

The data listed in Table 6 are the final results of the whole co-scheduling.

Table 6. Result of second time scheduling

Customer order	Manufacture unit	Order product cost	Delayed delivery(day)
R_{21}	A_2	200,600	0
R_{51}	A_5	803,200	0
R_{71}	A_7	401,200	0
R_{83}	A_7	903,150	0
R_{41}	A_3	1,204,200	0
R_{12}	A_2	2,111,400	12
R_{63}	A_7	927,150	11
R_{43}	A_3	2,200,850	13
R_{62}	A_8	1,330,250	10
R_{81}	A_5	1,652,150	15

5.3.2 Simulation of non-co-scheduling

In order to convenient for comparing the co-scheduling model, this paper make a research on non-co-scheduling under the same condition. Input the same simulation data into the non-co-scheduling program, the results are shown in Table 7.

Table 7. Results of non-co-scheduling

Customer order	Manufacture unit	Order product cost	Delayed delivery
R_{12}	A_1	2,286,000	3
R_{21}	A_2	200,600	0
R_{43}	A_4	2,138,700	4
R_{41}	A_4	1,565,400	2
R_{51}	A_5	803,200	0
R_{63}	A_6	845,750	0
R_{62}	A_6	1,298,000	2
R_{71}	A_7	401,200	0
R_{81}	A_8	1,583,800	6
R_{83}	A_8	1,278,900	7

5.4 Analysis of the simulation results

Based on these the simulation data, calculate evaluation index of the two scheduling models. From the total production cost and production load balance two aspects comparative analysis respectively.

First, for production cost, adapt co-scheduling model can save 2354700 yuan, shown in Table 8.

Table 8. Total production cost of two scheduling mode

Scheduling mode	Cost
Co-scheduling	26,779,150
Non-co-scheduling	29,133,850
Cost variance	-2,354,700

Second, for production load balance, the production rate variance of co-scheduling is lower than non-co-scheduling, down to 0.0325 from 0.2506. The comparisons are listed in Table 9.

Table 9, production load rate variance of two scheduling mode

Manufacture unite	Production load rate	
	Co-scheduling	Non-co-scheduling
A1	0.906	1.1801
A2	0.3979	0.0855
A3	0.5135	0.1923
A4	0.8018	1.109
A5	0.5532	1.1478
A6	0.4493	1.2644
A7	0.3734	0.1265
A8	0.4826	1.3965
Production load rate variance	0.0325	0.2831

From Table 9 we can see that, production load is very imbalance by non-co-scheduling , 5 manufacture units' production load rate are over 1, occupy 62.5% of the total manufacture units, the highest load rate has reached 1.4. However, by co-scheduling, all the manufacture units are stay in balance state, only two manufacture units reached 80% and 90%, the production load rate of most manufacture units are about 50%, and the production load rate variance are only 0.03, it was improved largely.

Above all, the co-scheduling model can reduce the production cost and the delayed delivery, improve the balance of the production load, and is benefit to optimize the efficiency of resource allocation and contribute to maximize the profit of the company. Especially for larger orders difference group companies, the effect of the co-scheduling model will be more obvious.

6 CONCLUSIONS

On the basis of information sharing, this paper constructed the group distributed manufacturing co-scheduling system model and compiled a co-scheduling algorithm based on heuristic rules, then this paper design simulation program for the co-scheduling model, and use the Matlab to simulate co-scheduling model. At last, the authors analyze the results, and verify the group distributed manufacturing co-scheduling model is scientific and effective. The co-scheduling model proposed by this paper provided a reference scheduling method for group companies, it is helpful for enterprise to open a scientific group distributed manufacturing co-scheduling system and realize the goal of collaborative product, on the basis of the guarantee enterprise agility to achieve the goal of lean production and maximize resource utilization.

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