

## Key Technologies of Reconfigurable Assembly Line For Mass Customization

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**Abstract.** For the dynamic and changeable market environment and personalized product requirements and other new rapid changes of production demands, a new method of reconfigurable assembly line for mass customization is put forward. In this paper, firstly introducing its background, the current developing condition and existing technical problems, then giving the definition of reconfigurable assembly line for mass customization; and then through the comprehensive analysis of key technologies, with result that the modeling technology of assembly line and the balancing and scheduling technology of reconfigurable assembly line are pointed out; and similarly conducting the analysis and research of the corresponding key technologies, the specific research methods are proposed at the same time. Integrating the technical problems and solutions, the paper provides an overall technical route of the research. Finally, the application prospect of the reconfigurable assembly line for mass customization is summarized and prospected.

### Introduction

Nowadays, modern manufacturing enterprises are faced with the dynamic and changeable market environments, so they should rapidly respond to the product personalized production and rapid changes in the market, cope with the new production environment needs, reduce investment in manufacturing system equipment and even the product cost, shorten the set-up time for product updating and transformation, improve product quality and enhance the competitive power of the enterprise and so on. In order to achieve the above purpose, manufacturing system or unit should have the characteristics of fast response and fast reconstruction. The mass customization and reconfigurable manufacturing system is put up with this background.

At present, the research on the assembly line system is a hot issue at home and abroad. N Bair, T Kidwai and M Mehrabi, Y Korof of the University of Michigan [1] developed the mixed flow assembly equipment for the radiator with the idea of modularization, and to achieve mixed flow assembly of the product. Jin-Lung Chirn and S. Hirak of the University of Cambridge [2] proposed the control architecture for the mixed flow assembly system on the basis of the idea of Holon and component. The University of Michigan [3, 4] applied the theory of variable flow to the reconstruction of the automotive assembly system and got the main reason for the quality through the testing and process knowledge, and then made adjustment for the assembly system. In order to achieve the purpose of fast response ability of dynamic unit design, the design specification of the module assembly unit which meets the customer requirements is designed by Ratchev. Setc. [5] of the University of Nottingham. Domestic scholar Q. Y Dong etc. [6] used PSO to solve the sequencing problem. X. M Huang etc. of the Tsinghua University [7] proposed the application of multi-agent manufacturing mechanism to achieve the flexibility and reconfiguration of assembly line system with the research background of automobile gearbox assembly line. D. Wei etc. [8] put forward the method of using genetic algorithm to solve the mixed species assembly line balancing problem for any given sequence.

From the point of view of the research on the assembly line system, the requirements for agile response to the market have been proposed. However, reconfigurable assembly line as a new advanced manufacturing system, its theoretical system is not perfect, especially basic modeling

theory and the control method in reconfigurable assembly line for mass customization: including system modeling, the optimal scheduling technology and so on, and they are still lack of complete research.

### **Definition Of Reconfigurable Assembly Line For Mass Customization**

Mass customization [9] is a kind of advanced agile production mode. It can be capable of designing and manufacturing the regular products with the efficiency and cost of mass production, so as to meet the needs of the market of small batch and multi-variety, and even quickly and cheaply develop the customized products for a single user. Reconfigurable assembly line is an assembly system with the function of actively responding to changes in the external environment and passively answering the internal disturbance of system. On the basis of the existing system, for the product mix production, it can perform the product sequencing or reconstruction of the system components, and change the structure of system, so as to adjust the system function and assembly ability to adapt to changes in the varieties of products or changes in market demand. The reconfigurable assembly line for mass customization is to meet the needs of mass customization, and realize the flexible and agile assembly. It should have the characteristics of modularization, scalability, autonomy and intelligence and so on. At the same time, it is the carrier of the macro production planning and the micro assembly process.

#### **Analysis Of Key Technologies Of Reconfigurable Assembly Line For Mass Customization**

**Modeling For Assembly Line.** The modeling for system is one of the most basic problems in study of reconfigurable assembly line, it can perform the analysis, simulation, optimization and control of the market uncertainty, the diversities of customer orders and all kinds of unpredictable factors in the manufacturing process. In recent years, many scholars have conducted many researches on reconfigurable assembly line from different aspects according to different needs. Singapore scholar Zha[10] applied the method of the combination of artificial intelligence and Petri net to the design of robotic assembly system, and modeling by knowledge Petri net. In the research, the knowledge representation based on rule and frame is mainly used, but the knowledge is described one by one by manual, and there are shortcomings of heavy workload and reliability, at the same time this modeling method is relatively isolated from the actual production situation and the knowledge expression is static, and the description is also not strong. Chan [11] established agile manufacturing system model based on the knowledge-based time object Petri net, but the knowledge rule is not clear, and the Petri net model is also complex. The scholar Jiang etc. [12] of china proposed the variable structure Petri net to the production system modeling, and raised the Petri net in the application of the dynamic discrete system to the new height. DCTPN is used for RMS modeling and the concrete modeling method is given by Kuo C. H etc. [13], but the method is lack of effective means of analysis and verification for the system after modeling.

Reconfigurable assembly line for mass customization belongs to the complex discrete event dynamic system, with real-time, dynamic and module characteristics. The existing models are mostly from a specific angle or a certain level to build manufacturing system function model, information model and dynamic model and so on. However, no model are perfect, it is hard to describe the whole picture of the complex reconfigurable manufacturing system only in one of the models. Therefore, synthesis of two or several composite modeling methods, the decomposition and combination of the model will become the developing direction of the research of manufacturing system model.

**Balancing Of Reconfigurable Assembly Line.** The problem of the assembly line balancing has a long time, and is very complicated and difficult, and also it is one of the important issues related to the production efficiency of the enterprise. Because the design of traditional assembly system only considers the single optimization target, and it's difficult to meet the needs of diversity, so it is more valuable to study the multi-objective balancing and sequencing problem. Multi-objective genetic algorithm can provide a good way to solve this problem, but it is hard to choose the multi-objective fitness function. Because of the variability of operative time and unpredictability of the fault, so the optimal design theory of the hybrid assembly system needs to be further improved.

The reconfigurable assembly line is a mixed flow assembly system based on the dynamic demand changes of the order production, which has the features of the diversification of customer's demand, the complicacy of the assembly process, the large data scale and so on. Therefore, in order to achieve the reconfigurable assembly line balancing performance and improve the efficiency of the assembly system, the optimal model of the assembly system equilibrium and the search algorithm based on artificial intelligence are the problems that must be solved, and also a direction worthy of study.

**Optimal Scheduling Of Reconfigurable Assembly Line.**Reconfigurable assembly line scheduling problem is the key to determine whether the assembly can run effectively. By determining the order of the different products into the assembly system, a target value is achieved, which can avoid the bottleneck of the system.How to get the optimal scheduling of reconfigurable assembly line is a hot issue at home and abroad. X. BZhao and K.Ohno[14] established minimum flow production line stopping time model, and the simulated annealing algorithm is used to solve the problem, but for multistage mixed flow production line scheduling problem research of mixed model assembly system is not in-depth.Tavakkoli[15] used the weighting method to transform three goals of the mixed flow assembly system into a single objective problem, and gives the optimization algorithm. A hybrid genetic-tabu search algorithm for mixed flow assembly line sequencing problem is proposed to improve the global searching ability and convergence of the algorithm by J. H Dong [16] et al.

General speaking, the reconfigurable assembly scheduling problem for mass customization has the features asmulti-objectivity, flexibility and dynamics anduncertainty. It should have the ability to solve the problem such as the emergence of the subsystem malfunction and other accidents.Currently, the optimization of reconfigurable assembly line scheduling is seldom studied, and the traditional assembly system scheduling mostly considers the single optimization target, it is difficult to meet the needs of the diversity, so the research on multi-objective scheduling problem is more valuable.

### **Technical Route And Research Method Of Reconfigurable Assembly Line For Masscustomization**

**Technical Route.**In view of the above technological object, the overall research idea is to construct reconfigurable assembly line management platform for mass customization. Firstly, achieving the reconstruction of the assembly system by the reconfigurable assembly line modeling; secondly, conducting the balancing and scheduling for the reconstructed assembly system; finally, evaluating the design of the assembly system. The technical route is shown in Fig. 1.

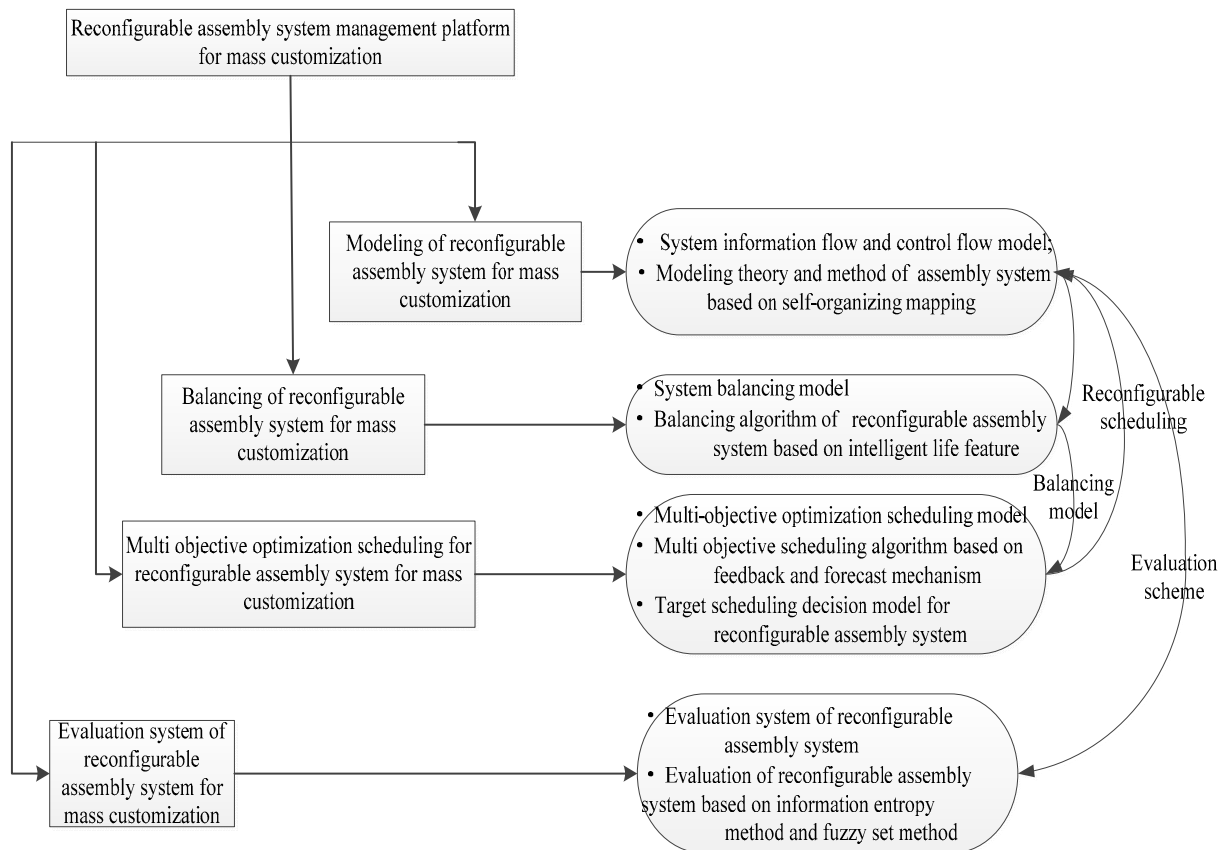


Fig. 1 Technical route of the research

**Research Method.**(1)Modeling method of reconfigurable assembly line for mass customization:Through preliminary studies, we found that a complex life system and the assembly line system have deep similarities (Fig. 2), human's self-organizing ability under the stress conditions will provide new ideas to solve the problem of reconfigurable assembly system.

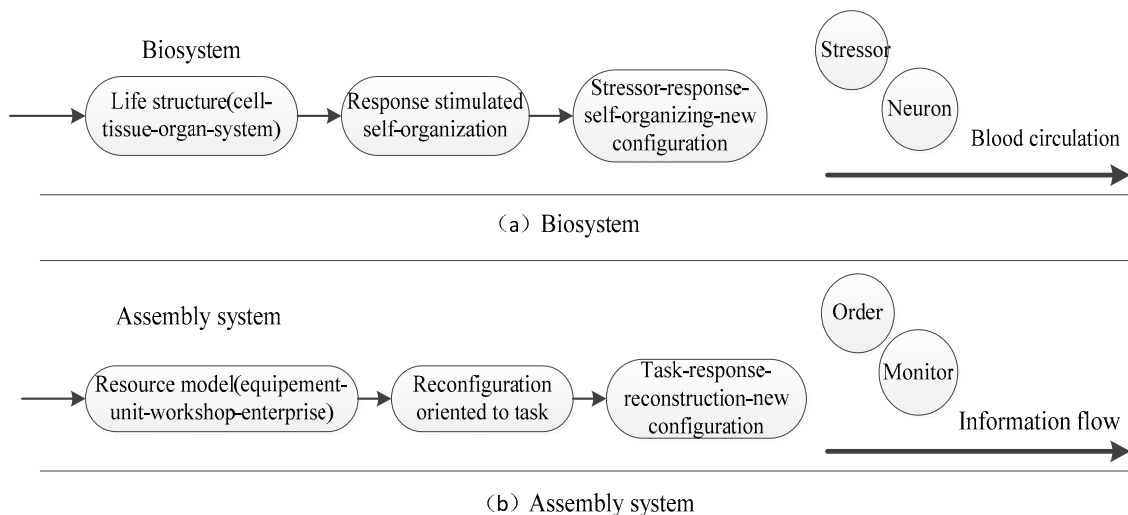


Fig. 2 Analogy chart of life system and assembly system

From the perspective of crossed multidisciplinary, the method is to study how to apply the biological adaptive control mechanisms and the rules of borrowing to model the reconfigurable assembly line for mass customization, and the modeling and intelligent control of the reconfiguration process of reconfigurable assembly line are carried out by using the method of combining the mathematical model and the intelligent computation and the reasoning.

(2)The model of reconfigurable assembly line balancing for mass customization: In view of the mass customization production mode, assembly line requirements are in planning the time zone of the low cost, quality and quantity of the production to finish product orders. The balancing targets

of reconfigurable assembly line for mass customization are minimum assembly cost, minimum assembly smooth index and availability of maximum assembly line. To solve the balancing model by the optimal theory and method of the new intelligence based on the behavior of life behavior, the balancing algorithm should have the characteristics of constraint handling mechanism, self-organizing learning, dynamic mechanism, parallel mechanism, immune mechanism and cooperative mechanism.

(3) Multi-objective optimization scheduling control for reconfigurable assembly line for mass customization: Firstly, on the basis of balancing the reconfigurable assembly line, taking several major factors that affecting optimal scheduling of reconfigurable assembly line into account, so a mathematical model of multi-objective scheduling for reconfigurable assembly line should be put forward. Secondly, facing the NP hard nature of reconfigurable assembly line scheduling problem, it intends to present Particle Swarm Optimization (PSO) based on feedback and prediction mechanism, and it can reduce the complexity of search space and obtain the non-dominated solution quickly. Finally, the modified AHP and entropy method are used to determine the subjective and objective weight values of the evaluation index of the reconfigurable assembly line scheduling decision model. At the same time, the gray correlation analysis is introduced into the multi-objective scheduling decision of the reconfigurable assembly line, and a new multi-objective scheduling decision model is proposed.

## Conclusion

Reconfigurable assembly line management system modeling and optimal scheduling method for mass customization will carry out effective balance, scheduling optimization and production management, then reduce the assembly cost and improve the efficiency of the assembly line. But as a new method of design, it is not mature and there are still lots of work to do. Therefore, whether from its own development or from the human social development strategy, the machinery manufacturing industry should strengthen the research and application of the method of reconfigurable assembly line design for mass customization on the basis of traditional manufacturing industry.

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