Research on Optimization Method of Workshop Process -level Manufacturing Process

Y. P. Wang[1], J. Zhang[2], K.X. Bi[3] and Z.M. Shi[4]

[1,2,3] Harbin University of Science and Technology, Harbin, China, 150080
[4]Qiqihar Heavy CNC Equipment Corp. LTD., Qiqihar Heilongjiang Province, China, 161005
[1]wypbl@163.com, [2]21czhangjing@163.com, [3]bikx@hrbust.edu.cn
[4]szmqzsk@163.com)

Abstract

For complexity of process-level manufacturing process in enterprise workshop, Lacking of the researching about the impact on production scheduling of workshop which made by manufacturing process ;To simplify the process of the workshop process-level processing, we can adopt a method that divide the processing operations into two kinds :universal and differentiated method; proposing the concept of process decoupling point, build a process-level manufacturing task decomposition model ;Using the method of directed hyper-graph to get the optimal processing path, achieving the simplification of the production scheduling process on the considering of the ability of enterprise resource ; In order to make the shortest time and the lowest cost and meet the individual needs of clients, making reasonable use of the resources, providing the technical support for the workshop production scheduling.

Keywords: *processes decoupling point; manufacturing process optimization; manufacturing task decomposition; production scheduling*

1. Introduction

The optimization of the manufacturing process is an important method to improve product quality, reduce manufacturing costs, and shorten the manufacturing cycle and realize the rational allocation of resources. The intense competition in the market forces enterprises to continuously improve production efficiency and ensure product quality in the manufacturing process, and at the same time minimize the consumption of energy and materials of the manufacturing equipment. The optimization of the manufacturing process can not only effectively track the optimal route for manufacturing equipment but also should meet the needs of production target, equipment performance and the change of state. The existing optimization of the existing manufacturing process contains two kinds of research. Firstly, the research is about the optimized analysis of working methods and technical process. Adopt the theory and method of human factor engineering, taking the operational procedures and working procedures as a research object, the purpose is to improve task measures and working processes. To reduce or even eliminate the redundant action, a rational operation structure and operation specification is established, making use of working measurement technology to determine the standard time. Secondly, the optimized analysis of the production system: through the combination of the theoretical principles of ergonomics, facilities planning and material handling, these methods are used to optimize factory layout, optimize logistics lines and workstation design, to eliminate and reduce unnecessary material handling, stagnation, waiting and congestion, and finally to improve production efficiency.

Currently many domestic and foreign scholars have made plentiful in-depth and detailed researches on the optimization of the manufacturing process, and they have gotten many achievements, such as, literature [1-2] have proposed multi-objective optimization method when we made a optimization of turning process, literature [3-4] have taken the delivery dates which proposed in customer order decoupling point as a restriction ,and got the best location method of customer order decoupling point according to their different ranges .As literature [5-6] have made the researches about the Optimal scheduling of technology process and manufacturing resource. As literature [7] has researched the gray relation analysis of the differences order batch scheduling in the circumstance of the mass customization, and obtain the optimal order production sequence scheduling method.

However, those methods which used in above literatures are generally too complex, too high cost, and need large workload, so the application and promotion of those methods in the enterprises is not conducive, In addition, there are few research that consider the method that combine manufacturing process optimization with production scheduling, There are clear deviations between theoretic and actual production scheduling, so when make a research on production scheduling methods with the actual theoretical significance, we should have a adequate consideration about the manufacturing process's impact on production scheduling ,through the simplification of the manufacturing process to decomposed one complex problem into multiple simple problems ,And realize the optimization of the final production scheduling results. This research provided theoretical and technical support for shop scheduling arrangements. On the basis of existing research methods, this thesis established a process decoupling point location model. Based on this model the structure of the manufacturing process is optimized, building manufacturing process directed hypergraph model in complex resource-constrained, providing an optimal processing path to manufacturing tasks, to support workshop production scheduling optimization allocation, and finally this model will be validated by cases.

2. The Optimization Framework of Workshop Process-level Manufacturing Process

The product design of the advanced discrete manufacturing enterprise takes the needs of the customer as a starting point. Based on the created and dynamically updated product family [8], the product's configuration design and variant design are completed. The results of product configuration design should be given in the form of a product BOM table in which we should find the number of parts of the products that meet the order demand, for the homemade devices in the BOM, the part properties including the process name of the parts, dimensions, parameters and other information [9]. On the basis of the specific processes, the result of part product configuration is output. In order to achieve the simplify of the production scheduling process in the complex resource condition, and use shortest time, lowest cost to meet the individual needs of customers, study and establish the process of decoupling point location model, and design the appropriate solution. Shown in Figure 1

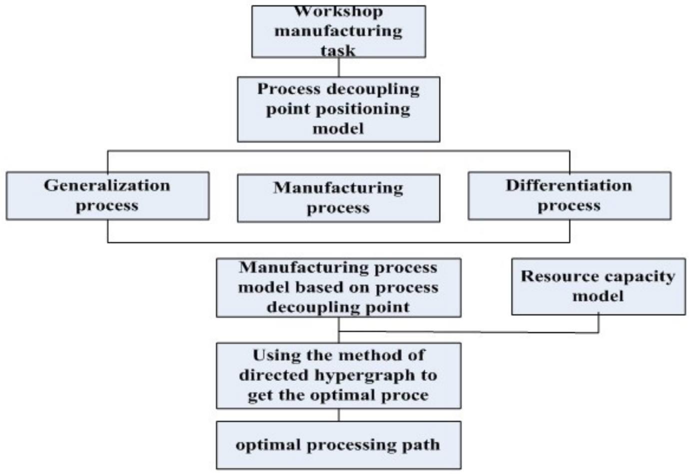

Figure 1. Manufacturing Process Optimization Framework

In order to support optimization structure of the manufacturing process in the complex resource environment, proposed an optimization method of manufacturing process structure that based on the directed hyper-graph .firstly, consider supporting resource capacity, Resources logical relationship and Available resources state of the manufacturing process to the hyper-graph model. Based on this model, according to the directed hyper-graph theory and the process semantics attached to the models, giving a set of formal structural optimization of dynamic manufacturing process definitions, rules, theorems, and the solution process, and ultimately reach the goal that shorten the manufacturing cycle, reduce production costs, and optimize the manufacturing process. Making a transformation from the manufacturing process optimization to the manufacturing processes that according to different optimization objectives, and select both of manufacturing resources and manufacturing are very process relative optimal from different manufacturing processes. In another word, it provides an optimal machining path for the processing task.

3 The Task Decomposition of Workshop Process-Level Manufacturing

3.1. The Model of Manufacturing Task

The model of workshop manufacturing task is the important basis that the enterprise better understand existing workshop processing ability structure and accordingly processing arrangement and production scheduling. The product model provides the decoupling point of the next step data support. Description of the main elements of formal of the model:

Product::=(Name,Code,Type,BOM,Deadline,Documentation,UserAttset,Owner-Ent,Status,AsInputv,AsOutput), Wherein, Name is product name; Type is product type; BOM is product BOM table; Deadline is product delivery; User Attest is related attributes set of feature domain the users add ,Status is the existing products state; As Input expressed as the product of the input function / process; As Output expressed as the product of output function / process.

Part::=(N,T,R,M,P1,P2,P3,P4,P5,P6), Wherein, N is part name; T is parts type; R is blank category; M is material category; P1 is dimension; P2 is processing method; P3 is processing type; P4 is processing cost; P5 is processing time.

3.2. The Process Decoupling Point

Process decoupling point is defined that the point is symbolized the manufacturing process which is changed from generalization production to differentiation production in the enterprise manufacturing process. The front end is the generalization processing products of the same processes, which are produced by the way of the mass production mode. The back-end is the products which meet the personalized needs of customers and are produced by the way of customization product mode. Decoupling point is not only symbolized the manufacturing process which transforms from "general character" processing parts to "Personality" processing parts, but also reflect the function of Positioning — completing the decoupling process of the cost, time and individual requirements.

(1) Suppose that a process decoupling is located in the manufacturing process .The total cost of the mode includes the cost of the producers, purchase cost ,cost of sales and the third party logistics enterprise cost.

(2) Suppose that the cost of producers include investment cost, processing cost, inventory cost of Universal semi-finished products, work in process cost, and customers waited cost.

(3) Suppose that the differentiation point of N kinds of products, which are discussed in the model, has been through the analysis of the order. The differentiation point is symbolized by $q_1, q_2, ...q_N$ respectively. It is the situation in which there is only one process decoupling point in manufacturing system;

(4) Suppose that D1 symbols quantity demanded which is received by universal manufacturing center, D2i symbols quantity demanded which is received by the i Customized manufacturing center.

3.3. Process-level Manufacturing Task Decomposition Model

Suppose that the Processing products of the same workshop working procedure are the N kinds of customized products in the same product family. Each kind of product is through the two stage including M production steps in total, so can realize delay production of customized products. The first stage is the generalization stage, which is constituted by universal process processing center. The second stage is the differentiation stage, which is constituted by N customized production center. Between the two stages, there is a concentrated stock point, which can store the generalization semi-finished products. p stands for the production step ,in which the process decoupling point may appear. q stands for the production step, in which the product begin to be produced by the personalized way. Model of the Manufacturing process is shown in Figure 2

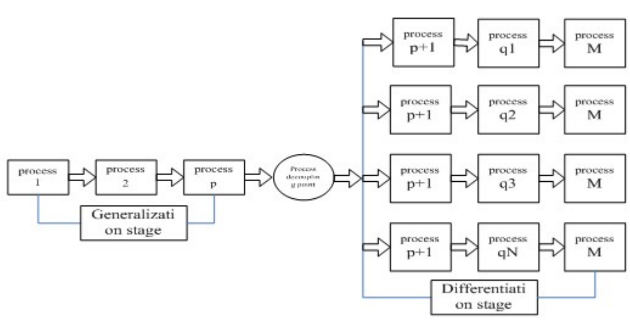

Figure 2. Process Model within the Producers

The first goal: The total cost of production system Z includes enterprise processing cost Z_2, supplier cost Z_1 covered by the enterprise, seller cost Z_3. The third party logistics enterprise cost Z_4, the cost model of mass customization production system is shown as follows:

$$\min Z(p) = Z_1(p) + Z_2(p) + Z_3(p) + Z_4(p) \quad (1)$$

The second goal: the time, from the core enterprise receiving order form to the product handed over to the customer, is shortest. The time, during which quantity demanded of N kinds of products can be accomplished, includes the order time in advance of the purchase, the processing time of the producers, the time taken up by the logistics activity, as follows:

$$\min T(p) = (\sum_{y=1}^{Y} T_{2y} + \sum_{l=1}^{L} T_{2l} + \sum_{b=1}^{B} T_{2b}) + [\sum_{j=p+1}^{M} N \cdot t_j(p) + \sum_{j=p+1}^{M} N \cdot r_j(p) + \sum_{i=1}^{N} (\lambda_{2i} - 1) \cdot r(p) \quad (2)$$

$r(p) = \max r_j(p)$, the range of j is $[p+1, M]$.When manufacturing enterprise adopts assembly line work, the time, between the leave factory time of the first two products, is the time covered by the longest production step in all process.

There are three basic constraints, shown as follows:

(1) Satisfy personalized requirements of customer: Personalized requirements of customer must be satisfied no matter where dose the process decoupling point positioning in the process of production, namely:

$$1 \le p \le q \le M \quad (3)$$

(2)The constraints of value-added ability of products, namely:

$$\alpha_1(p) < h_1(p) < \alpha_{2ij}(p) \quad (4)$$

(3) The constraints of production capacity, namely:

$$0 < \varepsilon_1(p) < \varepsilon_{2ij}(p) < 1 \quad (5)$$

4. The Manufacturing Process Optimization based on Process Decoupling Point

4.1. Manufacture Resource Model

For the characteristics of process level manufacturing process, in the product manufacturing process, resource ability of the workshop itself should be taken into account, at the same time need to describe resources occupation, precede manufacturing task allocation according to workshop resources condition, in order to support manufacturing process optimization. In this paper, use the description of resource ability to realize the mapping between the process model and the resource model, and through the ability to realize the resource allocation. So, the manufacturing resource model can be described for formal.

ResM::=(SR,CR) (6)

Among them: SR means simple resources, CR means Combination resourcesCR={sri|i=1,2,…,n},sri∈SR;

ResM=<Cap,Sta,SerCost> (7)

Among them: Cap means Resource capacity, Sta means Resource state, SerCost means the service costs for Resource

4.2. Manufacturing Process Optimization

In this paper, we use the elements as input/output, processing activities and manufacturing resources and the relationship between them to describe the manufacturing and processing activities ,this description is based on the process decoupling point, the distinction between the production of generic production and differentiated production; Each processing activities should deal with the specific input information and produces a corresponding output under the support of manufacturing resources. One output of the processing activities may be the input of another processing activities, the manufacturing process can be initially described as below by the directed hyper-graph [10]:

Define the manufacturing process's directed hyper-graph model. PM=(V, E), in which 'v' is the node collection of the directed hyper-graph, V=(RV, AV, DV), Among them, the 'RV', 'AV' and 'DV', respectively represent the resource node, active node and material node; 'E' represent the edges of the hyper-graph, E=(IE,OE,RE) 'IE' is the input side, 'OE' is the output side edge of the , 'RE' is the support side that resource made for the campaign, for each side, e=(a, b),and (a□ACT, b□(V-ACT))∪(a□DV, b□(V-DV))∪(a□RV, b□(V-RV)) is feasible.

For a processing, a set of input, output or support resources appear in the way of the logical "and", and always appear together in the entire manufacturing process, we can describe it use one input, output, or resource supported nodes, in the model description, we should abide by the following rules :

The first rule ,the number of manufacturing resource nodes is least .in the manufacturing process modeling ,the number of the node that describe the manufacturing resources as little as possible, and be sure the support resources nodes with two manufacturing processes' intersection is not exist. The second rule, the number of input/output nodes is least .in the manufacturing process modeling, the number of the input/output nodes das little as possible, and be sure two input/output nodes have no intersection.

The definition of the manufacturing process's direct hyper-graph model should take the resources logical relationship into account PH=（V,E）, where, 'V' is the hyper-graph nodes collection V=(RV, ActV , DV), among them, 'RV', 'Act V' and 'DV' ,respectively represent resource node 、active node and material node. 'E' is the edges of the hyper-graph , E=(IE,OE,RE), 'IE' is the input side, 'OE' is the output side edge of the , 'RE' is the support side that resource made for the campaign, for each side, e=(a,b),and (a□ACT, b□(V-ACT))∪(a□DV,b□(V-DV))∪(a□RV,b□(V-RV)) is feasible .If the mobile input side is iei, and the relationship relative to the activity is the logical AND, we can use the ultra edge to describe it, that is |T(iei)|>1,if the relationship of outputs is the logical AND, and the output side is oei, then |H(oei)|>1,among them, T(iei) represent the collection of tail nods,|H(oei)| represent the collection of head node. If the resource support side is rei, and the relationship between the support resources and the activity is the logical AND, then |T(rei)|>1; And for∀dv, dvj∈DV, then dvi∩dvj=∅, ∀ rvi, rvj∈RV, then rvi∩rvj=∅, and the |DV|and |RV|are all minimum, Shown in Figure 3.

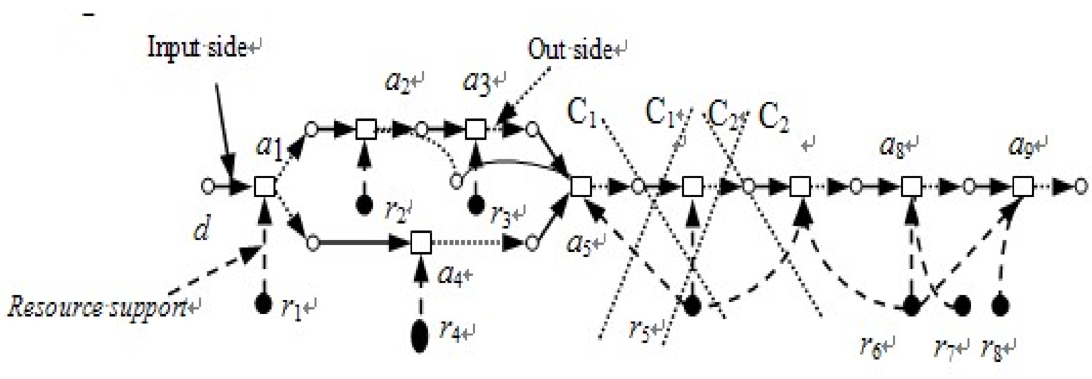

Figure 3. Directed Hyper-Graph Model of Business Process Considering Resource Logic Relation

5. Analyzing the Example

Put steam turbine rotor as an example. Use different methods of manufacturing processes for analysis and comparison to illustrate the advantages of this method. The manufacturing process of rotor structure and process equipment is shown in Figure 3. Select 5 discussions of processing activities:

(1) If the condition of support processing equipment should not be considered, the five processing activities will be combined from the perspective of optimizing with the goal of minimum time. However, as the graph 3 shows condition of equipment which actually processed the rotor, there cannot be support processing equipment that can finish this five processing activities and this five processing activities cannot be combined. So, in the process of structure optimizing the availability of equipment which supports machining should be considered.

(2) If the combination status of the process equipment should not be considered, the process of machining will be similar as graph 4 shown. But the activity a7 of rotor processing need to be finished in support of r5 and r6, the activity a8 of rotor processing need to be finished in support of r6 and r7.This condition could not be finished without considering the logical relation of processing equipment, so it is powerful of the analytical method of this article.

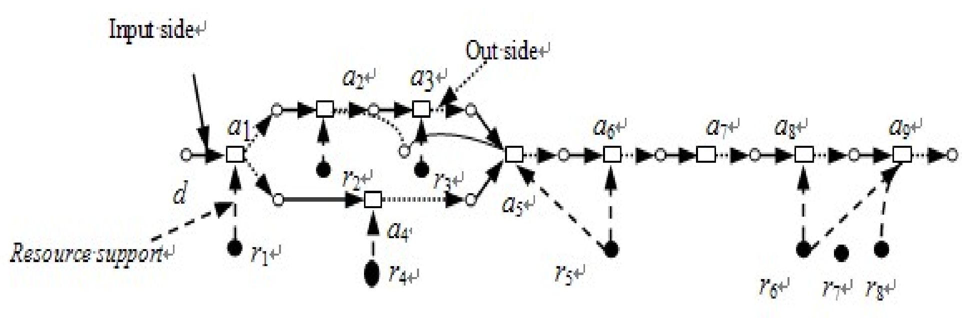

Figure 4. Process Hyper-graph Model without Considering Resource Logic Relation

(3) Methods of this paper take the state into account, in which processing equipment can be supported, for example, in the process described in Figure 3.when processing equipment r7 is

occupied in a moment, manufacturing process can not go on ,namely, methods of this paper support manufacturing process structure optimization based on the usable state of processing equipment.

(4) The dealing and analysis method of incident can be supported by the method of this thesis. There are many uncertain elements in the process of critical component rotors. For example the damage of equipment, variation of processing time, and change in quantity demanded, change in date of delivery, machining of repaired rotors, all of the above conditions will directly influence the accuracy of model processing and make the result obtained from original model not optimal, even unfeasible. These uncertain elements will influence the stability of resources scheduling in machining. Considering the logical relation of machining equipments in processing, as graph 3 shows, the model is able to optimize rotor manufacturing process to meet the producing needs in time depending on the optimizing goal when the uncertain incidents happen in rotor processing.

6. Conclusion

This paper presents an optimization method based on the manufacturing process of the process decoupling point, established a process decoupling point location model ,this model take the cost of production an the delivery time as the target, and take satisfying individual demands of clients as constraint. And solving to get the manufacturing process of optimal decoupling point, On this basis, we establish a directed hyper-graph model, support the manufacturing process optimization in complex resource circumstance, when use this method to carry out the structural optimization of the manufacturing process , considered the impact of the manufacturing process for production scheduling, decomposing one complex problem into several simple problems, and considered supportive and constrained effect on optimization which made by the manufacturing resources circumstance ,getting the optimal path through the resolving of the manufacturing process according to optimization goals. Finally, analysis advantages a correctness of this method in the way examples comparison.

Acknowledgements

This paper is supported by Science and Technology Research Project of Heilongjiang Educational Committee of China (11531037), Natural Science Foundation Project of Heilongjiang Province of China (E2007-19), University Science Park Entrepreneurial Talent of Innovation Talents of Science and Technology of Harbin Application Technology Research and Development Project (2013RFDXJ001).

References

[1] A. and D., “Multi-objective Optimization of Multipass Turning Processes”, International Journal of Advanced Manufacturing Technology, vol. 32, no. 9-10, **(2007)**, pp. 902-910.
[2] A. R. Yildiz and F. Ozturk, “Hybrid Enhanced Genetic Algorithm to Select Optimal Machining Parameters in Turning Operation”, Engineering Manufacture, vol. 220, no. 12, **(2006)**, pp. 2041-2053.
[3] J. Olhager, M. Rudberg and J. Wikner, “Long-term Capacity Management: Linking the Perspectives from Manufacturing Strategy and Sales and Operations Planning”, International Journal of production Economics, vol. 2, **(2001)**, pp. 215-225.
[4] X. G. Xu, “The Positioning Research Of Customer Orders Decoupling Point In Mass Customization”, Doctoral Dissertation Of Harbin Institute of Technology, vol. 6, **(2007)**.
[5] M. Lv, X. D. Sun and G. Wang, “Resource modeling to support manufacturing process optimization under uncertain environment”, Computer Integrated Manufacturing Systems, vol. 12, no. 6, **(2010)**, pp. 2611-2616.
[6] X. F. Ma and X. D. Dai, “Research on networked manufacturing resources optimization configuration”, Computer Integrated Manufacturing Systems vol. 10, no. 5, **(2004)**, pp. 23-527.

[7] C. Wang, X. B. Liu, Y. C. Ling and G. Z. Zhao, "Production scheduling model based on the finite capacity of discrete manufacturers", Science-Technology and Management, vol. 14, no. 5, **(2012)**, pp. 99-102.
[8] Z. Y. Li, E. S. Qi and Y. L. An, "The study on production scheduling and its model constructing", Manufacturing Automation, vol. 27, no. 2, **(2005)**, pp. 17-21.
[9] B. Yang and Z. G. Cheng, "Directed Hypergraph Partitioning Algorithm of Grid Task Scheduling", Journal of System Simulation, vol. 20, no. 15, **(2008)**, pp. 4112-4117.
[10] Y. H. Zhang, Y. Yang, M. J. Wei and T. Lei, "Design approach based on product semantics relationship", Computer Integrated Manufacturing Systems, vol. 14, no. 6, **(2008)**, pp. 1063-1069.