Research on Assembly Line Modeling and Simulation Optimization

Fuli Huang, Wenhua Zhu, Bin Bai, and Baorui Li

CIMS and Robot Center, Shanghai University, Shanghai 200072, CHN

Abstract. In this paper, assembly line is discussed with plant simulation. Firstly, the method of assembly line modeling is proposed. Secondly, assembly line simulation optimization is researched. Finally, assembly line modeling and simulation optimization are both described by an instance.

Keywords: Assembly line, Plant Simulation, Modeling, Simulation optimization.

1 Introduction

Assembly line is the effective combination of Man and machine, reflecting the flexibility of the equipment fully, integrating conveying system, accompanying jig and testing equipment organically in order to meet the requirements of product assembly. According to the type of object assembly, assembly line can be divided into Single-Model Assembly Line, Multi-Model Assembly Line and Mixed-Model Assembly Line. No matter which type of assembly line, generally has the following basic characteristics [1]: 1) High level of professionalization. In the assembly line, one or several products are produced fixedly; in every workstation, one or several processes are completed fixedly.2) The production with obvious rhythmic. The time of process on each workstation should meet the beat of requirements for ease to avoid the products packing and waste time in workstation, since the driving devices move with a certain speed. 3) The workstations are put in order according to the process sequence , assembly object does unidirectional movement between the workstations.

Assembly line is discrete event system, which widely used in the manufacturing industry. The traditional assembly line simulation is based on mathematical model, which is time-consuming. Generally, it can't meet the demand of product's fast response to the market. In this situation, the computer simulation arises at the historic moment, which can quickly and accurately finish simulation, as a result of shortening the production cycle, reducing manufacturing costs. There are many computer simulation software. Especially, Plant Simulation is object oriented, graphical, integration of modeling, simulation tools, which used to call eM-Plant until the takeover of Siemens. Plant Simulation has the following characteristics [2]: 1) The object-oriented modeling. As a modeling object, properties and methods are encapsulated as a separate entity in Plant Simulation, which can be accessed by other

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objects. 2) Support layer type structure. Layered modeling can be realized and other hierarchical structure can be added in the course of modeling. 3) The WYSIWYG graphics work environment. Modeling, simulation and animation can be intuitive displayed in the interface of Plant Simulation.4) Easy to control. SimTalk language embedded in Plant Simulation can achieve fine, flexible control. 5) The data processing is simple. Plant Simulation provides various forms of interfaces, 3D display and HTML report. Because of the above features, Plant Simulation is applied to research assembly line in this paper.

2 Assembly Line Modeling

2.1 Assembly Line Modeling Basis

Assembly line modeling needs to plan organization structure, which is very important for modeling, especially when assembly line is more complex, as well as the situation of requiring different person to complete different parts. If the structure of the organization is well organized, it's easy to find the object in modeling process. It is not only easy to manage, but also can improve the efficiency of the modeling effectively with the good organization structure. The organizational structure of assembly line usually have a feeding workstation, assembly workstation, grinding-in workstation, detection workstation, laying-off workstation, mobile equipment, transportation equipment, lifting equipment, rotating equipment and testing equipment, etc. Object library must be corresponded to simulation software library after planning organization.

Plant Simulation provides objects library of the basic modeling, including logistics object, information flow object, the user interface object and moving object. Logistics object have the ability to change the moving objects parameters of the object, including workstation, buffer, feeding workstation and laying-off workstation, etc; Information flow object can control and record the data of simulation, and most of the information flow objects are presented in the form of table, including variables, table, storage file, trigger and circulation, etc; The user interface object is the method of the communication between simulation model and the user, which not only can provide system simulation of relevant information for users, but also can be a control simulation tool for users; The moving object refers to the object that physical location is not limited to one place, such as the assembly parts of the assembly line, the vehicle and tray of transport parts. The system model can be built according to actual production with inheriting and duplicating objects. Practical application is also convenient. The corresponding object model can be generated with the mouse click and the drag of corresponding object icon.

2.2 The Design Method of Assembly Line Modeling

Assembly line modeling needs to base on the actual resources. Firstly, the information of assembly line should be collected into the resource database of assembly line, then

the information will be classified in the aspect of organization structure according to function, the classification of this treatment is easy for corresponding actual assembly line in modeling.

Modeling is the process of constantly extracting Plant Simulation object library according to the information resource of assembly line. In the course of modeling, constraint model will be needed, the constraint conditions is different as the different products, this is because regardless of which kind of assembly lines are for the products, and different products have different processes, namely the assembly process library restricts the arrangement and order of modeling in assembly line. Figure 1 is the specific design flow chart of assembly line.

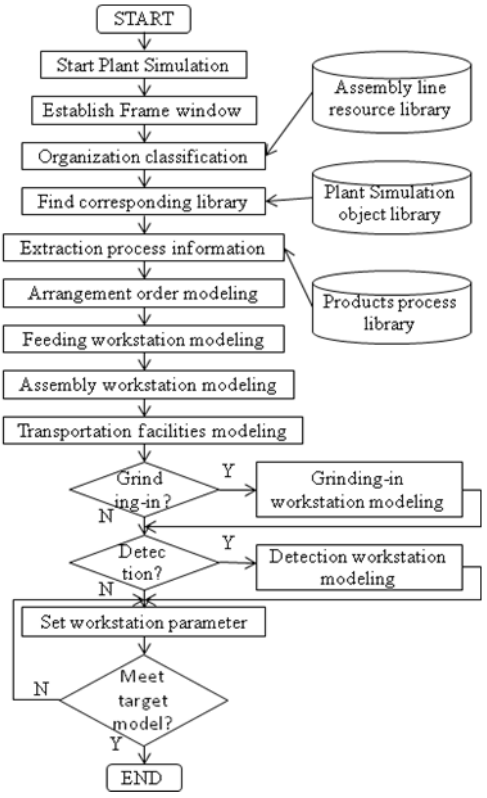

Fig. 1. Flow chart of assembly line modeling design method

3 Assembly Line Simulation Optimization

The simulation operation of the simulation model can only provide feasible scheme in certain conditions, not giving the optimal solution of the problem, and simulation optimization technique is general embed in the process of simulation, which is the

process finding the best input variable value from feasible domain, making the output be the optimal solution or satisfied solution, and the goal is to consume the least resource while get the most information in simulation experiment , and let the user decide easily [3].

Plant Simulation has many assembly line optimization tools, such as genetic algorithm, bottleneck analysis, which can find the bottleneck of restricting production and optimize the system allocation parameters with genetic algorithm. The optimization of assembly line is realized through the followings methods.

3.1 Equipment Layout of Assembly Line

Production equipment layout and material handling system design impact the production costs and profits of manufacturing enterprise , Tompkins research thinks a manufacturing enterprise materials handling cost takes up 10% ~ 30% of the total cost in production, from production efficiency it can be highest improved three times[4]. This shows, the reasonable design equipment layout is effective way to reduce material flow rate to optimize the assembly line. Equipment layout is typical problem of quadratic assignment, it is the design considered from the process principle, and the following is its design method.

1) The known n equipments and between handling quantity size is W_{ij} (i=1,2,…,n, j=1,2,…,n), and n fixed positions, and the distance between the working place is D_{ij} , rating the total material flow to a minimum, namely.

$$\min \sum_{i=2}^{n} \sum_{j=2}^{n} W_{ij} \times D_{ij} \tag{1}$$

When homework unit number n is smaller, heuristic method is more convenient, it includes Construction and Improvement. Construction starts thoroughly according to the determined rules, every time addressing a work unit to a certain work place until all of the candidates are arranged with the corresponding work units garrisoned in homework. While Improvement is to determine an initial layout, and then improves decorate Settings through the mutual exchange or change workplace of some homework unit, the most common method of exchange technology.

When homework unit number n is bigger, this problem turn to be NP-complete problem, along with the increase in the number of operating unit layout, the solution space exponential expands, the combination explosion phenomena appears, the solver is very difficult. At this time, the use of genetic algorithm for solving this kind of problem is more convenient, and at the same time Plant Simulation provides general genetic algorithm to solve these problems, it is GA wizard, which can be search in the solution space extensive and get the global optimal solution.

2) The known n quantities of material handling between operation departments are W_{ij} (i=1,2,…,n, j=1,2,…,n),and work units and the area, reasonable arrangement of the

relationship between the operation departments make all the material flow rate minimal or close to the minimum [5]. It is convenient to use SLP theory under this situation, using SLP method for the equipment layout is to make analysis for the relationship between the unit works, including the mutual relationship of the logistics and the non-logistics, after a comprehensive, obtains the comprehensive relation tables of each department. Then, according to each homework unit's position displayed in the comprehensive relation tables, draw the related graphs of operation department position, combining the operating unit area with the actual locations, concluding relevant figures of the work unit area, through the correction, the feasible layout can be obtained, and finally by evaluation, scheme will be decided.

3.2 Balancing of Assembly Line

In the industrialized developed country, according to relevant data statistics, the industrial assembly production will have wasted 5% to 10% of the production time in balancing delay [6]. This is because after the differentiation of homework, the operation time of each process could not be completely equal in theory and fact , each working procedure is not imbalance.

In order to solve each the imbalance of the working procedure, the working time of each procedure must be averaged, and the assignments must be standard at the same time, in order to make assembly line flow smoothly. Assembly line balancing is the equalize of all the process, adjust the work load, in order to make a similar operation time as far as possible. The purpose of assembly line is to make the optimized of the assembly line in time, generally speaking, it is will reduce free time of each station to a minimum. through finding, analyzing and improving the problem, making the assembly line to a new higher balance, and then in the new conditions, again through the continuous circulation of finding, analyzing and improving problems, to improve the production efficiency continuously. Plant Simulation provides general genetic algorithm which is GA wizard to solve this problems

3.3 Distribution Scheduling and the Optimization of AGV Car

After the model building, certain methods of control also need to provide to make that the simulation process really reflect the actual production. Plant Simulation provides object-oriented simulation control language of SimTalk, and it provides interpretation and debugging tools for editors, defining the control of material flow object and information flow object. Taking the SimTalk language of the control program of material flow object and information flow object as the trigger condition of the control strategy and the trigger of operation after execution can let the simulation process execute according to actual production, being the basis of the further analysis and optimization [7]. The following is the scheduling strategy of the assembly line of AGV car, it can control the distribution of material.

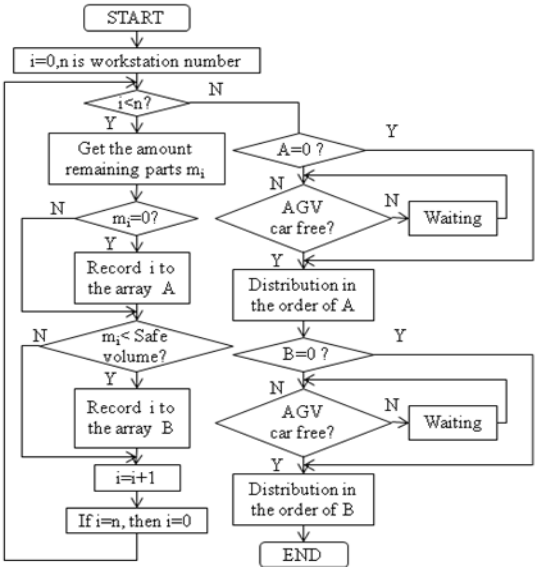

Fig. 2. Flow chart of AGV car scheduling strategy

Assembly line materials are not only large number of handling, but also has the characteristics of the strong relevance around the working procedure of handling, handling short distance, and low carrying mechanization, so the study of AGV distribution optimization is imperative. By changing the different distribution strategies, the time distribution, distribution path and the distribution priority order information, AGV distribution optimization evaluate distribution capacity, finding out the bottleneck and improve it.

4 Application Instance

This application instance is the assembly line of vacuum circuit breaker, this line has fifteen assembly workstations, one grinding-in workstation, five inspection workstations. Using the method of this paper to make this assembly line modeling and simulation optimization, the following is the specific steps.

1) Modeling assembly line by Plant Simulation.

Different products have different process, modeling the assembly line according to the process. Under the condition of meeting the requirement of the process models according to the actual situation of the assembly lines.

2) The equipment layout design of the assembly line.

Genetic algorithm is applied for equipment layout, taking the coding of work location as chromosomes, and equipment can be thought of as a chromosome genes, it turns to the most common scheduling problems in genetic algorithm, which is to code the series machine. Using genetic calculate to find the optimal solution, calculating the

minimum material flow rate by the optimal solution equipment layout, so as to realize the optimization of the assembly line, shorten the work hour.

3) Assembly line balancing.

Assembly line balancing realize optimization by genetic algorithm of Plant Simulation, the first is the problem statement and coding, expressing the coding method by assembly sequence, and the length of the chromosome is equal to the task number, expressing each task by a digital, and the deposit sequence is the order of the assembly sequence, and then work will be assigned to workstation according to the assembly sequence, making the sum of the assembly time of each workstation is not greater than the beat of production; GA Optimization is applied to create initial coding and Evaluate is applied to inspect the rationality of code; The reasonable coding is stored in GA Optimization as father generation; GA Sequence is applied to cross and generate the descendant, and the rationality of coding will be inspected by the Evaluate; The reasonable code is applied on workstation distribution and fitness evaluation by Function; GA Optimization call termination method to record the optimal several groups of results in Best Solution list.

4) Design the distribution of the scheduling and optimization of AGV car.

This instance adopt the distribution of the scheduling with the center of workstation , and the scheduling is cater to workstation and the active distribution, predicting location and time demand according to production plan and Material list, actively delivering materials to workstation on time. Scheduling process adjusts operation of the system according to the changing logistics information, Tools and the type and quantity of assembly parts, distribution path and time distribution are decided by the assembly relations, demand and assembly product. Because the time of each workstation follows a triangle assembly distribution, it will lead to the assembly parts requirement inconsistency, needing to adjust dispatching information according to the change of assembly parts.

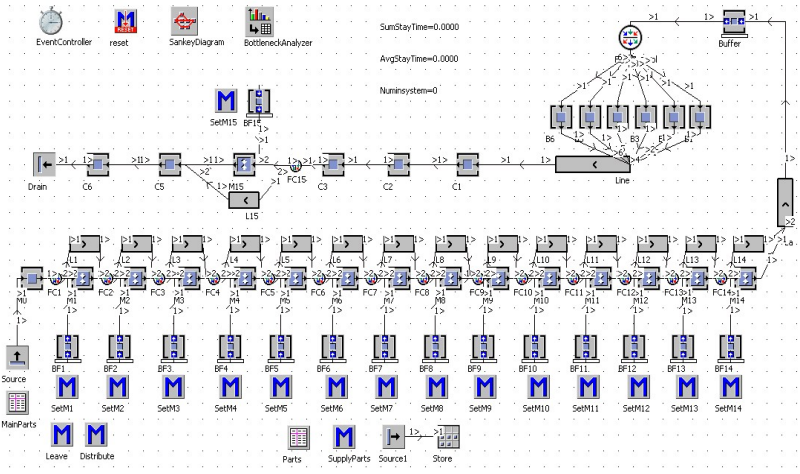

Fig. 3. The assembly line of vacuum circuit breaker

5) Handle assembly line information.

After assembly line modeling and simulation optimization, Plant Simulation also provides statistical analysis tools, experimental tools, various statistical analysis of charts can display the utilization rate of buffer, equipment, personnel dynamically, and it will help to analysis the data on the assembly line effectively

The modeling and simulation optimization of Vacuum breaker assembly line is shown in figure 3.

5 Conclusions

Research on assembly line with Plant Simulation software gets the design method of general assembly line modeling. Modeling method and genetic algorithm is applied for the modeling and simulation optimization of vacuum circuit breaker assembly line, and research on scheduling of AGV car in the assembly line concludes the general strategy of AGV car scheduling and optimization, verifying the correctness of the method through the instance in this paper. At the same time, research on optimization and improvement of the assembly line can satisfy the enterprise's requirement of improving and optimizing assembly line based on the existing assembly line, and it can greatly improve the efficiency of the enterprise.

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