RESOURCE ALLOCATION ALGORITHM AND JOB SCHEDULING OF VIRTUAL MANUFACTURING WORKSHOP

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***ABSTRACT**: Virtual manufacturing workshop is a prerequisite for the application of manufacturing workshop system in production practice. With the aid of simulation platform, the development of resource scheduling system can be carried out more smoothly. The resource allocation and job scheduling would directly affect the competitiveness and efficiency of the manufacturing enterprises. Based on the virtual manufacturing, this paper explores the application of fuzzy resource allocation algorithm in the virtual manufacturing workshop, and studies the problem of real-time job scheduling in the manufacturing workshop. The research results show that: with the help of the real-time job scheduling simulation platform, the full automation from manufacturing resource input to the product output could be achieved. The target of job scheduling is to meet the satisfaction of both the manufacturers and the customers. The job scheduling algorithm based on the double-layer rule combination is relatively simple and easy to implement; and the job scheduling algorithm based on adaptive rules is more in line with the actual manufacturing process. This paper provides a theoretical basis for realizing efficient production and configuration of manufacturing workshops.*

***KEYWORDS**: virtual manufacturing, simulation platform, resource allocation, job scheduling, adaptive rules*

1 INTRODUCTION

With the continuous increase in people's demand for living materials, the production level of the manufacturing industry is improving continuously. However, the unceasing emergence of new technologies, new methods, new materials and new processes has brought great challenges to the physical manufacturing workshops (Chu et al., 2014). The traditional large-scale production mode can no longer meet the demands of the fast-developing times, and the lean, small-batch and multi-variety production mode is becoming the trend of physical manufacturing (Harris et al., 2017; Mild and Salo, 2009). The virtual manufacturing workshop stimulates the product design, processing, assembly and other processes on the computer, it is a test system and method for the actual production, and the whole virtual manufacturing workshop is generally composed of virtual processing platform, virtual production platform, virtual business platform and product data management, etc. (Mu et al., 2017). Of course, regardless of virtual manufacturing workshop or real manufacturing workshop, resource allocation and job scheduling are important factors that affect the actual production efficiency (Mati et al., 2011).

Resource allocation is a prerequisite for job scheduling. Job scheduling is to issue production and material scheduling instructions according to the production goal and environmental status of the manufacturing enterprise in the purpose of achieving high production efficiency (Zhang and Gu, 2009). Effectively implementing the resource allocation algorithm can ensure that the various production resources and materials in the workshops could be supplied on time and in volume, and they won’t occupy too much public space, that is, implementing an effective resource allocation method is an important means to enhance manufacturing competitiveness (Yan and Zhang, 2007). The resource allocation algorithms of the manufacturing workshops are generally complicated in modeling and calculation, and the job scheduling has the characteristics of dynamic, uncertain, multi-constraint and multi-objective, which have resulted in a few problems in the management, scheduling and optimization during the actual production process, and these problems can greatly affect the production process (Aurich et al., 2009; Zhao et al., 2002). Resource allocation and job scheduling generally take the optimization of cost indicator and performance indicator as the target, and mostly adopt the fuzzy resource allocation algorithms (Hedberg et al., 2017). Based on virtual manufacturing, this paper explores the application of fuzzy resource allocation algorithm in the virtual manufacturing workshop, and studies the problem of real-time job scheduling in the manufacturing workshop, the research of this paper provides a theoretical basis for realizing efficient production and configuration of manufacturing workshops.

2 A SIMULATION PLATFORM FOR REAL-TIME JOB SCHEDULING OF MANUFACTURING WORKSHOP

The resource allocation in the manufacturing workshop is a complex job scheduling process, so it's necessary to construct an accurate resource allocation scheduling model for the problem (Zhang et al., 2015). With the help of the simulation platform, the development of resource scheduling system can be carried out more smoothly, the practicability of the system could be tested online before it's applied in the production practice (Yan et al., 2008). The simulation platform gives important support for the decision-making in each manufacturing stages such as system design, processing, and operation, etc., with the help of the simulation platform, the optimal structure and configuration scheme could be chosen for the system, so as to provide the most suitable scheduling scheme for the actual production and operation (Li et al., 2015). If a model constructed by the simulation platform wants to describe the original system more thoroughly and factually, both its modeling complexity and simulation time would increase accordingly. The simulation platform adopted the radio frequency identification (RFID) technology, and the device mainly consisted of three parts: electronic tags, antennas and the RFID reader (Wang et al., 2016).

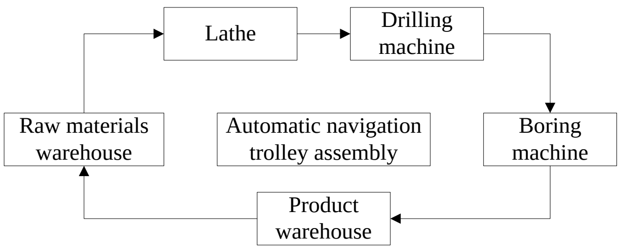

Fig. 1 Distribution of equipment in the simulated workshop

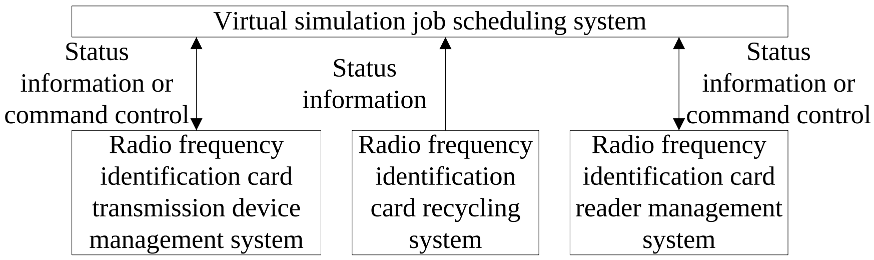

Fig. 2 Virtual simulation platform system

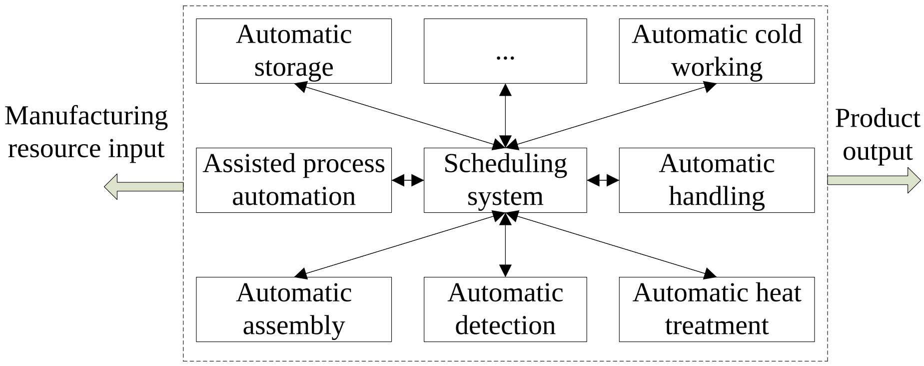

Fig. 3 Composition of the fully-automated manufacturing system

Fig. 1 shows the distribution of the equipment in the simulated workshop. Each equipment uses the wireless network interface to transmit the signals, and the transmission component of each equipment receives scheduling instructions in real time and performs related operations according to the requirements of the scheduling instructions. Fig. 2 shows the virtual simulation platform. The entire simulation platform includes three parts: the RFID card transmission device management system, the RFID card recycling system, and the RFID card reader management system. The main function of the transmission device management system and the reader management system is to realize the simulation platform's status information or command control instructions, while the recycling system only achieves the feedback of the status information of the simulation platform. Fig. 3

shows the composition of a fully-automated manufacturing system. The entire scheduling system includes automatic storage, assisted process automation, automatic assembly, automatic detection, automatic handling and automatic cold/heat treatment or processing, etc., which has realized full automation from manufacturing resource input to product output.

3 WORKSHOP RESOURCE ALLOCATION ALGORITHM AND CONFIGURATION OPTIMIZATION

3.1 Workshop resource scheduling and configuration optimization

In real workshops, the resource information of the production process includes the equipment information, resource management information, processing capacity information, real-time status information and tooling information, etc. The resource scheduling and configuration system will determine the optimal route for each processing task and feed back the resource configuration results to the resource configuration layer. The entire process includes production task order generation, production task decomposition, resource scheduling and configuration, resource reservation and scheduling, and scheduling execution and optimization. The resource allocation follows a certain algorithm flow as shown in Fig. 4. By calculating the fitness value, the non-dominated sorting of resources is determined, the individual resources are selected and the fitness value and distance are calculated, the duplicate individuals are removed, and the processes are corrected and updated. The workshop resource allocation algorithm can achieve real-time dynamic scheduling and allocation of the resources, and efficiently realize the manufacturing tasks of the production orders. Under virtual manufacturing conditions, the heterogeneity of production resources is high and the sources of production resources are wide. Fig. 5 shows the structure of the workshop production resource model. Production resources include the production resource capacity, real-time status of workshop production resources, production resource service cost, and real-time production task information. The virtual production process is the same as the actual production process, and the production resources do not show a linear change with time. Fig. 6 shows the change of the resource allocation output capacity of a manufacturing workshop with time. As the amount of task varies in different time periods, the change of output capacity of the resources is irregular, and the processing capacity characterizes the scale of the output capacity of the workshop resource set within the specified time period.

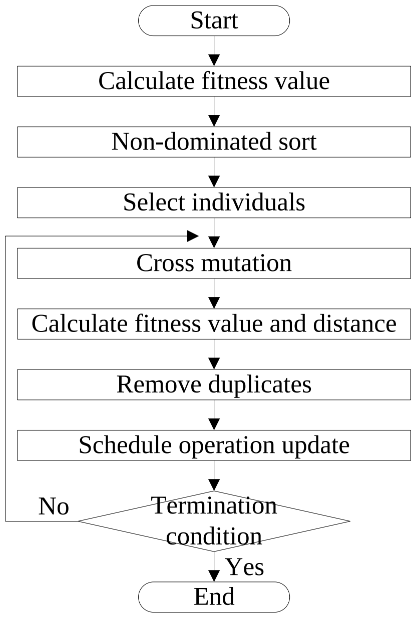

Fig. 4 Resource allocation algorithm flow

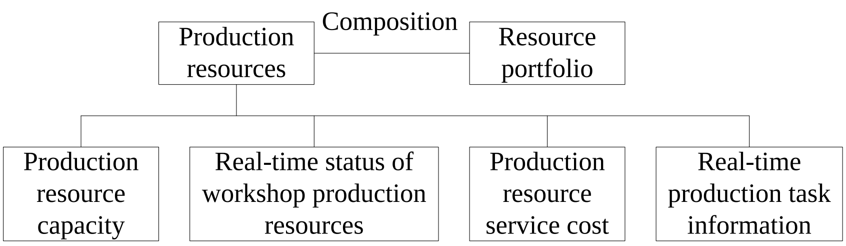

Fig. 5 Structure of workshop production resource model

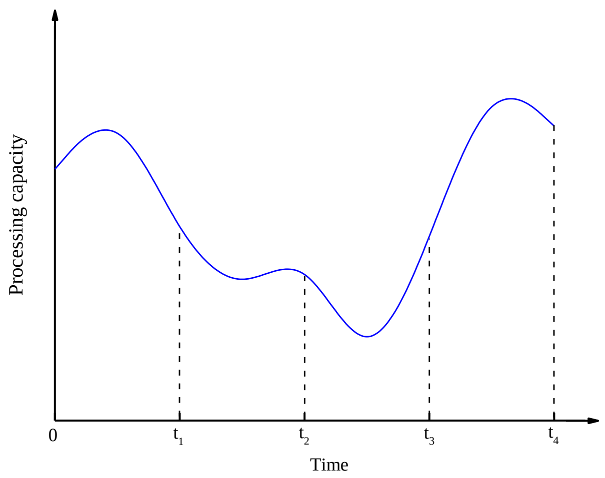

Fig. 6 Resource allocation output capacity of a manufacturing workshop with time.

3.2 Resource allocation and scheduling optimization model based on the degree of satisfaction

Fig. 7 is the production scheduling target system. The overall target of production scheduling is to meet the satisfaction of both the manufacturers and the customers. In terms of manufacturer satisfaction, it includes the capacity indicator and the cost indicator, the capacity indicator includes the optimized resource utilization, the shortest production cycle, and the high equipment utilization; the cost indicator includes the reduced stock, operating cost reduction, and the maximum profit; the customer satisfaction includes delivery on time, delivery by required quality, and delivery by required quantity. According to the time-money satisfaction resource allocation optimization method, different resource allocation models are dynamically generated in real time based on the requirements of different workshops. On the simulated platform for manufacturing workshops, parameters should be input according to the actual production environment, so that not only the accuracy of real-time production task information could be ensured, but also the production cost could be controlled, the optimal objective of the production task cost can be expressed as:

$$\text{MinC}=\sum_{i=1}^{n} C_i \quad (1)$$

Wherein, C_i represents the cost of the i-th process.

The optimal objective of the time of the processing task is:

$$\text{Mint}=\sum_{i=1}^{n} t_i \quad (2)$$

Wherein, t_i represents the time of the i-th process.

In many cases, the optimal cost and optimal time of a production task may conflict, and the optimal resource allocation scheduling will change with the time and the cost. Under such conditions, it is necessary to consider the weights of time and cost for the benefit of the entire enterprise. If the production cost has a greater weight, then the resource allocation should be optimized preferentially so as to achieve minimum production cost; if the processing time has a greater weight, then the processing time should be shortened preferentially so as to achieve the shortest processing time.

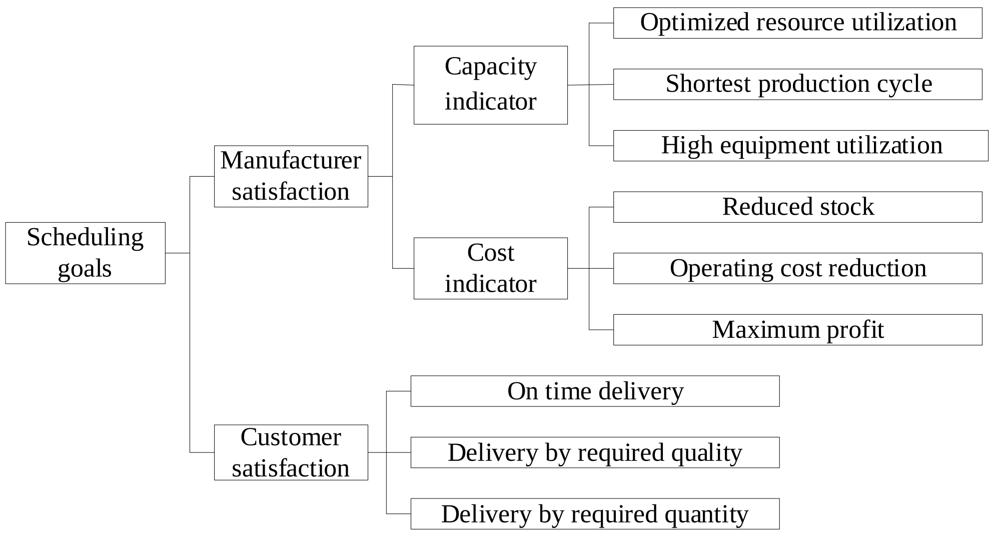

Fig. 7 Production scheduling target system

4 JOB SCHEDULING METHOD BASED ON VIRTUAL MANUFACTURING WORKSHOP

4.1 Real-time job scheduling method based on rule combination

Fig. 8 shows the classification of production resource information. Production resource information includes workshop production material information, technical document information, product information, etc.; wherein the production resource information includes basic resource information, real-time management information, resource capacity information, resource status information and tooling information. At present, the job scheduling of the workshop is to meet the resource requirements of the actual manufacturing workshops. However, sometimes the occurrence of emergencies would disrupt the real-time job scheduling system model. The optimization model studied in this paper was constructed based on the satisfaction degree of manufacturers and customers (cost-time), so the job scheduling rules will change or adjust according to the changes in the weight of the optimization target. The job scheduling based on cost-time double-layer rule combination needs to apply workpiece processing rules to sort the workpieces in the workpiece collection, and then apply the equipment selection rules to sort the processing equipment in the equipment collection, after that, according to the sorting results of the workpieces and the equipment, the workpieces and equipment were matched and optimized.

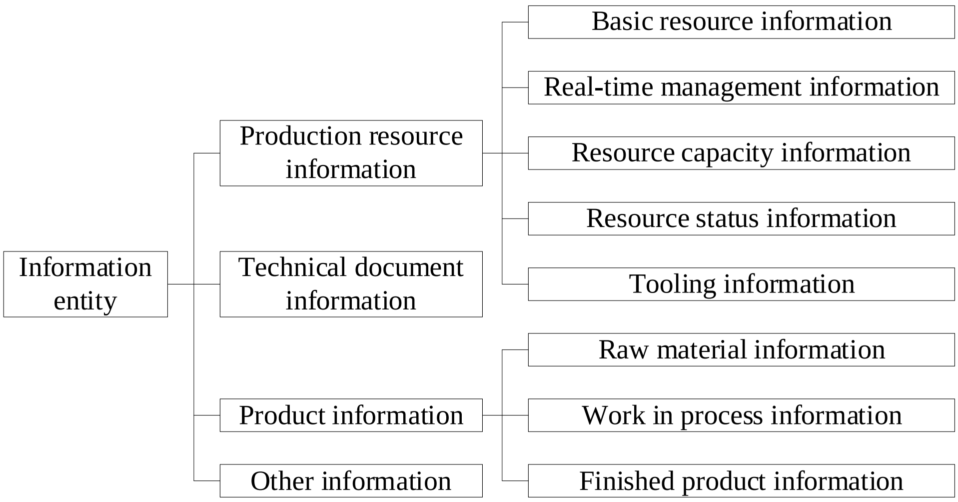

Fig. 8 Classification of production resource information

4.2 Real-time job scheduling method based on adaptive rules

Although the job scheduling algorithm based on two-layer rule combination is relatively simple and easy to implement, simply optimizing a single target will seriously disrupt the original production order and make the initial job scheduling harder. Fig. 9 shows the structure of the functions of job scheduling in the production system, according to the customer orders and sales forecasts, the main production plan and material demand plan are formulated, then the material requirement plan is edited as a material inventory; if the capacity requirement plan satisfies the production condition, then workshop scheduling could be performed.

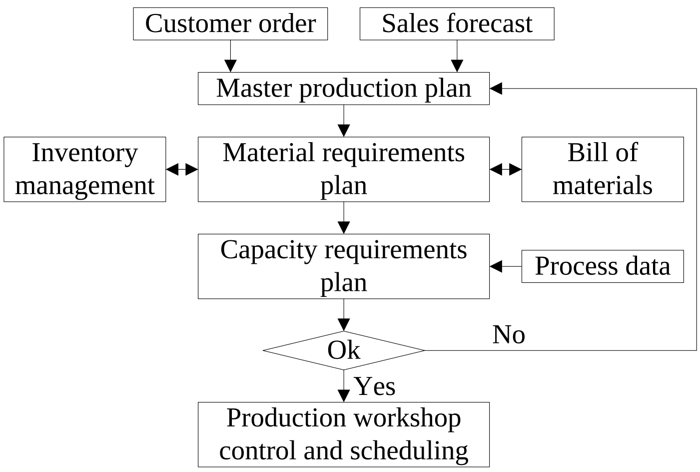

Fig. 9 Functions of job scheduling in production system

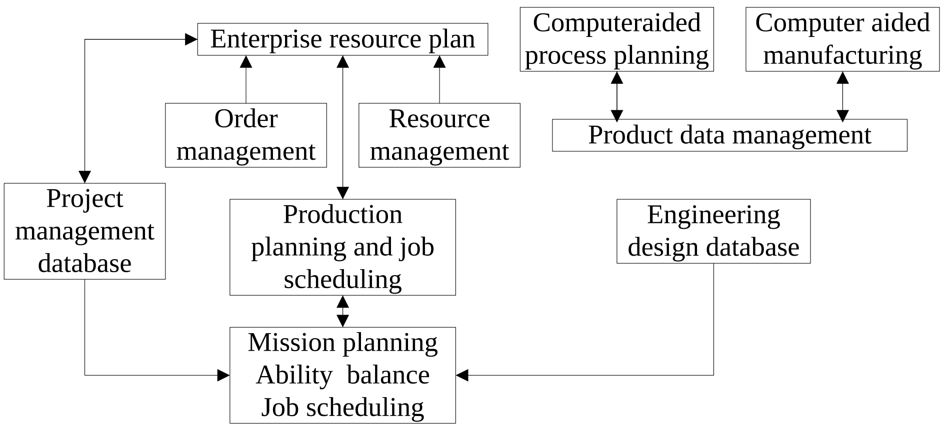

Fig. 10 Job scheduling modules

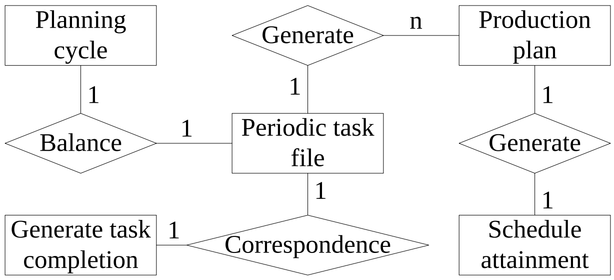

Fig. 11 Periodic task equilibrium entity-relation

Fig. 10 is a relationship diagram of the job scheduling modules. The diagram is divided into three parts: the production cycle and task planning module, the production line capacity balancing module, and the production line job scheduling module. The job scheduling based on double-layer rule combination an ideal job scheduling method. Considering the balance of the production line, the processing time of the workpieces, station balance, processing latency time, and delivery time, etc., an adaptive rule should be selected for the real-time job scheduling. Fig. 11 is the periodic task equilibrium entity-relation diagram, periodic task equilibrium entity relations should be formulated based on virtual manufacturing, under adaptive rules, the planning cycle and the periodic task files reach equilibrium, and the completion situations of periodic tasks and production tasks correspond to the production plan.

5 CONCLUSIONS

Based on the virtual manufacturing, this paper explored the application of fuzzy resource allocation algorithm in the virtual manufacturing workshop, and studied the problem of real-time job scheduling in the workshop. The specific conclusions are as follows:

(1) The entire simulation platform included three parts: the RFID card transmission device management system, the RFID card recycling system, and the RFID card reader management system. On this platform, the entire scheduling system realized full automation from manufacturing resource input to product output.

(2) Under virtual manufacturing conditions, the heterogeneity of production resources is high and the sources of production resources are wide. The processing capacity characterized the scale of the output capacity of the workshop resource set within the specified time period. The virtual production process was the same as the actual production process, as the amount of task varied in different time periods, the change of output capacity of the resources was irregular,

(3) The job scheduling of the workshop is to meet the resource requirements of the actual manufacturing workshops. The job scheduling algorithm based on the double-layer rule combination is relatively simple and easy to implement; but the job scheduling algorithm based on adaptive rules is more in line with the actual manufacturing process.

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