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Discrete System Modeling for Large Ship Subsection Welding Workshop Based on Plant Simulation

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Key words: ship welding workshop; plane segmentation; surface segmentation; Plant Simulation; discrete system simulation.

Abstract: Discrete System Modeling for Large Ship Subsection Welding Workshop Based on Plant Simulation, Plant Simulation software was used to simulate the discrete system. This paper introduces in detail the process flow of the production line in a shipyard for substation welding and intelligent transformation of the workshop, including the plane subsection production line and curved subsection production line. Using Plant Simulation, a simulation model of the plane production line and curved surface production line was established to simulate the production plan. The simulation of production scheduling and failure rate factors was comprehensively considered, and the control interface of the production line model was designed. Finally, the indicators for evaluating the production line were given.

1. Introduction

The current shipbuilding technology level mainly has the following deficiencies: (1) the automation level of shipbuilding equipment is still low; (2) there is a large shortage of digital shipbuilding technology; (3) the capacity of informatization of shipbuilding is insufficient, process control data support is low. Combining the current level of shipbuilding and the status of intelligent production workshops, the construction of subsection welding smart workshops should be the first step in the process of promoting the shipbuilding industry in the shipbuilding industry in China. Through the establishment of subsection welding intelligent workshops, practice Smart manufacturing technologies are used to improve the efficiency and quality of shipbuilding, and lay the foundation for smart manufacturing in the entire shipyard. Li Chuan studied the surface segmentation scheduling problem based on the virtual pipeline, established a mathematical model of job team and workshop scheduling, solved it with a heuristic genetic algorithm, and developed a software system for the surface segment pipeline scheduling[1]. . Zhang Zhiying analyzed a series of problems in the actual operation of the planar segmentation pipeline, combined with the characteristics of the planar segmentation production line, proposed a new scheduling model, based on which, with the minimum maximized completion time as

the optimization goal, through the branch The bounding method solves the problem that the established model and algorithm solves the scheduling problem of the planar segmented pipeline more quickly and efficiently than the hybrid GA algorithm[2] . Zheng Junli analyzes the characteristics of shipbuilding, constructs a mathematical model of staged dispatch, applies an improved algorithm to solve [3], and proposes a new spatial dispatching method, which further validates the new dispatch method in solving practical problems. The validity of the problem. Wang Jianjin proposed a new hierarchical nested space scheduling algorithm, corresponding to different dynamic adjustment strategies at different times of segmented manufacturing, and designed a working flow to achieve dynamic spatial scheduling [4]. Through the establishment of a discrete system simulation model, the influencing factors and scheduling strategies are analyzed. Finally, the system software based on the dynamic space scheduling method is developed. Domestic research on production scheduling of hull section construction generally does not take into account unexpected factors in actual production, and many assumptions are made on the production environment. Actual production processes will have a large number of factors that affect production efficiency, such as equipment failure, staff turnover, and plan changes. Etc., thereby limiting the practical application effect.

In this paper, based on the actual process flow and job processing time data of a substation welding digital transformation workshop, using the eM-Plant simulation modeling software [9], the flat subsection welding production line and surface subsection in the subsection welding workshop are completed. The modeling of the simulation model of the segment welding production line comprehensively considers the factors such as the failure rate factor of the production workshop and the scheduling plan factors, which further improves the authenticity of the simulation system. Interactive interface development of the simulation system and integration of the system model.

2. Workshop plane segmentation production process

The substation welding digital transformation workshop of a shipyard consists of two types of work areas, which are the flat sectional assembly line work area and the curved segmented tire frame work area. The site layout is shown in Figure 1.1.

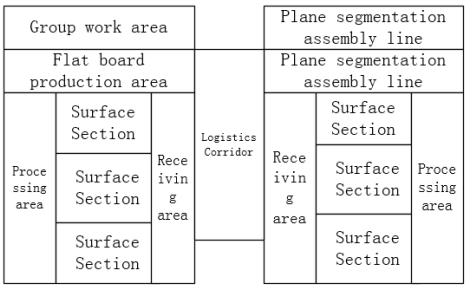

Figure 1.1 Site layout of subsection welding workshop

The production process flow of plane segmentation [5] is shown in Fig. 1.2. In each station, with a certain amount of time, the amount of work on each station is not equal, and the production tempo is adjusted by changing the number of people,

equipment, and the number of stations.

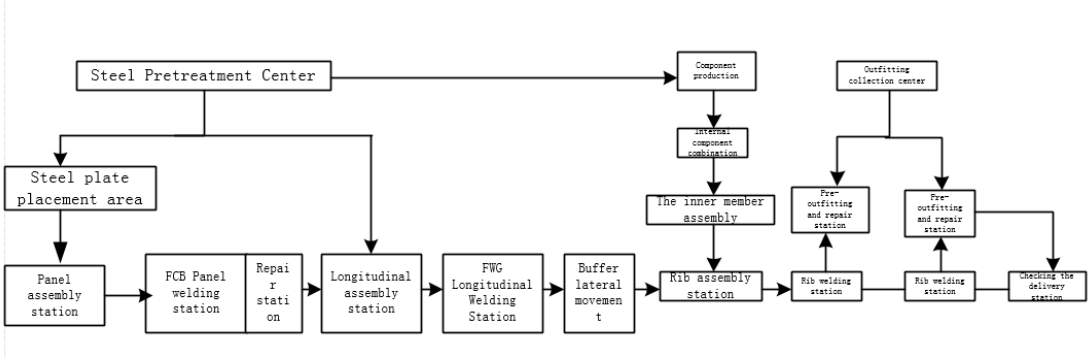

Figure 1.2 Process flow of flat sectional production line

Surface segmentation is another very important intermediate product for ship construction. The workload of surface segmentation accounts for more than 70% of the total workload of the segmented welding shop. The construction of surface segmentation is mainly based on assembly and welding. Compared to plane segments, curved segments are larger and heavier.

The construction process of surface segmentation is shown in Figure 1.3 below:

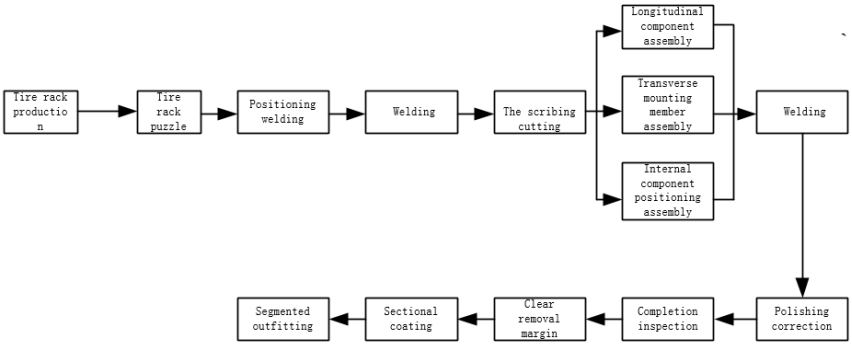

Figure 1.3 Surface segment assembly process

The virtual assembly line operation mode is flexible, and the operation team can control the production beats of each station, to a certain extent, it can improve the efficiency of curved surface segmentation and achieve balanced production.

3. Main modeled object

3.1 Planar pipeline modeling

There are a total of 10 stations in the plane subsection production line, in which the puzzle assembly, the longitudinal assembly, the rib assembly, and the pre-assembly are assembler stations. The Assembly object is used to simulate these assembly stations, and the rest belongs to the processing station, using the Singleproc object to represent.

Source/Source1/Source2/Source3/ simulates the loading of steel plates, Longitudinal ribs, ribs, and fittings. The steel plates are represented by Container objects, and the longitudinal, rib, and armored items are represented by Entity objects. They are Entity1, Entity2, respectively. Entity3, set the load of the mobile object,

Container object can load 20 Entity1, 50 Entity2, 100 Entity3.

According to the process flow and station configuration of the preceding two sections of the ship subsection welding workshop plane subsection production line, the establishment of the plane subsection assembly line simulation model is shown in Figure 2.1.

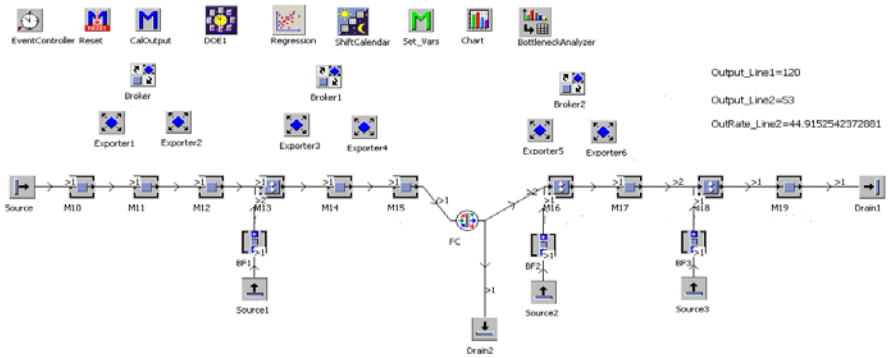

Figure 2.1 Physical model of the assembly line

The Flow Control object is used to implement segmented shunting, with 70% of the controlled segment entering the trail and 30% moving out of the line to the center of the surface.

Using the Exporter object and the Broker object to simulate the job team scheduling of the workshop, such as the puzzle job. When the puzzle assembly work is carried out, three skilled workers are required to perform the spot welding operation. At this time, the puzzle assembly station issues a service request to the Broker object. At the same time, the Broker object manages a plurality of task teams and dispatches the jigsaw welding team 1 to complete the jigsaw assembly welding process.

3.2 Surface Production Line Modeling

Similarly, the curved section production line was modeled [6]. Based on the virtual pipeline principle, the simulation system of the curved section production line was established as shown in Figure 2.2. At this point, the task team does not move and is "moved" on the production line according to certain procedures.

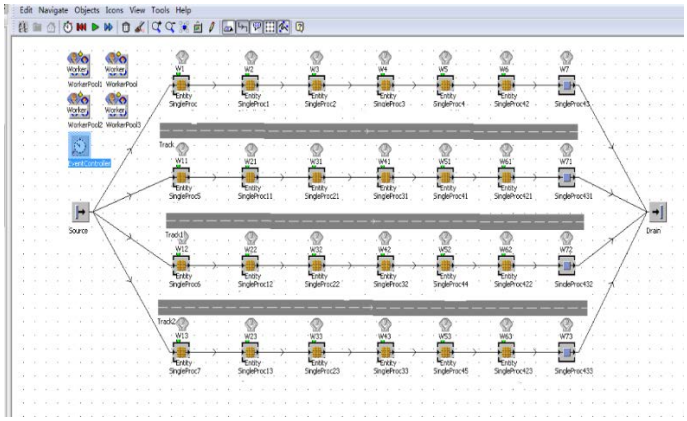

Figure 2.2 Surface Segmentation Virtual Pipeline Physical Model

3.3 Workshop Production Planning Simulation

Shipyard production and production plans generally use Excel. In order to reduce the workload of simulation input data, the data in the shipyard's production schedule Excel spreadsheet needs to be directly imported into Plant Simulation, and the data link between Excel and Plant Simulation should be realized before the production plan is issued. Pre-inspect the production plan and judge whether the production plan is reasonable. Call the Read excel file interface function in the method and run the command to read the Excel data into Plant Simulation's table file.

3.4 Scheduling plan and failure rate factor simulation

(1) Schedule plan.

A shift schedule is established by shift calendar objects, the operation of the production line is specified during the shift schedule, and the production line is stopped at a time other than the shift plan. The scheduling plan developed in this paper is shown in Figure 2.3 below.

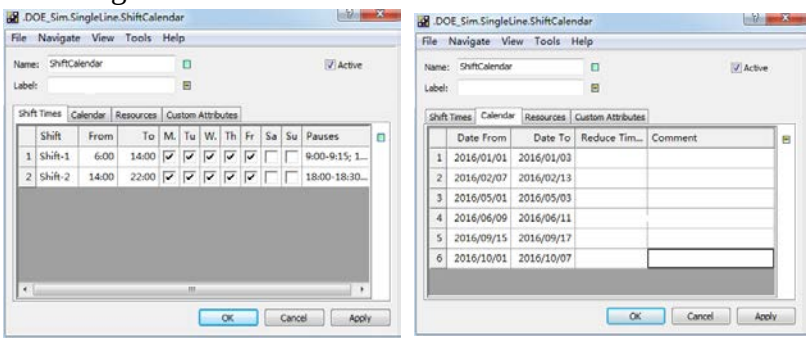

Figure 2.3 Schedule plan

(2) Failure rate factor.

Each station on the production line may malfunction due to machine failure or human operation error, resulting in the station can not run normally. Therefore, the failure rate factor needs to be considered. In the singleproc object, the Failures tab can be used on the device. Availability is set. Availability refers to the availability of the device, that is, the rate at which the device does not fail. The MTTR represents the average repair time, which indicates the average time to repair the fault after the device fault occurs.

3.5 Production line model control interface integration

There are many variables, parameters and models in the discrete system simulation model. Different control strategies need to be programmed to run different programs. Therefore, these information needs to be organized to facilitate centralized management and monitoring. In addition, the shipbuilding process can be divided into multiple manufacturing stages, and each manufacturing stage can be parametrically modeled separately, which helps the user to grasp the influence of various factors on the simulation model building process from an overall perspective.

4. Line balance indicators and optimization indicators

When designing a production line in a subsection welding shop, it is necessary to use a plurality of evaluation indicators to evaluate the production line model. This

article divides the indicators into two categories: production balance indicators and optimization indicators. The balance of production can be measured by the three parameters of line balance rate, balance loss rate and smoothness index. The optimization indicators include equipment utilization, man-hour rate utilization, and output capacity. These three evaluation indicators are easy to observe and have a greater impact on the production process. They are the three major quantities that need to be considered when the system is optimized

(1) Production line balance indicator

The balance of the production line can be evaluated by the beat of the production line, whether there is a bottleneck station, etc. The beat of the production line refers to the interval between the completion of the continuous production of two products on the production line [7]. The production line beat formula is as follows:

$$MT = \frac{T_w}{Q} \tag{1}$$

MT indicates the production cycle of the production line, T_w indicates the total production man-hour for the production line to complete the planned production, and Q indicates the number of processed products completed in the production line production plan.

The balance of the production line can be measured by the production line balance rate and smoothness index [7]. The formula for calculating the balance ratio P of the production line:

$$P = \frac{\sum_{j=1}^{n} T_j}{m \times \max(T_i)} \times 100\% \tag{2}$$

P represents the balance of the continuous production of the production line and $\max(T_i)$ represents the maximum working time in the production line. The formula for the smoothness index (SI) is:

$$SI = \sqrt{\frac{\sum_{i=1}^{m} \left(CT - T_i\right)^2}{m}} \tag{3}$$

SI represents the deviation of the processing time of various process equipment on the production line [8].

The balance of the production line mainly refers to whether or not to balance the production and processing time of each workstation is nearly equal when scheduling tasks to each workstation. There are many factors that need to be measured in the balance process of a production line. If a mathematical method is used to solve the solution, the workload is large and difficult to solve. By establishing a simulation model and performing simulation optimization, the solution is more convenient and more complex factors can be considered.

(2) Equipment utilization $\varepsilon_{equipment}$

The equipment in the subsection welding workshop includes equipment such as FCB imposition welding machine, FWG vertical bone welding equipment, rib pull-in device, and multi-room cabin welding robot system. Increasing the utilization rate of these equipment will greatly help improve the efficiency of the entire production line. Operating rate refers to the ratio of the actual operating time of the machine to the total working time. This is a statistic that varies discretely over time. Its time-varying function is the following "busy" function:

$$A(t) = \begin{cases} 1 \\ 0 \end{cases} \tag{4}$$

If the device is busy at time t 1, at time t 0 is idle.

The operating rate is the area under the curve A(t) divided by the simulation running period:

$$\varepsilon_{equipment} = \frac{\int_0^T A(t)dt}{T} \tag{5}$$

Equipment utilization should be at a high level of issues, not too high or too low. The long-term operation rate of the equipment is too high, which indicates that the production line has a large workload. When the production task is further increased, it will become a bottleneck device and the production line will be blocked. Therefore, the equipment utilization needs a reasonable margin. When the operating rate of the production line is too high, the capacity of the production line for reserve operations is insufficient and it is easy to cause obstruction. If the operating rate is too low, the equipment cannot be used effectively.

(3) Utilization rate of working hours $\varepsilon_{personnel}$

Working hours utilization refers to the ratio of the actual attendance time of the workers to the scheduled working hours. This is also a statistic that varies discretely over time. Its time-varying function is the following "busy" function:

$$B(t) = \begin{cases} 1 \\ 0 \end{cases} \tag{6}$$

The man-hour utilization rate is the area under the curve B(t) divided by the simulation operating cycle:

$$\varepsilon_{personnel} = \frac{\int_0^T B(t)dt}{T} \tag{7}$$

(4) Output capacity $Q_{production\ line}$

How many products can be processed or manufactured in a segmented welding shop over a period of time, including plane segmentation, curved segmentation, etc., are the most intuitive index parameters of the welding shop manager.

$$Q_{production\ line} = \sum v_{equipment} * \varepsilon_{equipment} * t_{personnel} * \varepsilon_{personnel} \quad (8)$$

Among them, $v_{equipment}$ represents the processing speed of the equipment, $\varepsilon_{equipment}$ represents the equipment operation rate, $t_{personnel}$ represents the working time of the personnel, and $\varepsilon_{personnel}$ represents the utilization rate of the working hours.

4 Conclusion

For the large-scale shipyard sub-plant scheduling problem, the discrete system modeling of large ship subsection welding workshops based on Plant Simulation is applied. The simulation model of the plane production line and surface production line is established to simulate the production plan, and the production schedule and failure rate are comprehensively considered. Simulation of factors, and the design of the control interface of the production line model, and finally the indicators for the evaluation of the production line. The establishment of this system will effectively solve the large-scale shipyard scheduling problem, and it is of great significance to vigorously promote the application of various types of intelligent manufacturing technologies on the production line.

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