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Research on the Process-level Production Scheduling Optimization Based on the Manufacturing Process Simplifies

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Abstract

Enterprises to achieve global optimization and better diversification and personalized product production scheduling, from the unity of the tasks and resources manufacturing, based on the perspective of global optimization in production scheduling method. With global production scheduling of matching and process model resources as the foundation for the realization of enterprise process production scheduling optimization and level continue working process decoupling point, this paper manufacturing task and manufacturing process is divided into generalization and differential theory , applications from manufacturing process optimization results obtained path, based on the manufacturing process optimization mathematical model to study the production scheduling, and by using the improved genetic algorithm, and finally for example. Above scheduling method simplified the scheduling process, reduce the scheduling of difficulty, shorten the time scheduling, and finally achieve enterprise resource efficient use.

Keywords: *Global optimization; Manufacturing process optimization; Process decoupling point; Production scheduling model*

1. Introduction

With the development of society and the development of technology of, manufacturing production way also has the evolution and change constantly. In order to pursuing high efficiency and low cost. Henry Ford put forward "a single product principle", namely mass production mode. However, this need for a single product market factors support the production of a stable market demand and long product life cycle is no longer applicable in today's market demand for increasingly diverse [1]. As products become increasingly prominent personality needs, and the gradual shortening of product life cycle, the mass customization mode appears. Its products have become diversified and customized through flexible and rapid response [1-2]. However completely custom service cost the demand is high, therefore, mass production and mass customization of combining the new method appeared .For manufacturing the mass customization shorter lead time and reduce the cost of the two aspects of the research, above this new method was put forward based on the prediction of the mass production stage and order based on the batch manufacturing stage and fully customized production stage production of the individualized product of the three phase models, it to the model as applied to various environmental factors were analyzed to obtain under mass customization born of the optimization of the scheme [3]. With customers on the enterprise production demand increase, the corresponding rapid

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response to the customer order needs of agile manufacturing production mode [4-5]and effectively reduce the production cost [6-7] and make full use of network resources sharing between enterprises manufacturing production mode and its corresponding scheduling method arise and gradually development [8].

However, there have been many scheduling not just need to a single production environment and the mode of doing research, and is more need to consider in two or more environment and mode of the actual production scheduling problem, and production planning and scheduling are enterprise actual production of important research object. Throughout the two perspectives, both macro and micro level of information and issues to meet the global production scheduling and parallel to the upper production planning, you can achieve global optimization of the entire production process. Manufacturing process and production scheduling process is closely linked. There are a lot of manufacturing process modeling, optimization, but not to make its and production scheduling problem closely and full consideration of the manufacturing process and the relationship between the production scheduling process. For simplification of the manufacturing process can achieve the optimization of production scheduling to simplify and thus facilitate the scheduling.

Through the above analysis, considered from the perspective of corporate global optimization, multi-enterprise resource optimization configuration, with each low-level production scheduling, and through the manufacturing process is simplified, so as to achieve the complexity of products in different production mode parallel production scheduling multiple objectives, and the simplified production scheduling optimization process has yet to be carried out comprehensive and in-depth study. This thesis is in the enterprise global optimization to focus research on the basis of its production scheduling, shop-level scheduling mathematical model and its solution to the completion of the process-level production scheduling optimization.

2. Based on the Optimization of the Manufacturing Process Production Scheduling Model is Established

2.1. The Idea of Model is Established

Existing production scheduling method in different classification according to order the scheduling method. However enterprise processing production is the smallest unit process. Production scheduling research in this article focused on the process perspective, the process according to the characteristics of the process as a unit production scheduling problems and production scheduling optimization.

Decoupling point of the introduction of processes in its upper part, the paper manufacturing process is divided into generic and differentiation, and drawn on the basis of the individual parts processing operations to choose from a number of optional path, according to the process decoupling point in the manufacturing process the position of each of the time and cost to establish a universal and differentiated two-stage production scheduling multi-objective mathematical model is solved to arrive at all the product components, production scheduling optimal path and the path length and path processing costs.

The scheduling method has the advantage as follows:

(1) Complexity is significantly reduced. This is because the process decoupling point positioning all the processes are divided into generic and differentiated; shop scheduling and process the optimal solution of the decoupling point get a complex problem into a simple

question and complex issues. Combination, which makes production scheduling problem solving greatly simplify.

(2) Reduce the dynamic randomness of manufacturing systems. When the arrival time or processing time of a job change, the traditional production scheduling process requires a lot of changes, process decoupling point location-based production scheduling process is composed of two phases, corresponding by changes caused by such problems will be much smaller.

2.2. The Objective Function Selection and Model Parameter Settings

1. The objective function

Manufacturing production scheduling is necessary to meet the delivery period, but also ensure that the processing costs of the minimum characteristics to meet customer demand for personalized on the basis of taking into account the scheduling between multiple process equipment occupy the time and hierarchy between the processing operations. Therefore, in this paper the scheduling objective and constraints objective are minimize processing costs and minimize processing time.

2. Model parameters

(1) Production plant processing equipment, collection of resource nodes are $RN' = (RN_1, RN_2, ..., RN_{j_1}, ..., RN_{m_1})$, where m_1 the total number of processing nodes is. N_l is the number of the activities of the workshop machining tasks MT_{i_1}. k_1 is the argument in the processing tasks cable , $k_1 = (1, 2, ..., N_l)$.(2) C_{i1} is the total cost of the processing tasks MT_{i_1} .(3) $C(i_1, k_1, j_1)$ is the cost of processing task in MT_{i_1} , k_1 activities using the resource j_1 .(4) $t_s(i_1, k_1, j_1)$ Start time of the first k_1 activities in the processing task in MT_{i_1} .(5) $t_e(i_1, k_1, j_1)$ is the completion time of the first k_1 activities in the processing task in MT_{i_1} .(6) t_{i_1} is the execution time of the workshop machining tasks MT_{i_1} .(7) T_{i_1} Completion date for the end of the workshop machining tasks MT_{i_1} .(8) DT_i is the delivery of the processing tasks MT_i .(9) Just like the Formula 2-1, η_j^{ik} is the index of system.

$$\eta_j^{jk} = \begin{cases} 1, Processing\ activitie\ \vee_k\ ?in\ MT_i\ completed\ in\ equipm\ ent\ resources\ node\ RN_j \\ 0, otherwise \end{cases} \tag{2-1}$$

(10)If there is to $e_{ij} \in E$, $PRESET(T_i)$ T_i, following the activities set, $SUCSET(T_i)$ is T_i successor collection activities. And T_j is the follow-up activities of T_i , T_i is T_j former after activities .Processing activities in the priority tasks defined as Formula 2-2.

$$\text{pri}(T_j) = \begin{cases} 0, & If\ PRESET(T_i) = \phi, \\ 1 + \max\limits_{T_j \in preset(T_i)} Pri(T_j), & otherwise \end{cases} \tag{2-2}$$

(11)If T_i is T_j former following, Must be after the completion of T_i for T_j ,is $pri(T_i) < pri(T_j)$ .Does not exist a connecting edge between the two tasks, these two activities can be performed in any order. Just like the Formula 2-1.

$$\text{pri}(T_j) = \begin{cases} 0, & If\ PRESET(T_i) = \phi, \\ 1 + \max\limits_{T_j \in preset(T_i)} Pri(T_j), & otherwise \end{cases} \tag{2-3}$$

2.3. Production Scheduling Model

1. Scheduling objectives- processing tasks cost-optimal

$$\text{Min} C = \sum_{i=1}^{n} C_i \tag{2-4}$$

$$\text{s. t.} \quad C_i = \sum_{j=1}^{m}\sum_{k=1}^{N_i} C(i,k,j) = \sum_{j=1}^{m}\sum_{k=1}^{N_i} C_j \times \eta_j^{ik} \times (t_e(i,k,j) - t_s(i,k,j)) \quad k \in (1, N_i) \ \ j \in (1, m) \tag{2-5}$$

For the purpose of the simplified model, assuming the same equipment processing task execution unit cost coefficient C_j are setting value, the use of the equipment and the implementation of the processing time is proportional to the cost.

2. Constrain objectives-under the premise to meet delivery the task average completion time optimal.

First make the following assumptions on the production scheduling problem in the process: i. Each work piece processing route and procedure of processing time is known, the time of transfer of the work piece or raw materials or ready is negligible. ii. Each machine in a certain moment can only process a work piece in which a process and the operation are not free to terminate. iii. One of the work piece on procedure before unfinished, next procedure can't start. iv. Each work piece only processing on the same machine.iv.with a work piece on a process is not completed before the next process can not be started.

(1)The production scheduling model target to time before the process decoupling point

$$Min\, t_1 = \sum_{i=1}^{n} t_{i_1} \tag{2-6}$$

$$\text{s. t.} \quad t_{i_1} = \sum_{j_1=1}^{m_1}\sum_{k_1=1}^{N_l} \eta_j^{ik} \times (t_e(i_1,k_1,j_1) - t_s(i_1,k_1,j_1)) \tag{2-7}$$

$$T_{i_1} = t_e(i_1, N_l, j_1) \qquad T_{i_1} \le DT_i \tag{2-8}$$

$$t_s(i_1, m_1) + M_1(1 - \eta_{imn}) \ge t_e(i_1, n_1) \tag{2-9}$$

$$t_s(i_1, k_1) + M_1(1 - \mu_{ijk}) \ge t_e(j_1, k_1) \tag{2-10}$$

$$pri(T_i) < pri(T_j) \qquad \eta_j^{ik} \in \{0,1\}, \sum_{k=0}^{N_i} \eta_j^{ik} = 1 \qquad k_1 \in (1, N_l), \qquad j_1 \in (1, m_1) \tag{2-11}$$

(2)The production scheduling model target to time after the process decoupling point

$$Min\, t_2 = \sum_{i=1}^{n} t_{i_2} \tag{2-12}$$

$$\text{s. t.} \quad t_{i_2} = \sum_{j_1=1}^{m_1}\sum_{k_1=1}^{N_l} \eta_j^{ik} \times (t_{el}(i_2,k_2,j_2) - t_{sl}(i_2,k_2,j_2)) \tag{2-13}$$

$$T_{i_2} = t_{el}(i_2, N_i, j_2) \qquad T_{i_2} \le DT_i \tag{2-14}$$

$$t_s(i_2, m_2) + M_2(1 - \eta_{imn}) \geq t_e(i_2, n_2) \tag{2-15}$$

$$t_s(i_2, k_2) + M_2(1 - \mu_{ijk}) \geq t_e(j_2, k_2) \tag{2-16}$$

$$pri(T_i) < pri(T_j) \tag{2-17}$$

$$\eta_j^{ik} \in \{0, 1\}, \sum_{k=0}^{N_i} \eta_j^{ik} = 1 \;\; k_2 \in (N_l, N_i), \qquad j_2 \in (1, m_2) \tag{2-18}$$

Therefore, the mathematical model of the time constraints of the production scheduling problem is as follows,

$$\min t = \min t_1 + \min t_2 \tag{2-19}$$

3. Based on Hybrid Genetic Algorithm for Shop Scheduling Solution of the Model

In this paper, an improved genetic algorithm to solve the structure shown in Figure 1, the genetic algorithm design of the scheduling model of production scheduling is as follows:

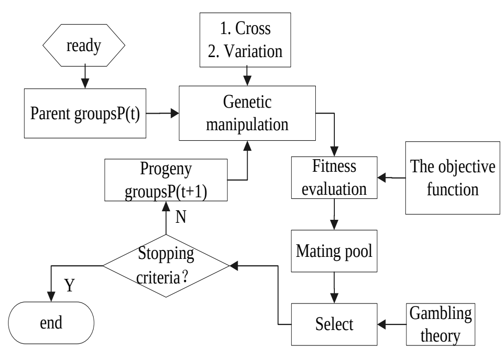

Figure 1. GA Solve Structure

(1) Chromosome description

Based on the activities of manufacturing tasks genetic, each genetic contains the serial number of the processing equipment used by the label of manufacturing tasks and perform the task label. Such a reasonable sort of understanding of all processing activities in space by a chromosomal. Is that an efficient solution of the problem, Processing activities in the priority level from left to right in turn reduce. This type of genetic algorithm for the transformation of the processing equipment in the same processing activities with a manufacturing task relatively easy to implement. Operation of the third coding genes can be modified. Therefore, the dynamic advantages, the exception occurs when the processing equipment, in order to ensure the normal execution of the processing activities. The only change to the resource nodes in the same scheduling scheme can achieve its function.

(2) Initialize groups

The classic genetic algorithm to optimize the number of individuals and groups at the same time. the first to complete the task is selected in the initial solution. Heuristic algorithm to operate or randomly generated initial solution. Constraints to test randomly generated initial solution to determine whether it is feasible. if selected, otherwise remove. This ongoing process in accordance with the pre-set iteration, until the group number of the number of predetermined solution space. At this stage include the following four steps:i. Topological sort conversion genome sequencing. ii. Feasible solutions from these sorts of problems. iii. Calculate the target value of each of this scheduling program. iv. Target value into fitness value.

(3) The intersection of the genetic algorithm

The crossover operator of this article is based on processing the sequence of tasks, the order crossover include the following steps: Step 1: randomly select a substring; Step 2: copy the above substring into the corresponding position, and produce an offspring. Step 3: Remove the existing symbols in the substring, the remaining sequence contains symbols of the prototype offspring; Step 4: In accordance with left to right the symbols into the rest of the remaining vacancies, producing an offspring. In this paper, in accordance with the process sequence of the cross in Figure 2. The proposed approach to meet in front of restrictive conditions and easy to implement. Shown in Figure3 based on the allocation of cross-processing equipment, a single-point crossover in genetic cross, one of the intersection of the two parent bodies have been identified, randomly determined, and transform the distribution by the processing activities at the point in front of parent body processing equipment.

Parent individual

P_1	11	12	22	21	32	31	13	23
P_2	12	22	11	21	13	23	31	32

Cross

Offspring

O_1	11	12	22	21	13	31	23	32
O_2	12	22	11	21	31	13	23	32

Figure 2. Based on the Sequence of Activities of the Cross

Parent individual

P_1	Activity	11	12	22	21	32	31	13	23
	Resources	3	2	1	3	2	1	3	2
P_2	Activity	12	22	13	11	21	31	32	23
	Resources	1	2	1	3	1	2	2	1

Cross

Offspring

O_1	Activity	11	12	22	21	32	31	13	23
	Resources	3	1	2	3	2	2	3	1
O_2	Activity	12	22	13	11	21	31	32	23
	Resources	2	1	3	3	1	1	2	2

Figure 3. Based on the Intersection of the Allocation of Resources

(4) Variation of the genetic algorithm design Neighborhood search-based mutation

Step 1: Start , $i \leftarrow 0$ .Step 2: $i \le pop\_size * p_m$ random selection of a variation of chromosomes to pick out the λ gene to construct the neighborhood, choose a good neighborhood and the neighborhood scheduling assessment chromosomes as the offspring ,Step 3; otherwise, perform step 4.Step 3: The Executive $i \leftarrow i+1$, proceed to Step 2. Step 4: end.

(5) Select the control parameters

This paper uses the control parameters include population size, crossover probability and mutation probability. Larger the group, the greater sample capacity, easy to improve the quality of the genetic algorithm search, but increased the computation of the individual adaptive assessment, reducing the convergence speed, the scale of the general population to take 20-200. The higher the crossover probability, the faster the formation of a new structure in groups, which is fine gene structure, is lost, the more. Crossover probability is too small, will lead the search block, general crossover probability of 0.6 to 1.0.Mutation probability is too large, and the genetic search will evolve into a random search. Mutation probability is too small, the earlier genetic information will not be restored, the general variation of probability of 0.005- 0.01.

4. Instances of the Model Validation

In order to verify the effectiveness of the production scheduling process decoupling point positioning method. Use this method to test for a workshop production data. The 10 different products in the workshop production of the same product family. The 10 processing procedures on 10 different machines, processing time matrix T and processing sequence matrix O as follows:

$$T[10 \times 10] = \begin{bmatrix} 12 & 12 & 12 & 12 & 12 & 12 & 12 & 12 & 12 & 12 \\ 9 & 9 & 9 & 9 & 9 & 9 & 9 & 9 & 9 & 9 \\ 17 & 17 & 17 & 17 & 17 & 17 & 17 & 17 & 17 & 17 \\ 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 \\ 11 & 11 & 11 & 11 & 11 & 11 & 11 & 11 & 11 & 11 \\ 8 & 17 & 21 & 30 & 25 & 27 & 18 & 20 & 19 & 10 \\ 11 & 6 & 12 & 17 & 24 & 25 & 20 & 16 & 13 & 15 \\ 25 & 23 & 19 & 20 & 22 & 28 & 20 & 24 & 18 & 23 \\ 29 & 28 & 27 & 20 & 28 & 27 & 30 & 25 & 20 & 17 \\ 16 & 18 & 19 & 20 & 24 & 18 & 10 & 15 & 10 & 13 \end{bmatrix} \qquad O[10 \times 10] = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 2 & 2 & 2 & 2 & 2 & 2 & 2 & 2 & 2 & 2 \\ 3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 \\ 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 \\ 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 \\ 6 & 7 & 8 & 10 & 8 & 9 & 7 & 6 & 10 & 9 \\ 7 & 9 & 9 & 6 & 10 & 8 & 9 & 7 & 8 & 10 \\ 8 & 10 & 10 & 8 & 9 & 7 & 8 & 9 & 7 & 8 \\ 9 & 8 & 6 & 7 & 6 & 6 & 10 & 8 & 9 & 6 \\ 10 & 6 & 7 & 9 & 7 & 10 & 6 & 10 & 6 & 7 \end{bmatrix}$$

The matrix line represents number from left to right order of product 1, product 2 ... product 10.column represents from top to bottom, to machine a processing machine, machine ... the machine 10.The device processing time fee(refers to, including he sum of equipment depreciation costs, device processing costs,equipment maintenance costs, the cost of the operator's working hours and business management costs)Information such as shown in Table 1, by calculating the dozens of products' processing costs is 797.120 Yuan. Control parameter values shown in Table 2.

Table 1. The Device Processing Time Fee

Machine	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
cost	520	280	140	150	750	1120	350	160	700	650

Table 2. Control Parameter Values

Parameter	Population size	Crossover probability	Mutation probability	Terminate the evolution algebra
Value	200	0.9	0.1	100

This paper presents the improved genetic algorithm to carry out the test on the computer, parameter selection as follows: the population size is 200, iterative algebra is 100, crossover probability is 0.9, mutation probability is 0.1.Processing time matrix and processing order matrix can make process decoupling point located in the fifth process. Therefore, the five processes can be mass-produced pre-production form of semi-finished products are stored in the warehouse. So that the scheduling problem transformed into sort of 10 kinds of products in five different machines.

Using MATLAB programming for simulation, Make span of the problem of the minimum is 298.Gantt Chart of the optimization results as Figure 4. If do not introduce the process decoupling point, the scheduling problem is sort of the 10 kinds of products in 10 different machines, through the above procedure to make the appropriate changes, the minimum make span is 365,Gantt Chart of the optimization results as Figure 5.

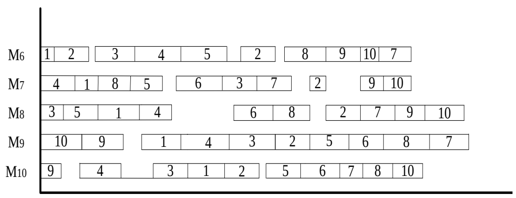

Figure 4. Scheduling Optimization Results after Introducing the Process Decoupling Point

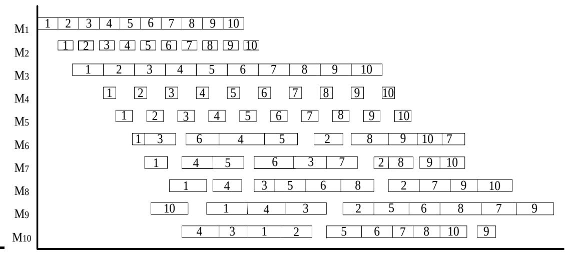

Figure 5. Scheduling Optimization Results Without Introducing the Process Decoupling Point

By comparing the above two test results, through the introduction of the process decoupling point positioning can greatly simplify the calculation process of scheduling, to shorten the completion time of the product, and mass production way ahead of schedule production processes in the process before the decoupling point. This part of the processing time can be greatly shortened based on the original .In order to provide customers low-price high-quality products.

5. Conclusions

Based on the global optimization point of view, on the basis of resources match and process model in the existing overall production scheduling, To achieve the production scheduling optimization of the business process level, use manufacturing process optimization to get the differentiated parts' several optional path, establish the mathematical model of production scheduling, this model to the time and cost as the objective function and use the improved genetic algorithm to solve. The scheduling method simplifies the scheduling process, reduce scheduling difficulty, shortening the scheduling time, to achieve efficient use of resources, finally application examples demonstrate the feasibility of the method.

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References

[1] Y. J. Xie, X. J. Gu and G. N. Qi, "Mass production and mass customization production", Group Technology and Production Modernization, vol. 4, **(2004)**.
[2] X. D. Zhou, G. S. Zou and F. J. Xie, "Review of Research on Mass customization", Computer Integrated Manufacturing Systems, vol. 9, no. 12, **(2003)**.
[3] W. Zhang and J. Lin, "Multi-stage production model based on mass customization", Computer Integrated Manufacturing Systems, vol. 2, no. 13, **(2007)**.
[4] Y. Li, J. Lin, Y. S. Lin and J. Q. Zheng, "Multi-agent Based Hybrid Scheduling Strategy Agile Manufacturing System", Journal of System Simulation, vol. 12, no. 21, **(2009)**.
[5] G. Li, "Research on intelligentized agile manufacturing system in distributed knowledge base architecture", Proceedings of 2010 Third International Symposium on Knowledge Acquisition and Modeling. 10, KAM2010, **(2010)**.
[6] A. Zhao and F. Qing, "Optimization of Networked Manufacturing System Based on Bottleneck Resources", International Seminar on Business and Information Management, vol. 2, **(2008)**.
[7] Z. Yong and F. Liu, "Information integration framework of workshop level DNC system for networked manufacturing", Journal of System Simulation, vol. 4, no. 14, **(2008)**.
[8] C. Liu, H. B. Shi and J. Yuan, "Modeling and performance analysis of manufacturing processes with stochastic machine failures", Computer Integrated Manufacturing Systems, vol. 9, no. 14, **(2008)**.

